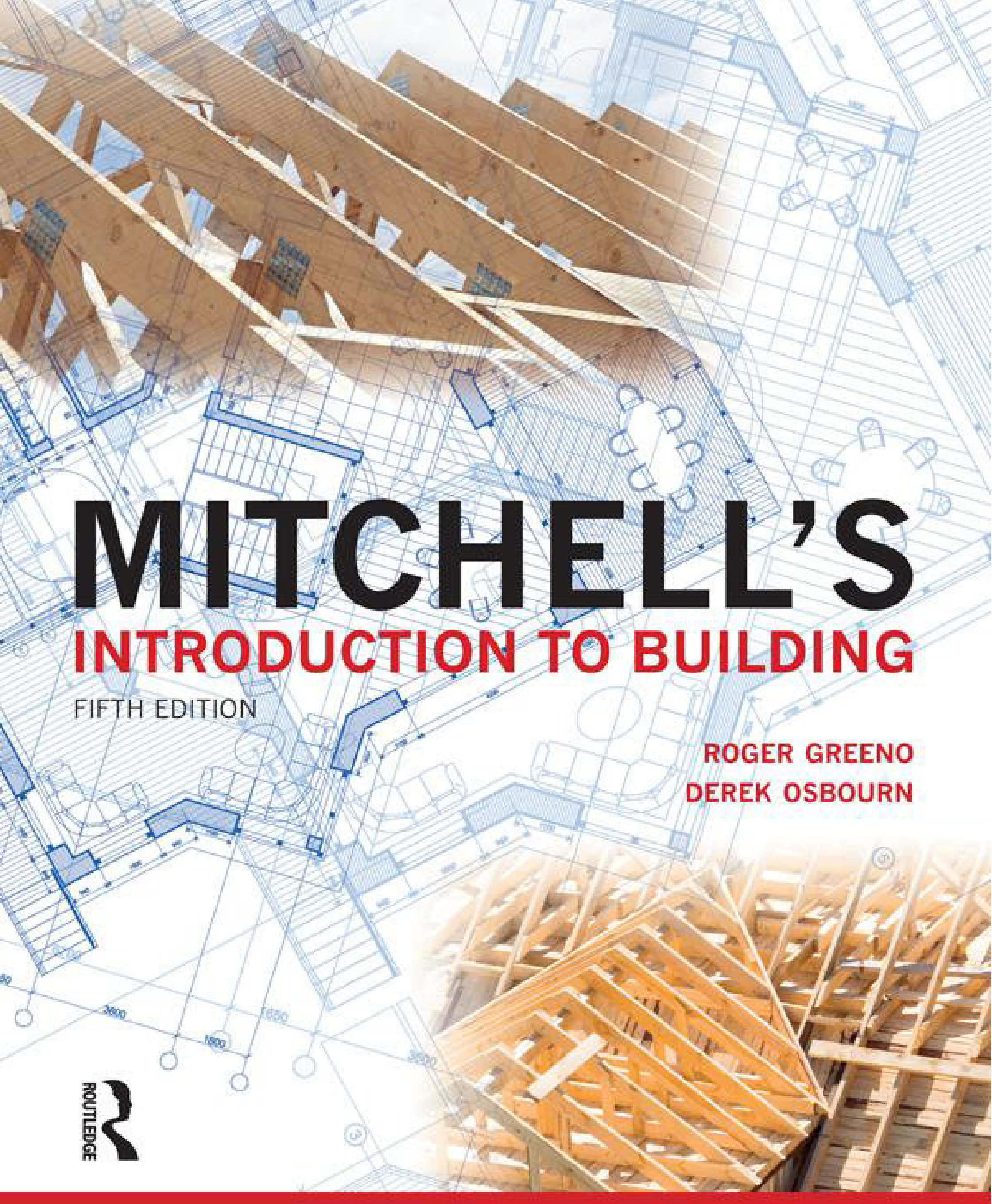

MITCHELL'S
INTRODUCTION TO BUILDING

FIFTH EDITION

ROGER GREENO
DEREK OSBOURN

ROUTLEDGE

Introduction to Building

Mitchell's Building Series

Fifth edition

Introduction to Building

Derek Osbourn
Dip Arch [Hons], RIBA, MSIAD

Roger Greeno
BA [Hons], FCIOB, FCIPHE, FRSA

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Contents

Preface to the fifth edition

The first edition of this book was published in 1985, before the tragic and untimely death of its original author Derek Osbourn. It is a compliment to Derek that his book has become an established part of the Mitchell's Building Series, and that the Higher Education team at Pearson Education acknowledge the benefits and values that its readers will find in the continuity of his work.

This fifth edition of Introduction to Building continues the established format of earlier editions, providing a blend of comprehensive text with supportive illustrations and individual chapter listings of research papers, Building Regulations and other related texts for further reading. Much of the traditional construction procedures are retained from previous editions, with regard to maintenance and repair of existing housing stock. Where necessary, the content has been amended and extended to cover the procedural and mandatory changes required by new government guidelines and legislation for development and construction work.

Specific changes include consideration of government directives and legislation affecting the need for sustainable construction, with regard to concerns for climate change and reduction of greenhouse gas emissions from buildings. Further initiatives emanate from the Egan Report and the subsequent Strategic Forum Report Accelerating Change, with reference to the Construction Act, the Construction (Design and Management) Regulations, contractual procedures and background to the Joint Contracts Tribunal (JCT) forms of contract, new Building Regulations affecting sound insulation, fuel energy conservation, thermal insulation, access for disabled people, and aspects of planning history with current processes.

This book remains a useful professional reference and an essential course reader for students of all construction-related disciplines, including architecture, construction management, building surveying, quantity surveying, estate and facilities management.

Roger Greeno

Acknowledgements

David Clegg gave invaluable guidance on the CI/SfB classification system; information for Figures 7.1 and 7.2 and Tables 7.1–7.3 was readily given by J.E. Moore. Teaching in the subject of this book, it is inevitable that I have also drawn upon much accumulated data supplied by others as documents or during discussions over many years. I apologise to those not credited and can only offer my sincere thanks.

George Dilks, assisted by Jean Marshall, prepared the final drawings and I owe thanks for the skilful and tolerant way in which sketches were interpreted. I am especially grateful to Nori Howard-Butôt for not only typing and retyping the draft, but also for making many important suggestions regarding content. Lastly, of course, my thanks go to the publishers, and particularly Thelma M. Nye for her enthusiasm, patience and extremely able editorial assistance.

Derek Osbourn
1984

I would like to thank Guy Thompson of Norman + Dawbarn Limited (Architects), Guildford, for the illustration in Figure 17.6 of one of their designs. I am particularly appreciative of the assistance provided by my former students, Mark Alford and Steve Adcock of Norman + Dawbarn, who helped to resource information.

I am especially grateful to the Osbourn estate for allowing me the opportunity to develop Derek's work. It has been a valued experience and a privilege to be associated with his concept.

It would be remiss not to acknowledge the publisher, without whom the book could not exist. My thanks to the many editorial staff of Pearson Education, whose enthusiasm to help me update the previous editions has resulted in the continuing success of this book. In particular, I am grateful to Pauline Gillett for her direction and guidance in preparing the manuscript for the fourth edition and Patrick Bond for his help with this fifth edition.

Roger Greeno
2012

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Figures

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R. 2000); Figure 18.54 from MIBS: Structure and Fabric Part 1, Pearson Education Limited (Foster, J.S. and Greeno, R. 2007) Fig. 7.15, p. 155.

Tables

Table 17.1 from Classification of building types, Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com.

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SI units

All quantities in this volume are given in SI units, which have been adopted by the United Kingdom for use throughout the construction industry as from 1971.

Traditionally, in this and other countries, systems of measurement have grown up employing many different units not rationally related and indeed often in numerical conflict when measuring the same thing. The use of bushels and pecks for volume measurement has declined in this country but pints and gallons, cubic feet and cubic yards are still both simultaneously in use as systems of volume measurement, and conversions between the two must often be made. The subdivision of the traditional units varies widely: 8 pints equal 1 gallon; 27 cubic feet equal 1 cubic yard; 12 inches equal 1 foot; 16 ounces equal 1 pound; 14 pounds equal 1 stone; 8 stones equal 1 hundredweight. In more sophisticated fields the same problem existed. Energy could be measured in terms of foot pounds, British thermal units, horsepower, kilowatt-hour, etc. Conversions between various units of national systems were necessary and complex, and between national systems even more so. Attempts to rationalise units have been made for several centuries. The following stages are the most significant:

- The establishment of the decimal metric system during the French Revolution.
- The adoption of the centimetre and gram as basic units by the British Association for the Advancement

of Science in 1873, which led to the CGS system (centimetre, gram, second).

- After circa 1900, the use of metres, kilograms and seconds as basic units (MKS system).
- The incorporation of electrical units between 1933 and 1950 giving metres, kilograms, seconds and amperes as basic units (MKSA system).
- The establishment in 1954 of a rationalised and coherent system of units based on MKSA but also including temperature and light. This was given the title Système International d'Unités which is abbreviated to SI units.

The international discussions which have led to the development of the SI system take place under the auspices of the Conférence Générale des Poids et Mesures (CGPM). The CGPM meet in Paris at intervals of every four to five years.

The United Kingdom has formally adopted the SI system and it will become, as in some 25 countries, the only legal system of measurement. Several European countries, while adopting the SI system, will also retain the old metric system as a legal alternative. The USA has not adopted the SI system.

The SI system is based on the seven basic units given in Table 1.

Table 1 The seven basic units of the SI system

Quantity	Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electricity	ampere	A
temperature	Kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

Degrees Kelvin apply to absolute or thermodynamic temperature; the Celsius scale is customarily used in many contexts. This book uses degrees Kelvin for temperature intervals – the difference between two temperatures. The degree Kelvin and the degree Celsius have the same temperature interval; it is only their datums which differ, 0 °C = 273.15 K. So K and °C are interchangeable when considering temperature intervals.

Besides the basic units, there are two others, given in Table 2. Degrees °, minutes ¢ and seconds ² will also be used as part of the system.

Table 2 The two supplementary units of the SI system

Quantity	Unit	Symbol
plane angle	radian	rad
solid angle	steradian	sr

From these basic and supplementary units the remainder of the units necessary for measurement are derived, for example:

Area is derived from length and breadth, measured in m^2.
- Volume is derived from length, breadth and height, measured in m^3.
- Velocity is derived from length and time, and is measured in m/s.

Some derived units have special symbols and some examples are given in Table 3.

Table 3 Some derived units and their symbols

Quantity	Unit	Symbol	Basic units involved
frequency	hertz	Hz	1 Hz = 1 c/s (1 cycle per second)
force, energy	newton	N	1 N = 1 kg m/s^2
work, quantity of heat	joule	J	1 J = 1 N m
power	watt	W	1 W = 1 J/s
luminous flux	lumen	lm	1 lm = 1 cd sr
illumination	lux	lx	1 lx = 1 lm/m^2

Multiples and submultiples of SI units are all formed in the same way and all are decimally related to the basic units. It is recommended that the factor 1 000 should be consistently employed as the change point from unit to multiple or from one multiple to another. Table 4 gives the names and symbols of the multiples. When using multiples the description or the symbol is combined with the basic SI unit, e.g. kilojoule kJ.

Table 4 The SI system of multiples and submultiples

Factor		Prefix	
		Name	Symbol
one thousand million million	10^{15}	peta	P
one million million	10^{12}	tera	T
one thousand million	10^{9}	giga	G
one million	10^{6}	mega	M
one thousand	10^{3}	kilo	k
one thousandth	10^{-3}	milli	m
one millionth	10^{-6}	micro	μ
one thousand millionth	10^{-9}	nano	n
one million millionth	10^{-12}	pico	p
one thousand million millionth	10^{-15}	femto	f

The kilogram departs from the general SI rule with respect to multiples, being already 1 000 g. Where more than three significant figures are used, it has been United Kingdom practice to group the digits into three and separate the groups with commas.

This could lead to confusion with calculations from other countries where the comma is used as a decimal point. It is recommended, therefore, that groups of three digits should be separated by thin spaces, not commas. In the United Kingdom the decimal point can still, however, be represented by a point either on or above the baseline.

Table 5 Comparison of some commonly used measures in metric and imperial units

Length

1 mile = 1.609 km	1 km = 0.621 mile
1 yard = 0.914 m	1 m = 1.093 yard
1 foot = 305 mm	1 mm = 0.039 inch
1 inch = 25.4 mm	

Area

1 square mile = 2.589 km^2 (259 ha)	1 km^2 = 247.1 acres
1 acre = 4046.86 m^2 (0.404 ha)	1 ha = 2.471 acres
1 $yard^2$ (square yard) = 0.836 m^2	1 m^2 = 1.196 $yard^2$
1 $foot^2$ (square foot) = 0.093 m^2	
1 $inch^2$ (square inch) = 645.16 mm^2 (6.45 cm^2)	1 cm^2 = 0.155 $inch^2$

Volume

1 $yard^3$ (cubic yard) = 0.765 m^3	1 m^3 = 1.308 $yard^3$
1 $foot^3$ (cubic foot) = 0.028 m^3	
1 $inch^3$ (cubic inch) = 16387 mm^3 (16.387 cm^3)	1 cm^3 = 0.061 $inch^3$

Capacity

1 gallon = 4.546 litre	1 litre = 0.220 gallon
1 quart = 1.137 litre	
1 pint = 0.569 litre	

Mass

1 ton = 1.016 tonne (1016 kg)	1 tonne = 0.984 ton
1 cwt (hundredweight) = 50.8 kg	
1 lb (pound) = 0.453 kg	1 kg = 2.205 lb
1 oz (ounce) = 28.35 g	1 g = 0.035 oz

Temperature

32° Fahrenheit = 0° Celsius (freezing point of water)
212° F = 100° C (boiling point of water)

Temperature conversion

Fahrenheit to Celsius: (°F − 32) × 5/9
  e.g. 150° F = 66° C
Celsius to Fahrenheit: (9/5 × °C) + 32
  e.g. 75° C = 167° F
Fahrenheit to Kelvin: (°F + 459.67) × 5/9
  e.g. 212° F
  (212 + 459.67) × 5/9 = 373.15 K
  373.15 K − 273.15 K (absolute zero temperature) = 100 K
  = 100° C

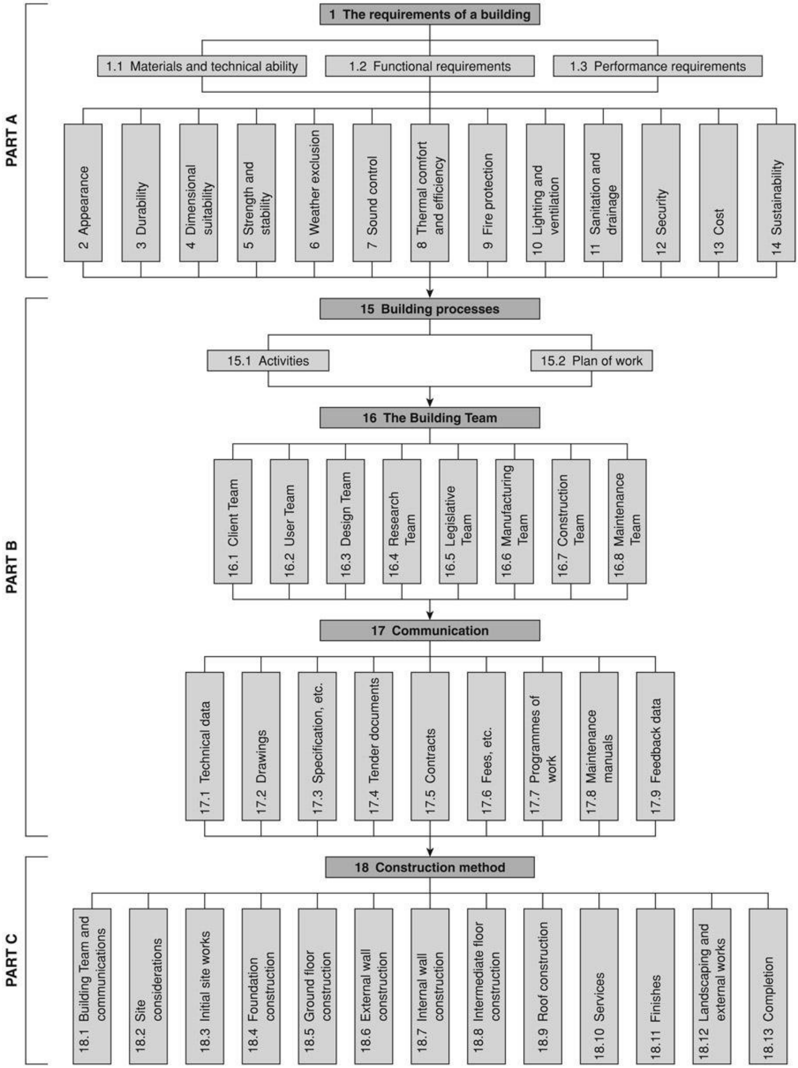
Introduction

This volume is intended for those who are commencing a serious study of the various academic and physical processes which are involved during the creation of a building. It is therefore primarily for students of construction management, building, architecture and interior design. It provides a basic introduction to building; each section is designed to stimulate interest and encourage further reading from the other more advanced volumes of Mitchell's Building Series. Further reading is provided at the end of each chapter, which includes relevant BRE Digests and Information Papers. These can be obtained from the Building Research Establishment's outlet at IHS Rapidoc, Willoughby Road, Bracknell RG12 8DW, or alternatively through the BRE website www.brebookshop.com.

The factors involved in the creation of a building are complicated, numerous and varied. To understand them in detail it would first be necessary to clearly identify each, and, after placing in a sequential order of dependence, provide a thorough analysis of the role they play. This would be an onerous task, since the factors are closely interdependent and generate subfactors which make a structured sequential order somewhat arbitrary. However, as an introduction to the subject, the various factors can be combined and simplified, an order established which relates to purpose and elementary knowledge, and a brief description given to clarify some of the considerations.

The main divisions which have been chosen for this book are as follows:

- Part A is an analysis of a building in terms of what it is expected to do: its function and performance.
- Part B is an analysis of a building in terms of the processes required, the Building Team which implements them, and the methods used for communicating information.
- Part C is an analysis of a building in terms of typical construction methods, the interaction of components and the processes for assembly.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18.10 Services
18.11 Finishes
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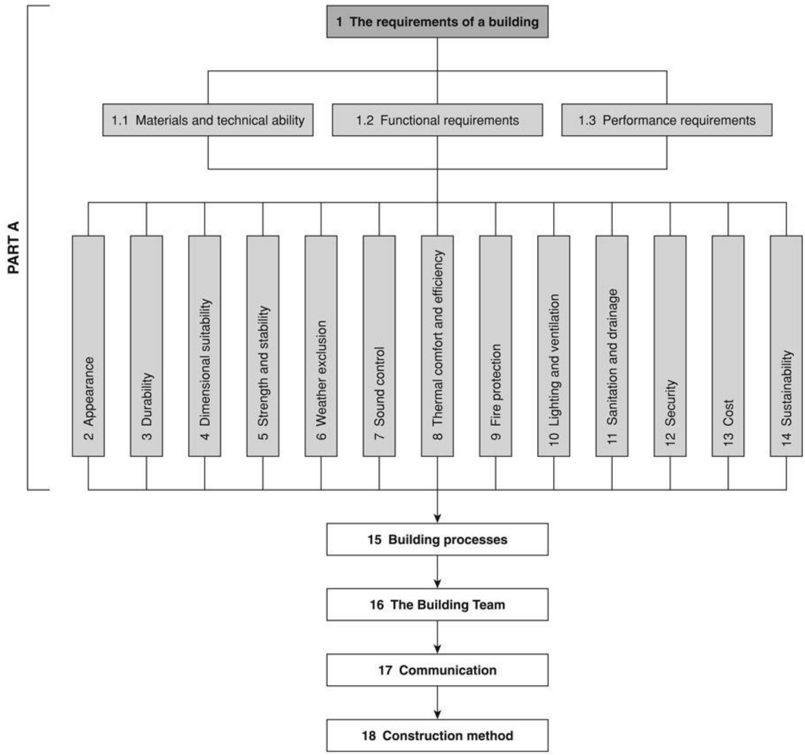
18.13 Completion

Part A
An analysis of a building in terms of what it is expected to do: its function and performance



1 The requirements of a building

CI/SfB (E)/(Y)

1.1 Materials and technical ability

When a building is constructed two main physical resources are involved. These are materials necessary to form the various parts, and technical ability to assemble the parts into an enclosure (Fig. 1.1). Initially, the materials employed were those which could most easily be obtained from the accessible areas of the surface of the earth. The technical ability was mostly simple, having evolved from the convenient methods of economically working the rudimentary characteristics of these available materials. The gradual widening in means of communication and corresponding developments in attitudes led to an increased range of these resources becoming available.

The current uses of particular construction methods no longer need to rely on locally available materials or traditional technical ability. Continued investigation has resulted in the enormous range of materials now becoming available which may be used singly, in combination with one another, or even to form new materials. Technological developments are interrelated with this range and use of materials, and enable virtually anything to be constructed.

Nevertheless, there are certain considerations which have always exerted some control on the indiscriminate use of resources. These controls remain, and now that the range of resources is wider, and attitudes towards the function of a building are more complicated, the selection of appropriate construction method becomes much more difficult. For this reason, it is first necessary to understand precisely what is required of a building before selecting an appropriate method of construction.

1.2 Functional requirements

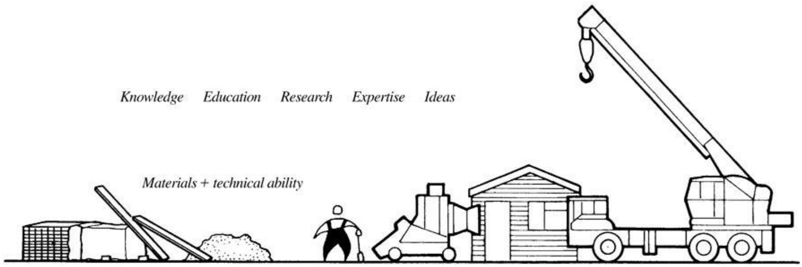


Figure 1.1 Construction method.

Elaborate shelters have been, and still are, made by most species of insects, reptiles and animals capable of using the readily available materials (earth, stones, branches and leaves, etc.) with the aid of the inherent manipulative skills (technology) of their arms, legs, wings, claws, beaks and jaws. Early humans also required shelter which provided security for them, their possessions and activities. However, they developed their inherent manipulative skills by inventing tools which led to less indigenous construction methods and also ways of changing the natural state of materials so that they could be used to greater advantage. Each innovation devised usually resulted in shelters, which, although initially providing a good standard of comfort and convenience, eventually became sub-standard accommodation as requirements became more elaborate. But, regardless of technical developments, the provision of a physically comfortable shelter was not the only or even the principal reason for building. From early times, a building was also required to give an established place of social and religious identity: it must indicate culture, status and mood, while creating the humanised space in which to learn, experience and carry out normal daily functions in comfort.

Sir Henry Wooten, a fifteenth-century humanist who adapted the writings of Vitruvius for his book, The Elements of Architecture (1624), wrote that a good building must satisfy three conditions:

- Commodity: comfortable environment conditions
- Firmness: stability and safety
- Delight: aesthetic and psychological appeal

These functional requirements are implicit in the provision of a shelter which is also a building fit for human habitation. A well-constructed building reflects contemporary attitudes towards environmental control, structural concepts and aesthetic excellence. And the materials and technical ability used throughout history have normally provided the means of achieving these particular ends.

1.3 Performance requirements

A modern building is expected to be a life-support machine (Fig. 1.2). It is required to provide the facilities necessary for human metabolism such as clean air and water, the removal of waste produce, optimum thermal and humidity control, privacy, security and visual/acoustic comfort. It is also required to be a source of self-generating energy for appliances, and provide means for communication with computer, television, telephones and postal services. In addition, a building must be safe from collapse, fire, storm and vermin; resistant to the physical forces of snow, rain, wind and earthquakes, etc.; and capable of adaptation to various functions, external landscaping or internal furniture arrangements. It must also be easily, economically, quickly and well constructed; and allow easy maintenance, alterations and extension as well as having a sustainable form of construction which can be adapted to changing trends and legislative requirements. All this must be accomplished in the context of providing a building which has character and aesthetic appeal.

Criteria of this nature form today's interpretation of the basic functional requirements for a building quoted earlier. In order for them to be conveniently considered, it is necessary to divide a building into the various related duties to be fulfilled and establish the precise performance requirements for each. When these duties are incorporated into a building where the functional requirements have been clearly defined, the selection of a suitable construction method (materials and technology) can be achieved by using the criteria given by the performance requirements under the following headings:

- Appearance
- Durability
- Dimensional suitability
- Strength and stability
- Weather exclusion
- Sound control
- Thermal comfort and efficiency
- Fire protection
- Lighting and ventilation
- Sanitation and drainage
- Security
- Cost
- Sustainability

Performance requirements cannot be placed in order of importance because any one of them may be more critical than another for a particular element of a building. Priority is normally dictated by the precise function and location of a specific building.

The use of these interrelated performance requirements in establishing a building design was instigated many years ago by the then Building Research Station (now Building Research Establishment, see page 156). Although firm principles have now been established, critical factors arise which result in fundamental changes in attitudes towards construction methods. In recent years, one such influence concerns the availability of energy resources for the production of building materials, and for the heating and lighting of buildings.

During the formation of the earth some 5 billion years ago, only a relatively small amount of hydrocarbon atoms were incorporated and these now form our fossil fuels of gas, oil and coal. These fuels have been continuously used in one form or another during the development of humankind and the rate of consumption has increased rapidly over the last 70 years. As a result of this situation, even if the world population were stabilised, the requirements for fuel were static, and the poorer countries remained undeveloped, there would be only another 40 years of gas

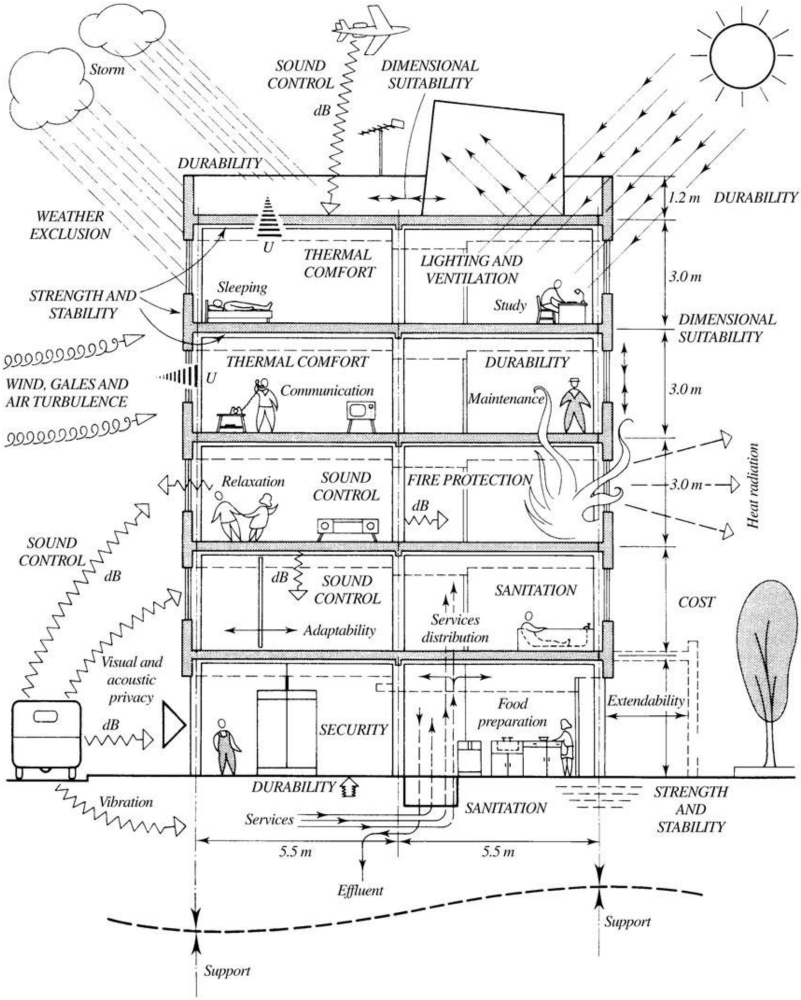


Figure 1.2 Performance requirements for a building.

supply, 25–30 years of oil, and 200–300 years of coal obtainable through easy access. Of the net energy consumed, about 50 per cent is subject to decisions by those involved in the design and construction of buildings (Fig. 1.3).

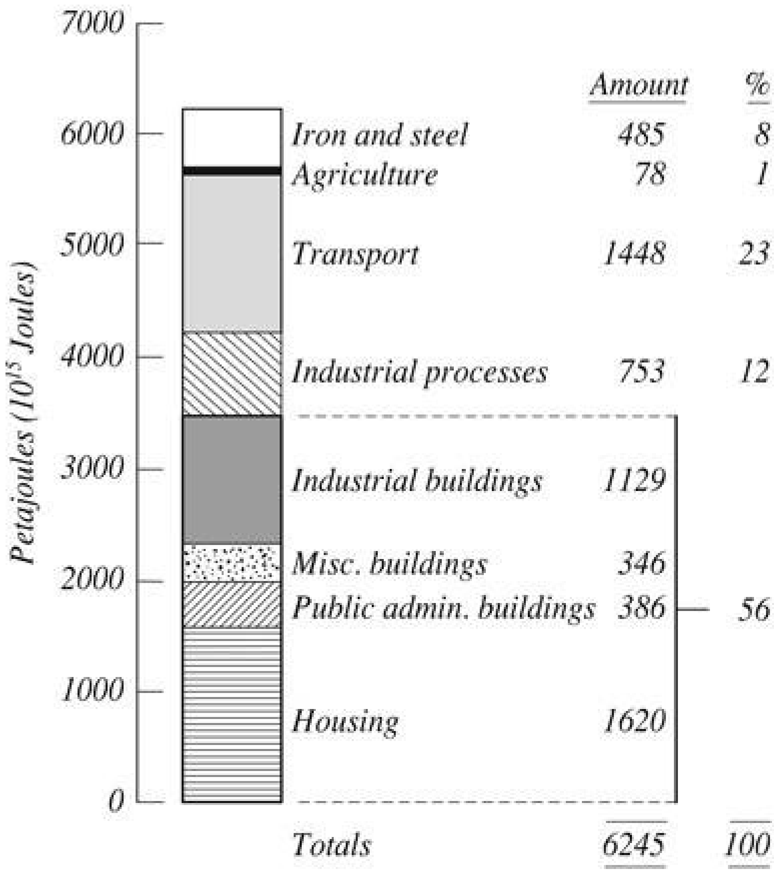


Figure 1.3 Energy consumed by the building industry during the late 20th century. See section 14.5 for comparison with recent data.

Converting our diminishing fuel resources into heat energy creates other problems and responsibilities for control and regulation of the combustion products. The byproducts of combustion and the noxious gases produced contribute to the greenhouse effect and depletion of the ozone layer in the atmosphere. Flue gases from boilers and electricity generating plant produce a blend of pollutants of which carbon dioxide is the most prominent, comprising about 80 per cent of the total. Means for assessing these carbon emissions and for limiting their impact by the creation of sustainable and energy-efficient buildings in the United Kingdom are addressed by the Building Regulations, Approved Document L: Conservation of fuel and power. See Chapters 8 and 14 for more information on this topic.

Constraints on water consumption have also become a responsibility for product manufacturers, building designers and users. In the United Kingdon, water is taken very much for granted, but given the fickle nature of the weather and an increasing population, sufficient supplies are not guaranteed. Over half of all water consumed is used in our houses.

The current need to consider conservation of our limited resources is resulting in new approaches towards the construction and maintenance of buildings. Many prejudices and preconceptions must be shed, and buildings of different appearance from those traditionally accepted could result. This premise will become more pertinent as the commonly used building materials become scarcer, either through gradual reduction in world availability or (more likely) through difficulties in obtaining them from the more remote regions of the earth. Table 1.1 illustrates the rate of annual consumption for certain metals compared with known reserves, and the total natural occurrences beneath the oceans as well as dry land. Although the future of these metals seems guaranteed for many years to come, it will become increasingly difficult and costly to establish the technology to mine in the more inaccessible regions. It is also highly probable that any future winning of these hitherto inaccessible minerals will produce dramatic ecological changes in the earth's surface and atmosphere. Although aggregates and cements for concretes, clays for bricks and timbers are similarly likely to remain in worldwide abundance for many years, their retrieval for conversion into building materials is becoming limited by environmental conservation issues. On a positive note as far as timber is concerned, worldwide attempts are being made to reduce indiscriminate deforestation, particularly the equatorial rain forests. Efforts are also being made to replenish the already depleted timber stocks in Europe through replanting, and in future timber may well become the critical building material.

Table 1.1 Mineral content of oceans and the earth's crust related to present consumption (million tonnes)

Metal	Known reserves	Current annual consumption	Total natural occurrence in oceans, including the seabed	Total natural occurrence in the first mile of the earth's crust (under dry land)
Aluminium	4 250	12	15 500	138 244 000 000
Copper	364	8	4 650	119 000 000
Iron	109 000	700	12 400	84 630 000 000
Lead	94	4	465	27 400 000
Nickel	90	0.5	3 100	135 960 000
Tin	4.4	0.25	4 650	67 760 000
Zinc	306	4.5	15 500	224 000 000

Nevertheless, the development of substitutes for the traditional building materials is likely to increase and these will cause people to reassess construction methods. These changes will be paralleled by changes in the performance requirements for the whole building. Research and development is continually taking place in these areas, and it is the duty of those involved in the design and erection of buildings to be aware of current trends. The achievement of this knowledge cannot be solely through any published building law or contemporary code of good practice, as by the time they have been established other discoveries and experiences may already have taken place.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 1 Environmental factors
Structure and Fabric Part 1	Chapter 1 The nature of buildings and building

Building Research Establishment

Principles of Modern Building	Vols 1 and 2, The Stationery Office
Information Paper 8/97	Water conservation (2 parts)
Information Paper 15/98	Water conservation
Information Paper 2/00	Water conservation: low flow showers and flow restrictors
Information Paper 16/05	Domestic energy use and carbon emissions: scenarios to 2050

Department for Communities and Local Government (DCLG)

Code for Sustainable Homes

Water Regulations Advisory Scheme (WRAS)

The Water Supply (Water Fittings) Regulations 1999, The Stationery Office

2
Appearance

CI/SfB (G)

The appearance of a building is initially determined by the activities to be accommodated, as these strongly influence the scale and proportion of the overall volumetric composition (Fig. 2.1). The shapes of the individual spaces forming the collective volume are defined by 'boundaries' which become the walls, floors, roofs, etc. These are ultimately required to conform with precise aesthetic and technical criteria, and the materials employed for these purposes are as numerous and varied as the methods which can be adopted for their use. However, the underlying principle remains that both aesthetic and technical criteria are affected by the composition, form, shape, texture, colour and position of the materials employed. To this must be added the skill with which they are placed in a building and the cost, since these factors often provide a deciding role.

2.1 Aesthetic aims or fashions

In a well-designed building, appearance is the reflection of a balance between aesthetic aims or fashions and the construction method derived from the desire for optimum environmental control, structural stability and logical techniques of instigation. Building designers of an earlier and simpler time than today had available only a comparatively limited choice of technical resources which, through the influences of sociocultural attitudes, led to particular ‘styles’ in the appearance of buildings. In contrast, the current range of resources, more complicated performance requirements and widening of cultural influences have created multifarious ‘styles’. Some of these evolve from an overwhelming bias towards ‘high technology’ and the absolute economies of industrial forms. However, if technology is allowed to dominate the aesthetics of a building without compromise, there is a loss of human understanding, scale and proportion and, perhaps, colour, form and texture. By way of comparison, some ‘styles’ endeavour to imitate the psychological appeal associated with the less complicated requirements of the past. Sometimes this may be done on the premise that a building of today, with its highly technological requirements, is beyond our aesthetic comprehension. The technological advantages may be accepted, but they are combined with efforts which deny their visual influences as well as reducing their performance efficiency.

A building design will invariably be unsuccessful if it relies purely on technology for aesthetic appeal, or purely on outmoded conventions of a past era. A skilful building designer, whatever his or her aesthetic leanings, resolves conflicts through detailed understanding and sympathetic consideration of all the performance requirements. None must be ignored or denigrated.

2.2 Relationship to other performance requirements

Although appearance is only an aspect of the total aesthetic quality, it is generally the one on which most first impressions of a building are formed. The majority of users have definitive ideas about what a building should look like and, apart from rules concerning 'correctness', their satisfaction or otherwise may be entirely subjective. In this respect, therefore, the requirement for 'appearance' to some extent contrasts with other performance requirements, although from a designer's viewpoint it is the factor which unites them all.

For this reason, reference is made in most of the chapters of the book to the effects on appearance arising

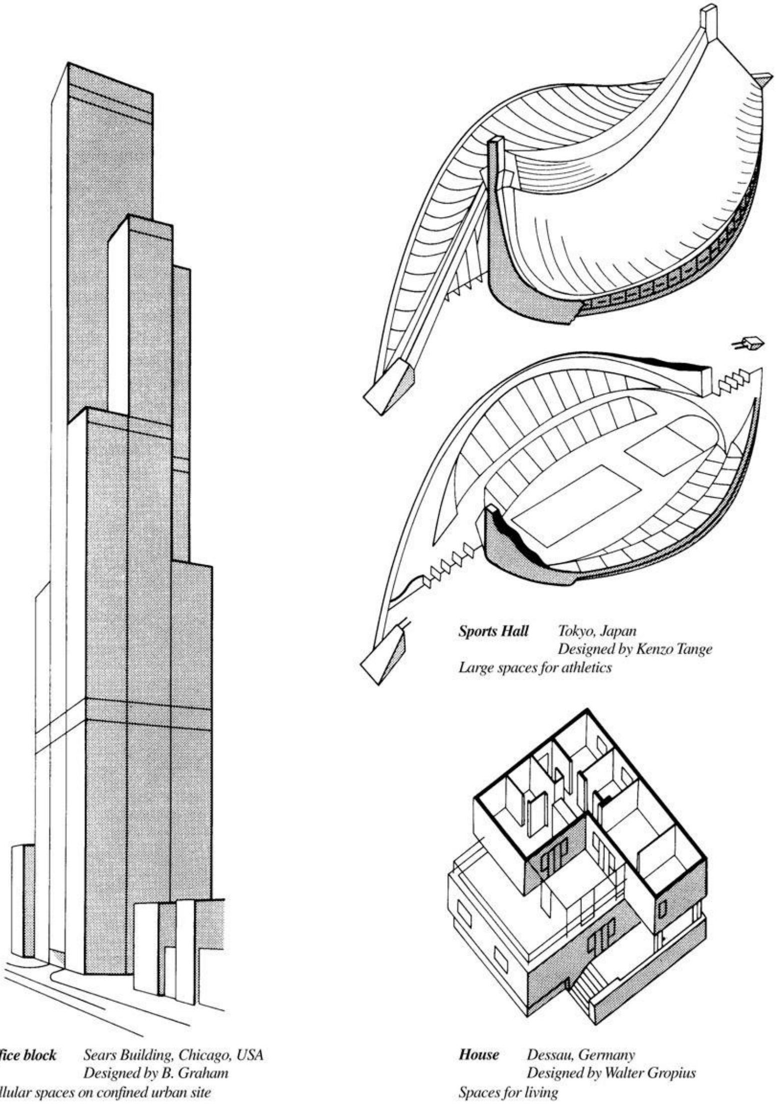


Figure 2.1 Effect of building function on appearance. (Adapted from material in Great Architecture of the World, published by Mitchell Beazley)

from decisions about other performance requirements. This serves in reinforcing the view that appearance and function are inseparable in a building, although the degree to which this may be recognised depends upon the skill of the designer. Even certain forms of 'decorative motif' may be based on a requirement to provide solar shading devices, or perhaps even form the structural tie between two separated flank walls. The appearance of a modern building should not rely on 'functional' or 'decorated functional' aspects alone. Properly controlled and sensitively located non-functional items (in terms of technical performance) – decorations, murals and sculptures – can be incorporated as an essential part of the overall aesthetic achieved by a building.

Some of the basic areas of consideration affecting the appearance of a building, both externally and internally, are as follows:

- The aesthetic objectives of the designer in terms of preferred form, shape, pattern, texture and colour, etc.
- The effects of location and siting on the design and construction methods adopted with particular reference to local planning guidelines, building bylaws, regulations and other relevant legislation.
- The design as part of the larger composition of the area – harmony with adjacent buildings and/or specific features, including landscaping.
- The 'viewing distances' applicable to the design.
- The use of a particular structural organisation.
- The use of materials that are suitable for particular applications which enhance, modify or even change the appearance of the design as it ages.

- The relationship of window and door openings, and the creation of a rhythm in the design.
- Architectural detailing used to reinforce the character required by the design and location, e.g. the use of particular types of window/door lintel construction, the creation of shade and shadows through location of components.
- The positioning of ductwork, service pipes, etc., and their contribution towards aesthetic character.
- The effects of maintenance on the initial design and subsequent use of a building (see section 2.3).

It is important that the aesthetic achieved by the smaller parts of a building is a reflection of the same design philosophy applied to its larger parts. The whole building, internally and externally (including approaches and landscaping), should display a similar character, taste, interest, wealth and aspiration. If sympathetically conceived and constructed, a homogeneous environment is created which is understandable to users, establishes interest, and develops taste for good design and construction generally.

2.3 Weathering and maintenance

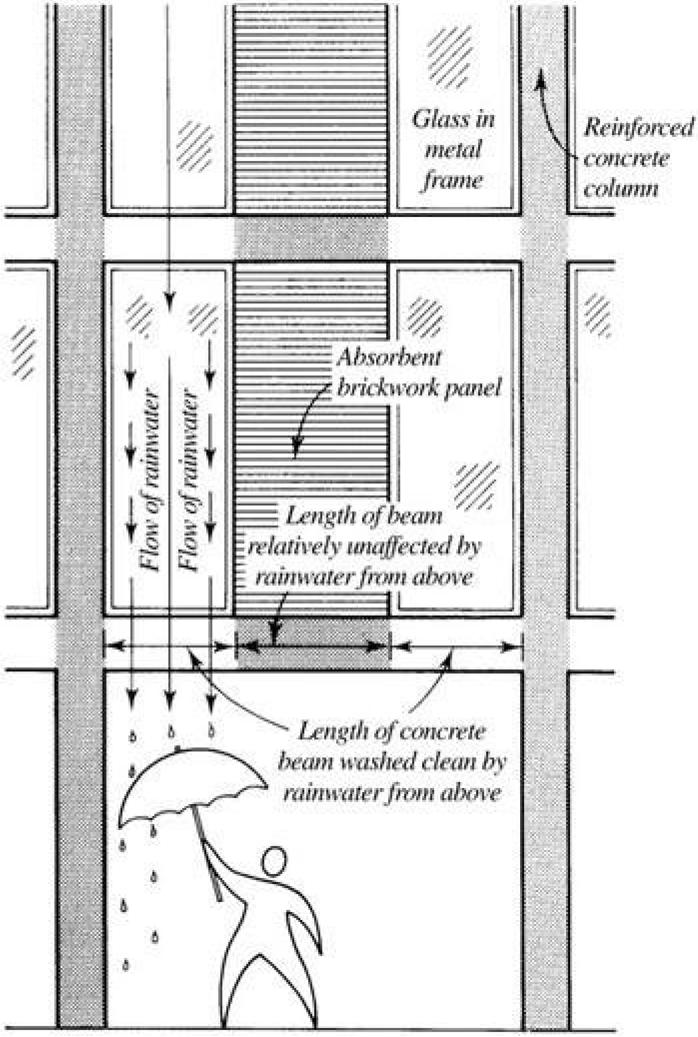


Figure 2.2 Effect of weathering on the appearance of a building.

More specific reference must be made about the necessity to anticipate the effects of future weathering and maintenance on the appearance of a building. Well designed and constructed, a building should accommodate the progress of time without causing a lessening of any functional requirement (see Chapter 3). Furthermore, the inevitable effects of weathering should make a positive rather than a negative contribution to the appearance of a building. This relies on carefully detailed constructional solutions which derive from a thorough understanding of the behaviour of materials to be used in a particular manner. Figure 2.2 illustrates a common design 'fault' which has marred the appearance of a building. The impermeable glass and metal frame surface within the opening between brick panels allows water to be caught, then to run over and clean the concrete beam immediately below. A lesser amount of rainwater will flow over the part of the beam occurring below the brick panels because of the greater absorption properties of the bricks. The result is a striped staining of
the concrete beam, which changes the appearance of the building in a manner presumably never intended by the designer. The provision of an adequate sill and drip below the opening to prevent the free flow of water over the beam face would have helped to overcome this problem. Alternatively, a continuous gutter could have been provided along the top of the beam, or the beam faced with a material less susceptible to staining.

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 1 The nature of buildings and building

Building Research Establishment

Digest 420 *Selecting natural building stones*
Digest 429 *Timbers: their natural durability and resistance to preservative treatment*
Digest 440 *Weathering of white external PVC-U*
Digest 446 *Assessing environmental impact of construction*
Digest 448 *Cleaning buildings: legislation and good practice*
Digest 449 *Cleaning exterior masonry* (2 parts)
Digest 460 *Bricks, blocks and masonry made from aggregate concrete* (2 parts)
Digest 494 *Using UK-grown Douglas fir and larch timber for external cladding*
Digest 500 *Using UK-grown Sitka spruce for exterior cladding*
Digest 503 *External timber structures: preservative treatment and durability*
Digest 508 *Conservation and cleaning of masonry* (2 parts)
Good Repair Guide 27 *Cleaning external walls of buildings* (2 parts)

3
Durability

CI/SfB (R8)

Apart from daily wear and tear by its users, a building is subjected to the constant influences of climate (wind, rain, snow, hail, sleet, sunlight), perhaps attack from vandals and vermin, or even damage by fire, explosions and structural movements. Both the inside and the outside of all buildings are therefore subject to forces which can cause deterioration during their life. Durability is the measure of the rate of deterioration resulting from these and other forces.

3.1 Changes in appearance

When related to external climatic or environmental factors, the durability aspects of a building are known as weathering. The action of frost, temperature variations, wind and rain on the materials of a building can cause changes in appearance by gradual erosion and/or the transportation of atmospheric pollutants which cause staining. Unless the building is carefully designed and detailed, these visual changes seldom enhance appearance and therefore produce disfiguration. The degree to which a building will suffer from erosion and/or staining depends upon many interacting variables. One involves the relationship between type and amount of atmospheric pollution with the exposure of a building to wind, rain, frost, snow and solar radiation. Their effects will be determined by the characteristics of the materials used in a building and include their capacity or otherwise for moisture absorption, as well as their surface profiles, orientation, texture and colour.

In an urban situation it is normal to see dark bands of staining below most horizontal projections (mouldings and sills, etc.) of a surface-permeable masonry wall. These projections provide a shield against direct rainfall or rainfall run-off from above, and dirt deposits are therefore left relatively undisturbed when compared with the lower regions of the wall (see also examples in Fig. 2.2). It is interesting to note that the design of projected mouldings for buildings of the past generally ensured an even weathering to the surrounding vertical surfaces. Nevertheless, although today's buildings are often devoid of mouldings and decorative devices, it is possible for designers to allow water to be guided down a specific route by means of ribbed projections or recessed grooves, and therefore to create 'controlled' areas of weathering which enhance rather than detract from the appearance of the building. Porous surfaces may accumulate dirt and dust, vertical surfaces stain according to roughness and absorptivity, surface colour affects visual density of staining, but carefully detailed designs can also use these properties to advantage.

It is first necessary to establish the degree of climatic exposure which is likely to affect a building (see Chapter 6). Generally, disfiguration will be slight where there is a moderate rainfall and a moderate rate of pollution, and constructional detailing needs to be far less 'bold' than for areas suffering greater amounts of rainfall and pollution. However, freak weather conditions can result from a group of tall buildings which create a weather pattern between them contrary to accepted predictions. Also, as buildings receive more direct rainfall on their upper storeys, high buildings are generally cleaner at the top and dirtier towards the lower storeys. This is caused by dust being washed down the face of the building and being retained at the point where the porosity of the surface absorbs (or constructional detailing collects and channels) a major part of the water. Low buildings, lacking exposure, will obtain an overall covering of pollution which will be unrelieved by washing. This is preferable to the random streaking to be seen on elevations which are subject to strong dust accumulation and which do not receive direct rainfall in sufficient quantity to provide overall cleansing.

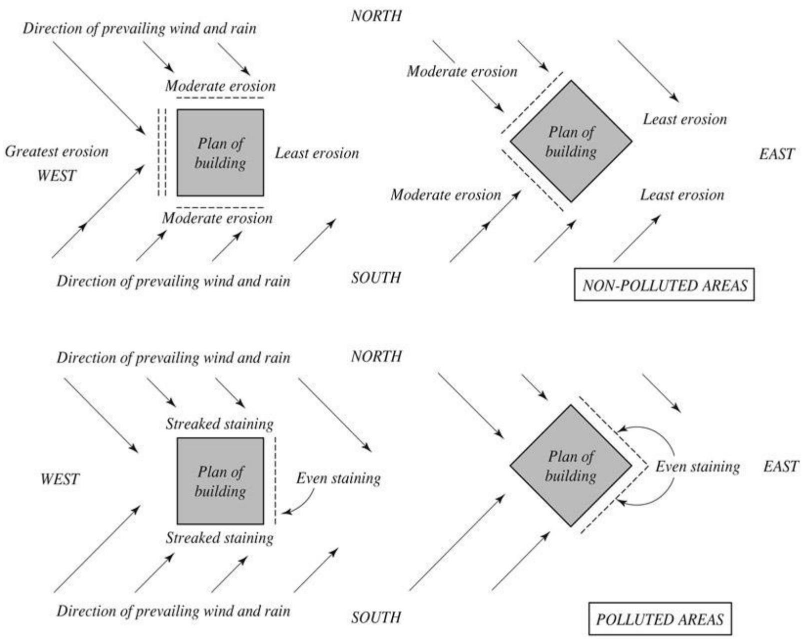


Figure 3.1 Effects of south-west and north-west rain-carrying winds on a building.

The prevailing rain-carrying winds in the British Isles blow mainly from the south-west and the north-west quarters (Fig. 3.1). In non-polluted areas the rain will be clean and will wash the building down. In polluted areas the rain will absorb the dust in the air and thus will be dirty when striking the surface. It will also carry dirt from the upper surface to the lower surface and cause staining. Southwest and north-west aspects of buildings will generally remain cleaner than the south-east and north-east aspects. North and north-east aspects are particularly liable to severe accumulation of dirt. Thus for a building to be cleaned the volume of clean rainwater must exceed the volume of dirty water passing over the surface. Snow has no beneficial cleaning effect.

3.2 Physical deterioration

Apart from causing the staining of a building, certain forms of weathering also result in chemical actions which cause physical deterioration by decay. From the time they are placed on a building site, all materials commence on a path of deterioration which could continue after a building has been constructed until a point is reached when they are not fulfilling a useful purpose. Again, the precise form of attack depends upon exposure conditions, and on the susceptibility of the materials used. (For further comment see section 3.1.) Corrosion, erosion and disintegration of materials and construction details can follow from the effects of changes in moisture content, frost, sunlight, soil and groundwater action, atmospheric gases, electrolytic action, fungal and insect attack, or domestic and industrial wastes, etc. Critical conditions are influenced by the selection of materials appropriate for their design function, detailing for their application, and the skilfulness of their installation. These provide the 'control' on the extent to which deterioration and decay may be allowed over a given period of time.

The durability factors concerned with the effects of fire, explosions and structural movements will be mentioned under the appropriate performance requirement to follow.

The problems of daily wear and tear by the users, and attack from vermin, vandals and burglars, also form an important part of the design criteria for the building. All involve the careful selection of appropriate materials and functional detailing as well as thoughtful overall planning which will lessen the likelihood of their occurrence.

3.3 Intended life span

Ideally, a chosen design and construction method should be able to resist all detrimental effects and provide prolonged durability. As economic considerations make this impossible, the selection of materials and assembly technique for a design should be made to ensure that their rate of deterioration will not impair the functional performance of a building, including appearance, during its intended life span. This period is difficult to quantify, so selection processes are generally influenced by an interrelationship between initial costs of materials and likely future maintenance costs. When deciding, it should be remembered that maintenance costs include not only labour and materials for renovation and for cleaning, but also sometimes financial losses resulting from the temporary curtailment of trade or business by the building owner or tenants while remedial work is being executed. Furthermore, where access for maintenance is difficult because of design detailing, consideration must be given to the cost of hiring scaffolding, special plant or even the provision of permanent gantries, mobile or otherwise. Gantries can form a dominant feature of the external or internal appearance of a building.

The degree to which subsequent maintenance of a building is possible, desirable or necessary provides the 'fine tuning' which assists in achieving an optimum design in terms of initial running and future costs. A designer must be expert in the choice of materials, or carry out necessary research into their physical and chemical properties, before devising construction techniques which will take full advantage of their potentialities. Continually rising costs are forcing serious consideration of designing buildings to give a guaranteed, but limited life span (limit state design). In this way, the life of a building is predetermined by quantifiable characteristics, including predictability of certain detrimental influences. For example, it would be unnecessarily costly to incorporate an earthquake-resisting structure in a building with an intended useful life of 20 years if the earthquake 'cycle' where the building is to be erected does not fall within this period. If available, the money saved by not using elaborate structural solutions can be effectively used on materials and constructional details with guaranteed performance requirements during the 20-year life of the building.

This approach can be extended to the statistical analysis of freak wind turbulences and amounts of rainfall in otherwise predictable climatic regions. However, financial savings in capital costs of construction methods (materials and technology) can only be made after thorough study and research have revealed the precise degree of durability achievable and therefore the life span of a building with minimal maintenance.

Further specific reading

Mitchell's Building Series

Environment and Services Chapter 2 Moisture

Building Research Establishment

Digest 217 *Wall cladding defects and their diagnosis*
Digest 251 *Assessment of damage in low-rise buildings*
Digest 268 *Common defects in low-rise traditional housing*
Digest 299 *Dry rot: its recognition and control*
Digest 330 *Alkali-silica reactions in concrete* (4 parts)
Digest 345 *Wet rots: recognition and control*
Digest 390 *Wind around tall buildings*
Digest 403 *Damage to structures from ground-borne vibration*
Digest 405 *Carbonation of concrete and its effect on durability*
Digest 406 *Wind actions on buildings and structures*
Digest 415 *Reducing the risk of pest infestations in buildings*
Digest 418 *Bird, bee and plant damage to buildings*
Digest 420 *Selecting natural building stones*
Digest 429 *Timbers: their natural durability and resistance to preservative treatment*

Digest 434 *Corrosion of reinforcement in concrete: electrochemical monitoring*
Digest 436 *Wind loading* (3 parts)
Digest 443 *Termites and UK buildings*
Digest 444 *Corrosion of steel in concrete* (3 parts)
Digest 455 *Corrosion of steel in concrete: service life design and prediction*
Digest 489 *Wind loads on roof-based photovoltaic systems*
Digest 491 *Corrosion of steel in concrete: a review of the effect of humidity*
Information Paper 8/00 *Durability of pre-cast high alumina cement concrete in buildings*
Information Paper 20/00 *Accelerated carbonation testing of concrete*
Information Paper 14/01 *Durability of timber in ground contact*
Information Paper 1/02 *Minimising the risk of alkali–silica reaction: alternative methods*
Information Paper 4/03 *Deterioration of cement-based building materials: lessons learnt*
Information Paper 9/07 *Performance-based intervention for durable concrete repairs*
Special Digest 1 *Concrete in aggressive ground*
Special Digest 3 *HAC concrete in the UK: assessment, durability management, maintenance and refurbishment*
Special Digest 5 *Wind loads on unclad structures*

Building Regulations

Regulation 7 Materials and workmanship

4
Dimensional suitability

CI/SfB (F4)

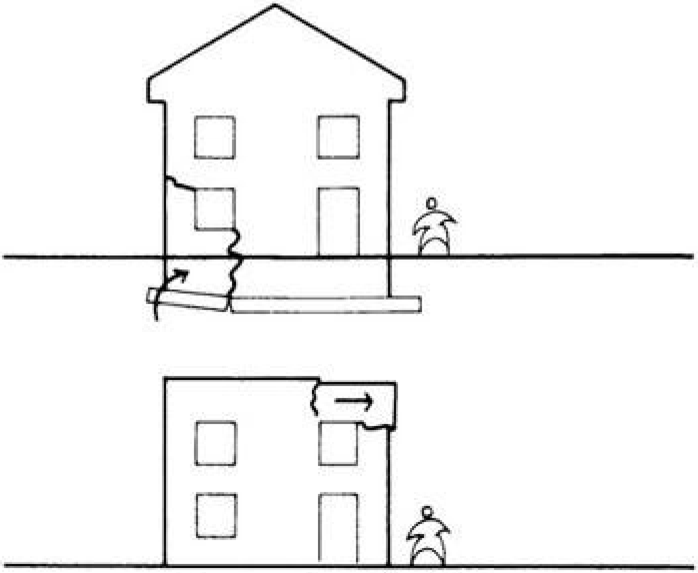
The dimensional suitability of a construction method involves the consideration of two areas:

- The manner in which movement of materials causes dimensional variations in a building, or parts of a building during its life.
- Appropriate sizes for the parts of a building which suit the materials available to fulfil specific design functions, cost ratios, manufacturing processes and assembly techniques.

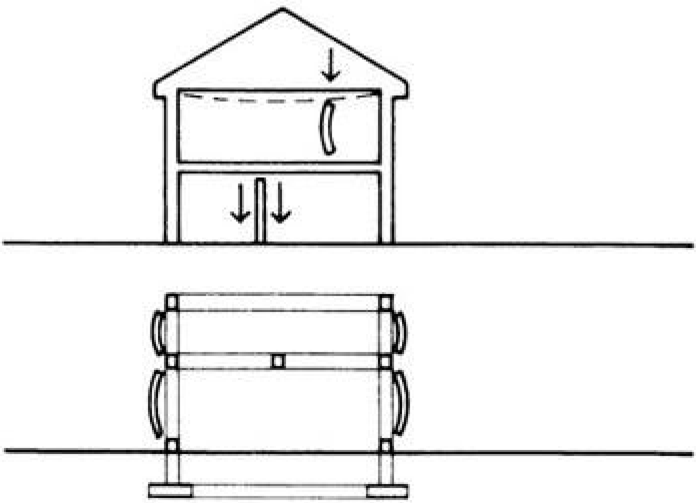
4.1 Movement

A building never remains inert; this is because changes in the environment and/or changes in loading cause dimensional changes in the building materials. Variations in moisture content and temperature produce movements in a building which tend to occur in relation to the stronger 'fixed points' in the building – between foundations and first floor, between top floor and roof, between partitions and main structure, or between panels and supporting frames (Fig. 4.1).

4.2 Irreversible and reversible movement



Movements due to effect of moisture and/or temperature change



Movements due to effects of loading

Figure 4.1 Typical movements likely to occur in a building.

The moisture content of porous building materials can cause irreversible movement or reversible movement. Irreversible movement is generally associated with establishing a 'normal' or atmospheric moisture level in the materials of a component which have recently been manufactured. For example, clay bricks leaving a kiln will be very dry and will immediately begin to absorb moisture from the air which causes expansion. Conversely, calcium silicate bricks will be more saturated than normal bricks because they are cured by autoclave processes and will
immediately shrink after manufacture as their moisture content moves towards an equilibrium with that of the atmosphere. For this reason, newly manufactured bricks should not be immediately used for building walls as cracking will inevitably occur (Fig. 4.2). Reversible moisture movement occurs in materials which are in use and generally involves expansion on wetting and shrinkage on drying. These movements have both immediate and long-term effects on the fabric of a building and thoughtful detailing is essential if damage is to be avoided. Care must be taken to ensure movements are reduced to acceptable amounts by limiting the uninterrupted heights and lengths of components and elements. This can be achieved through a precise knowledge of the characteristics of the materials involved and the incorporation of movement joints at centres beyond which excessive movement is likely to occur (Fig. 4.3). These movement joints should be positioned so as to take account of their visual effect on a building. It is important not to confuse changes in the size of materials due to absorption of moisture with the problems associated with moisture movement

through materials. Movement through materials will be dealt with in Chapter 6.

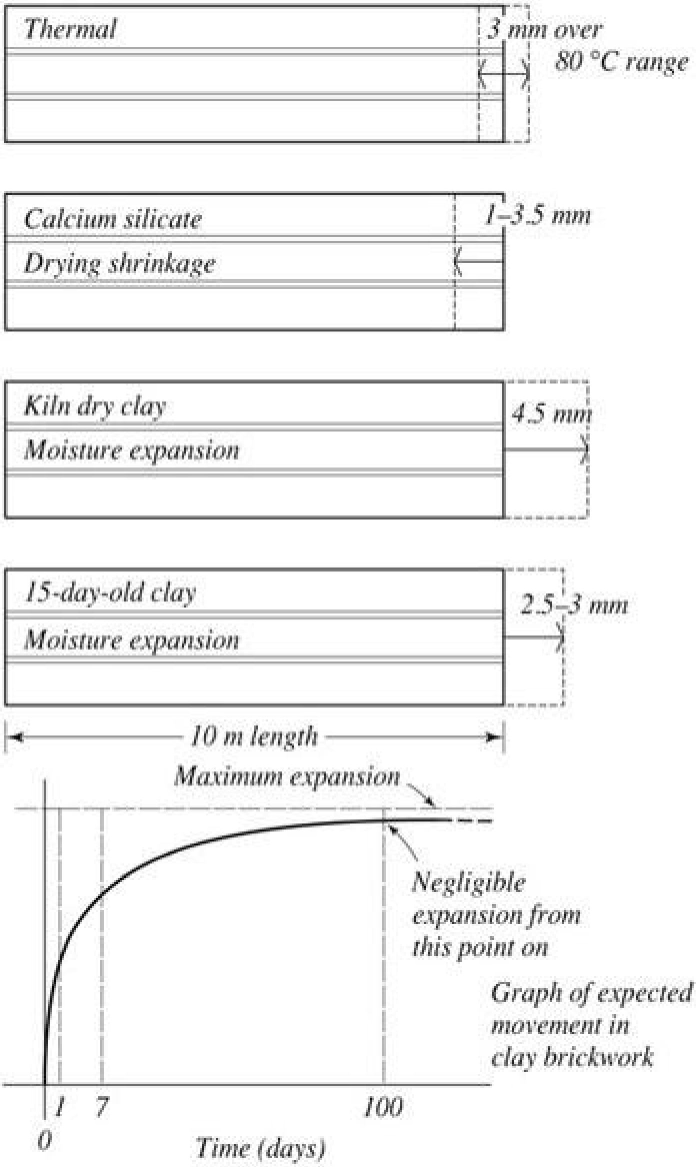

Thermal
3 mm over
80 °C range
Calcium silicate
Drying shrinkage
1–3.5 mm
Kiln dry clay
Moisture expansion
4.5 mm
15-day-old clay
Moisture expansion
2.5–3 mm
10 m length
Maximum expansion
Negligible
expansion from
this point on
Graph of expected
movement in
clay brickwork
0
1
7
100
Time (days)

Figure 4.2 Moisture and thermal movements in calcium silicate and clay brick walls. (Based on data provided by the Brick Development Association)

Most building materials also expand to a greater or lesser extent with rises in temperature, and if they are restrained could induce considerable stress, producing cracking, bowing, buckling or other forms of deformation. Severe damage to walls can be caused by attempting to restrain beams and slabs – particularly where temperature ranges are likely to be great. Fortunately, dramatic failures of this nature are not very common. But daily (diurnal) temperature ranges are a frequent cause of damage to a building; this can occur immediately in the form of buckling metal sills, cracking glass, etc., or over a period by causing gaps in a weather-impermeable construction which allows the free penetration of moisture. The same care needed in constructional detailing and the provision of movement joints, which is required to limit moisture movements, is also necessary when considering thermal movements. In fact, both problems are often interrelated. In general terms, irreversible moisture movement in porous building materials is greater than reversible movement, and reversible moisture movement is usually less than movement due to temperature changes.

4.3 Softening and freezing

Detrimental effects resulting from temperature changes are also caused as a result of softening and of freezing. The majority of materials used for a building will not become softened by normal climatic temperature. However, those containing bituminous or coal tar pitch (e.g. asphalt and bituminous felts used for roofs, floor finishes, damp-proof courses, etc.) are liable to become more and more plastic as temperatures rise. This can produce indentation and perforation under load, or result in elongation causing their displacement. A bituminous damp-proof course can soften sufficiently for the load of a wall above to squeeze it outwards from its bedding and even upset the stability of the wall. This problem is most likely to occur on exposed south-facing walls.

Freezing causes a rather special form of thermal movement and, in this respect, is not dissimilar from the chemical attack described in Chapter 3. Sometimes water may penetrate into a structure and freeze along a junction between two materials. In forming ice lenses, the water expands by about 10 per cent and causes considerable damage. Water freezing in air pockets or other fissures in the mortar of brickwork can cause spalling of the joint and the adjoining arrises of brickwork. If the water freezes within the body of a material, a similar disintegration process will occur. A clear understanding is required about

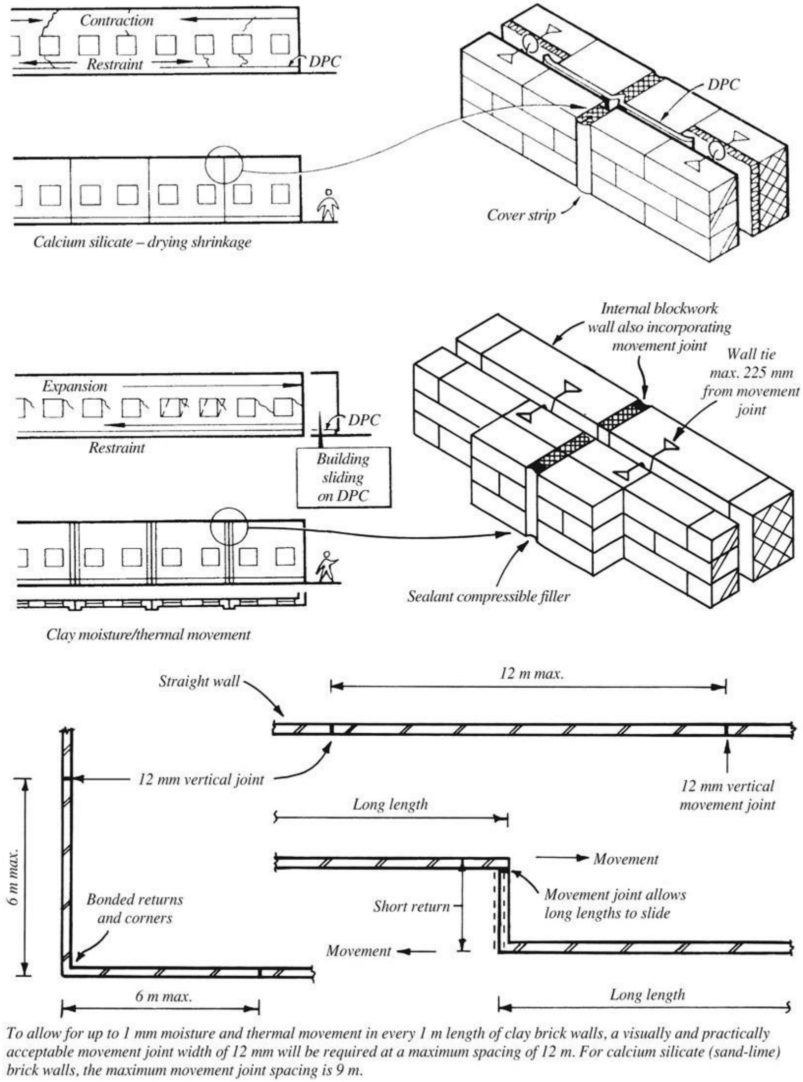


Figure 4.3 Moisture and thermal movements in brick walls.

the ratio between amount of water absorbed and the volume and distribution of pore space available if this phenomenon is to be avoided. The presence of moisture in certain materials, even in very minute quantities, can produce chemical changes that lead to movement. The corrosion processes of iron and steel form a porous layer of rust, which becomes liable to expansion. This action can cause spalling of the concrete cover when the metal bars of reinforced concrete beams become rusted.

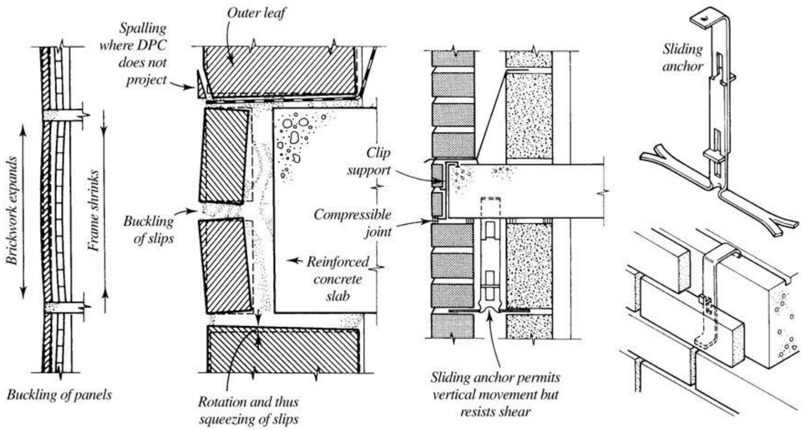


Figure 4.4 Movement joints to panel walls. (Based on data provided by the Brick Development Association)

4.4 Shrinkage

By way of contrast, the chemical action for setting Portland cement produces a volumetric shrinkage. Constructional detailing should take this into account by allowing adequate gaps or tolerances between in situ concrete components and other materials. This is particularly true when detailing the junction between an in situ concrete frame and a brick infill panel, which is liable to expansion due to moisture absorption and climatic temperature increases (Fig. 4.4).

4.5 Loading

As most materials used for buildings are elastic to some degree, a certain amount of plastic flow or creep will occur over a period of many years, depending upon the type and amount of load or force to which they are subjected. Regardless of this long-term movement, however, structural elements such as beams and columns of any material are likely to be subject to initial deflection. This will occur even as their superimposed loads accumulate during construction and will continue until full loading conditions are achieved. Construction methods should take into account the possibility of these movements by ensuring adequate tolerances between structural and non-structural parts of a building to avoid the effects of crushing and cracking. For example, the details for an internal partition of a framed building should ensure that the performance requirements (particularly strength and stability) are not negated by any deflection inherent in the nature of the materials from which beams and columns are formed (Fig. 4.5). If the tendency towards deflection or creep becomes too great in the external fabric of a building, secondary problems could develop from moisture penetration through cracks, etc. Similar problems may arise if a supporting or loading condition of a building is altered and the new conditions cannot be accommodated by the existing construction methods.

4.6 Appropriate sizes

Even the simplest form of building requires thousands of individual components for its construction (Fig. 4.6). With traditional building practice, these products were completely unrelated in dimension and necessitated the use of skilled workers to scribe, cut, fill, lap and fit them together on the site. Such techniques were notoriously wasteful of both materials and labour. In order to make a building financially viable today, it is necessary that products are manufactured to sizes which coordinate with each other

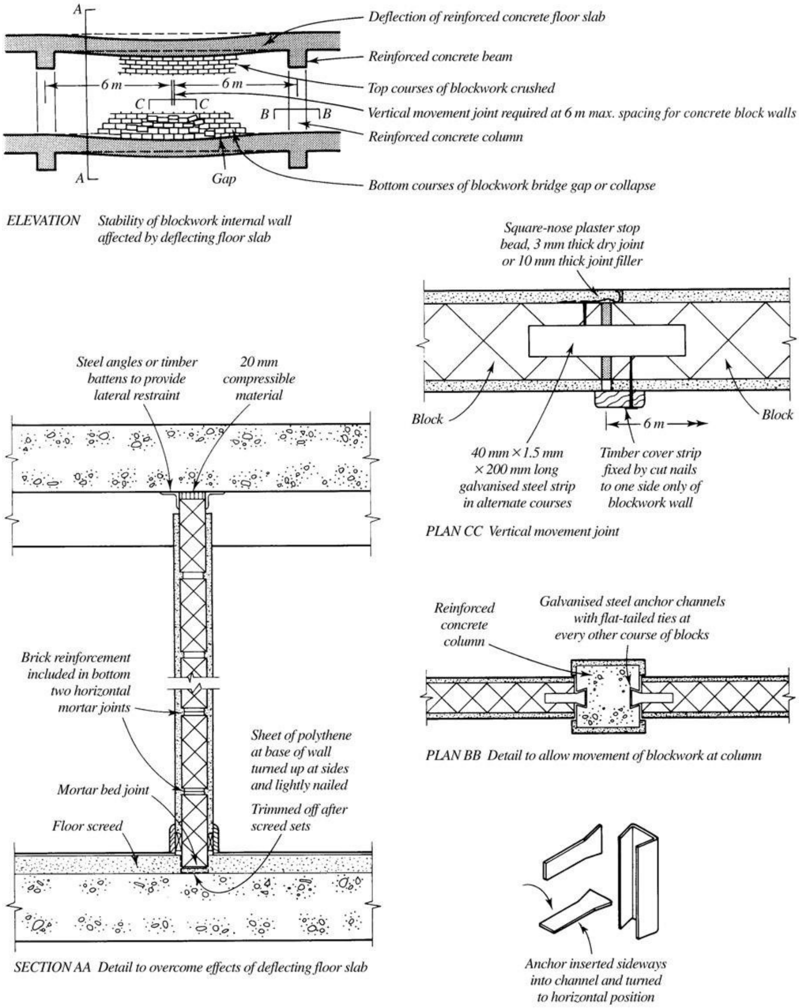


Figure 4.5 Deflection of reinforced concrete beams and the stability of non-load-bearing blockwork internal wall.

so they can be assembled on site without the need for alteration. This means that the role of the manufacturers becomes much more important as they must ensure the overall dimensions between various products coordinate, and ensure jointing methods between each allow connection with other related products. Products which can be easily assembled together using simple jointing methods are theoretically likely to be less reliant on exacting site skills to fulfil their intended functions. However, in practice, the ease and success of the joint again relies on adequate interpretation by the manufacturer of all performance requirements, labour skills and actual site conditions.

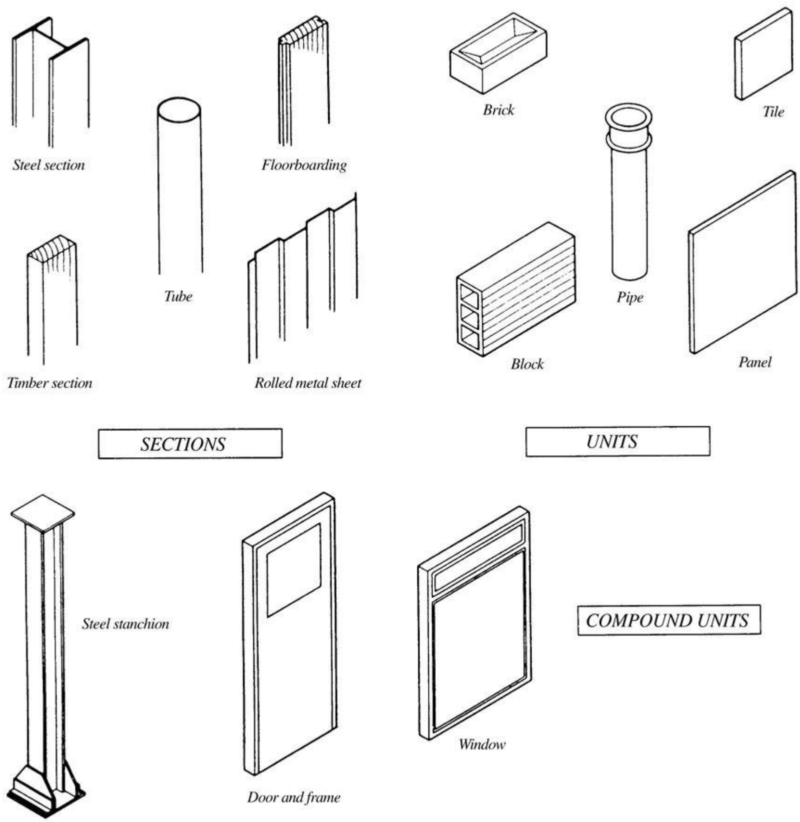


Figure 4.6 Component types.

4.7 Dimensional coordination

Apart from providing savings in materials and labour, the use of dimensionally coordinated products for a building eases the processes of selection by allowing a greater range of similar items to be available (Fig. 4.7). In addition to the availability of home-based products, a designer can select from those abroad, providing they follow the same system of dimensional coordination (see section 16.6).

Many of the sizes of basic building materials used today derive through history and are directly related to the human scale (anthropometrics – see Chapter 12). The clay brick, for example, was dimensionally standardised during medieval times relative to its weight, so as to enable easy manipulation by one hand, leaving the other hand free to operate a trowel. This standard size, now translated to 215 mm × 102.5 mm × 65 mm (BS EN 771–1: Specification for masonry units. Clay masonry units), has given rise to the conventional aesthetic of a brick-built building. When used in large quantities, the bricks, together with their joints and the bonding method, determine the scale and proportion of the overall shape and thickness of the walls, as well as the size of window and door openings, etc. Provided the window and door components are manufactured to be fitted into an opening formed by the brick dimensions without adjustment, the building shell can be constructed easily and economically. Similarly, internal partition units, floor joists, cupboards, floor and wall finishes should also be available in dimensions suitable to those of brickwork; see section 18.7.1.

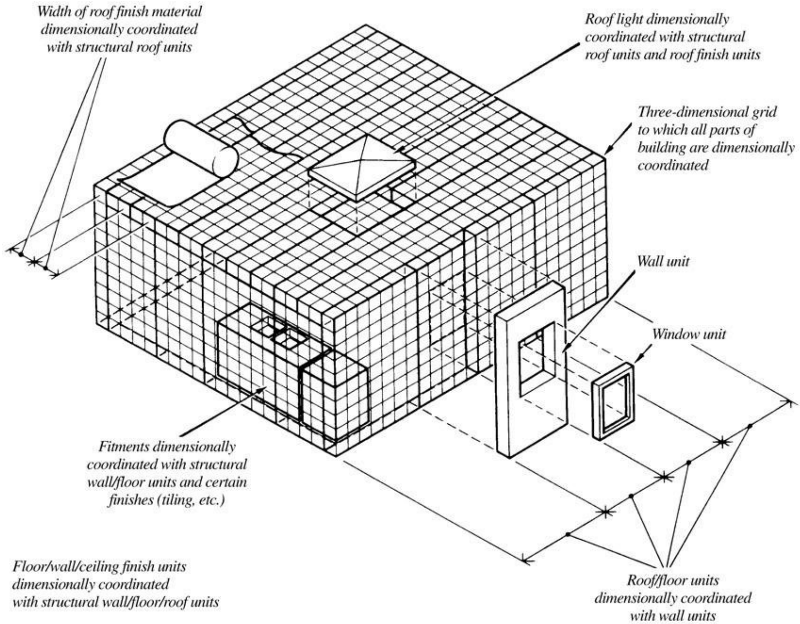


Figure 4.7 Using dimensionally coordinated components which fit together to form a building.

Certain manufacturing processes and some materials cannot conveniently conform with common dimensional standards. For example, walls of stone, concrete or plastics will have different dimensional characteristics to walls of brick. It is necessary, therefore, that manufacturers should be given a guide on the likely range of dimensions for which particular components will be required, and the variations for which they should allow within this range. Accordingly, a range of overall dimensions of components related to building use, anthropometric requirements and manufacturing criteria has been recommended. Figure 4.8 illustrates the recommendations for the vertical dimensions used in the construction of a house. There are similar recommendations for the horizontal dimensions. In order not to overstretch the resources of manufacturers and to further rationalise the available range of components, BS 6750: Specification for modular coordination in building states that components should be manufactured in basic incremental sizes of 300 mm as first preference, or 100 mm as second preference, with 50 mm and 25 mm being allowed up to 300 mm (Fig. 4.9). For a more detailed explanation, see Chapter 1 of Internal Components in Mitchell's Building Series.

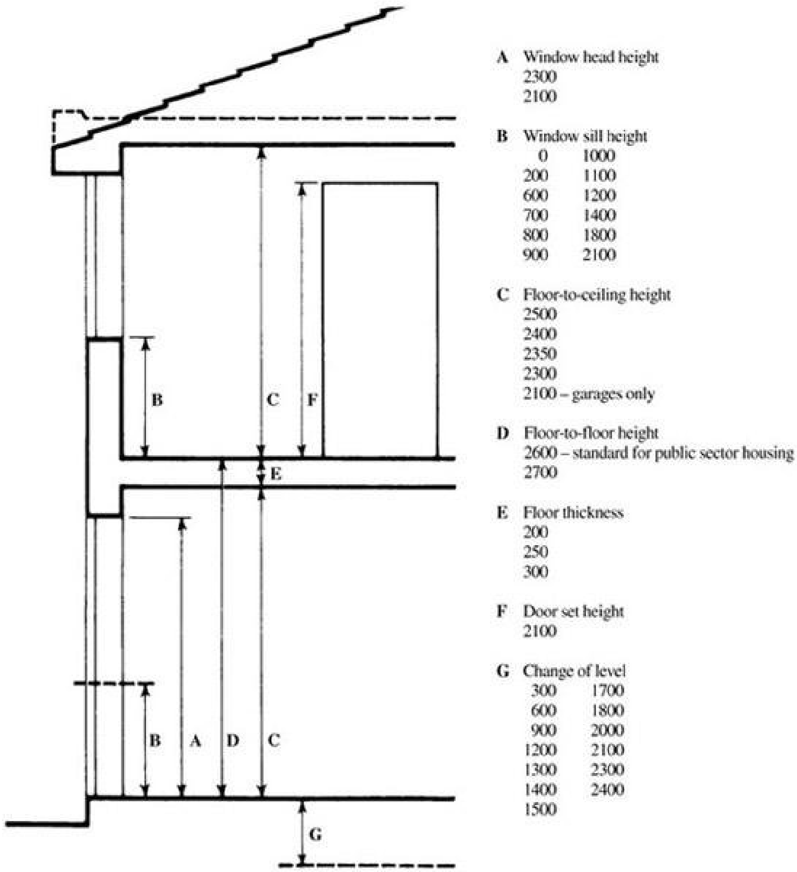


Figure 4.8 Recommended vertical controlling dimensions for housing.

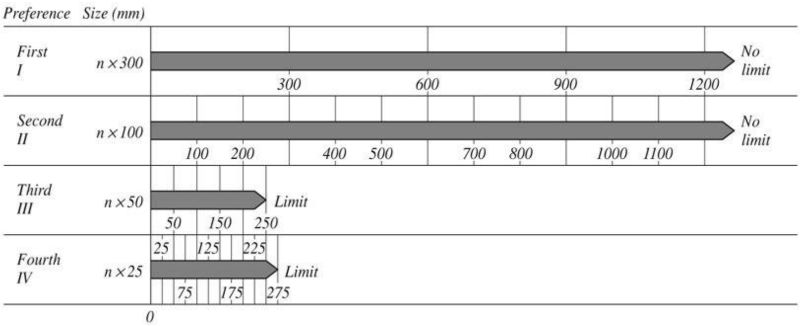


Figure 4.9 Preferred linear sizes for components used in a building.

4.8 Modular coordination

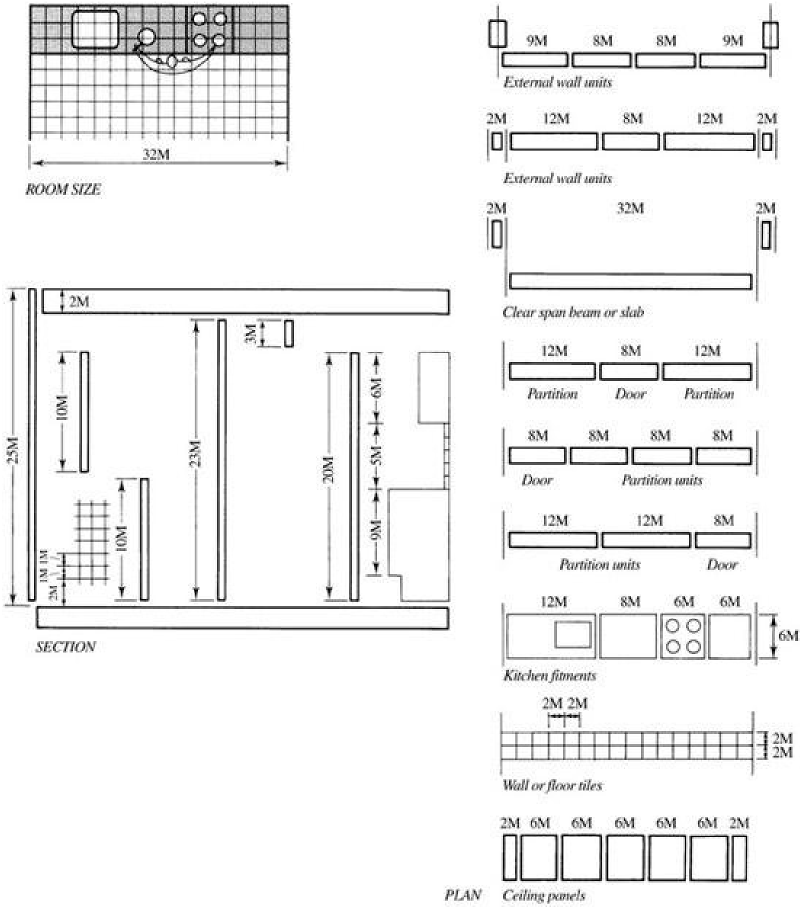


Figure 4.10 Using modular coordinated sizes in a building (M = standard module of 100 mm).

Attempts have been made to persuade manufacturers to agree to manufacture components in standardised modular increments of 100 mm, which is the dimension most common in building products at home and abroad. This system is known as modular coordination and, when adopted, means that a building is designed within a three-dimensional framework of 100 mm cubes. A successful design relies on the certainty that a vast range of products will be available for the construction – a range which can be selected from almost any country adopting the dimensional system. Products requiring to have dimensions greater than the basic module are manufactured so as to be a multiple of the basic module (Fig. 4.10); or, if they are required to be smaller, are manufactured so that when placed together their combined dimensions suit either the basic module or a multiple thereof. Although the idea of modular coordination has been in existence for a considerable time, many products will remain in imperial and uncoordinated dimensions until it becomes cost viable for manufacturers to replace their machinery.

4.9 Jointing and tolerances

Whether modular or otherwise, components cannot be manufactured to precise dimensions to suit a regular three-dimensional grid. Allowance must be made for jointing the component, as well as for inaccuracies in the products due to material properties (shrinkage, expansion, twisting, bowing, etc.) and manufacturing processes (changes in mould shapes, effects on materials, etc.). Furthermore, allowance must be made for positioning the components on site. This is particularly important for very large and heavy components which are manoeuvred into position by cranes, etc., and final location could vary by as much as 50 mm. Allowances of this nature are known as tolerances; if manufacturers supply products without these tolerances, cumulative errors in trying to place each component on a grid line would result in not only a building of incorrect overall dimensions, but also a great deal of frustration in the fixing of secondary items such as windows, or furniture and finishes within the building (Fig. 4.11). An important document covering the aspects of tolerances is BS 5606: Guide to accuracy in building.

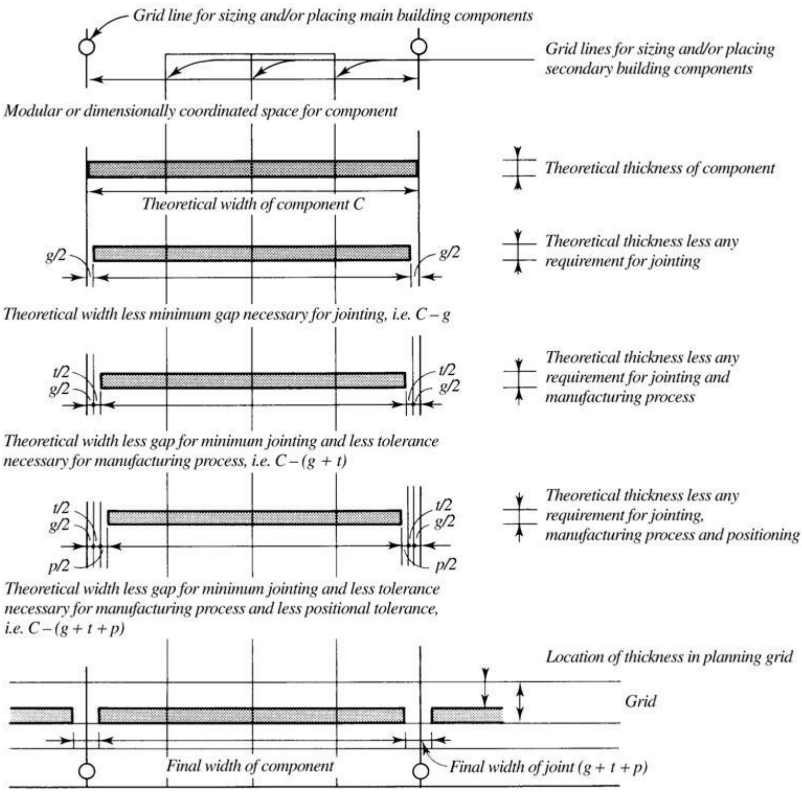


Figure 4.11 Tolerances allowed when designing components: a simplified method of arriving at the 'final dimension' of a component. More accurate but more complicated calculations

are now available in BS 6954-1, 2 and 3: Tolerances for building.

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 2 The production of buildings Chapter 3 Structural behaviour
Structure and Fabric Part 2	Section 3.3 Foundation design Chapter 4 Walls and piers (movement control) Chapter 5 Multi-storey structures (movement control) Chapter 6 Floor structures (movement control) Chapter 9 Roof structures (movement control)

Building Research Establishment

Digest 163 *Drying out buildings*
Digest 223 *Wall cladding: designing to minimize defects due to inaccuracies and movements*
Digest 227 *Estimation of thermal and moisture movements and stresses* Part 1
Digest 228 *Estimation of thermal and moisture movements and stresses* Part 2
Digest 343 *Simple measuring and monitoring of movement in low-rise buildings* Part 1 Cracks
Digest 344 *Simple measuring and monitoring of movement in low-rise buildings* Part 2 Settlement, heave and out of plumb
Digest 357 *Shrinkage of natural aggregates in concrete*
Digest 361 *Why do buildings crack?*
Digest 475 *Tilt of low-rise buildings with particular reference to progressive foundation movement*
Good Repair Guide GR1 *Cracks caused by foundation movement*

Building Regulations

A1 Loading
A2 Ground movement
A3 Disproportionate collapse

5
Strength and stability

CI/SfB (J)

The strength of a building refers to its capacity to carry loads without failure of the construction method; stability refers to the ability of a building to resist collapse, distortion, localised damage and movement.

5.1 Dead, live and wind loads

A building is required to resist loads imposed by gravity as well as other externally and internally applied forces: loads and forces from roofs, floors and walls must be transferred by load-carrying mechanisms to the supporting ground.

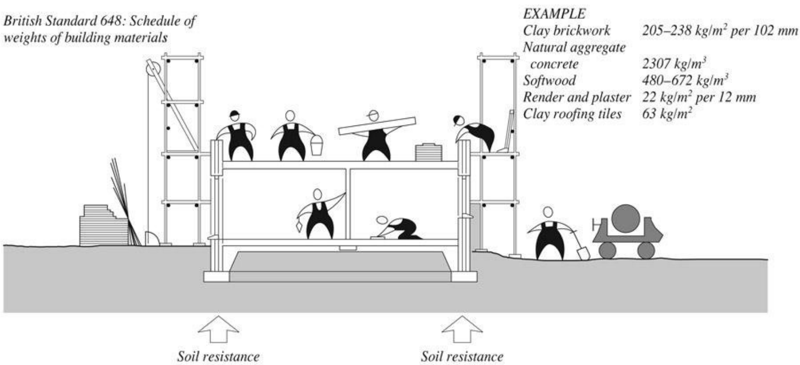


Figure 5.1 Building loads: dead loads.

The loads and forces acting on a building are shown in Figures 5.1 to 5.3; they comprise the following:

- (a) The weight of all the materials from which it is made (bricks, mortar, concrete, timber, plaster, glass, nails, screws, etc.). These weights are more or less constant during the life of a building and are called dead loads; they can be calculated from tables for weights of materials, etc.
- (b) The weight of people using a building, and their furniture, goods, storage, etc. These weights are called live loads or imposed loads and, as they will vary, an average maximum load can be assumed from tables giving values applicable to the particular use of a building.
- (c) Various forces may be applied to a building during its life such as those resulting from wind, physical impact by people, machines, or explosion, and ground movements caused by changes in soil characteristics, earthquakes, mining subsidence, etc. The calculation of these forces is much more problematic and relies on adequate research and experience. Maximum wind loads (gusts) for various locations in the country have been tabulated and should be consulted before finalising the structural requirements for a building.

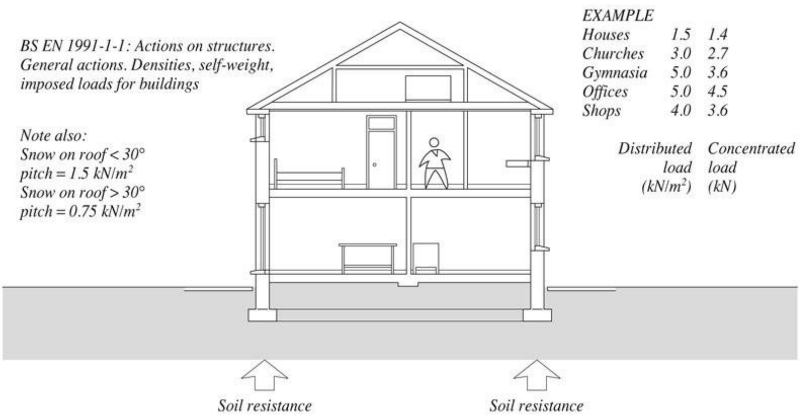


Figure 5.2 Building loads: imposed loads.

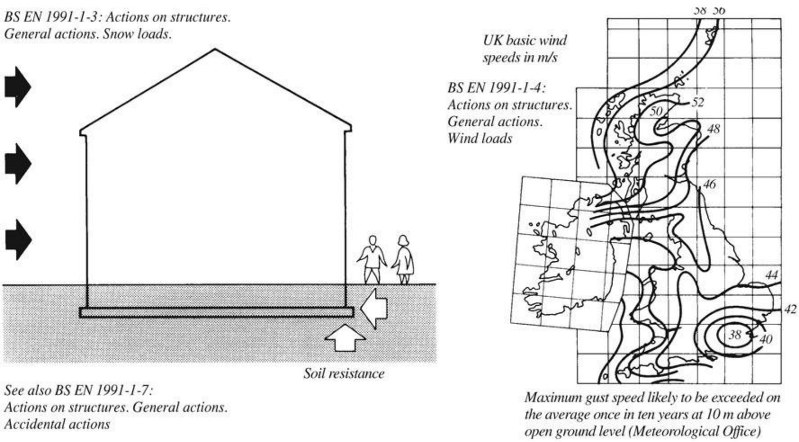


Figure 5.3 Building loads: wind loads.

These loads and forces must be resisted by the supporting soil so that a building remains in equilibrium. A building can be visualised, therefore, as being ‘squeezed’ between the downward applied loading and the upward reactions of the supporting soil.

5.2 Structural organisation

There are four basic methods of structural organisation which can be employed in a building to ensure loads, forces and soil reactions act together in providing equilibrium to a building. The choice of method for a particular building is initially dictated by strength and characteristics of the soil providing support and analysis of the precise nature of all the structural influences. Structural influences are closely related to the function of the building and involve consideration of such factors as whether long or short spans are required, the height of the building, and the weight of materials necessary to fulfil other performance requirements, etc. Often, the juxtaposition of existing buildings provides positive guidelines or maybe limitations on the selection of structural form for a new building.

The structural organisation of a building forms one of the most important aspects which influence appearance and other functions. Since technological solutions are now available which make almost every structural organisation possible, an increasing burden of responsibility is being placed on designers to make rational decisions. The rigorous limitations imposed by simpler construction methods (materials and technology) no longer exist, and it is now feasible to develop a building with volumetric spaces (plan and height) greater than ever before; smaller, to complicated configuration; or to the same size using much less material.

Nevertheless, although perhaps interpreted with greater understanding, certain basic structural principles still remain. Expressed simply, the four basic methods involved in the use of construction methods resist the combined building loads by compression, tension or a combination of the two. These methods are defined by various terms, but here will be called: continuous structures, framed structures, panel structures and membrane structures.

5.3 Continuous structures

These are continuous supporting walls which transfer the combined loads and forces through their construction, mainly by direct compression (Fig. 5.4). Materials commonly used for this purpose are stone, horizontal timber logs, brick, block and concrete. In this respect, continuous supporting walls may be the oldest form of structural organisation.

Walls constructed from fairly small units such as bricks, blocks or stones rely on their strength by being laid in horizontal courses so that their vertical joints are staggered or bonded across the face of the wall (Fig. 5.5). The compression loads which may initially affect individual, or a series of, bricks, blocks or stones can be successfully distributed through a greater volume of the wall. The units are held together and separated by an adhesive mixture known as mortar, thereby completing the structural (and environmental) enclosure. This mortar also serves the function of taking up any dimensional variations in the bricks or blocks so that they can be laid in more or less horizontal and vertical alignment. Mortars usually consist of water-activated binding mediums of cement and lime, and a fine aggregate filler such as sand, in the proportion of one part binder to three parts aggregate. Lime aids workability, but is now rarely used in mortar as it may be substituted with a proprietary liquid plasticiser.

Masonry cement may be preferred, as this has an integral plasticiser. Masonry cement is not suitable for producing concrete.

Laterally applied forces which could create tension in the wall are resisted by its preloaded condition. The weight of materials forming the wall, together with any loads they carry from floors or roof, combine in counteracting the tendency for horizontal movement or overturning as a result of horizontally applied forces, e.g. wind. Alternatively, where preloading is insufficient, the action of lateral forces can be resisted by the provision of buttresses at predetermined centres to resist the tendency for overturning (see Fig. 5.4). A system of buttresses or piers can be used to provide stability to a long length of wall. Walls which are serrated or curved in plan will also be stronger than straight walls because they are more able to resist laterally applied forces.

Additional stability can also be provided by the floor(s) and roof of a building, provided there is adequate connection at the junction between horizontal and vertical elements. A wall which is laterally braced in this manner has the advantage of using considerably less material to support the same load as a thick unbraced wall (Fig. 5.6); see also section 5.7.

When it is required to provide openings (e.g. doors and windows) in a building using continuously supporting walls, it is necessary to use a beam or lintel made from a material or combination of materials capable of resisting both compression and tension forces resulting from the loads above. These loads must be transferred to the sides of the opening or jambs. Stone can be used for a lintel, but it provides only a limited resistance to tensile forces relative to its depth and therefore permits only small openings. Timber, steel, a combination of steel bars and concrete (reinforced concrete), or steel angles and bricks, can be suitable materials for lintel construction, although care must be taken to ensure their durability corresponds with the intended life of the building (see Chapter 3). Arches formed over openings use materials in direct compression only, in a similar manner to the wall itself. Therefore, arched openings are often considered by design purists to be more compatible with the aesthetic of this form of wall construction (Fig. 5.7).

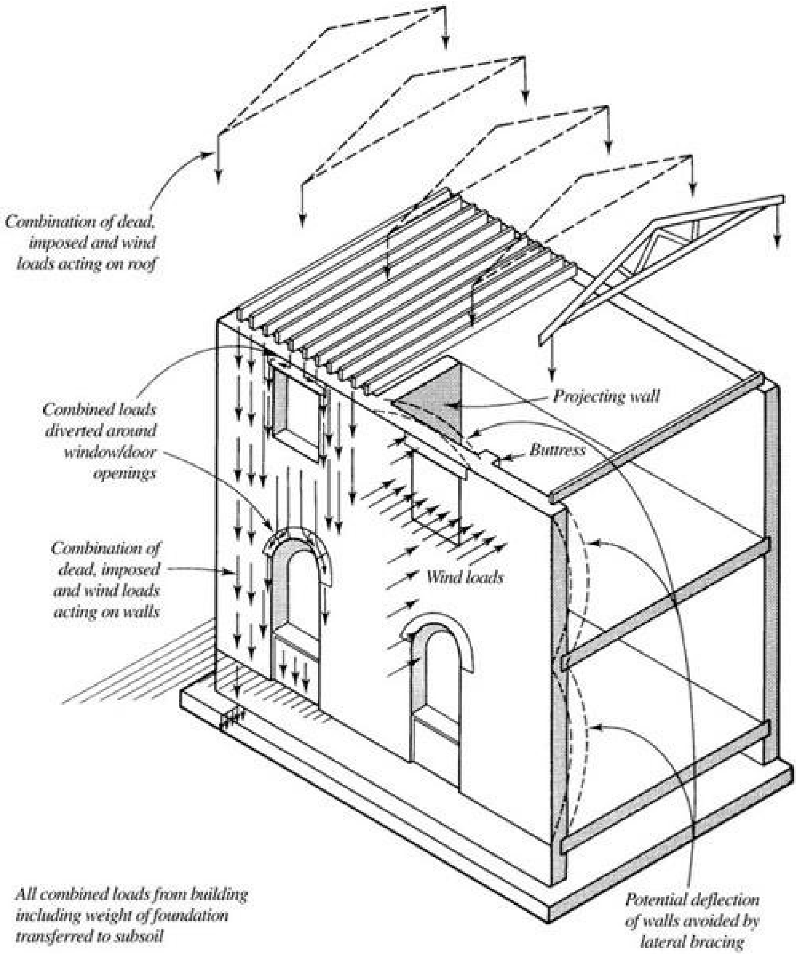


Figure 5.4 The transfer of loads in continuous structures.

5.4 Framed structures

These consist of a framework of timber, steel or reinforced concrete consisting of a regular system of horizontal beams and vertical columns (Fig. 5.8). The beams resist both compressive and tensile forces and transmit loads from the floors, roof and walls to the columns. The columns are required to resist mainly compressive forces; they transfer the beam loads (and the self-weight of beam and column) to the foundation and finally to the supporting soil. This obviously results in more concentrated loads being supported by the soil than for a similar weight of building using continuous supporting walls, unless special forms of foundations are used. The infill panels between the framework used to provide the external wall can be constructed of any suitable durable material which fulfils performance requirements satisfactorily. If the wall material is positioned away from the framework so as to be externally or internally free of the columns and beams, it is known as cladding. Both panel and cladding walls are generally non-load-bearing, although in practice they must carry their own weight (unless suspended from above), resist the wind forces acting on their external face, perhaps provide support for internal fixtures, shelves, etc., and

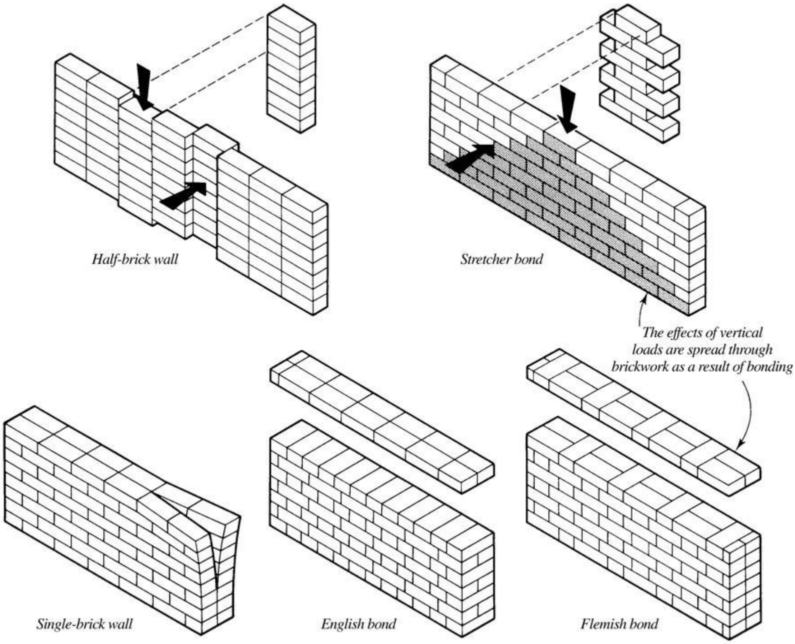


Figure 5.5 Effects of bonding in small building units used for walling.

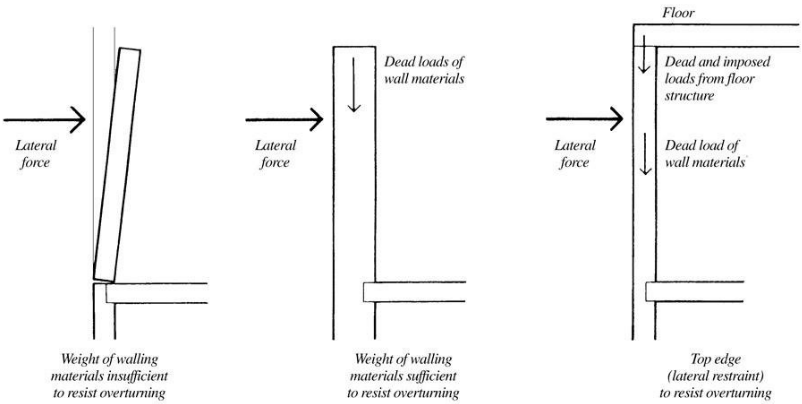


Figure 5.6 Lateral bracing of walls.

resist localised impact forces. However, depending upon the form of construction adopted, the resulting loads are usually transferred back to the supporting columns and beams by their fixing method. A structural framework and panels, or cladding walling, is an example of composite construction. Here the use of different materials to provide independent functions requires careful constructional detailing and skilled work to ensure an entirely successful enclosure.

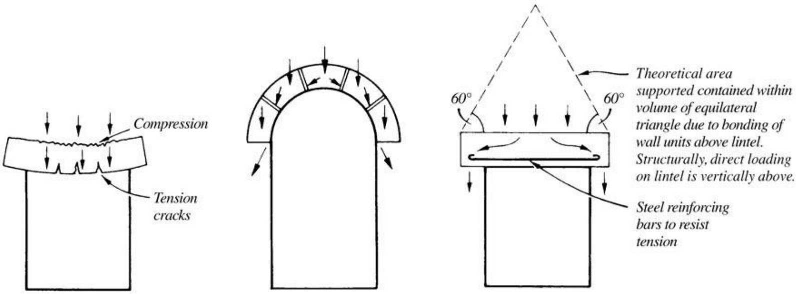


Figure 5.7 Reinforced concrete lintels and block arches.

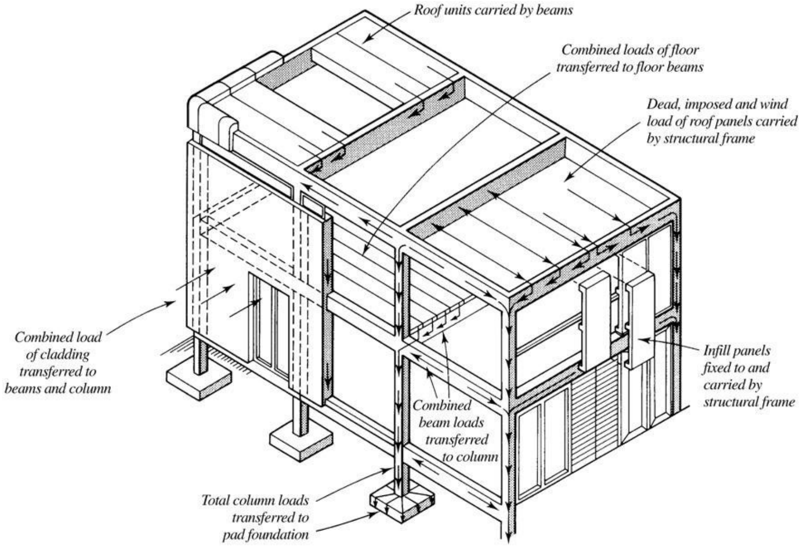


Figure 5.8 Transfer of loads in framed structures.

The external appearance of a framed structure will vary according to the location of the beams and columns relative to the external wall. Figure 5.9 indicates the basic permutations. When the structural frame is not located within an enclosing panel wall, additional precautions may be necessary to protect the frame against possible detrimental effects resulting from an outbreak of fire (see section 9.3), and also from the effects of weathering when the frame is external to the wall. Although this may present no special problems for reinforced concrete – other than a slight increase in cross-sectional area – the use of timber and exposed steel frames requires special consideration. Table 5.1 provides a brief checklist of the structural materials used for a framed building. (See section 4.4 regarding the use of in situ concrete framework with clay brick infill panel wall construction.)

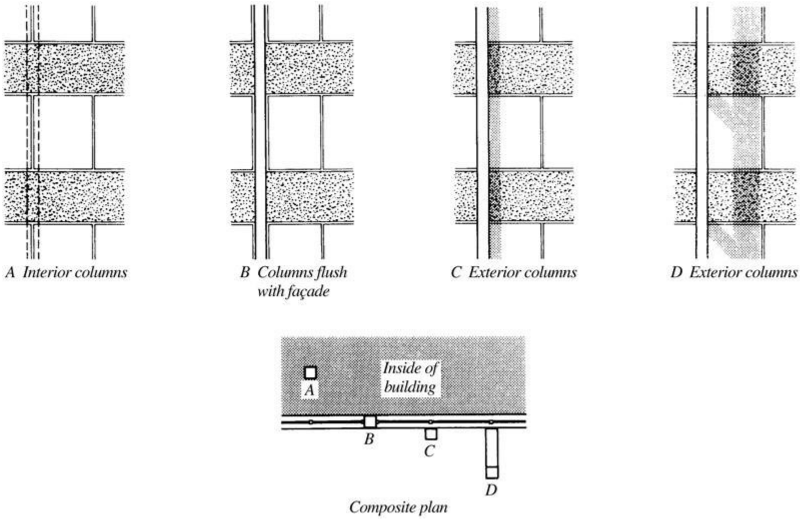


Figure 5.9 Position of structural frame (column) and its effect on a building's appearance. (Adapted from material in Multi-storey Buildings in Steel by Hart, Henn and Sontag)

5.5 Panel structures

These include preformed load-bearing panel construction for the walls, floors and roof which carry and transfer loads without the use of columns and, sometimes, beams (Fig. 5.10). This is similar to continuous supporting wall construction, but each panel is designed to resist its own imposed loads, as well as other performance requirements. They are generally more slender than most other forms of construction and are dimensionally coordinated so as to be interchangeable within their specific functional requirement. The main structural material of a panel is generally of steel or timber, and this can be faced with a suitable material (plywood, flat or profiled metal sheet) and incorporate thermal insulation to form a sandwich construction. (Certain forms of sandwich construction are also used for non-load-bearing panel cladding for a framed building.) Panels can incorporate window and door openings. The combined loads which this form of construction collects can be transferred to the supporting soil by continuous distribution or by concentrating them in a similar manner to that adopted for framed buildings.

5.6 Membrane structures

Thin non-structural membranes forming walls and roof (often combined in one place) are supported by tension and/or compression members (Figs 5.11 and 5.12). A typical example of this is a tent where the walls and roof are formed of canvas and the main structural support of timber or steel. Most permanent structures can be formed by columns, compression members, from which cables are suspended, tension members, which support a plastic membrane. Alternatively, a reinforced plastic or canvas membrane can be supported by air, as in inflatable structures. In this case the membrane is in tension because of the compression forces exerted by the air under pressure. Both these examples are suitable for a building where certain of the performance requirements discussed in Part A of this book do not form an essential part of a proposed building enclosure.

Table 5.1 Comparison between timber, steel and reinforced concrete as structural framing

Criteria	Material		
	Timber	Steel	Reinforced concrete
Availability	Mostly imported as dimensionally coordinated sections	Most iron ore imported	UK supplies of aggregates and cement Steel is mostly imported
Conversion	Factory-converted sections and components Preformed components manufactured to fine tolerances under factory conditions	Steelworks produce bulk sections and components manufactured in factory-controlled conditions Components manufactured to fine tolerances under factory conditions	Factories and steelworks convert into basic use materials (aggregates, cement, bar reinforcement) Precast concrete components manufactured to fine tolerances under factory conditions
Site operations	Erected by skilled and semi-skilled operatives Components relatively lightweight and to fine tolerances	Site erected by skilled operatives Very accurate within small tolerances Heavy sections used need crane	*In situ* structures erected by semi-skilled and unskilled operatives Various shapes possible dependent upon potential of formwork material (up to 40% of total cost) May need crane although *in situ* materials can be pumped to higher levels Precast components erected by skilled operatives
Site progress	Components relatively lightweight and can be quickly erected Foundation work less Progress dependent upon weather conditions unless protection provided	Heavy components but can be erected quickly Mistakes difficult to correct Progress dependent upon weather conditions unless protection provided	Slow progress when necessary to wait for hardening before commencing next sequence or trade Multi-storey structures can be formed near ground level and raised into position
Site progress	Once erected floor/roof components can be placed and building sealed against weather	Once erected floor/roof components can be placed and building sealed against weather	Slow sealing against weather; design can help by using repeat formwork
Fire protection	Not considered to be good fire risk although designs can take account of 'sacrificial' sections to provide insulation (see text) Poor spread of flame characteristics, but can be improved by chemical treatment Damaged timber irreparable	Not considered to be good fire risk and generally must be insulated for all but very small structures Possible to expose sections providing design permits shielding isolation or cooling (see text) Spread of flame characteristic depends on type of insulation provided Damaged steel irreparable	Steel reinforcement insulated by concrete cover High inherent degree of fire protection and nil spread of flame Fire resistance periods can be improved by selecting aggregate to reduce spalling Damaged reinforced concrete can be repaired
Adaptability	Easily adapted during construction Extensions easy to provide	Difficult to adapt on site owing to precut lengths or difficulty in cutting Extension can be achieved providing access to original sections available through fire protection	Can be adapted Difficult to provide extension of existing structure (steel reinforcement must be exposed) and separate new structure required
Maintenance	Finished with preservative stain, varnish or paint system Intumescent paint can be decorative and provides fire resistance Designs must provide protection against insect and fungal attack	Needs regular maintenance if not encased or weathering steel Intumescent paint can be decorative and provides fire protection	Self-finish quality depends on site skills and formwork quality

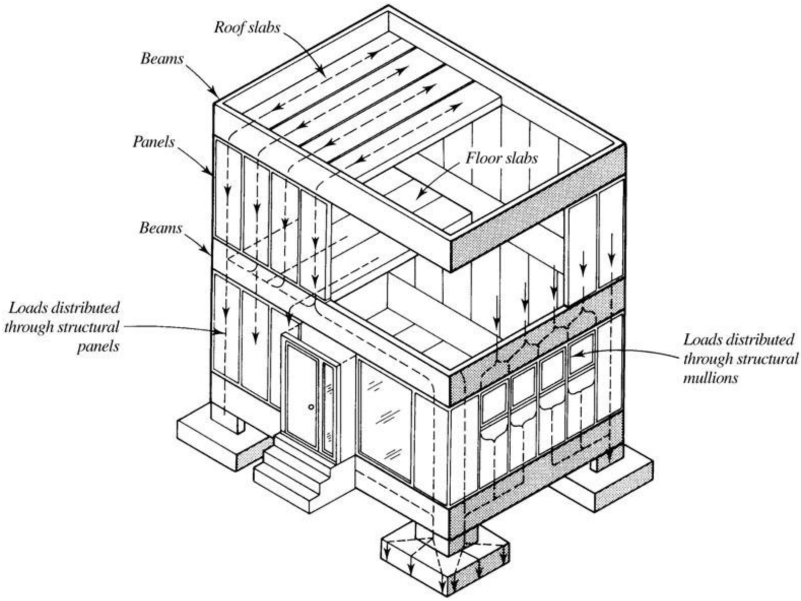


Figure 5.10 Transfer of loads in panel structures.

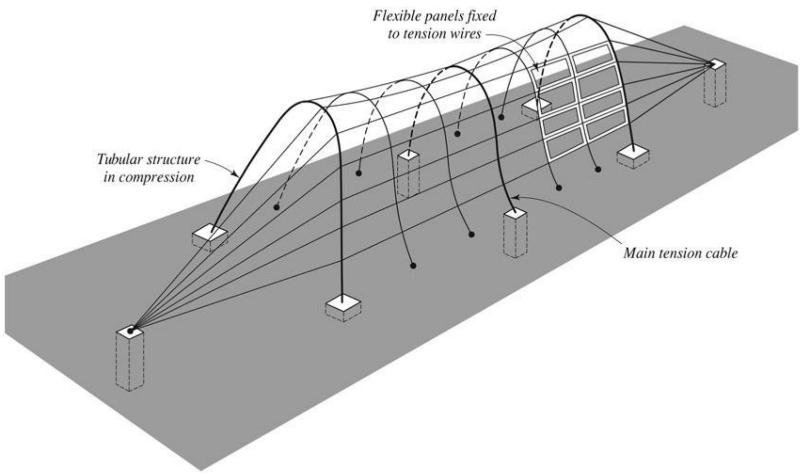


Figure 5.11 Using tension cables.

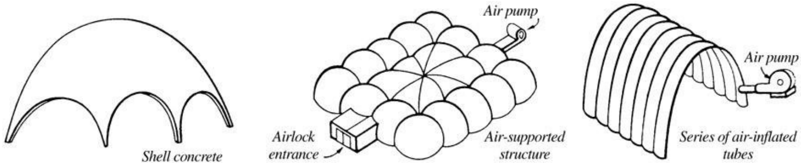


Figure 5.12 Using membrane structures.

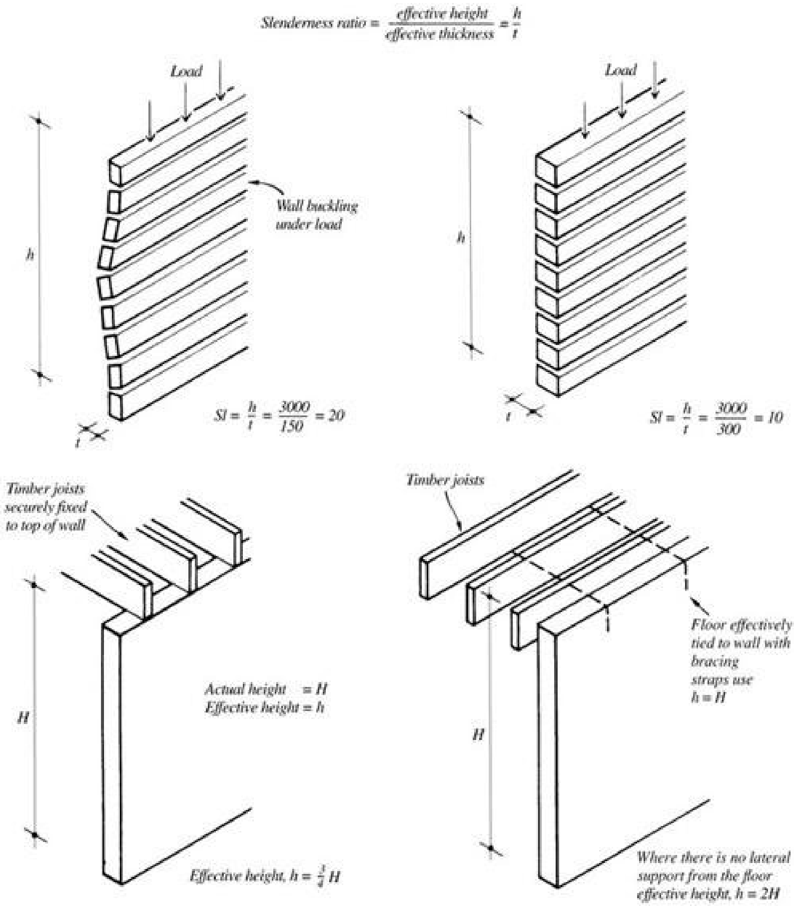


Figure 5.13 Slenderness ratio and lateral bracing in walls.

5.7 Slenderness ratio

Whenever the structural organisation of a building involves the resistance of vertical loads by a wall or column in compression, adequate thickness of sufficiently strong material must be employed in their construction to avoid crushing. A short wall or column can ultimately fail by crushing. But as height increases, ultimate failure is more likely to occur under decreasing loads by buckling. This form of failure results from lack of stiffness in a wall or column which causes bending to occur because, in practice, it is impossible to ensure that vertical loads act through the vertical centreline of their support. Very tall, thin walls or columns will buckle before crushing, short squat walls crush before buckling, and walls of intermediate proportions may fail by either method.

Obviously, the greater the height of a wall or column and the tendency towards buckling, the more critical becomes the relationship between thickness and height. This relationship is known as the slenderness ratio; as this ratio increases, so the load-carrying capacity of the wall or column decreases (Fig. 5.13). Because the stiffness of a wall or column can be increased by lateral bracing as described in section 5.3, for calculation purposes the dimensions used for the effective height and thickness can vary from the actual height and thickness in order to obtain a realistic slenderness ratio. The amount of variation depends on the degree and effectiveness of connection provided between the horizontal and vertical components. For example, where a wall is loaded by a floor construction which provides continuous lateral support (reinforced concrete slab or adequately connected timber joists), the height of the wall can be taken for calculation purposes to have effective height (h) equivalent to three-quarters of the actual height (H). This will give a slenderness ratio which either permits theoretically slightly less strong materials to be used than if no concession had been given, or permits the wall to be thinner and occupy less plan area. However, if the floor gives no lateral support whatsoever, the rules of calculation will double the actual height of the wall and vastly increase the slenderness ratio. A further correction factor may be applied to the slenderness ratio used for calculation purposes when applied loads are resolved eccentrically to the centre of the wall (Fig. 5.14). The design of columns is also subject to similar requirements regarding slenderness ratios and correction factors for eccentric loadings (Fig. 5.15).

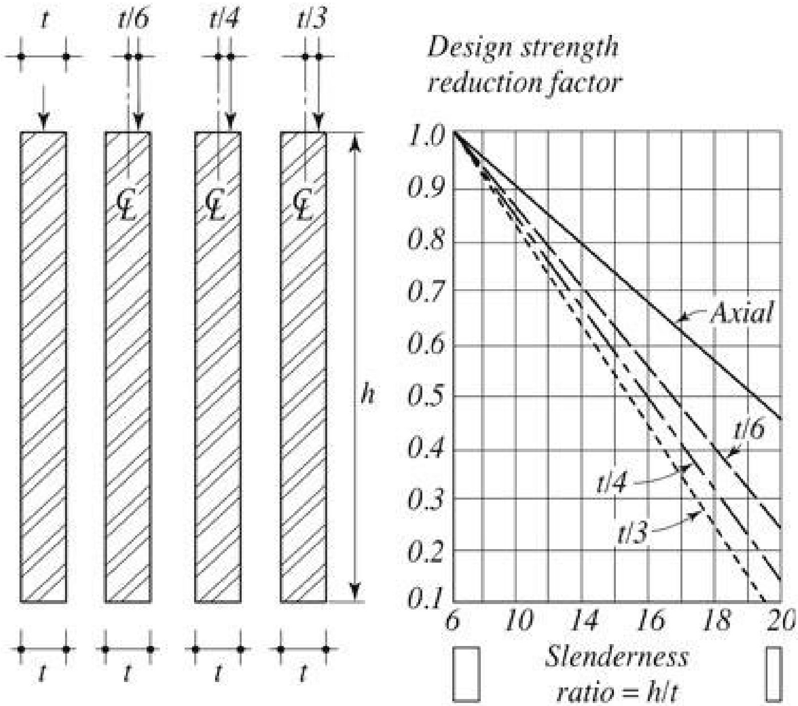


Figure 5.14 Correction factors applied to walls according to the eccentricity of loads. (Based on data provided by the Brick Development Association)

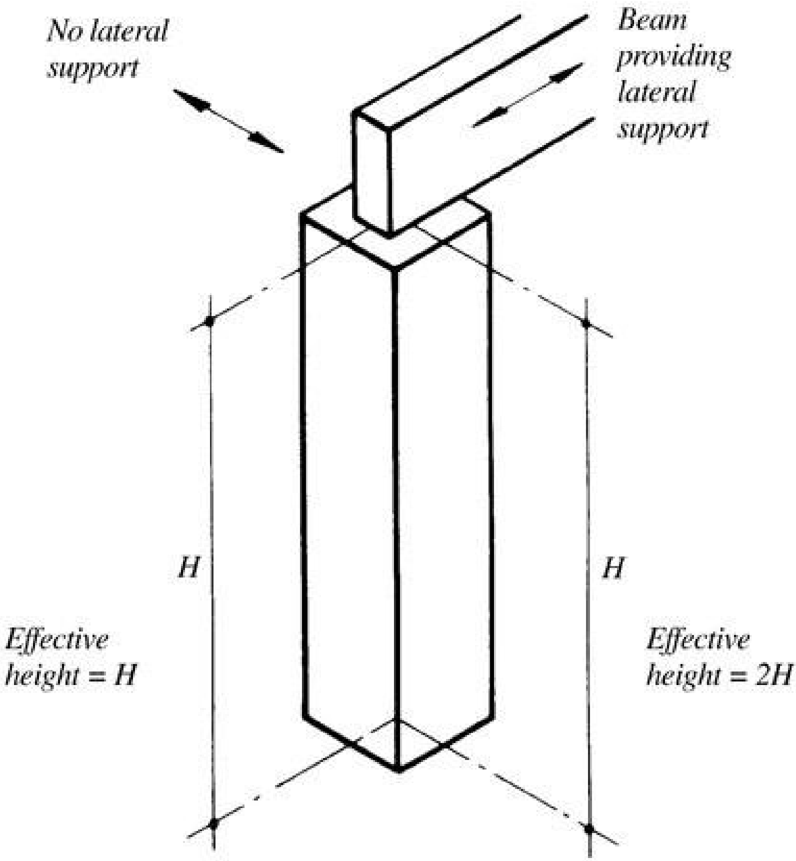


Figure 5.15 Slenderness ratio and lateral bracing in columns. (Based on data provided by the Brick Development Association)

5.8 Diagonal bracing

For frame buildings, the provision of effective lateral bracing will vary according to how well the materials employed will permit a rigid joint to be created between horizontal and vertical components. Very rigid joints can easily be created between beams and columns made of reinforced concrete, but it is more difficult for beams and columns made of steel and very hard when they are made of timber. When jointing techniques cannot provide sufficient lateral restraint, the structural frame can be made more rigid by inserting diagonal bracing in various locations around a building, or by using shear panels (Fig. 5.16).

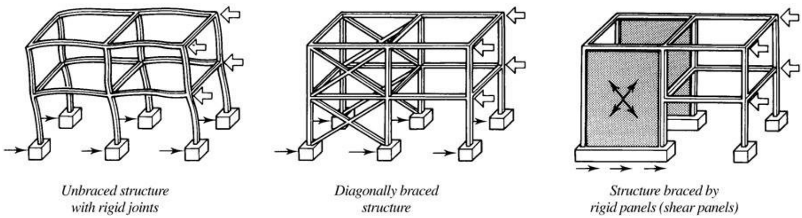


Figure 5.16 Use of diagonal bracing in frame structures. (Adapted from material in Multi-storey Buildings in Steel by Hart, Henn and Sontag)

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 1 The nature of buildings and building Chapter 3 Structural behaviour Chapters 4–10 Functional requirements sections or subsections
Structure and Fabric Part 2	Chapter 4 Walls and piers Chapter 5 Multi-storey structures Chapter 6 Floor structures Chapter 9 Roof structures

Building Research Establishment

Digest 12 *Structural design in architecture*
Digest 284 *Wind loads on canopy roofs*
Digest 346 *The assessment of wind loads* Parts 1–8
Digest 362 *Building mortar*
Digest 390 *Wind around tall buildings*
Digest 406 *Wind actions on buildings and structures*
Digest 416 *Specifying structural timber*
Digest 439 *Roof loads due to local drifting of snow*
Digest 441 *Clay bricks and clay brick masonry* (2 parts)
Digest 460 *Bricks, blocks and masonry made from aggregate concrete* (2 parts)
Digest 468 *Autoclaved aerated concrete 'aircrete' blocks and masonry*
Information Paper 11/05 *Innovation in concrete frame construction*

Building Regulations

A1 Loading

6
Weather exclusion

CI/SfB (H1)

Weather exclusion is concerned with methods of ensuring that wind and water (rain and snow) do not adversely affect the fabric of a building or its internal environment.

6.1 Wind and water penetration

Wind can cause direct physical damage by collapse or removal of parts of a building. It can cause dampness by driving moisture into or through a building fabric, and also excessive heat losses from the interior of a building by uncontrolled air changes.

Water penetration can produce rapid deterioration, as discussed in Chapter 2, and cause the fabric of a building to become moist enough to support life, including bacteria, moulds, mildew, other fungi, plants and insects. Saturated materials also permit the quick transferral of heat (water is a good conductor) and this, together with the other factors mentioned, will cause an uncomfortable, unhealthy and uneconomical building.

The sources of water likely to penetrate a building include not only those from rain and snow, but also those from moisture contained in soil or other material in immediate contact with the building fabric. For water to penetrate, there must be openings or passages in the building fabric through which it can pass, and a force to move it through these openings or passages. Without these two factors, the building fabric would remain in a water-tight condition. Most buildings, however, have window and door openings, are made from lapped or jointed parts, or from porous materials ready to absorb moisture; wind currents and eddies are also normally present.

Condensation may also create moisture problems, considered in Chapter 8. Damage by flooding is beyond the scope of this book.

6.2 Exposure zones

Construction methods of earlier periods were generally capable of permitting a certain amount of wind and water to penetrate through to the interior of a building. Shapes for buildings were devised for particular climatic exposures which best provided an initial defence, and the constructional detailing endeavoured to provide a final barrier.

By way of progress, modern construction methods are expected to give almost total exclusion against wind and water penetration. With ever-changing fashions for building shapes – sometimes borrowed from areas vastly different in climatic influences – care must be taken to ensure that constructional methods are suitable for the exposure conditions dictated by the specific location and disposition of a building. That is to say, before considering form and construction method research must be carried out to reveal the degree to which a proposed building will be exposed to driving rain. In the United Kingdom, initial assessment can be obtained by reference to the driving rain index (DRI) for the particular location as published on maps by the Building Research Establishment (Fig. 6.1). Values are obtained by taking the mean annual wind speed in metres per second (m/s) and multiplying by the mean annual rainfall in millimetres. The product is divided by 1 000 and the result is used to produce contour lines linking areas of similar annual driving rain index in m^2/s throughout the country:

- Sheltered exposure zone refers to districts where the DRI is 3 or less.
- Moderate exposure zone refers to districts where the DRI is between 3 and 7.
- Severe exposure zone refers to districts where the DRI is 7 or more.

The value for a particular location within 8 km of the sea, or a large estuary, must be modified to the next zone above (sheltered to moderate, and moderate to severe) to take account of unusual exposure conditions. Furthermore, modifications may also be necessary to allow for local topography, special features which shelter the site or make it more exposed, roughness of terrain, height of proposed building and altitudes of the site above sea level. The proportion of driving rain from various directions within one particular location can be obtained by reference to driving rain rose diagrams (Fig. 6.2).

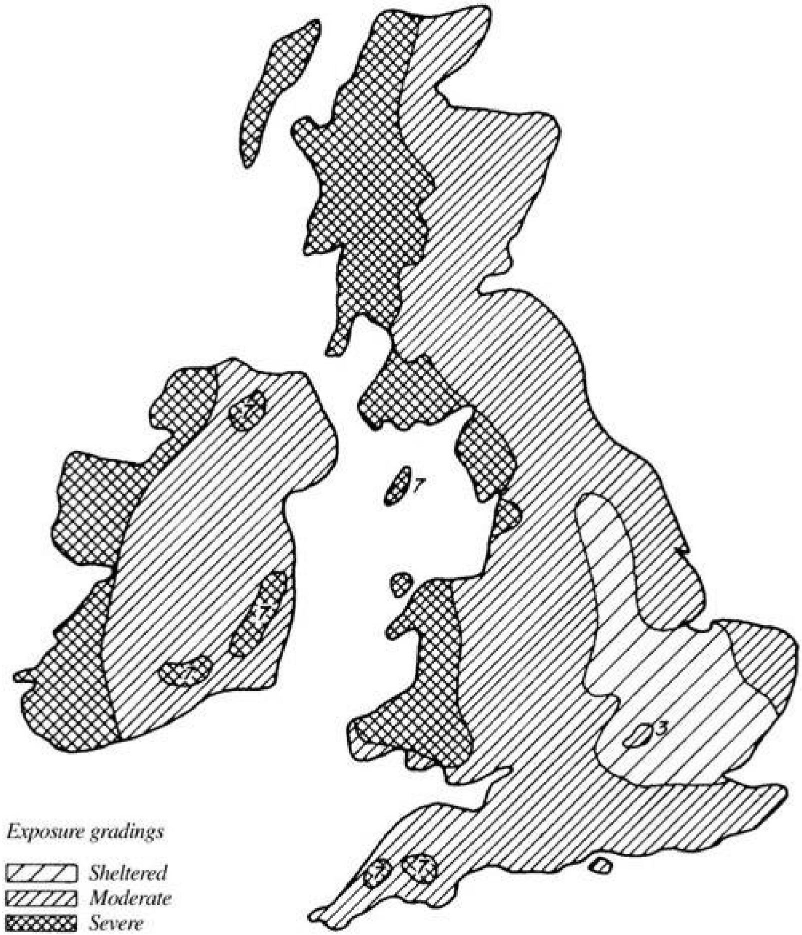


Figure 6.1 Driving rain index.

For greater accuracy, reference should be made to BS 8104: Code of practice for assessing exposure of walls to wind-driven rain. This provides an alternative rose analysis for the extent of driving rain in various locations, to permit an exposure expectation for each face of a building. It is expressed in litres/m^2 per spell, where spell is the period that wind-driven rain occurs on a vertical face of a building. Figures for a wall annual index expressed in litres/m^2 per year can be derived from this data, as can local spell and local annual indices. This does not mean that a designer need adjust construction detailing for different elevations, but it will reveal which aspect of a building is most vulnerable to water penetration. This guidance is also helpful in assessing areas most compatible to lichens, mosses and other growths that can have a deteriorating effect on structure. The BS code provides a series of maps of the United Kingdom with superimposed rose diagrams allocating numerical values (Fig. 6.3) to specific areas.

One of the most important lessons to be learnt from driving rain indexes and roses is that design and construction details, of necessity, may vary from one exposure zone to another; details suitable in a sheltered exposure zone would probably leak if simply transferred to a severe exposure zone without modification. For instance, in the severest of exposures structures should not have walls constructed with full cavity fill insulation. A minimum 50 mm air gap (see Fig. 6.5) is necessary to prevent dampness bridging the insulation.

Figure 6.2 Driving rain rose diagram.

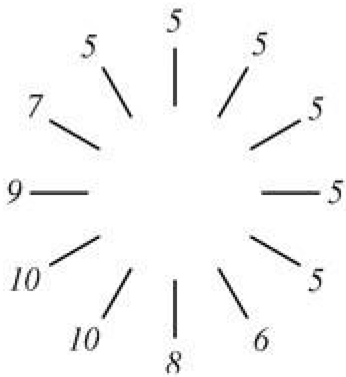


Figure 6.3 Spell and annual rose values (source BS 8104), e.g. building with a south elevation = 8.

6.3 Macro- and microclimates

However, there can exist a danger in using only meteorological climatic data of this nature for the final selection of appropriate material and constructional detailing. This data reveals the general climate, or macroclimate, liable to affect a building in a particular location. There is also a microclimate surrounding the immediate outer surface of a building, i.e. not more than 1 m from the surface of a building. This is created by specific environmental conditions arising from the precise form, location, juxtapositions and surface geometry of a building. A designer is expected to know when design ideas are liable to cause the microclimate to vary significantly from the macroclimate and make adjustments in materials and/or constructional detailing accordingly. Where there is no past experience, it may be necessary to make models of a building and its surroundings, test them under simulated environmental conditions and

record the precise effects. For example, detailed analysis has revealed that tall buildings can
receive more rainwater on their walls than on their roofs, especially on elevations facing the wind. Under these circumstances, rain is often driven vertically up the face of the building, making it necessary to use constructional details different from those considered suitable for lower buildings in the same exposure zone (Fig. 6.4).

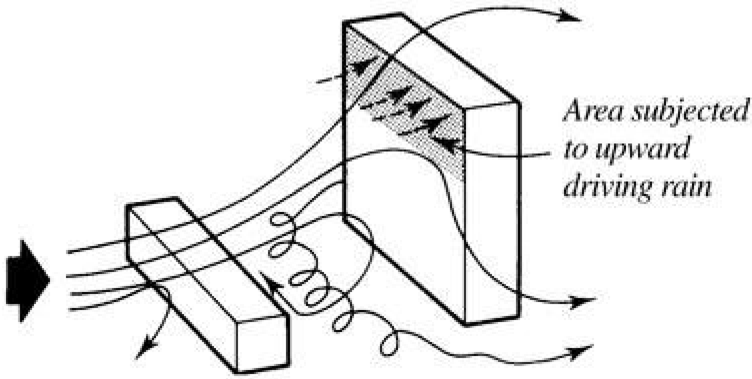


Figure 6.4 Alteration of general climate conditions as a result of building disposition and shape.

6.4 Movement of water

Besides the numerous construction methods, there is a very wide range of materials and combinations of materials from which to choose when designing a building. Providing they are carefully matched to exposure conditions, all options can function with equal efficiency in controlling the movement of water from the exterior to the interior of a building. The precise way this is achieved will vary; it will depend upon the properties of the materials employed and the manner in which they are arranged to form the weather barrier. Figure 6.5 illustrates the three basic arrangements for the external fabric of a building where:

- walls initially act as a permeable barrier which permits subsequent evaporation of absorbed water;
- walls and roofs act as semipermeable barriers which permit a certain amount of water to penetrate until reaching a final barrier;
- walls and roofs act as an impermeable barrier which diverts water on contact.

When rain falls or is driven on porous building materials, such as most brick types, some stones, or blocks, it is absorbed then subsequently removed by natural evaporation. This process occurs when water adheres to the pores of the material. And if the adhesive force between the water molecules and the wall material is greater than the cohesive force between the molecules themselves, the water is drawn in by capillary action. A strong wind increases the rapidity of absorption, and only evaporation resulting from changes in the climatic conditions (rain ceases, temperature rises, air currents become warmer) will prevent the moisture penetrating through the thickness of the material. Earlier construction forms ensured that this thickness was sufficient to prevent water penetration by capillary action. Current economic trends and the need for energy conservation (saturated material loses about 10 times more heat through it than when dry) have now firmly established elemental construction methods made up of several materials of thinner cross-sections. These are employed to provide an external initial weather check which is combined with materials used to provide internal thermal insulation. The external and internal components are separated by a water barrier (an air cavity or a vapour control layer) to interrupt the continuous flow of water from outside to inside. In this way, potentially wet areas are isolated from those which must remain permanently dry.

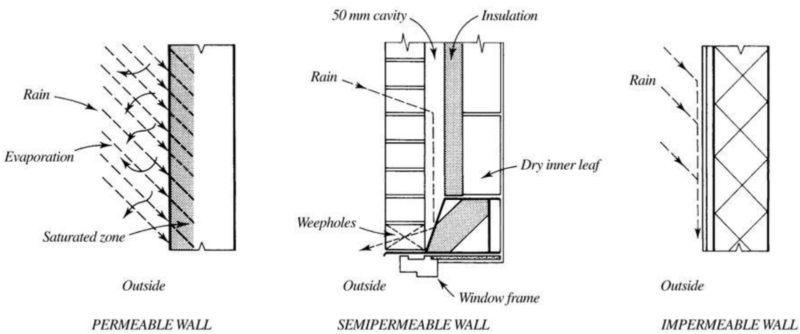


Figure 6.5 Movement of water in walls of different construction.

Constructional detailing must attempt to reduce the movement of water as much as possible. It is particularly important to ensure that the water barrier is incorporated
in such a way that moisture is not trapped and kept in a position for a period of time liable to cause damage.

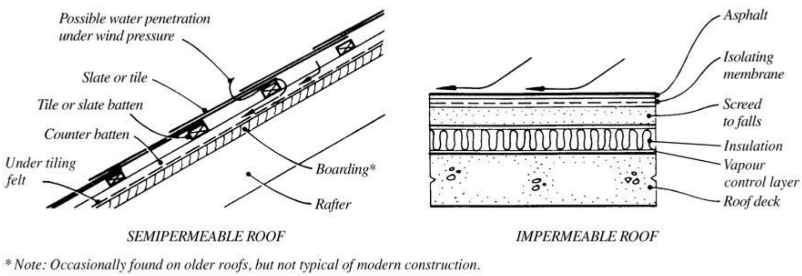


Figure 6.6 Movement of water in roofs of different construction.

For similar reasons, when rain falls or is driven on building materials theoretically assumed to be entirely impervious, e.g. dense concrete, glass, metal, bituminous products or plastics, precautions must be taken to ensure quick and efficient run-off. The quantity of water must never be underestimated; on a glass wall of a building it can be as much as 5 litres per 10 m^2 of façade.

A typical flat roof construction to provide a weather-resisting barrier would consist of sealed lengths of multilayer bituminous felt or a continuous homogeneous layer of asphalt (Fig. 6.6). A comparable pitch roof construction to resist the penetration of water under the influence of gravity would incorporate an outer surface finish of lapped tiles or slates backed by an impervious water barrier. Further comments about this form of construction are included in Chapter 18.

6.5 Joints

The need for joints arises because of the necessity to link, lap or bond materials together when providing the continuous and efficient weather enclosure for a building. Unless the many interrelated factors which influence their position and type are very carefully considered, they can form the weak link in the enclosure.

The first rule is to ensure that as much water as possible is kept away from this vulnerable point where two or more materials are brought together, each perhaps having different characteristics and connected in some way with yet other types of materials. The designs for roofs and walls can provide shelter to their joints, or channel free-flowing water in predetermined directions to permit either collection or discharge to less damaging areas. The effects of wind-driven rainwater must always be taken into account in this respect, and boldly profiled upstands and overhangs at joint positions are desirable when it is difficult to form a continuous 'membrane-type' seal between two building components.

The actual method of forming a joint will initially depend upon the physical and chemical properties of the materials involved. The comments made in Chapter 5 regarding movements and appropriate sizes are particularly relevant. The joint can be expected to behave in a similar manner to the surrounding surfaces by stopping water penetration at the outermost places, or by allowing water to be collected from its recesses and returned to the outside. Within these two extremes, there is a vast range of jointing possibilities (Fig. 6.7).

Some of the main joints necessary to provide a weather-resisting enclosure for a simple design of a timber-framed window in a brick/block cavity wall are illustrated in Figure 6.8. These include the use of mortar for the brick-work outer leaf of the wall, an impervious water barrier membrane (DPC) between brickwork and window frame, a seal between window frame and glass, and draught proofing between window sash and frame. The profiles between the fixed and opening parts of the window frame are also specially designed to reduce the movement of wind-borne water to the interior of the building.

Draught-excluding devices can also be fitted in this gap to eliminate the flow of air and the possibility of heat loss. The

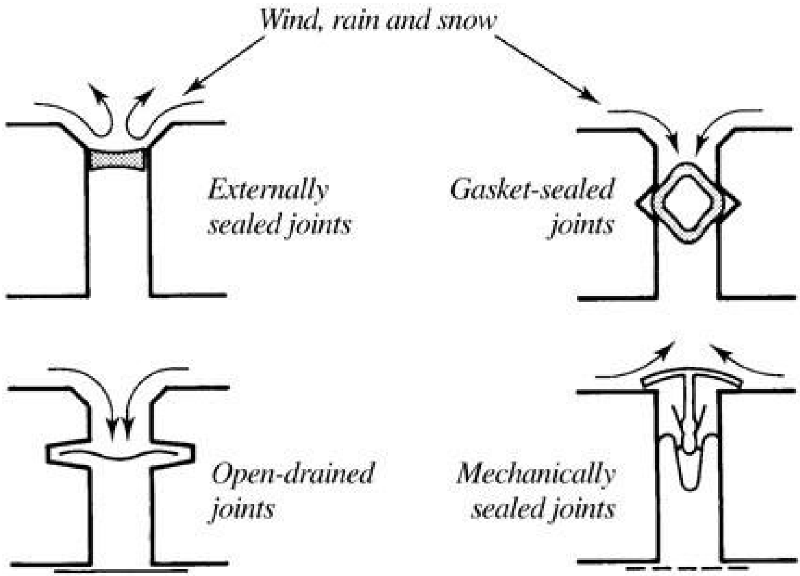


Figure 6.7 Types of jointing to resist the penetration of water.

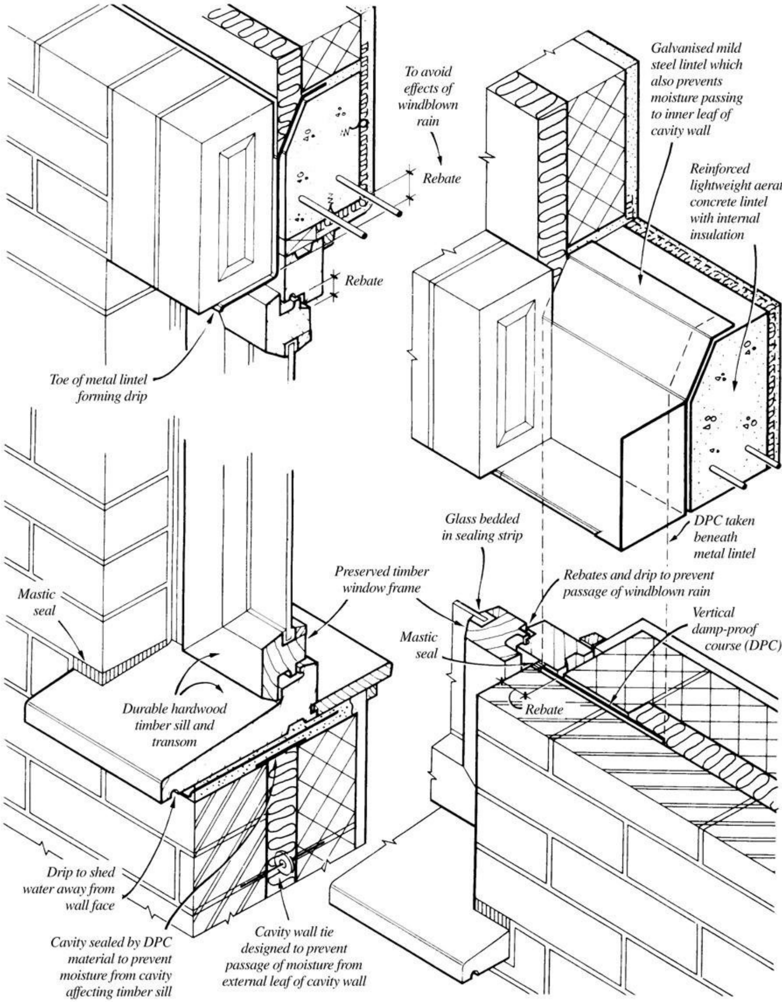


Figure 6.8 Some construction methods used to resist water and wind penetration through a window opening in a fully insulated brick/block masonry wall. Note: this diagram is representative of many existing constructions, but the lintel and reveal details no longer satisfy new-build thermal

insulation requirements for housing in the United Kingdom due to potential for cold/thermal bridging. See section 18.6.5.

relationship between the type of brick and the type of mortar used in the outer leaf of brickwork is also important, as indicated by Figure 6.9.

One of the most important aspects of joints in a building involves their effect on appearance. The particular type of brick bond (stretcher, Flemish, Dutch, Quetta, etc.) and the width, profile and colour of mortar joint can have as much impact on the appearance of brickwork as the colour and shape of the bricks themselves. Similarly, the precise location and profile of the joints in preformed panel and in situ reinforced concrete walls will assist in determining not only the overall scale and proportion of a building, but also the pattern and rhythm of features on the façade. The surface texture created by the need to channel water away from widely spaced joints of preformed wall units also helps in creating the particular character and expression of a building.

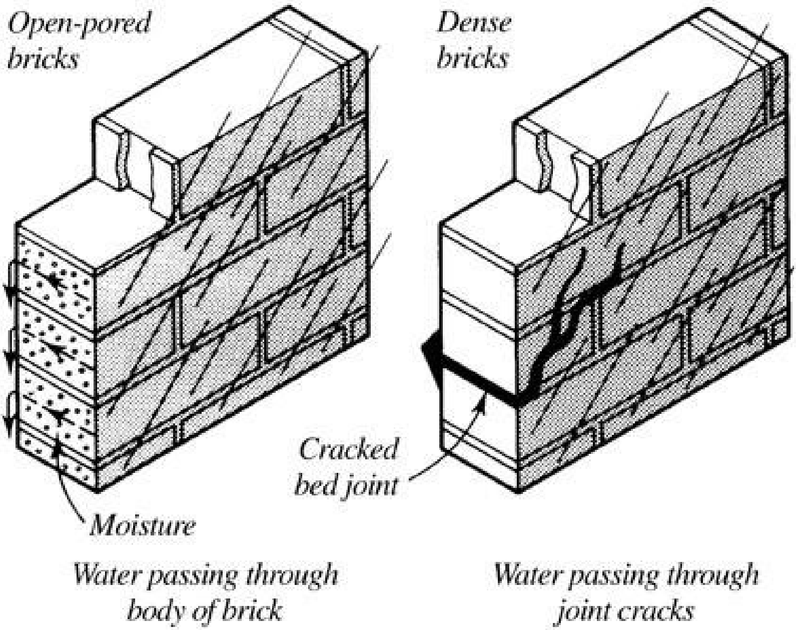


Figure 6.9 How water can penetrate brickwork.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 1 Environmental factors Chapter 2 Moisture Chapter 3 Ventilation and air quality
Structure and Fabric Part 1	Chapter 5 Walls and piers Chapter 7 Roof structures Chapter 8 Floor structures Chapter 9 Fireplaces, flues and chimneys

Building Research Establishment

Digest 217	*Wall cladding defects and their diagnosis*
Digest 312	*Flat roof design: the technical options*
Digest 346	*The assessment of wind loads* Parts 1–8
Digest 350	*Climate and site development* Parts 1–3
Digest 380	*Damp-proof courses*
Digest 390	*Wind around tall buildings*
Digest 406	*Wind action on buildings and structures*
Digest 419	*Flat roof design: bituminous roofing membranes*
Digest 428	*Protecting buildings against lightning*
Digest 436	*Wind loading* Parts 1–3
Digest 469	*Selecting gaskets for construction joints*
Report 59	*Directional driving rain indices for the UK – computation and mapping*
Report 262	*Thermal insulation: avoiding the risks*, 2nd edition

Good Building Guide GG 33 *Building damp free cavity walls*
Good Building Guide GG 68 *Installing thermal insulation* (2 parts)
Special Digest SD5 *Wind loads on unclad structures*

Building Regulations

A1	Loading
C2	Resistance to moisture
L	Conservation of fuel and power
Regulation 7	Materials and workmanship

7
Sound control

CI/SfB (P)

The control of sound in a building must be considered from two aspects:

- The elimination or reduction of unwanted sound generated by sources within or outside a building (sound attenuation).
- The creation of good listening conditions within a building where speech and music need to be clear, unmarred by sound reverberation and echoes.

7.1 Unwanted sound

Figure 7.1 indicates the main ways by which sound can be transmitted into and through a building. This involves movement through air or other elastic media formed from solids, liquids or gases, airborne sound, or movement through a solid structure resulting from an impact force, impact sound. Both are transmitted by direct paths from source to recipient or by indirect paths along adjoining elements. Transmission by indirect paths is known as flanking transmission. High levels of unwanted sound, or noise, can lead to a breakdown in people's mental health or even damage their hearing. Unwanted lower levels of sound are a nuisance and become a source of constant irritation, causing a loss of concentration.

7.2 Noise outside a building

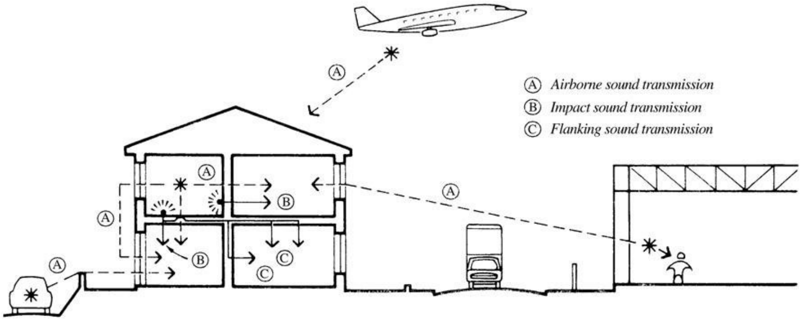


Figure 7.1 Unwanted sound.

Apart from industrial operations, external noise nuisance is most often caused by motor traffic and it is necessary for the designer to be familiar with the noise climate liable to affect the performance of a building. This is the range of sound levels achieved for 80 per cent of the time – the remaining 20 per cent being divided equally between
sound levels occurring above and below the main range. The upper limit of the noise climate is called the 10 per cent level (L10) and has become the unit used for specifying extreme exposure conditions to traffic noise. Measurements are taken at a 10 m distance over a period of 18 hours between 0600 and 2400 on a normal weekday. This provides a basis of data for consideration of government compensation or grants. These may be awarded for installation of noise controls in houses adjoining new or upgraded main highways and motorways.

Similar compensation procedures are available for exposure to aircraft noise. This can be assessed by a noise and number index (NNI), originally devised by the Wilson Committee on Noise in 1963. It is somewhat dated, but nonetheless an established and accepted measure of subjective noise from aircraft. It considers the frequency of movements during the day and the loudness of each. The formula is:

NNI = (average peak PNdB) + 15(log N) − 80

where:

- PNdB = logarithmic average of highest level of all flights
- logN = logarithm to the base 10 of the number of aircraft
- 80 = factor to allow for a zero annoyance at 80 PNdB

e.g. if the average peak is 105 PNdB (approx. 92 dBA) and the number of flights is 120, then:

NNI = 105 + 15(log120) − 80 = 56.2

Unreasonable levels commence above 50.

Since 2002 the European Directive on Operating Restrictions at Community Airports (Directive 2002/30/EC), requires alternative measures for noise mapping at locations around airports. Equivalent average noise energy known as L_{eq} is a measure of the noise in dBA as planes fly over, in combination with a measure of the relative quiet between flights. Another indicator known as N_{70} counts the number of overflights exceeding 70 dBA at ground level. Whatever method is used, contours representing sound levels can be mapped to specific locations.

Local authorities have powers and duties to control noise nuisance under the Environmental Protection Act 1990 and the Control of Pollution Act 1974. The latter provides means of creating noise abatement zones for the long-term control of noise from fixed sources such as may exist in areas of mixed residential and industrial development. This act also provides the power to control noise on construction and demolition sites which, although usually short-lived, may inflict severe discomfort on normally peaceful neighbourhoods. Nevertheless, prevention is better than cure, and various documents exist which attempt to control the initial output of noise such as BS 5228: Code of practice for noise and vibration control on construction and open sites; the Road Traffic Act 1988, Part II: Construction and use of vehicles and equipment; and the Health and Safety at Work, Etc., Act 1974, incorporating the Control of Noise at Work Regulations 2005.

7.3 Noise inside a building

As indicated by Figure 7.1, the movement of either airborne or impact noises inside a building is a complex process involving transmission through walls and floors by direct and/ or flanking paths. The relative weight and rigidity of a building fabric and the nature of construction affect the amount of transmission. Current building legislation attempts to define minimum standards for domestic construction methods which provide an acceptable degree of control. However, modern society requires the increasing use of sound-producing equipment for home entertainment devices and the frequent involvement of noisy household appliances. These requirements often conflict with the simultaneous trend towards lightweight materials and less homogeneous methods of assembly used for a building. Joints in constructions are particularly liable to cause weak links when considering sound control as a problem. The methods used to control the movement of sound within a building are similar to those adopted to control sound from external sources, although external sound is also reduced by weather exclusion measures, i.e. components having greater thicknesses and weights.

7.4 Frequency, intensity and loudness

When analysing the control of noise, it is useful to clarify the two basic factors, frequency and intensity, which initially influence the kind of sound received by the human ear.

Sound is normally created in the air when a surface is vibrated and sets up waves of alternating compression and rarefaction. The distance between adjacent centres of compression is known as the wavelength of the sound, which for human hearing varies from about 20 mm to 15 m. The number of complete movements or cycles from side to side made by the particles in the air (or any other elastic medium) during the passage of sound waves determines the frequency of the sound; this is usually quoted as the complete number of cycles made in a second, the number of hertz (Hz). The greater the number of cycles per second or hertz caused by the vibrations, the higher the pitch of the sound. People are most affected by frequencies between 500 Hz and 6 000 Hz (Fig. 7.2). Similar waves can also be produced by air turbulence during explosive expansion of air or a combination of vibration and explosive expansion.

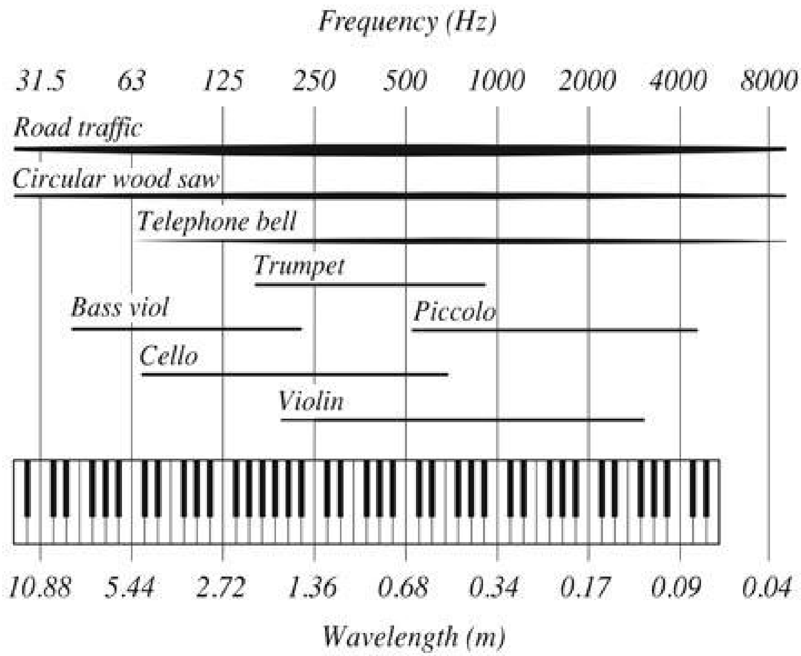


Figure 7.2 Sound frequencies.

The intensity of sound is a measure of the acoustic energy used in its transmission through the air. It is calculated from:

$$I = P \div 4\pi r^2$$

where:

- I = Intensity at distance (W/m^2)
- P = Power at sound source (W)
- r = Distance from source (m)

Sound intensity level (SIL) is expressed in decibels (dB) conforming to a logarithmic scale (regular proportionate increments rather than equal increments) which closely approximates the way sound is heard. This scale of constant ratios gives a manageable scale and practical measure for sound strength over a range of sounds (Table 7.1). SIL can be calculated from:

$$10 \log(I \div I_0)$$

where:

- log = Logarithm to the base 10
- I = Intensity at distance (W/m^2)
- I_0 = Intensity at the threshold of hearing (taken as: 1×10^{-12} W/m^2)

The actual decibels produced by a particular external airborne sound will be reduced according to the amount and characteristics of the intervening space between source and recipient. There is a theoretical reduction of 6 dB each time the distance from the source is doubled. Sound that is perceived twice as loud as another is measured 10 dB higher. Therefore, a sound intensity of 80 dB is twice as noisy as that of 70 dB. One decibel is one tenth of a bel, attributed to Alexander Graham Bell.

In practice this amount may be modified by such factors as whether the source is a single point, a continuous line or an area origin; the source height; the amount reflected during its transmission; the effectiveness of screening devices provided by trees, other buildings, embankments, etc.; and meteorological conditions. In addition, the ability to hear a given sound within a building will depend to a considerable extent on the background noise generally existing within the interior. General room sounds created by radio, television and conversation often make traffic noises far less noticeable. Furthermore, the number of decibels created by a particular source does not necessarily provide an indication of how loud it sounds because the human ear is more sensitive to high-frequency sounds than to low. Therefore, the subjective loudness of a noise is measured by a weighted scale known as dBA, which gives an overall intensity with a bias towards high-frequency sounds that represent the variations in sensitivity of the human ear. Other frequency weighted scales are also available (dBB, dBC and dBD). Sound measurements are taken from sound level meters which for most purposes have electronic circuits weighted to the dBA scale. These hand-held devices convert air pressure variations caused by sound emissions into a voltage variation displayed on the meter in increments of dBA.

Table 7.1 Typical sound intensity levels

Source of noise	Sound intensity (dB)
Four-engine jet aircraft at 100 m	120
Riveting of steel plate at 10 m	105
Pneumatic drill at 10 m	90
Circular wood saw at 10 m	80
Heavy road traffic at 10 m	75
Telephone bell at 10 m	65
Average male speech at 10 m	50
Whisper at 10 m	25
Threshold of hearing, 1000 Hz	0

7.5 Defensive measures

The first and obvious defence against the intrusion of unwanted airborne sound lies in placing as much distance as possible between the source and the recipient. For example, activities accommodated by the function of a building requiring a quiet environment (sleeping, studying, lecturing, etc.) can be placed remote from the external noisy distraction of motorways, sports stadiums and industrial applications. Further reduction can then be provided by the fabric of a building, although the precise nature of material and construction technique most suitable to reduce intrusive sound can be fairly complicated to assess. Nevertheless, data is available which specifies desirable sound levels within a building according to functions (Table 7.2), and construction methods can be selected which provide the necessary sound reduction to achieve these goals relative to the anticipated external noise environment. Similar considerations apply to the reduction of unwanted sounds which may occur inside a building.

Table 7.2 Acceptable intrusive noise levels in respect of broadband random frequency noise (e.g. road traffic)

Location	Noise level (dBA)
Banks	55
Churches	35
Cinemas	35
Classrooms	35
Concert halls	30
Conference rooms	30
Courtrooms	35
Council chambers	35
Department stores	55
Hospitals, wards	35
Hotels, bedrooms	35
Houses, living	45
Houses, sleeping	35
Lecture rooms	35
Libraries, loan	45
Libraries, reference	40
Music rooms	30
Offices, private	40
Offices, public	50
Radio studios	30
Restaurants	50
Recording studios	30
Shops	55
Telephoning, good	50
Telephoning, fair	55
Television studios	35
Theatres	30

These are optimum levels and may be exceeded by 5 dBA except in the critical situations shown in **bold**.

The amount of sound control or sound attenuation* provided by certain construction methods has been established over the frequency range 100–3 150 Hz (roughly corresponding to the lowest and highest frequencies normally experienced in a building). For this reason data for these forms of construction is useful when it is necessary to provide sound attenuation for broadband noise, but may be misleading when comparing dissimilar but adjoining methods of construction, or when noise is concentrated predominantly at selective frequencies, e.g. related to dBA scale.

For practical purposes, however, the airborne sound attenuation of a construction is controlled by four factors:

- Mass or weight per unit area Attenuation increases by approximately 5 dB for a doubling of weight or doubling of frequency.
- Discontinuity Elimination of direct sound paths where mass is insufficient by isolating those surfaces which receive the sound from those which surround the listener. The effect of a cavity between depends on its dimension in relation to the wavelength of sound to be controlled. Generally, a minimum practical gap of 50 mm is suitable for high frequencies, but a wider gap is necessary for low frequencies. Discontinuity must not incorporate any bridging along which sound may travel.

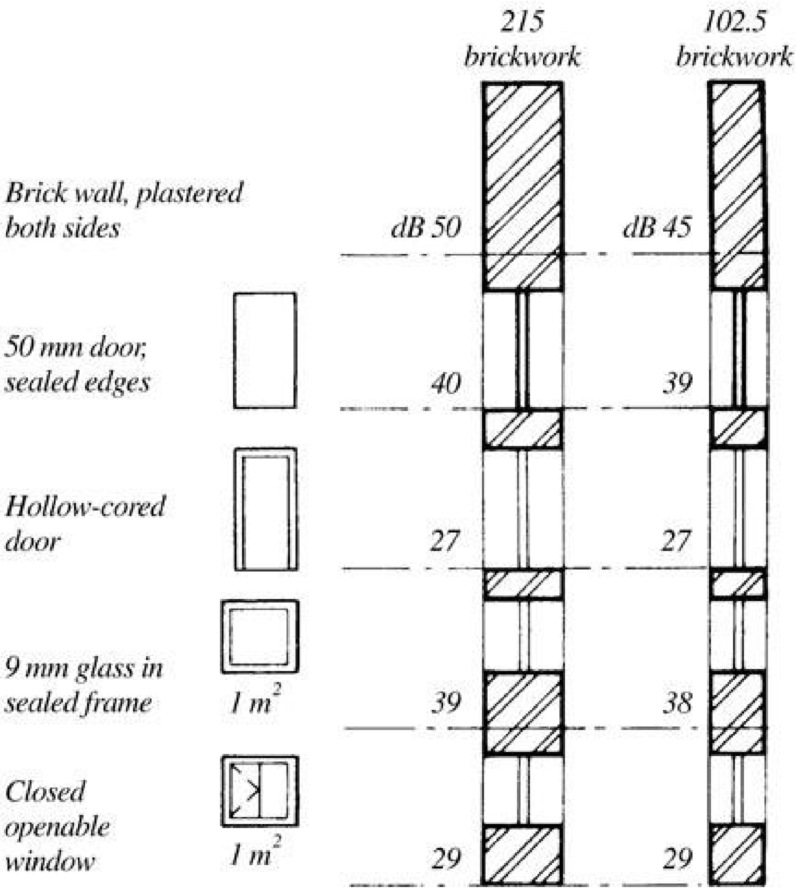


Figure 7.3 Sound attenuation: effects of openings in walls. (Based on data provided by the Brick Development Association)

- Stiffness Elimination of vibration by sound waves. When incident sound waves have frequencies similar to those created by vibration of the construction, the sound attenuation will be less and unrelated to that theoretically provided by its mass.

- Uniformity Elimination of direct air paths through the construction. This applies not only to openings, holes and cracks, but also to materials which are not in themselves airtight. In the case of doors and windows, no matter how heavy the surrounding wall may be, the net sound attenuation will be limited to a maximum of about 7 dB above that of the door (Fig. 7.3).

The control of the effects of impact noise in a building requires different consideration from those given above. For example, the noise heard below a floor subject to impact noise will bear little relation to the airborne noise it causes in the room above. For the room below, weight has no advantage and the only defence is to prevent the transmission of the impact sound to the structure by using a soft floor finish or a finish which is isolated from the structure.

7.6 Listening conditions

Sound within a room consists of two components: direct, which travels in a straight line through the air from the source to the recipient; and reverberant, which is the sum of all the sound reflections from the room surfaces (Fig. 7.4). As discussed in section 7.4, the direct noise decreases at the rate of 6 dB for each doubling of distance from the source, whereas the reverberant sound is theoretically constant throughout the room. This means that in a room containing a single source there is a zone where the direct sound predominates; immediately beyond this another zone will occur where neither direct nor reverberant sound predominates, and then finally a zone where the reverberant component predominates. The sizes of these zones depend upon the dimensions of the room as well as the quantity and quality of the absorbent surfaces present.

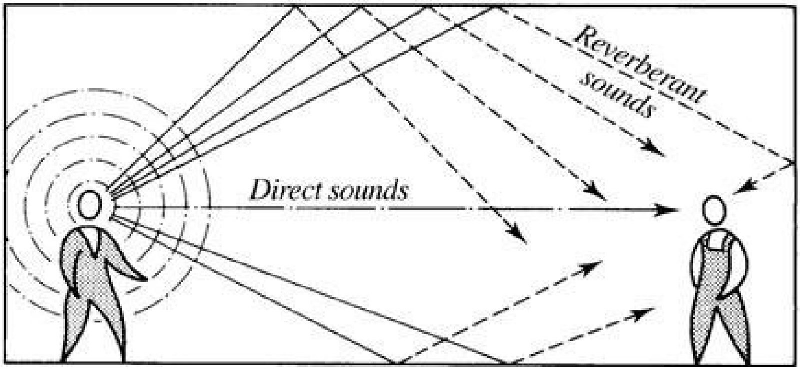


Figure 7.4 Direct sound and reflected (reverberant) sound.

7.7 Blurring and echoes

Reverberant sound can be extremely useful in large rooms such as auditoriums, where controlled reflections can send the sound levels to positions normally too distant to receive adequate sound from the direct path. However, focusing reflections in this way is a relatively skilled process, and if misjudged, reverberant sound and direct sound will be heard at slightly different intervals, thereby creating blurring (reflection arriving 1/30 to 1/15 second after direct sound) or echoes (more than 1/15 second discrepancy). Further explanation of the precise science used to achieve audibility and clarity of performance in auditoriums is beyond the scope of this book, and reference should be made to one of the many excellent monographs available on this subject for further clarification.

7.8 Sound absorption

It is important to differentiate between sound attenuation, as described earlier, and sound absorption. Attenuation is concerned with the passage of sound energy through a barrier; absorption with the sound reflection capabilities of the surfaces within a room or space. Sound produced by speech or music may be reflected several times from walls, floors or ceiling before the residual energy in the sound waves is negligible. The continuance of sound during this period is known as reverberation, and the interval between the production of the sound and its decay to the point of inaudibility is known as the reverberation time. The sound-absorbing properties (absorption coefficient) of a surface are measured by the amount of sound reduction which occurs after waves strike the surface. Coefficients vary from 0 to 1, i.e. perfect reflection (hard surface) to total absorption (open window); see Table 7.3.

The sound levels in a room build up to a level which is determined by the absorption characteristics of the room. This can cause discomfort to the occupants, and increases the likelihood of noise being transferred to adjoining rooms where the original attenuation standards were sufficient. The provision of sound-absorbent materials on the surfaces of the room containing the sound source will eliminate these possibilities. If a room has mostly hard surfaces, no soft furnishings and few occupants to absorb sound effectively, it is usually not difficult to make a four-fold increase in absorption and obtain a reduction of 6 dB. However, care must be taken when selecting absorbent materials that the coefficient matches the frequency of the offending sound(s).

Table 7.3 Sound absorption coefficients

Item	Unit	Absorption coefficient at different frequencies		
		125 Hz	500 Hz	2000 Hz
Air	m^3	0	0	0.007
Audience (padded seats)	person	0.17	0.43	0.47
Seats (padded)	seat	0.08	0.16	0.19
Boarding or battens on solid wall	m^2	0.3	0.1	0.1
Brickwork	m^2	0.02	0.02	0.04
Woodblock, cork, lino, rubber floor	m^2	0.02	0.05	0.1
Floor tiles (hard)	m^2	0.03	0.03	0.05
Plaster	m^2	0.02	0.02	0.04
Window (5 mm)	m^2	0.2	0.1	0.05
Curtains (heavy)	m^2	0.1	0.4	0.5
Fibreboard with space behind	m^2	0.3	0.3	0.3
Ply panel over air space with absorbent lining	m^2	0.4	0.15	0.1
Suspended plasterboard ceiling	m^2	0.2	0.1	0.04

Table 7.4 Typical sound insulation values

Type of construction	SRI (average dB in the range 100–3150 Hz)
Brick/brick cavity wall, plastered	53
Brick/block cavity wall, plastered	49
Lightweight clad timber frame wall	38
215 mm brickwork, plastered	50
102.5 mm brickwork, plastered	45
50 mm dense concrete	40
100 mm dense concrete	45
300 mm lightweight concrete	42
12.5 mm plasterboard	25
Solid core door (25 kg/m^2)	26
Window, 4 mm single glazed	27
Window, 10 mm single glazed	31
Window, 4–12–4* double glazed	28
Window, 6–100–6* double window	37
Window, 10–200–10* double window	46
Roof (tiled) + 12.5 mm plasterboard ceiling	30
Roof (tiled) as above, with 100 mineral wool insulation	38
Flat roof, 100 mm reinforced concrete (230 kg/m^2)	48

* glass thickness–air space–glass thickness.

$$T = 0.5 \div 100$$
$$T = 0.005$$
$$SRI = 10 \log (1 \div 0.005)$$
$$SRI = 10 \log 200$$
$$SRI = 10 \log 2.30$$
$$SRI = 23\ dB$$

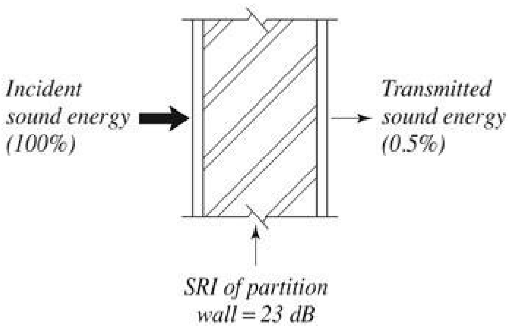


Figure 7.5 A wall transmitting 0.5 per cent of the sound energy incident on the exposed side at a given frequency.

7.9 Sound reduction

A sound reduction index (SRI) may be used as a measure of the insulating effect of construction, against direct transmission of airborne sound. For consistency, tests are simulated in a laboratory where no flanking sound paths are possible. Insulation varies with frequency and the SRI is measured at octave* intervals between 100 and 3 150 Hz. The arithmetical average is usually similar to the value at 500 Hz and this is generally a convenient figure for calculations and comparisons. Some typical values are shown in Table 7.4.

Accurate values for SRI can be obtained by calculation (see Fig. 7.5) from the laboratory data, using the following formula:

$$\mathrm{SRI} = 10 \log(1 \div T)$$

where:

- log = Logarithm to the base 10
- T = Transmitted sound energy ¸ incident sound energy

Further details of laboratory analysis of sound insulation can be found in BS EN ISO 10140 (Parts 1 to 5): Acoustics. Laboratory measurement of sound insulation of building elements.

7.10 Sound insulation regulations

The Building Regulations for England and Wales require resistance to the passage of sound:

- between dwellings – houses and flats (Approved Document E1) (see Table 7.5)
- within a dwelling (Approved Document E2)

The regulations also have application to:

- common internal parts of buildings (Approved Document E3)
- acoustic conditions in schools (Approved Document E4)

It is not necessary to test every wall or floor in every new building on a site. Sample testing determined by the building control authority is adequate to ensure quality control standards are achieved. The equipment used can be a compact hand-held sound-level meter which converts variations in air pressure to variations in voltage. These variations are shown on a scale corresponding to decibels. The value indicated is the root mean square (RMS) of the signal, which is a type of uniform average, rather than extreme values.

Table 7.5 Insulation performance requirements for elements of construction which have a separating function (Building Regulations A.D. E1)

Situation	Airborne sound min. values (dB)		Impact sound max. values (dB)	
	Dwellings	Residential*	Dwellings	Residential*
Purpose built, i.e.				
new-build walls	45	43	–	–
new-build floors and stairs	45	45	62	62
Conversion/change of				
use/refurbishment walls	43	43	–	–
floors and stairs	43	43	64	64

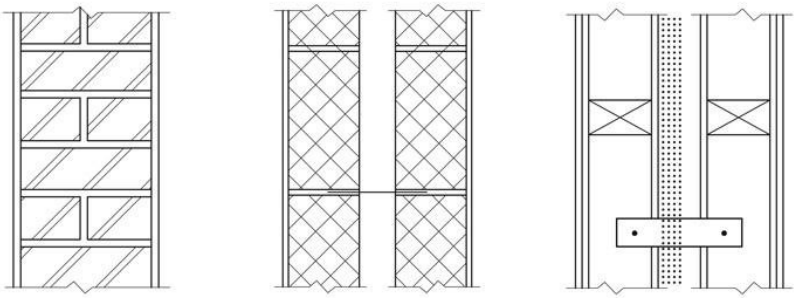
* Residential applies to a room in a hostel, student hall of residence, hotel, boarding house or residential home.

The type of construction suitable for separating walls can be heavy- or lightweight. Heavyweight walls reduce airborne sound by virtue of mass. Cavities can reduce sound by discontinuity or separation. Lightweight walls such as timber framing rely on a combination of mass, discontinuity and absorption of sound by a mineral fibre quilt. Table 7.6, Figures 7.6 and 7.7 provide a selection of standard constructions for separating walls and floors.

Table 7.6 Elements of construction to provide a separating function

Construction to include plastered room faces	*Min. mass per unit area (kg/m²)*
Solid walls:	
215 mm brickwork	375
215 mm concrete block	415
190 mm *in situ* concrete	415
Cavity walls:	
102 mm brickwork + 75 mm cavity	415
100 mm concrete blocks + 75 mm cavity	415
100 mm lightweight concrete blocks + 75 mm cavity	300
Timber frame wall:	
100 × 50 mm structural frame (×2), quilting of mineral wool in cavity (25 mm) or frames (25 mm each) + double layer of plasterboard (30 mm) each side	N/A
Floors:	
See Figure 7.7	

Solid masonry | *Cavity masonry* | *Lightweight timber frame*



Brick density 1610 kg/m³
Block density 1840 kg/m³
13 mm lightweight plaster, min. mass per unit area – 10 kg/m²

Concrete block density 1990 kg/m³.
75 mm min. cavity
13 mm lightweight plaster

As Table 7.6.
Plywood sheathing in cavity for structural purposes
Plasterboard min. mass per unit area – 9 kg/m²
40 × 3 mm galv. steel continuity straps at 1.2 m

Figure 7.6 Separating walls.

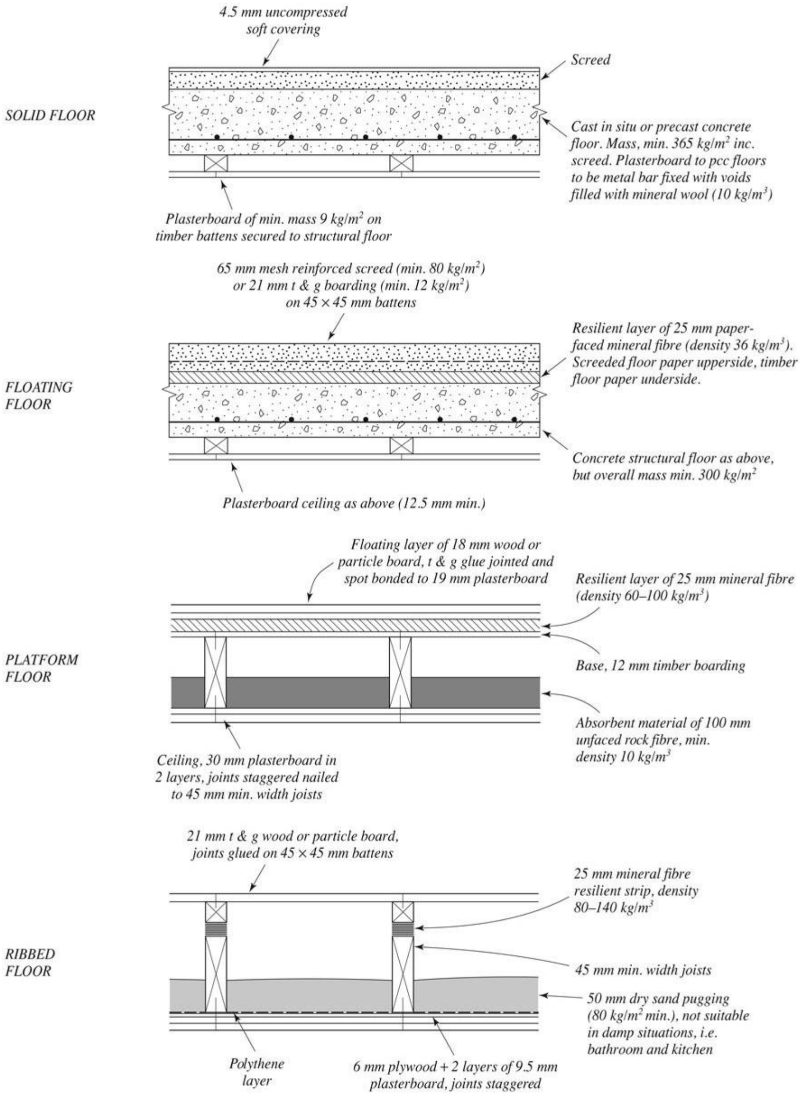


Figure 7.7 Separating floors.

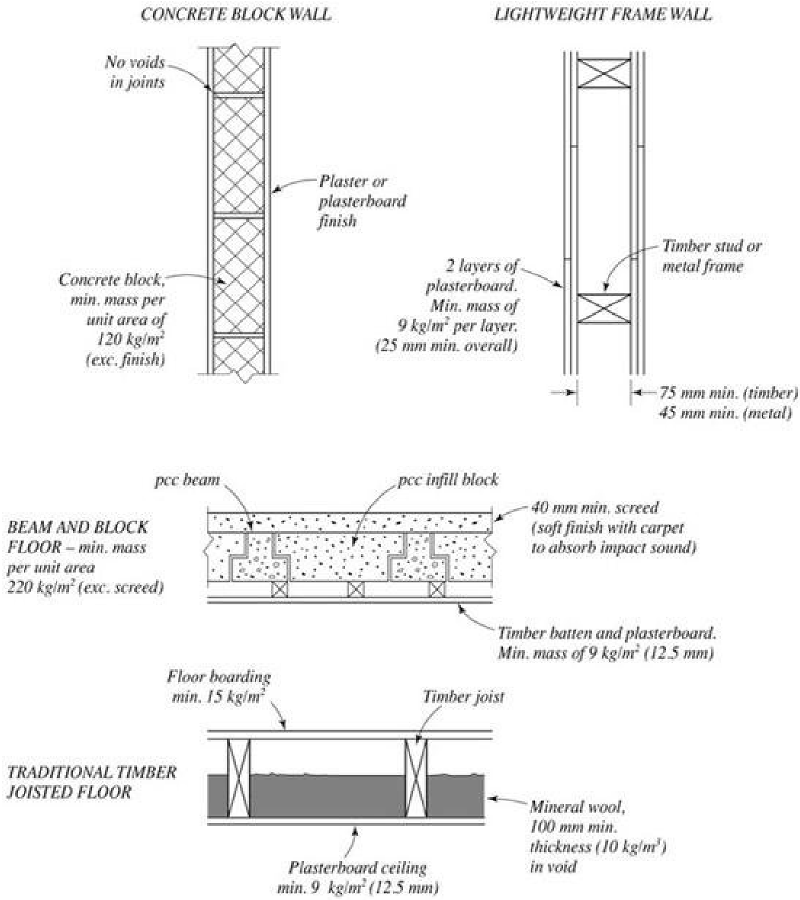


Figure 7.8 Internal walls and floors.

The minimum laboratory test value for walls between a bedroom or a room containing a WC and other rooms and floors within any new dwelling or new residential buildings, including those created by change of use, is 40 dB (Building Regulations Approved Document E2). Some examples which satisfy this requirement for reasonable resistance to sound are shown in Figure 7.8.

7.10.1 Junctions between elements of construction

The void in cavity wall construction provides an unrestricted passage to transmission of sound. At the junction of an external cavity wall with sound-resisting separating walls and floors, the construction is modified to maintain continuity of resistance to flanking sound transmission. Some examples using a cavity stop are shown in Figure 7.9. A cavity stop is a flexible moisture-resistant material inserted to bridge junctions of elements of construction, unless the cavity is fully filled with mineral wool or other material specified for thermal insulation purposes. A cavity stop can also function as a cavity barrier to fire at separation of compartments within buildings, see Building Regulations Part B – Fire Safety, Approved Document B3 Internal fire spread (structure), Concealed spaces (cavities) in Volumes 1 and 2.

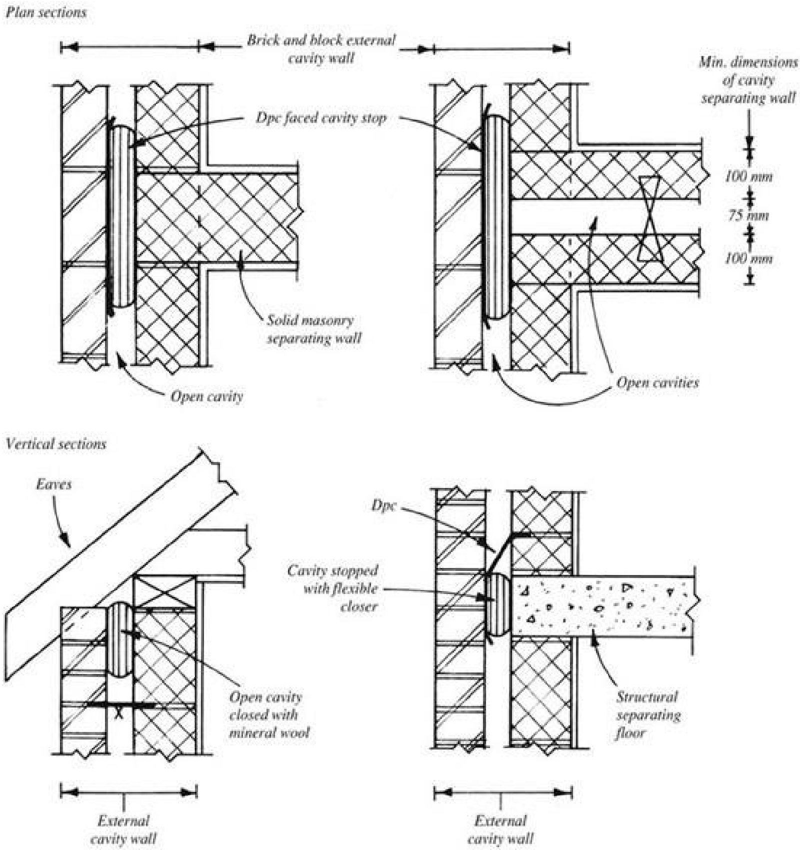


Figure 7.9 Cavity stops at junctions.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 6 Sound

Structure and Fabric Part 1	Chapter 5 Walls and piers (functional requirements) Chapter 7 Roof structures (functional requirements) Chapter 8 Floor structures (functional requirements) Chapter 10 Stairs (functional requirements)

Building Research Establishment

Digest 162	*Traffic noise and overheating in offices*
Digest 293	*Improving the sound insulation of separating walls and floors*
Digest 337	*Sound insulation: basic principles*
Digest 338	*Insulation against external noise*
Digest 379	*Double glazing for heat and sound insulation*
Digest 453	*Insulation glazing units*
Information Paper 6/94	*The sound insulation provided by windows*
Information Paper 4/01	*Reducing impact and structure-borne sound in buildings*
Information Paper 14/02	*Dealing with poor sound insulation between new dwellings*
Information Paper 2/06	*Rain noise from glazed and lightweight roofing*
Good Repair Guide 22	*Improving sound insulation*

Department for Education and Skills (DfES)

Building Bulletin 93 The Acoustic Design of Schools, TSO

Department for Communities and Local Government (DCLG)

Planning Policy Guidance 24 Planning and noise

Building Regulations

E1 Protection against sound from adjoining dwellings or buildings etc.
E2 Protection against sound within a dwelling etc.
E3 Reverberation in the common internal parts of buildings containing dwellings etc.
E4 Acoustic conditions in schools.

Other Guidance

Robust Details Handbook – Alternative to pre-completion sound testing of separating walls, floors and stairs. Published by Robust Details Ltd.

Notes

* Avoid the term 'sound insulation' so as not to confuse it with 'thermal insulation'. Effective sound insulation requires a higher density of material, effective thermal insulation a lower density.

* An octave is a range of frequencies between any frequency and double that frequency. For example, 500 Hz is one octave above 250 Hz. Octave bands for frequency analysis usually have frequency centres ranging between 31.5 and 8 000 Hz (see Fig. 7.2).

8
Thermal comfort and efficiency

CI/SfB (M)

A building must provide a satisfactory thermal environment for its occupants as well as for the mechanical systems it accommodates. Energy within the human body produces uninterrupted heat at varying rates in order to maintain an ideal temperature of 37 °C in the internal organs. However, heat is lost by the body through radiation, convection and evaporation from the skin and the lungs, and there is a continuous process of adjustment to ensure a thermal balance between heat produced and heat lost. It is particularly important that the brain temperature is maintained constant. The factors in the local environment which govern heat loss include not only air temperature but also air movement, relative humidity and the radiant temperatures from surrounding surfaces.

The fabric of clothing and that of a building perform similar functions by maintaining temperature control through passive means which regulate natural flows of heat, air and moisture vapour. As a building involves a volume many times larger than that contained by clothing, and provides environmental conditions suitable for many occupants in different spaces, it must also provide active means for thermal comfort not unlike that achieved by the human body itself (Fig. 8.1).

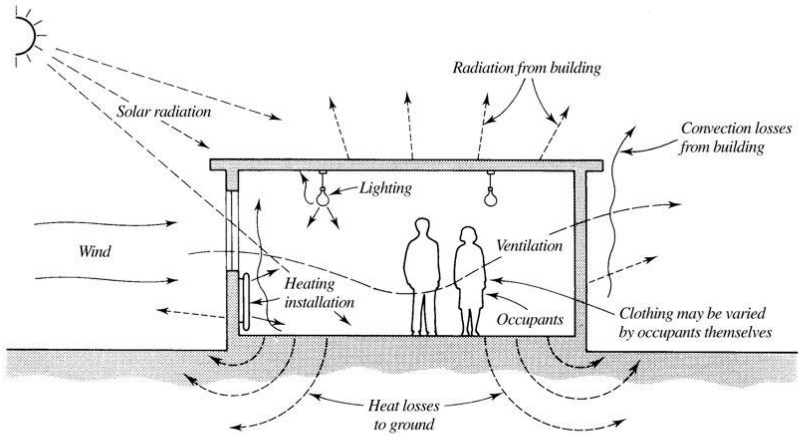


Figure 8.1 Heat balance of building in relation to internal and external influences.

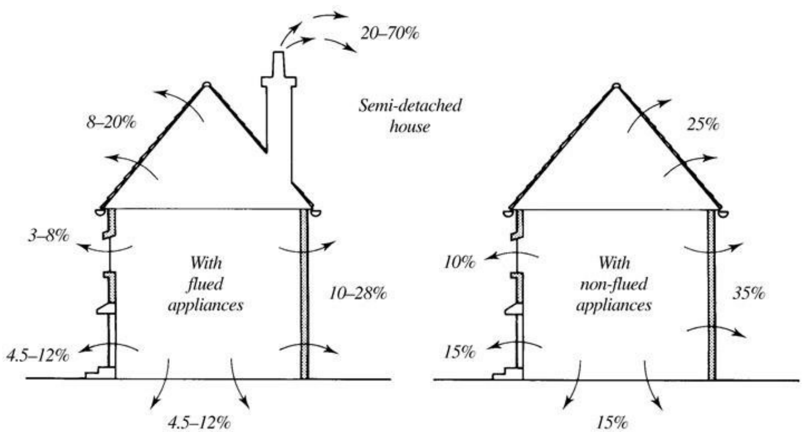


Figure 8.2 Potential percentage heat losses from domestic buildings.

8.1 Passive means

Simply stated, the creation of thermal comfort within a building by passive means involves the reduction of the rate of heat losses from the inside to the outside in colder climates, and the reduction of heat gains from the outside to the inside in warmer climates. In both cases the transfer of heat is regulated by the external fabric of a building which can provide varying degrees of thermal insulation. The type and amount necessary to achieve ideal conditions varies according to resource availability, climate of locality and the degree of exposure (Fig. 8.2).

In the United Kingdom the thermal performance of a building fabric is directly affected by such detailed criteria as seasonal changes and extremes of temperature; temperature differences between day and night (diurnal range); sky conditions (amount of sunlight and overshadowing); incoming and outgoing heat radiation; rainfall and its distribution; the effects of water absorption and repulsion on materials and their forms (weathering); air movements; and other special features influenced by location and orientation. A designer must interpret these requirements in conjunction with fashions in appearance for a building, together with the current legal requirements which endeavour to control atmospheric pollution and conserve the use of fuel for space heating by regulating the amount of heat loss from a building to the external environment.

8.2 Heat transfer

Heat may be lost from a building fabric to the external environment by convection (movement of heat by hot liquid or gas); conduction (transfer of heat through solids); and radiation (transfer of heat from a surface across a vacuum, gas- or liquid-filled space, or a transparent solid). Natural ventilation causes convection losses and takes the form of a stack effect (Fig. 10.5), where warm air rises in a building, eventually escaping to be replaced by colder air. Controlled ventilation is desirable as one of the functions of a building, e.g. trickle vents in window frames (Fig. 10.6). Air leakage through gaps where external components meet should be prevented with a silicone mastic seal, e.g. window frames to wall, and joists to inner leaf support. Airtightness with draught-proof seals must also be provided at openings, e.g. doors, window sashes and loft hatches. Heat energy losses through the building fabric should be minimised by continuity of insulation about the external envelope.

Solid building materials used for a building fabric lose heat from warm to cold face by conduction. The ability of a material to conduct heat is known as its conductivity (l) value, and is measured by the amount of heat flow (watts) per square metre of surface area for a temperature difference of 1 K per metre thickness, i.e. W m/m^2 K or W/m K. When comparing the insulation properties of a material to that of others, it is generally more convenient to use its resistivity value (r) because it takes no account of size or thickness. Resistivity is therefore expressed as the reciprocal of the conductivity, i.e. m K/W.

In order to calculate the actual thermal resistance (R) offered by a particular material of known thickness, the formula used is actual thickness (m) × m K/W, i.e. R has units of m^2 K/W. The higher the R value, the better the thermal resistance and the insulating performance of the material (Table 8.1). And the lower a material's density, the greater its properties of insulation.

Table 8.1 Thermal conductivity and thermal resistances of some materials

Material	Conductivity (W/m K)	Resistance* (m^2 K/W)
Brickwork		
105 mm	0.84	0.125
220 mm	0.84	0.262
335 mm	0.84	0.399
Plaster		
15 mm hard	0.5	0.03
15 mm lightweight	0.16	0.09
10 mm plasterboard		0.06
Cavity		
Unventilated	–	0.18
With foil face		0.3
Behind tile hanging		0.12
Tile hanging	0.84	0.038
Expanded polystyrene		
25 mm	0.033	0.76
13 mm	0.033	0.39
Glass fibre		
50 mm	0.035	1.43
75 mm	0.035	2.14
100 mm	0.035	2.86
Aerated concrete		
100 mm	0.22	0.45
150 mm	0.22	0.68
Softwood, 100 mm	0.13	0.77
Weatherboarding, 20 mm	0.14	0.14

* The thermal resistance of a structural component is expressed as:

$$R = L \div \lambda$$

where: L = thickness of element (m)
λ = thermal conductivity (W/m K)

It is unfortunate that generally these relationships of density are counter to the noise control and structural qualities required from a material. A solid monolithic wall may be up to three times the thickness required for structural purposes in order to provide an acceptable level of thermal insulation. If a dense structural material is filled with pockets of air, its thermal insulation characteristics can be vastly improved while maintaining much of its strength characteristics. However, if these air pockets are allowed to become filled with water from exposure to rainfall or ground moisture, their insulation value will be cancelled altogether. This is because water is a much better conductor of heat than air; a saturated material could permit about 10 times more heat to be transferred through it when compared with its ‘dry’ state.

Any heated material will radiate heat from its surface; bright metallic surfaces generally radiate least and dark surfaces the most. In this respect, radiation and absorption characteristics of materials correspond. Some construction methods incorporate air cavities which reduce the amount of heat transfer by conduction (and the passage of moisture) from inner warm materials to outer cold materials. Some heat, however, will be transferred across cavities by radiation, and the absorption (and reflection) properties of the adjacent surfaces across the cavity will be significant to the thermal insulation value of the construction. (The performance of the cavity as an insulator will be impaired if convection currents take place.) Radiation losses generally depend on the emissivity – the rate of radiant heat emission – from the surface and values depend upon roughness of surface, the rate of air movement across it, its orientation or position, and the temperature of the air and other bodies facing it.

Table 8.2 Surface and air space resistances

Typical internal surface resistance values (R_{si}): Situation	Resistance (m^2 K/W)
Walls	0.123
Floors/ceilings – upward heat flow	0.104
Floors/ceilings – downward heat flow	0.148
Roofs – flat or pitched	0.104

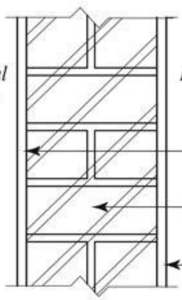
Typical external surface resistance values (R_{so}): Situation	Resistance (m^2 K/W)		
	Sheltered	Normal	Severe
Wall, high emissivity	0.080	0.055	0.030
Wall, low emissivity	0.110	0.070	0.030
Roof, high emissivity	0.070	0.045	0.020
Roof, low emissivity	0.090	0.050	0.020
Floor, high emissivity	0.070	0.040	0.020

Note: Emissivity varies with the effects of surface texture, amount of air movement, air temperature, surface orientation and temperature of adjacent materials. High emissivity is appropriate for most dull, textured building materials. A low emissivity could relate to light and reflective surfaces.

Typical air space resistances (R_a): Situation	Resistance (m^2 K/W)
Flat or pitched roof space	0.180
Beneath tile hanging	0.120
Void in a cavity wall	0.180
Between high and low emissivity surfaces	0.300
Sealed/unventilated spaces	0.180

8.3 Thermal insulation values

It is unrealistic to rely on empirical rules to establish forms of constructions which provide satisfactory resistance to heat transfer as well as weather resistance, strength and stability and many of the other performance criteria. Moreover, current construction methods are generally less bulky than those used years ago, as greatly reduced thicknesses of materials are employed in combination with each other, each layer, leaf or skin perhaps fulfilling only one very specific function. The thermal comfort properties of these materials used in combination can only be assessed by calculating the amount of heat transfer from internal to
external air (in cold climates). The thermal resistance properties of each layer must be taken into account, along with other factors relating to their surface texture and juxtapositions within the construction.



	L Thickness (m)	÷	λ value Conductivity (W/m K)	=	R value Thermal resistance (m^2 K/W)
Sum of external and internal surface resistances	(0.123	+	0.055)	=	0.178
Render	0.012	÷	0.57	=	0.021
Brickwork	0.215	÷	0.84	=	0.256
Render and plaster	0.015	÷	0.50	=	0.030
Total thermal resistance					R = 0.485

To calculate U value of element: $U = \frac{1}{R} = \frac{1}{0.485} = 2.062\ W/m^2\ K$

Figure 8.3 U value calculation for a one-brick-thick solid wall.

The internal to external thermal transmission rate of all the layers of a construction is known as a U value and is more accurately defined as the number of watts transmitted through 1 square metre of construction for each single degree Kelvin temperature difference between the air on each side of the construction, i.e. W/m^2 K. It is calculated by taking the reciprocal of the sum of all the thermal resistance values (R values of all materials used and any air cavities) as well as the internal and external surface resistances (Tables 8.1 and 8.2 and Fig. 8.3).

As the wall shown in Figure 8.3 is consistent and continuous in its construction, i.e. the mortar and brick-work have similar density and thermal properties, the U value calculation is relatively straightforward. Therefore the thermal transmittance of this element is:

$$U = \frac{1}{R}$$

where R is the sum of all the separate resistances for different materials or structural components in the element and the surface resistances, i.e.

$$U = \frac{1}{R_{si} + R_1 + R_2 + R_3 + R_{so}}$$

where:

- U = Thermal transmittance (W/m^2 K)

- R_{si} = Internal surface resistance (m^2 K/W)
- R_1 , R_2 , R_3 = Thermal resistance of structural components (m^2 K/W)
- R_{so} = External surface resistance (m^2 K/W)

Note that R_a , the resistance for an air space, is included with the summation where a cavity or voids occur in the construction. Typical value is: 0.180 m^2 K/W.

Walls with differing materials and composition (Fig. 8.4) will require more detailed calculation to determine the U value. The Proportional Area Method allows for inconsistent construction such as the relatively dense mortar between lightweight concrete blocks. Here the mortar will have a much higher thermal conductivity and a thermal bridging effect in the wall. However, the Combined Method (BS EN ISO 6946: Building components and building elements – thermal resistance and thermal transmittance – calculation method) is now preferred. This method provides a U value which represents the average of the upper and lower thermal resistance (R) limits.

Proportional area method of U value calculation applied to the brick/block insulated cavity wall shown in Figure 8.4:

Standard block face size + mortar,

$$450 \times 225 \text{ mm} = 101\,250 \text{ mm}^2$$

Standard block face/format size,

$$440 \times 215 \text{ mm} = \underline{94\,600 \text{ mm}^2}$$

The face area of 10 mm deep mortar per block

$$= \quad 6\,650 \text{ mm}^2$$

Proportional area calculations:

Mortar 6 650 ÷ 101 250 = 0.066 or 6.6%
Block 94 600 ÷ 101 250 = 0.934 or 93.4%

Thermal resistance (R) calculations:

Outer leaf and insulation (all unbridged)

R_{so} = 0.055
Brickwork = 0.122
Insulation = 2.857
3.034 × 100% = 3.034 m^2 K/W

Inner leaf (unbridged part)

R_{si} = 0.123
Plaster = 0.081
Blocks = 0.682
0.886 × 93.4% = 0.828 m^2 K/W

Inner leaf (bridged part)

R_{si} = 0.123
Plaster = 0.081
Mortar = 0.170
0.374 × 6.6% = 0.025 m^2 K/W

Now:

$$U = 1 \div \sum R$$

Therefore:

$$U = \frac{1}{3.034 + 0.828 + 0.025} = 0.257 \text{ W/m}^2 \text{ K}$$

but 0.020 W/m^2 K to be added for the use of vertical twist-type wall ties in the wide cavity
Therefore, corrected U value = 0.277 W/m^2 K

Combined method of U value calculation applied to Figure 8.4:

Upper and lower thermal resistance (R) limits are calculated from the formula:

$$R = \frac{1}{\Sigma(F_x \div R_x)}$$

where:

- F_x = Fractional area of section x
- R_x = Total thermal resistance of section x
- Section x represents the different thermal paths

The wall (Fig. 8.4) can be seen to have two different thermal paths:

1. Through the concrete blocks.
2. Through the mortar between concrete blocks.

The remainder is consistent.

The upper limit (R) for the section containing concrete blocks is:

$$
\begin{aligned}
R_{so} &= 0.055 \\
\text{Brickwork} &= 0.122 \\
\text{Insulation} &= 2.857 \\
\text{Concrete blocks} &= 0.682 \\
\text{Plaster} &= 0.081 \\
R_{si} &= \underline{0.123} \\
& 3.920 \text{ m}^2 \text{ K/W}
\end{aligned}
$$

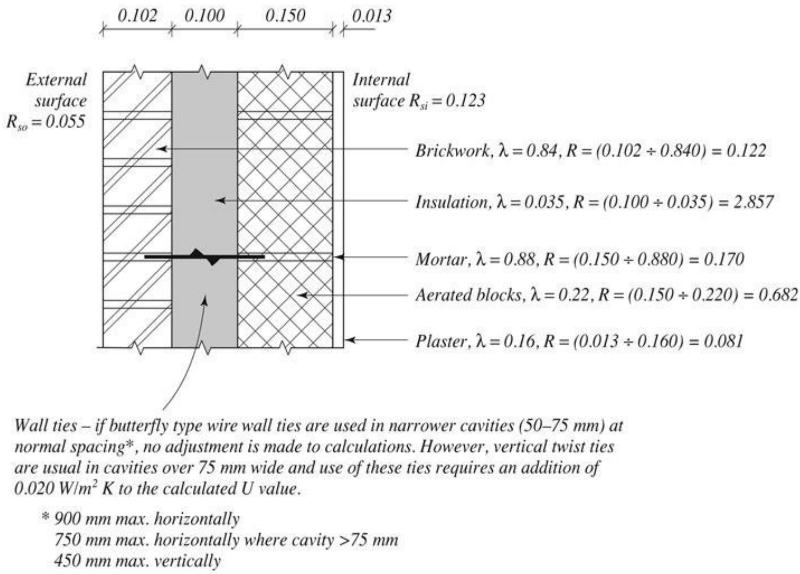


Figure 8.4 Fully insulated cavity brick and block masonry wall.

The fractional area of this section containing blocks is 0.934

The upper limit (R) for the section containing mortar is:

$$
\begin{aligned}
R_{so} &= 0.055 \\
\text{Brickwork} &= 0.122 \\
\text{Insulation} &= 2.857 \\
\text{Mortar} &= 0.170 \\
\text{Plaster} &= 0.081 \\
R_{si} &= \underline{0.123} \\
&\quad 3.408 \text{ m}^2 \text{ K/W}
\end{aligned}
$$

The fractional area of this section containing mortar is 0.066

The upper limit of resistance (R) is:

$$
\begin{aligned}
R &= \frac{1}{(0.934 \div 3.920) + (0.066 \div 3.408)} \\
&= 3.881 \text{ m}^2 \text{ K/W}
\end{aligned}
$$

The lower limit of resistance (R) is the summation of all the layers:

$$
\begin{aligned}
&R_{so} && = 0.055 \\
&\text{Brickwork} && = 0.122 \\
&\text{Insulation} && = 2.857 \\
&\text{Bridged layer} && \\
&\quad = 1 \div (0.934 \div 0.682) + (0.066 \div 0.170) && = 0.569 \\
&\text{Plaster} && = 0.081 \\
&R_{si} && = \underline{0.123} \\
& && \quad 3.807 \text{ m}^2 \text{ K/W}
\end{aligned}
$$

The total resistance (R) of the wall is taken as the average of the upper and lower limits:

$$(3.881 + 3.807) \div 2 = 3.844 \text{ m}^2 \text{ K/W}$$

$$U = 1 \div R$$
$$U = 1 \div 3.844 = 0.260 \text{ W/m}^2 \text{ K}$$

As before, 0.020 W/m^2 K is added to the calculation for the use of vertical twist-type wall ties in the wide cavity. Therefore the corrected U value is 0.280 W/m^2 K.

See also, BRE Report 443 Conventions for U value calculations.

The calculated U value for a particular construction is unlikely to provide an entirely accurate thermal transmittance rate because the heat flow conditions through the construction will vary with the amount of solar radiation, moisture conditions and the effects of prevailing winds. The quality of workmanship and supervision will also have an effect. Nevertheless, calculated U values are a reasonable guide for comparing the thermal insulation values of different forms of construction and as an indication as to whether or not the heat energy losses from a building are within the limitations of building legislation. The higher the U value, the poorer the thermal insulation properties of an element of construction. Also, a U value refers to the total constructional thickness of an element, whether consisting of a single layer of material or a combination of materials, with or without separating cavities.

The Building Regulations, Approved Document L: Conservation of fuel and power, Energy Peformance Certificates (section 8.3.1) and the Code for Sustainable Homes (Chapter 14) aim to increase the energy efficiency of buildings and thereby to reduce the emission of burnt fuel gases into the atmosphere. These are generally known as greenhouse gases and they include:

- carbon dioxide
- chlorofluorocarbons
- hydrochlorofluorocarbons
- hydrofluorocarbons
- methane
- nitrous oxide
- perfluorocarbons
- sulphur hexafluoride

Carbon dioxide (CO_2) is the least powerful but it is the most prominent, accounting for about 80 per cent of all greenhouse gas emissions globally. Therefore, current thermal insulation and boiler efficiency calculations are designed specifically to reduce its contribution to the greenhouse effect. This term is widely used and includes changes to atmospheric conditions such as global warming and ozone depletion, leading to the physical effects of polar melting and rising sea levels.

Requirements for new buildings in the United Kingdom generally include an enclosing envelope of insulation, double glazing throughout and draught sealing of all doors, opening windows, loft hatches and other gaps at interfaces in the building fabric. Effectiveness of these provisions and the efficiency of hot water and heating systems can be calculated by assessment for an Energy Peformance Certificate and the Standard Assessment Procedure outlined in section 8.4. U values for elements of construction are shown in Figure 8.5, but variations can apply to these depending on the contribution made by many other energy-related factors. For dwellings some of the most significant contributory factors are considered in section 8.4.

8.4 Criteria for appraising the thermal efficiency of buildings

An Energy Performance Certificate (EPC) applies to buildings that are newly built and to existing buildings that are altered, extended, refurbished or modified to change their use. An example of the latter category could be conversion of a house into flats. An EPC is also required as part of the marketing particulars when selling or letting a building. Some exemptions apply, mainly to listed buildings, temporary buildings, monuments and churches.

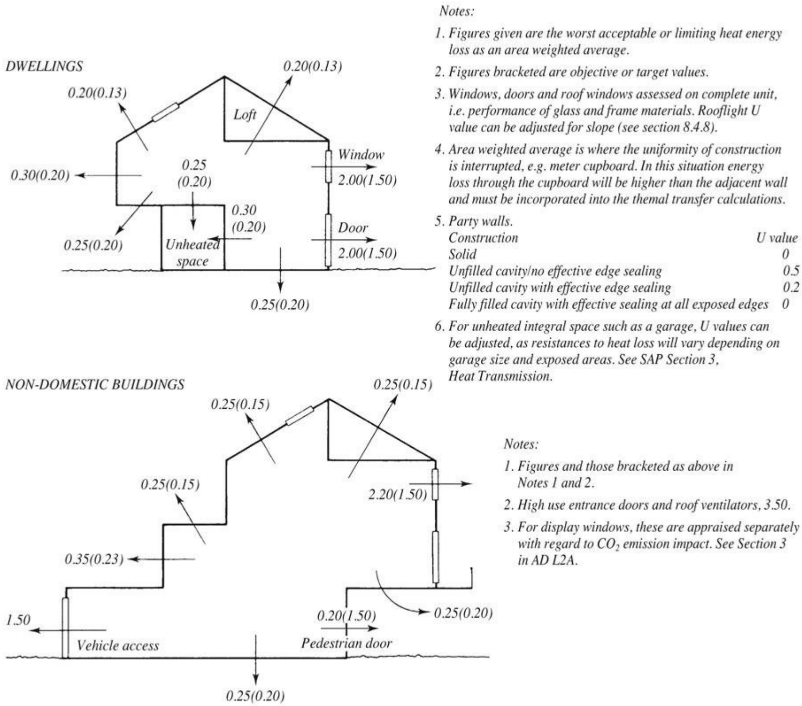


Figure 8.5 Limiting and objective U values.

An EPC survey is based on an asset rating for fuel consumption relative to the type and size of building, its location, age, design and method of construction. This is measured by the amount of carbon dioxide (CO_2) emitted by the energy-producing appliances, e.g. hot water and heating boiler. An EPC surveyor's report can also contain recommendations for improvements such as an increase in roof space insulation. Rating is graded from a high energy efficiency of A down to G representing a poor standard. The Standard Assessment Procedure (SAP) numerical rating used specifically for residential dwellings is applicable to the production of EPCs as there is a direct relationship between both ratings as shown in Table 8.3.

Table 8.3 Comparison of EPC and SAP ratings

EPC rating	SAP rating
A	(92–100)
B	(81–91)
C	(69–80)
D	(55–68)
E	(39–54)
F	(21–38)
G	(1–20)

The average SAP rating for all homes in the UK is about 50, typical of houses constructed in the 1930s. If modernised with loft and cavity wall insulation and replacement double glazing, the value could rise to about 70. Houses constructed to the energy conservation measures of the mid-1990s have a value of around 80 and contemporary construction practice should produce a rating close to, if not, 100. It is possible for the SAP rating to exceed 100 where on-site power generation enables a net export of energy.

As previously indicated, thermal transmittance U values of the external elements are a very important factor. They will significantly contribute to the EPC and SAP calculations that determine the potential CO_2 emissions for buildings. For dwelling homes this measure of CO_2 is known as the Dwelling Emissions Rate (DER). For non-domestic buildings it is known as the Building Emissions Rate (BER). DER and BER are compared by calculation with a Target Emissions

Rate (TER) and should not be greater than this value. The TER is an energy performance requirement for a particular building, obtained by calculating the likely mass of CO_2 emissions in units of kg per m^2 of floor area per month and annually. Tables, calculation sheets and formulae to determine DER and TER are published in the government's Standard Assessment Procedure for Energy Rating of Dwellings, with further guidance in the Building Regulations, Approved Document L1. For buildings other than dwellings where the BER is required, procedures differ and AD L2 should be consulted.

Principal criteria for assessment of all building types:

- Floor area and volume
- Materials of construction
- Air tightness/quality of construction
- Openings in the external envelope
- Glazing system
- Incidental solar gains/orientation of openings/ overheating
- Thermal insulation type and amount
- Ventilation characteristics and equipment
- Heating (boiler) and cooling (air-conditioning) equipment efficiency and associated thermostatic controls
- Type of fuel
- Renewable and alternative energy use/energy recovery facilities
- Energy management systems
- Lighting controls/efficacy of fittings

8.4.1 Incidental solar gains and glazing orientation

The effects of solar gain can be a beneficial energy supplement in the winter months, but quite the opposite in summer if not controlled. The effects of solar overheating are considered in section 8.4.2. Window areas are limited as explained in section 8.4.8. This is not just to restrict the heat losses from within, but to regulate external gains. Table 8.4 provides a comparative guide to average seasonal solar gain data measured from October to April in the London area. Units are expressed in GJ per m^2 of external construction.

Table 8.4 Solar gain potential

Construction	Orientation	Dwelling thermal capacity		
		Light	Medium	Heavy
Double glazing	N	0.162	0.189	0.216
	S	0.513	0.621	0.711
	E	0.306	0.369	0.423
	W	0.306	0.369	0.423
Opaque fabric/structure	N	0.005	0.006	0.007
	S	0.017	0.021	0.024
	E	0.011	0.012	0.015
	W	0.011	0.012	0.015

Definitions: Light – timber or steel frame inner leaf with brick cladding
Medium – brick and lightweight block cavity wall
Heavy – solid brick or cavity brickwork inner and outer leaf

8.4.2 Solar overheating

Solar gains through the outer fabric of a building can be advantageous in the winter, but provision should be made to limit these gains in summer. Otherwise, to maintain reasonable levels of comfort, expensive fuel-consuming air-conditioning will be necessary, thereby opposing the concept of fuel energy saving and reduction in atmospheric pollutants. Solar controls can be passive or active, and include limiting window areas, particularly those with southerly exposure, designing in thermal capacity (see Table 8.4) or installing shading devices such as automatic or manually controlled awnings. A compromise between glazed area and desire for natural lighting may be necessary, to moderate the use of internal lighting.

8.4.3 Ventilation characteristics

Ventilation is essential for internal comfort. Particular requirements apply to all habitable rooms and especially to sanitary accommodation, bathrooms and kitchens. Internal air movement to the exterior is a potential heat energy loss and must be regulated as defined in the Building Regulations, Approved Document F: Ventilation. Chapter 10 provides some examples. As airtightness by sealing of the external envelope is now standard for new construction, it is important to establish the right balance with controlled ventilation. The Building Regulations recognise the simplest of facilities from trickle vents let into the window head, to ducted passive stacks and mechanical assisted

energy recovery systems. A general comparison between likely ventilation rates for dwellings of various construction standards and potential heat losses is given in Table 8.5. Table 8.9 indicates typical ventilation rates for specific rooms.

Table 8.5 Dwelling ventilation heat losses

Location	Construction	Ventilation rate (a/c per hour)	Heat loss rate (W/m^3 K)
Sheltered	Well-sealed modern	0.5	0.17
	Average	1.0	0.34
	Draughty/unmodernised	1.5	0.51
Exposed	Well-sealed modern	1.0	0.34
	Average	1.5	0.51
	Draughty/unmodernised	2.0	0.68

Note: a/c per hour refers to the volume air changes per hour.

8.4.4 Type and efficiency of boiler

Domestic hot water and heating boilers are rated on an alphabetic scale from A to G, as shown in Table 8.6. This classification is based on an independent testing facility to establish the Seasonal Efficiency of a Domestic Boiler in the United Kingdom, known by the acronym SEDBUK. See the website www.boilers.org.uk for a comparison of manufacturers' products.

The Building Regulations require that only gas or oil fired boilers of the highest grade (A), i.e. greater than 90 per cent efficiency, may be installed in new premises and as replacements in existing dwellings. These high-efficiency boilers are otherwise known as condensing boilers, because the burnt fuel that primarily heats the water is directed by a fan around the boiler heat exchanger to create a secondary heat transfer before being discharged via the flue. This secondary heating produces some condensate for draining to a suitable outlet. Exceptional circumstances such as impracticalities of installation may allow some relaxation of regulations and a lower band rated boiler to be installed. If permitted, a trade-off against other energy conservation measures such as very low U values or an energy recovery system will be required. Solid fuel boilers are produced to a standard acceptable under the HETAS (Heating Equipment Testing and Approval Scheme).

8.4.5 Type of fuel

The type of fuel chosen for hot water and heating by the end user will depend on availability and comparable costs. The Building Regulations are principally concerned with the amount of carbon dioxide (CO_2) emitted per unit of fuel energy supplied. A measure of this is the factors listed for a variety of fuels in Approved Document L1A. Figures range from 1.00 for mains gas to 1.47 for grid electricity. The relatively high factor for electricity allows for the carbon emissions at power station generating source, as when consumed, the efficiency is close to 100 per cent. The appropriate factor is included in the formula for determining the carbon DER as part of the SAP assessment.

Table 8.6 Domestic boiler rating

Grading band	SEDBUK efficiency (%)
A	>90
B	86–90
C	82–86
D	78–82
E	74–78
F	70–74
G	<70

8.4.6 Type of hot water and heating system (see also section 8.9.1)

Traditional hot water systems have a gravity or convection circulation between boiler and hot water storage vessel. This is slow and inefficient in the use of fuel. All new hot water systems should have pumped circulation with the heating system. Conventional radiator heat emitters require a boiler hot water flow temperature of about 80 °C, whereas under floor panels or coils of pipe can be served with water at about 50 °C. Under floor systems have the effect of heating up and storing energy in solid floors, slowly dissipating heat so that internal temperature swings are less pronounced and less frequent, reducing boiler activity.

Other considerations:

- Decorative effect log or coal, gas-fuelled fires should have limited or restricted use. These appliances are an aesthetic feature that may be used as a supplementary heat source, but they are fuel inefficient when compared with a central source system.

- Insulation of hot water and heating flow and return pipes to prevent unnecessary heat losses. Hot water storage vessels are usually insulated as a manufacturing standard.
- Thermostats applied to both hot water and heating systems, preferably to control a motorised diverter valve to each provision from a single pumped boiler flow pipe.
- Separate thermostats required for heating to upper and lower floors, each connected to a motorised valve to regulate the hot water to separate circuits. This is known as zone control or zoning, and is a requirement for all dwellings. Those exceeding 150 m^2 living space/floor area to have independent time and thermostatic control in at least two zones.
- Thermostatic radiator valves may be fitted to each heat emitter for individual control. These are standard fittings to all bedroom radiators.
- Programmer required to provide overall system management. This is basically a 24-hour clock controller, traditionally set to provide hot water and heating twice a day, or bypassed when either or both are needed all day. More advanced versions can provide pre-settings for 7 days or 28 days.
- Solar panels (see also section 8.10) may be considered as a supplementary energy source in the United Kingdom. They generally occupy an area of about 40 m^2 of south-facing roof space for a typical house. The optimum roof pitch is about 40°.
- A boiler interlock is a feature provided by most equipment manufacturers. This facility prevents the

boiler water temperature thermostat switching the boiler on when the water jacket temperature drops below its presetting, even when the time controller is on. Instead, the boiler fuel valve and circuit pump are controlled by the room or hot water thermostats.

8.4.7 Energy management systems

The quality and sophistication of these advanced programmers varies considerably. There are basically two types:

1. Compensated circuit A computerised controller receives information from both internal and external air temperature sensors. From these it can regulate the boiler water supply temperature. The warmer the external air, the cooler the delivery hot water to emitters, and vice versa.
2. Optimum start controller This is a variation using an external air sensor to provide information for the programmer to determine the optimum start-up time of the boiler. On milder days, fuel savings will result in a system start later than provisionally programmed.

Table 8.7 Indicative U values for uPVC or wood-framed glazing systems

Glazing	Void	U value (W/m^2 K)
Single	–	5.6
Double, float glass ×2	Air	2.7
Double, float glass ×2	Argon	2.6
Double, float glass + Low 'E'	Air	2.0
Double, float glass + Low 'E'	Argon	1.7
Triple, float glass ×3	Air	2.0
Triple, float glass ×3	Argon	1.9
Triple, float glass ×2 + Low 'E'	Air	1.4
Triple, float glass ×2 + Low 'E'	Argon	1.3

Notes:

1. Thicker glass and an increased void width will reduce the U value.
2. Metal frames will increase the figures given by up to 20 per cent unless insulation is incorporated into the hollow sections and a thermal break (synthetic rubber seal) positioned to reduce conducted heat loss.

8.4.8 Openings in the external envelope

The thermal transmittance limitations for windows, doors, roof windows and roof lights are shown on page 63.

Factory-sealed double-glazed units are standard in modern buildings. Triple glazing is also possible, but with each additional pane of glass, light transmittance reduces by about 15 per cent. Solar heat transmittance is reduced by up to one-third by using tinted glass. The glass thickness and void width will have some effect on the thermal efficiency of the unit. Table 8.7 provides some comparisons for 4 mm double and triple glazing, separated by a 16 mm air or argon-filled void. Also included is lowemissivity or Low 'E' glass. This type of glass is used for the inner pane and has an outer surface coating of microscopically thin metal oxide, designed to reflect long-wave heat radiation back into a room, while being permeable to short-wave solar heat radiation and sunlight.

Figure 8.5 shows limiting and objective U values for wall and roof openings. These values assume that the window occupies a vertical plane. Adjustment should be made for inclination as indicated in Table 8.8.

Example: a double-glazed rooflight positioned at an inclination of 50° in a newly built dwelling:

The limiting U value of 2.00 W/m^2 K is adjusted for the inclination of glazing with an increase of 0.30 W/m^2 K. This provides a revised limiting U value of 2.30 W/m^2 K.

An alternative acceptable measure is the European Window Energy Rating Scheme (EWERS). This establishes the thermal efficiency of a window system and rates it on an alphabetical scale of A (> 0) down to G (< −70). A rating of D (-30) is acceptable; see the British Fenestration Rating Council's website, www.bfrc.org.

Table 8.8 Adjustment of U values (W/m^2 K) for slope

Inclination	Double-glazed	Triple-glazed
<70°	0	0
60°–70°	+0.2	+0.1
40°–60°	+0.3	+0.2
20°–40°	+0.4	+0.2

Inclination	Double-glazed	Triple-glazed
<20°	+0.5	+0.3

8.4.9 Quality of construction

In terms of energy conservation, construction of the external building fabric should be to a high degree of thermal insulation and airtightness. Vulnerable areas at construction interfaces, such as wall and eaves, and window or door openings and wall, should be built to the standards prescribed in the guidance (see page 74) accompanying the Building Regulations, Approved Document L. Alternative construction is acceptable, but whichever is used, sample buildings are subjected to air pressure testing. The objective is to attain an air permeability of less than 7 $m^3/h/m^2$ of envelope area, the worst acceptable being 10 $m^3/h/m^2$ when pressurised to 50 Pascals (Pa or N/m^2). Leakage can be detected by using smoke pellets.

8.4.10 Lighting

- External lighting applies to fixtures attached to the exterior of a dwelling and any others associated with that dwelling. It does not include lighting to common areas in flats and communal accesses. Provisions for economic use are an individual lamp capacity not greater than 100 W, with an automatic facility to switch off when there is adequate natural light and when not required at night. Alternatively, the light fitting should be of the socket type that will only accept lamps with an efficacy greater than 45 lumens per circuit watt, i.e. compact fluorescent lamps.

Efficacy can be defined as the efficiency of lamps in lumens per watt (lm/W), where a lumen is a measure of visible light, often expressed as lumens per square metre (lm/m^2) or lux, i.e. illuminance. See Chapter 10, section 10.3.

- Internal lighting compliance is achieved where fixed lighting positions in living rooms and other most used locations in a dwelling are provided with lamps of a luminous efficacy greater than 45 lumens per circuit watt and with a total output greater than 400 lamp lumens. Low energy use light fittings (fixed lights or lighting units) should be provided at not less than three for every four fixed light fittings in the main dwelling spaces. Fluorescent and compact fluorescent lamps satisfy this requirement, tungsten filament lamps do not.
- For details of design procedures and calculations that can be applied to determine lighting requirements in buildings relative to energy use, see: BS EN 15193: Energy performance of buildings. Energy requirements for lighting, BS EN 12464-1: Lighting of work places. Indoor work places, BS EN 12464-2: Lighting of work places. Outdoor work places.

8.5 Measurement of carbon emissions

The carbon index method is an established measure for carbon assessment which provides a numerical comparison between dwellings. The assessment criteria are based on calculated carbon dioxide emissions in kilograms or tonnes per year relative to dwelling floor area. The following formulae may be used:

$$CF = CO_2 \div (TFA + 45)$$
$$CI = 17.7 - (9 \log_{10} CF)$$

where:

- CF = Carbon factor
- CO_2 = Carbon dioxide emission in kg/year
- TFA = Dwelling total floor area in m^2
- CI = Carbon index
- $\log_{10}$ = Logarithm to the base of 10

e.g. a dwelling of 180 m^2 total floor area producing CO_2 emissions of 2 500 kg/year:

$$CF = 2\,500 \div (180 + 45) = 11.11$$
$$CI = 17.7 - (9 \log_{10} 11.11) = 8.29\ (8.3)$$

The carbon index is represented between 0 and 10, rounded to one decimal place. All new dwellings should have a value of at least 8.0. Worksheets from SAP can also be used to determine the annual CO_2 emissions.

8.6 Condensation and thermal bridging

The consistency of construction is a very important factor, as illustrated in Figures 8.6 and 8.7. Here most of the construction is of layered form but is 'bridged' at intervals by a material or an air space providing less thermal resistance. This results in variations in thermal transmittance values along the construction and the occurrence of cold bridging. The slightly cooler internal surface at the point of the cold bridge provides a dew-point temperature at which the warm internal air cools, causing droplets of water (condensation) as well as dust to be deposited locally, i.e. pattern staining.

In practice, it is also necessary to prevent the occur-rence of condensation at the surface or within material(s) used for a building fabric (Fig. 8.8). This takes place when atmospheric temperature (dry bulb) falls below the dew-point temperature – a property that depends upon the water

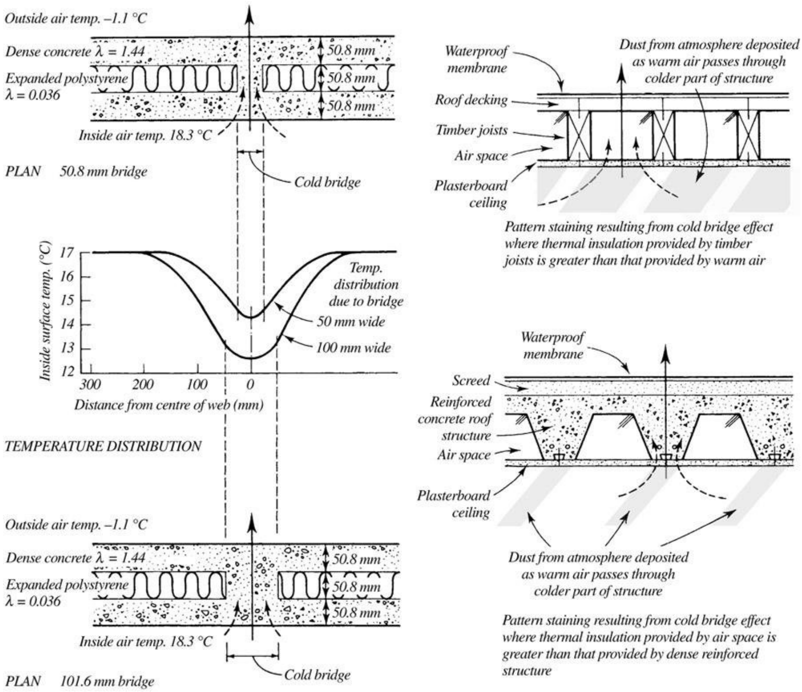


Figure 8.6 Cold bridge and pattern staining. (Adapted from material in Materials for Buildings by Lyall Addleson)

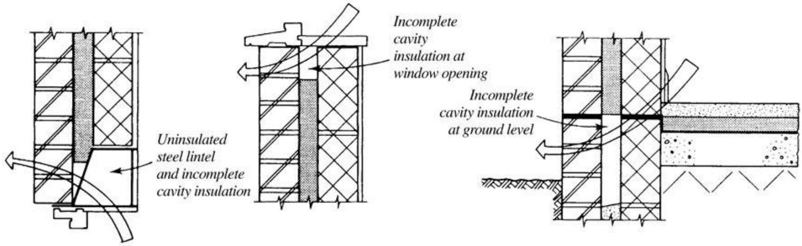


Figure 8.7 Cold bridging by incomplete cavity insulation.

vapour content of the air and therefore upon the vapour pressure. The amount of water vapour contained in the atmosphere will fall according to temperature and relative humidity (ratio of vapour pressure present to completely saturated air).

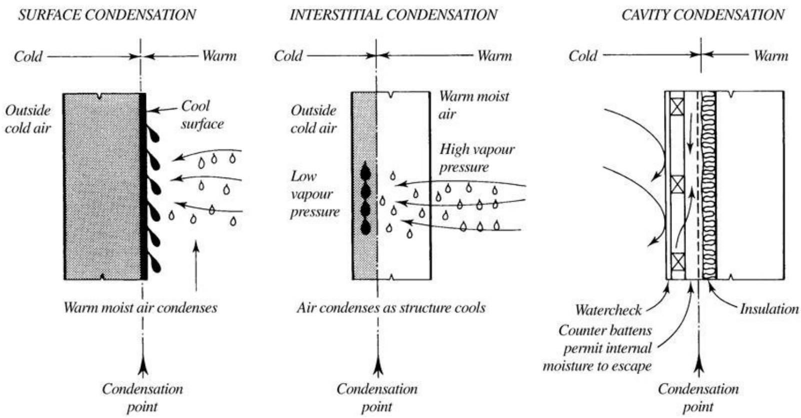


Figure 8.8 Forms of condensation.

Surface condensation is likely to occur when air containing a given amount of water vapour is cooled by coming into contact with a cold plane. High relative humidity, more than 80 per cent, will cause mould growths on the surface of organic materials or droplets of water on non-organic surfaces. This risk can be reduced by keeping internal surfaces at a higher temperature than the dew-point of the internal air, which involves carefully balancing the building fabric insulation and internal heating and ventilating requirements. Simply to increase the insulation value of the building fabric may only move the dew-point of the air into the body of the material and produce interstitial condensation, causing a loss of insulation and deterioration.

One solution to the damage caused by surface and interstitial condensation is to use a construction method which makes the condensation or dew-point coincide with a cavity which separates external weathering layers from internal insulating layers (see section 6.4). This cavity should be ventilated, and the moisture formed by condensation (together with any which penetrates the external weathering layers) must be adequately collected and diverted to the outside. When a cavity cannot be incorporated in the correct position relative to the point of condensation, then a vapour control layer or membrane must be used. This consists of a thin impermeable sheet (e.g. plastics or reinforced aluminium foil) and should be placed on the warm side of the insulating material to prevent transference of moist air from the warm interior of a room into the fabric of the building (see Figs 18.37 and 18.61). Care must be taken to ensure that the sheets are adequately lapped and folded at their edges to prevent moisture penetration. A vapour control layer must also be incorporated for composite construction methods employing different layers of materials providing varying thermal and vapour resistance properties. The problems associated with the practical application of vapour control layers are discussed in section 18.9.6.

Modern forms of construction and living patterns have greatly increased the risk of condensation, not only upon internal surfaces, but also within wall, floor and roof constructions. Traditional construction allowed moisture vapour to pass more easily through its fabric and through air gaps around doors and windows. There was often less moisture vapour to be vented, owing to lower temperature requirements and greater ventilation rates at moisture sources (air bricks and chimney flues, etc.). See also section 10.4 for a summary of current legislation governing the ventilation of rooms in domestic buildings.

8.7 Thermal capacity

The selection processes for a building fabric to provide satisfactory thermal comfort conditions must include consideration of the form of space heating to be employed. When the heat source remains virtually constant, it may be considered expedient to adopt a building fabric which will
store heat or have a high thermal capacity. For example, masonry walling material will gradually build up a reservoir of heat or thermal mass while it is being warmed. When the heat source ceases for a short period (i.e. overnight) or when the external temperature drops below normal, the stored heat will be slowly given back. At any event, the internal wall surfaces will feel relatively warm and comfortable, and the possibility of condensation occurring will be less likely, except during the period when the heat source is initially resumed. In hot climates, very thick and heavy construction buffers the effect of very high external daytime temperatures on the internal climate of the building.

When intermittent heat sources are used, or other marked fluctuations from steady temperatures occur, dense construction will be slow to warm up, and lower surface temperatures may be present for some time. This will give rise to discomfort for the occupants and condensation. In rooms used occasionally, and therefore requiring only intermittent heating for comfort, lining the interior surfaces with material of low thermal capacity, incorporating a vapour control layer, will reduce the amount of heat required and produce a quick thermal response. Alternatively, a construction method of entirely low thermal capacity can be adopted (timber walling incorporating vapour control layer and thermal insulation in spaces between structural members), and often this is the chosen form where the need to conserve fuel resources is paramount. In both cases – internally insulated dense construction or lightweight construction – less heat will be stored and the room will cool more rapidly when the heat source is curtailed. One acceptable compromise is to adopt a dense construction with thermal insulation on the external face. In this way, once a wall has been warmed, there will be a long period before it is finally dissipated completely, during which time the heat source may be resumed again.

8.8 Heat gains

Unwanted solar heat gain into a building can be a source of considerable thermal discomfort and interrupt the working of normal methods of space heating. However, heat gains of this nature can be modified by careful adjustment of the amount of glazed areas (either fixed or openable); the type of glass used for windows; building and configuration; thermal character of the building fabric; surface colours and texture;

and the degree of absorption permitted by exposed materials. The usual methods adapted are shading or screening devices, increasing the thermal capacity of the building fabric, and adopting a reflective outer surface. Nevertheless, with special reference to colder climates like the United Kingdom, the beneficial physiological and biological effects upon humans, animals and plants should be considered before deciding to eliminate solar heat gains altogether.

Besides solar sources, considerable heat gains can be encountered when the function of a building requires the use of large amounts of energy. Office lighting systems and mechanical ventilation plant, exhibition display cases and lamps, and even people crowded together in supermarkets, cinemas, swimming-pools and disco halls can all create a considerable amount of heat. In large buildings the heat generated in this way may sometimes mean that cooling or ventilation plant is needed instead of heating plant, even during the cold winter season. The designer of such a building must ensure the correct thermal balance between heat requirement, heat inputs or gains and the required insulation standards for the building fabric. Considerable financial benefits may also be obtained if the heat gains can be transformed and stored for later use; see also section 8.3.

8.9 Active means

To arrive at a suitable method of space heating for a building requires examination of the fuel to be used as a source of heat, the methods of distributing the heat source to the heat emitters, and the appropriate means of heat output. Detailed analysis of these factors is beyond the scope of this book, but it will be realised from the immediately preceding paragraphs that they exert a profound influence on the thermal comfort standards achieved by a building.

With few exceptions, any form of heat emission can be powered by any fuel. The choice currently available includes fossil fuels (wood, coal, gas and oil); electricity; alternative renewable energy resources (solar, animal wastes, geothermal, tidal, wind, wave, and ambient energy from light fittings, mechanical plant and even human beings). Fossil fuels are being consumed at an increasingly rapid rate to keep up with comfort standards for today. In order to regulate consumption of these finite resources and to control the atmospheric pollution from their combustion, the following items now have high priority:

- Sustainable construction techniques.
- Increasing building insulation standards.
- Developing more efficient fuel combustion plant.
- Introducing energy management systems.
- Promoting schemes and systems to renew and reuse energy.

Wood is a renewable resource, but as materials for building purposes are also being depleted, it is becoming an extremely valuable commodity which is far too important to burn. Electricity is generated mainly from fossil fuels, and for this reason ideally should not be used as a direct heating source because its production by this means is both inefficient and expensive.

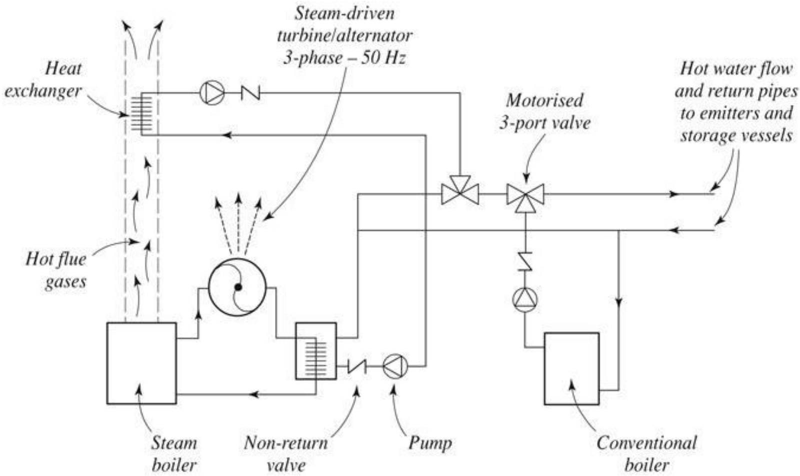


Figure 8.9 Principles of a CHP installation.

The increasing use of nuclear reactors for the production of electricity, using naturally occurring resources, certainly makes a more viable heating source. Developments in nuclear fusion (there is still an ample supply of uranium) could make electricity the major future source for thermal comfort, provided conversion to a useful form can be accomplished in safety and without danger of radiation or pollution to people and the countryside. Fear of these happening is one of the reasons for increasing interest in the use of certain renewable resources and ambient alternative energy sources for generating electricity, e.g. wind- and wave-powered turbines.

Combined heat and power (CHP) systems have enjoyed far more success. Size of plant can vary from small units applied to hotels, schools, etc., to larger-scaled district heating/energy systems. The principle shown in Figure 8.9 uses the surplus energy in flue gases and cooling water from conventional oil-or gas-fired electricity generators, directed through heat exchangers for use with hot water storage and heating.

One of the most important decisions, as far as user comfort is concerned, is the choice of the form of emitter (radiator, convectors, ducted warm air, etc.); see Figures 8.10 and 8.11. Figures 11.1 and 11.2 show installation principles. The selection of emitter is influenced by the response of a building fabric to changes in external air temperature, to temperature variations caused by the sun, and to the heat gains from changing occupancy, cooking or the use of other heat-producing equipment. If discomfort is to be avoided, either from underheating or overheating, the response of the heating system must be equal to or shorter than the response of the building fabric. The response of the fabric is determined by its mass, the degree and position of insulation, the reflectivity of external surfaces where exposed to the sun, and the area and orientation of windows. Furthermore, time and temperature controls have a vital role to play in achieving economy of operation; the generally available controls are not yet able to provide immediate response to changes in temperature, so there may be a time lapse, creating discomfort.

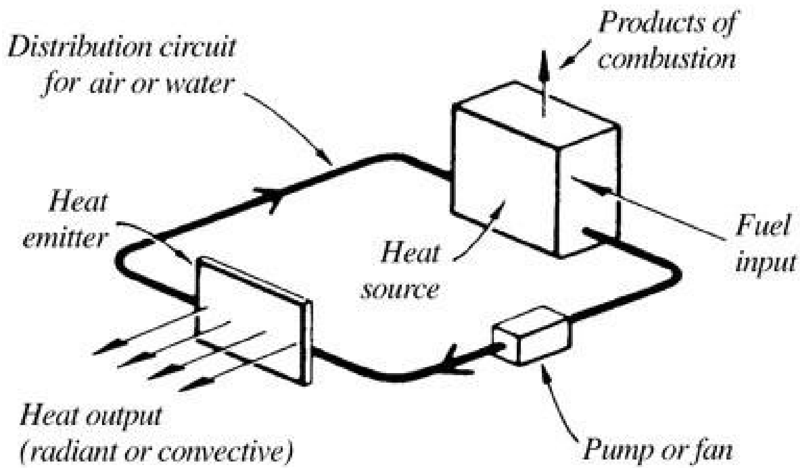


Figure 8.10 Circuit diagram for heater.

8.9.1 Space heating and hot water controls – general requirements

Provisions in the Building Regulations as outlined in section 8.4 are intended for systems with centralised boiler heat energy sources and not individual solid fuel, gas or electric heaters. Electric storage heaters are included, with an expectation that units have an automatic charge control mechanism (thermostat) to regulate the energy consumption relative to room temperature.

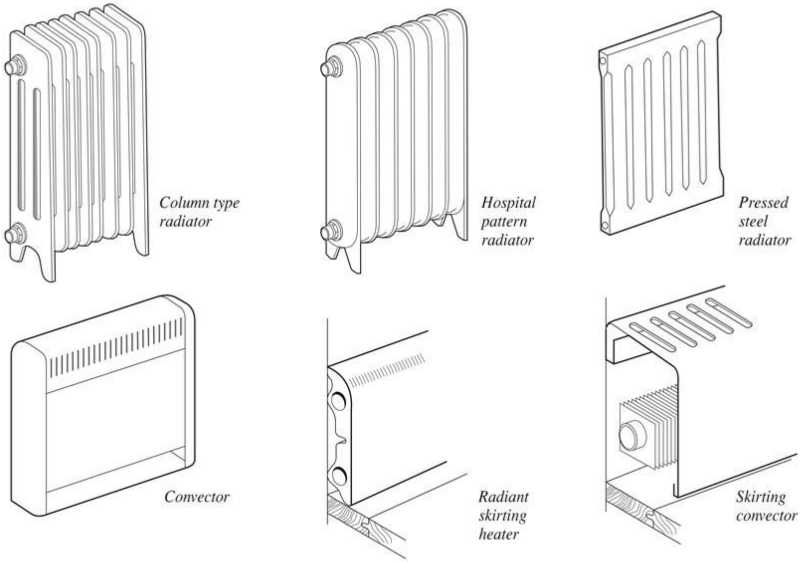


Figure 8.11 Heat emitters.

Conventional gas- or oil-fired boiler systems of hot water or warm air circulation satisfy the regulations if they contain the following:

- zone control
- timing control
- boiler control
- Zone control – a means of controlling individual room temperatures where different heating needs are appropriate. This may be achieved by fitting thermostatic radiator valves to each emitter, or by using room thermostats to control zoned circuits. For instance, kitchen and workroom temperatures need not be the same as in living areas. Some examples with minimum air change rates are listed in Table

8.9. Large dwellings should be zoned into maximum floor areas of 150 m^2 with each zone having separate time controls.

- Timing control – systems should be capable of being programmed to provide both hot water and space heating independently at predetermined times. This applies specifically to gas- and oil-fired installations, and solid fuel boiler systems with forced air draught electric fans. Separate timing is unnecessary for boilers with an instantaneous draw-off facility, e.g. combination boilers and natural draught solid fuel boilers.

Table 8.9 Typical internal design temperatures and air infiltration rates

Location	Temperature (°C)	Air changes per hour
Bathroom	22	2.0
Bedroom	18	1.0
Bed/sitting room	21	1.5
Dining room	21	1.5
Hall/landing	18	1.5
Kitchen	18	2.0*
Living room	21	1.5
WC	18	2.0

* Note: See Building Regulations, Approved Document F1: *Means of Ventilation*, and section 10.4 in this book.

- Boiler control – gas- and oil-fired boilers should be controlled within the programmed cycle by room thermostats for space heating and a storage cylinder thermostat for hot water. Where thermostatic radiator valves are deployed, overall control from a room

thermostat should disconnect the boiler and pump when there is no demand for heat. A thermostatic pipeline switch would be suitable to control stored hot water. See
also, comments on boiler interlock in section 8.4.6. Additionally, manufacturers provide a manually controllable working thermostat within a boiler and a limit (high-temperature) thermostat as a supplementary safety cut-out on boilers applied to larger non-domestic installations.

Additional requirements for domestic hot water storage systems include:

- Storage vessels to have a minimum of 35 mm factory-applied polyurethane foam insulation (minimum density = 30 kg/m^3).
- Insulated primary pipework with pumped circulation.

See also:

- Building Regulations, Approved Document G3: Hot water supply and systems.
- Building Regulations, Approved Document L1: Conservation of fuel and power in dwellings.
- Water Manufacturers' Association: Performance specification for thermal stores – 1999.
- Domestic Building Services Compliance Guide.

Additional requirements for hot water storage systems in non-domestic buildings include:

- Particular attention to correct sizing of plant to avoid energy wastage.

- Supplementary use of renewable and alternative energy power sources.
- Minimising number and length of hot water draw-off pipes (see Fig. 11.1).

See also: Building Regulations, Approved Document L2: Conservation of fuel and power in buildings other than dwellings.

8.10 Solar energy

Notwithstanding section 8.8, the reuse of solar energy is becoming increasingly important as an alternative means of both space and water heating, and various forms of construction have been devised which ‘capture’ this free resource. For example, a glazed conservatory on the south side of a building will create an accumulation of heat which can be absorbed into an interior wall of high thermal capacity (Fig. 8.12). The heat stored in this manner will be emitted into the interior spaces at night or during other periods of no sunshine. The amount of heat absorbed by an internal wall of this nature can be regulated by louvres opening in the conservatory so that excessive heat gains will not occur and cause discomfort. This system is known as a passive solar energy resource.

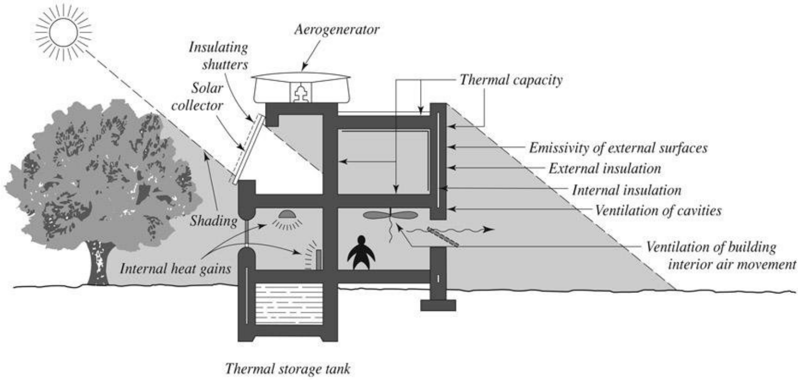


Figure 8.12 Using solar energy.

Active solar systems have been the subject of considerable research over the past 50 years. Basic systems consist of an exposed glass collector panel, behind which are located pipes containing water circulated through a heat exchanger in a storage vessel – see Figure 8.13. More recent developments are far more sophisticated and include collectors inside clear glass vacuum-sealed cylinders, as well as power generation from photovoltaic fuel cells. In the United Kingdom, the water heated by solar means can provide a useful supplement to hot water and space heating systems, whereas in many parts of the world it is

the principal energy resource due to the high levels of solar radiation.

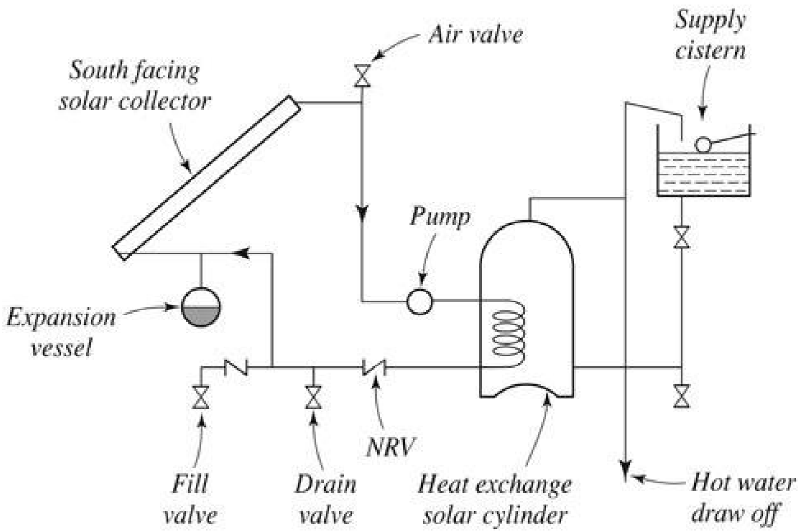


Figure 8.13 Principle of solar-powered hot water system.

The potential for solar energy is considerable as solar radiation can be quite effective even on cloudy days. In the United Kingdom, the average amount of solar radiation on a south-facing roof inclined at an optimum angle of about 40° is around 1 000 kW/m^2. Previously, there has been some reluctance to accept these systems in the United Kingdom, as the capital outlay may take several years to recoup in fuel savings. Also, the exposed panels can be perceived as a visual intrusion on the appearance of a building. However, for all new building work, there is now a requirement for efficient use of fuel, and solar panels are a viable means for attaining this – see section 14.6.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 5 Heat
	Chapter 7 Thermal installations
	Chapter 5 Walls and piers
Structure and Fabric Part 1	Chapter 7 Roof structures
	Chapter 8 Floor structures

Building Research Establishment

Digest 145	*Heat losses through ground floors*
Digest 162	*Traffic noise and overheating in offices*
Digest 180	*Condensation in roofs*
Digest 254	*Reliability and performance of solar collector systems*
Digest 297	*Surface condensation and mould growth in traditional-built dwellings*
Digest 302	*Building overseas in warm climates*
Digest 324	*Flat roof design: thermal insulation*
Digest 336	*Swimming pool roofs: minimising the risk of condensation using warm-deck roofing*
Digest 339	*Condensing boilers*
Digest 355	*Energy efficiency in dwellings*
Digest 369	*Interstitial condensation and fabric degradation*
Digest 370	*Control of lichens, moulds and similar growths*
Digest 377	*Selecting windows by performance*
Digest 379	*Double glazing for heat and sound insulation*

Digest 404 *PVC-U windows*
Digest 438 *Photovoltaics: Integration into buildings*
Digest 453 *Insulating glazing units*
Digest 454 *Thermal mass in office building* (2 parts)
Digest 465 *U values for light steel-frame construction*
Report 262 *Thermal insulation: avoiding risks*
Report 443 *Conventions for U value calculations*
Report 497 *Conventions for calculating linear thermal transmittance and temperature factors*
Information Paper 3/90 *The 'U' value of ground floors: application to building regulations*
Information Paper 7/93 *The 'U' value of solid ground floors with edge insulation*
Information Paper 12/94 *Assessing condensation risk and heat loss at thermal bridges*
Information Paper 14/94 *'U' values for basements*
Information Paper 15/94 *Energy efficiency in new housing*
Information Paper 20/94 *Energy use in the housing stock*
Information Paper 3/95 *Comfort, control and energy efficiency in housing*
Information Paper 15/95 *Potentional carbon emission savings from energy efficiency in housing*
Information Paper 3/96 *Potential carbon emission savings from energy efficiency in commercial buildings*
Information Paper 7/97 *Energy use and carbon dioxide emissions for UK housing*
Information Paper 1/00 *Air tightness in UK dwellings*
Information Paper 5/01 *Solar energy in urban areas*
Information Paper 5/02 *Dwellings and energy efficient lighting*
Information Paper 11/02 *Retrofitting solar shading*
Information Paper 12/02 *Control of solar shading*
Information Paper 3/03 *Dynamic insulation for energy saving and comfort*
Information Paper 13/04 *An introduction to building with structural insulated panels*
Information Paper 16/05 *Domestic energy use and carbon emissions: scenarios to 2050*
Information Paper 4/06 *Airtightness of ceilings: energy loss and condensation risk*

Building Regulations

G3 Hot water supply and systems
L1 Conservation of fuel and power in dwellings
L2 Conservation of fuel and power in buildings other than dwellings

Department for Communities and Local Government (DCLG)

The Code for Sustainable Homes
Domestic Building Services Compliance Guide
Non-Domestic Building Services Compliance Guide

Department of Energy and Climate Change (DECC)

The Standard Assessment Procedure

Other Guidance

Limiting thermal bridging and air leakage: Robust construction details for dwellings and similar buildings. Published by The Stationery Office.
The Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations.
The European Energy Performance of Buildings Directive (EU).

9
Fire protection

CI/SfB (K)

It is ironic that, although fire is used in the manufacture of most materials and can provide the thermal conditions required in a building, it can also be highly destructive to a building and its occupants. Death or injury by fire is particularly horrifying and incidents naturally receive special concern in the minds of most building occupiers. Account must also be taken of the financial loss of a building and its contents when considering the full effects of devastation by fire. Losses can be in excess of £1 billion per annum when taking account of the current inflationary trends in the cost of material and labour.

The design and construction method employed for a building must therefore safeguard occupiers from death or injury and also minimise the amount of destruction. These goals can be achieved through an understanding of the nature of fire and its effects on materials and construction used in a building; methods of containing a fire and limiting its spread; methods of ensuring the occupants of a building being attacked by fire can escape to safety; and methods of controlling a fire once it has started.

9.1 Combustibility

Fire is a chemical action resulting in heat, light and flame (a glowing mass of gas), accompanied by the emission of sound. To ignite, a fire needs a combustible substance (fuel), oxygen, a source of heat such as from a flame, friction, sparks, glowing embers or concentrated solar rays and a chemical chain reaction as shown in Figure 9.1. Once fire has developed, heat is usually produced faster than it is dissipated to its surroundings, therefore the temperature rises with time. The fire will burn out once the fuel is removed, become smothered if oxygen is not available, die if the heat is removed by water, for example, or by inhibiting the combustion reaction. Before this happens, however, a fire is likely to ignite nearby material, causing the fire to spread through a building, and perhaps to adjoining buildings by processes which include radiation.

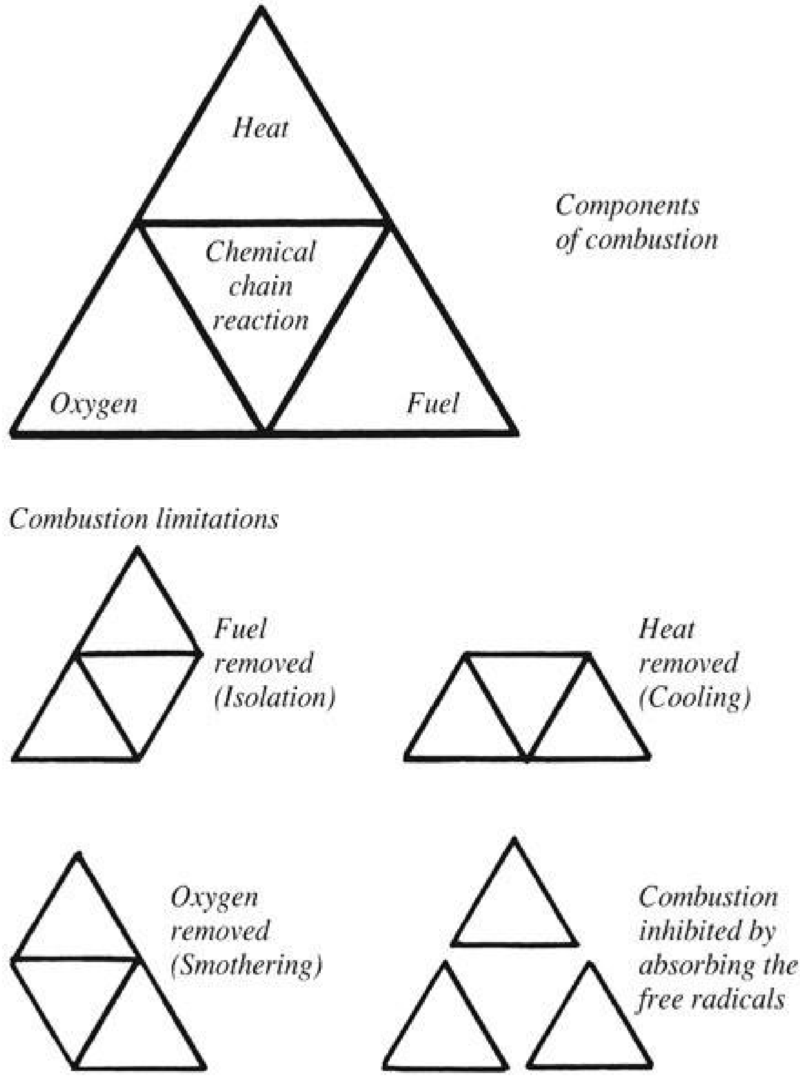


Figure 9.1 The fire tetrahedron/pyramid (represented two-dimensionally)

In the context of fire protection, materials used in a building fall into two broad categories: combustible and non-combustible. To determine the extent of combustibility or non-combustibility of a material or application, BS 476: Fire tests on building materials and structures, should be consulted. It is produced in several parts to cover the extensive and varied testing procedures for fire propagation, ignitability of materials, resistance to fire, etc. It will generally be found that inorganic materials are non-combustible, e.g. stone, brick, concrete or steel, whereas organic materials are combustible, e.g. timber and its by-products (fibreboard, plywood, particle board, etc.) as well as petrochemical products, including plastics.

9.2 Fire resistance

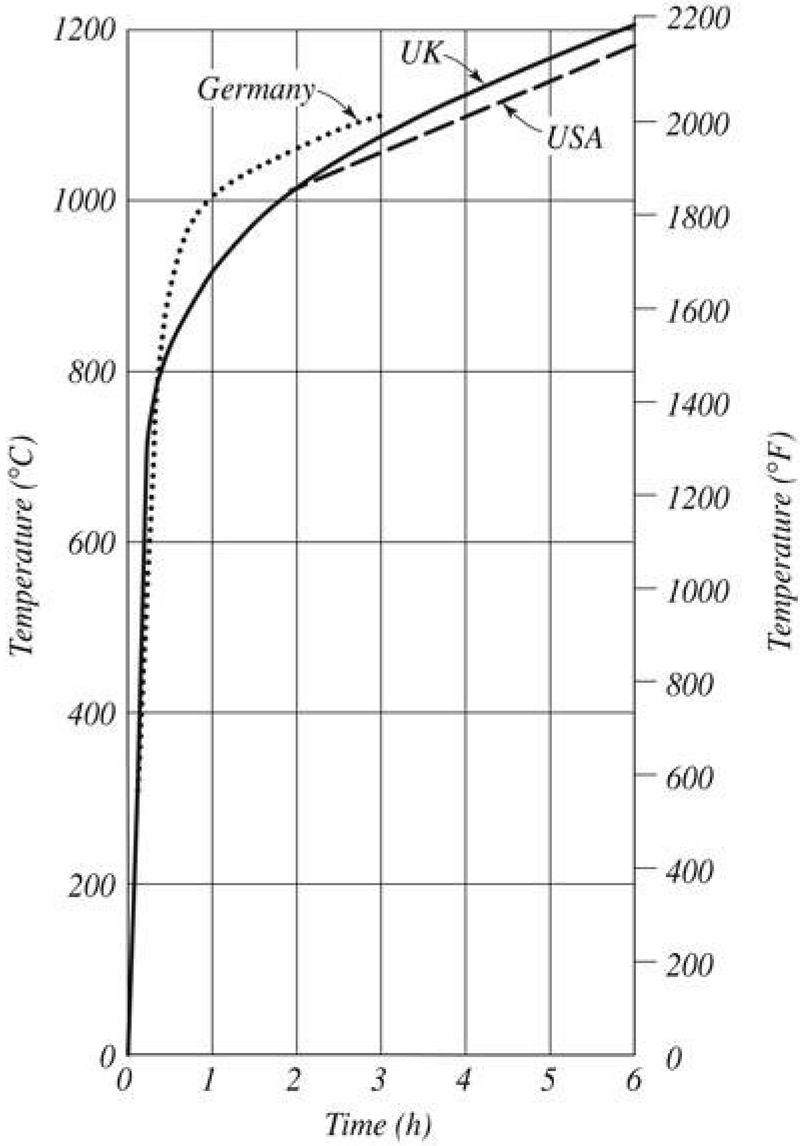


Figure 9.2 Time–temperature curves used in different countries.

In situations where it is imperative that a building must not contribute fuel to a fire, only non-combustible materials should be employed. However, even if practical, the sole use of non-combustible materials will not necessarily avoid the spread of a fire generated by the burning contents of a building. Avoidance of this requires the parts of the building – materials and construction used for elements (walls, floors, etc.) – to have fire resistance. This is the term used to describe the ability of an element of building construction to fulfil its assigned function in the event of a fire without permitting the transfer of the fire from one area to another. BS 476-21 and 22: Methods for determination of the fire resistance of load-bearing and non-load-bearing elements of construction, respectively, establish a time period during which elements can be expected to perform this function. A sample must be subjected to a simulated building fire which, research has indicated, rises in temperature according to duration; see the time–temperature curve in Figure 9.2. The tested element is then rated according to the time (0.5, 1, 2, 3, 4, 5 or 6 hours) it is able to fulfil three performance criteria. These criteria approximate to those necessary to ensure the reasonable safety of occupants and contents in a building, including time to discover the fire and make a safe escape. The performance criteria (Fig. 9.3) applied in the tests are as follows:

- Resistance to collapse (previously referred to as stability) A load-bearing element of construction must support its full load during a fire for a specified period. This minimum period varies from 15 minutes up to 2 hours, depending on which part of a building it relates to and the purpose grouping or type of building it applies to. See tables in Appendix A of Approved Document B to the Building Regulations.

Figure 9.3 The meaning of fire resistance.

- Integrity Structural resistance to the passage of flames and hot gases. Failure occurs when cracks or other openings form, through which flame or hot gases can pass; this would cause combustion on the side of the element remote from the fire.

Table 9.1 Minimum fire resistance for structural elements of construction in buildings of various purpose groups

Building type	Height (m) to top-storey floor	Compartment floor area (m^2) per storey, max.		Compartment volume, max. (m^3)		Fire resistance (min)
		Multi-storey	Single storey	Multi-storey	Single storey	
Storage:						
non-sprinklered	<18			20 000	440 000	90
	18–30			4 000	N/A	120
sprinklered	<18			40 000	no limit	60
	>18			8 000	N/A	90
	>30			8 000	N/A	120
Industrial:						
non-sprinklered	<18	7 000	N/A			90
	18–30	2 000	N/A			120
sprinklered	<18	14 000	N/A			60
	>18	4 000	N/A			90
	>30	4 000	N/A			120
Shops:						
non-sprinklered	<18	2 000	2 000			60
	<30	2 000	2 000			90
sprinklered	<18	4 000	no limit			60
	<30	4 000	no limit			60
	>30	4 000	no limit			120
Offices:						
non-sprinklered	<5	no limit	no limit			30
	<18	no limit	no limit			60
	<30	no limit	no limit			90
sprinklered	<18	no limit	no limit			30
	<30	no limit	no limit			60
	>30	no limit	no limit			120
Dwellings:						
houses	<5					30
	>5					60
apartments	<5					30
	<18					60
	<30					90
	>30					120

Note: Data given is for general guidance. Specific applications, including basements, may require some modification – see Table A2 of Building Regulations, Approved Document B: *Fire safety*.

- Insulation The ability of the construction to resist fire-transmitted heat. Failure occurs when the temperature on the side of the element remote from the fire is increased generally by more than 140 °C, or at any point by more than 180 °C above the initial temperature.

The period of fire resistance suitable for particular elements of a building depends on the functions to be accommodated and the volume, height and floor areas of the spaces involved (Table 9.1). In addition to the Building Regulations, more stringent requirements are likely to be determined by the Loss Prevention Certification Board (representing insurers) and recommendations in BS 5306: Fire protection installations and equipment on premises.

Combustibility cannot be equated with fire resistance: one is a characteristic of a material, the other relates to the performance of an element as a whole. For example, an external wall of fibre cement profiled sheeting (non-combustible) on a mild steel frame (non-combustible) has no notional period of fire resistance because a construction of this nature would rapidly permit fire to spread by heat transfer, i.e. it would not meet the insulation requirement of fire resistance. Conversely, an external wall of timber cladding (combustible) on timber studs (combustible) with a plasterboard internal lining (combustible because of paper sheathing) will provide full fire resistance for a period of half an hour. However, there are cases where legislation requires both fire resistance and non-combustibility, e.g. external walls of a building located in close proximity to a boundary.

9.3 Spread of fire

The spread of fire within a building and from one building to another can most effectively be restricted by the identification and isolation of potential hazards. Therefore, the first defence involves siting. Having established that potential fire risks exist by the nature of the functions accommodated, it is necessary to select the appropriate siting for a building relative to safety of nearby properties. An extreme example might be that of a building accommodating particularly dangerous fire hazards (e.g. manufacture and/or storage of highly flammable chemicals). This should be located in a remote part of the countryside, away from properties likely to be damaged by heat radiation caused as a result of the fire.

Building legislation exists (Building Regulations, Approved Document B: Fire safety) to restrict fire spread by stipulating periods of fire resistance and construction methods appropriate to the function of a building, as discussed earlier. It also limits the use of certain construction methods according to their distance from other properties and/or boundaries. For example, only a nominal amount (0.1 m^2) of unprotected combustible material (such as timber cladding) is permitted on an external wall of a small residential building if this is within 1 m of its boundary. The unprotected area can increase relatively between distances of 1 m and 6 m; over 6 m the amount is unrestricted. Windows, doors and other openings in external walls are also carefully controlled since, unless special forms are used, they do little in stopping the spread of fire from inside or into a building. Regulations restrict the positioning, size and amount of these openings according to function (fire risk of a building as well as location of the external wall relative to other properties and/or boundaries).

Whereas the general approach on walls and floors is to 'contain' the fire, there is no legislative requirement for the external surfaces of a roof to have fire resistance. Instead reference is made to test procedures in BS 476-3, which grades the suitability of specific roof coverings according to their ability to resist external penetration by fire and their resistance to surface spread of flame.

The spread of fire within a building can similarly be restricted by the special segregation of particular fire hazards. Also, fire-resisting compartments or ‘cells’ can be used to limit the spread of a fire through a building. The precise location, enclosed volume and period of fire resistance required again depends on the nature of the activities accommodated. The height of a building and the ease with which its occupants can escape, and/or fire-fighting can be successfully carried out, are also deciding factors (Fig. 9.4). Structural organisation (see section 5.2) is also important in this respect. Whereas continuous masonry wall construction with reinforced concrete floors uses materials capable of providing a high standard of fire resistance, the ‘infill’ type of constructions needed for framed buildings must be carefully selected to provide adequate fire resistance as well as fulfilling other performance requirements, including compatibility and continuity with the support system.

One aspect of the fire-resisting requirements is that the structural organisation of a building should not collapse or deform before the occupants can escape safely. A collapse will be of major importance when considering the spread of fire and also fire-fighting (see section 9.7), and framed structural organisation may need special consideration relative to the materials employed. As long as sufficient insulating cover of concrete is provided to the steel bars of reinforced concrete columns and beams, adequate defence against the untimely collapse or deformation is reasonably easy to achieve. However, steel columns and beams (Fig. 9.5) can present bigger problems since, depending on the precise physical composition, their ultimate strength is about 50 per cent when subjected to a temperature of 550 °C. This can be achieved within 15 minutes in a BS 476 test fire, as already indicated in Figure 9.2. Unless special design techniques are employed which keep temperature below this level for at least the required fire-resisting period of a building, structural steel sections must be insulated with a solid or a hollow casing. This protection must also be compatible with the prevailing environmental and functional conditions. External casings should be weather and impact resistant, durable and of acceptable appearance to maintain their effective life in a building. Similarly, internal fire-insulating casings may be required to withstand knocks from trolleys, to provide fixings for fitments and space for service pipes or cables, as well as to be aesthetically suitable.

Interestingly, timber columns and beams can provide greater fire resistance than unprotected steel. Figure 9.6 indicates the use of sacrificial timber, which provides effective insulation to structural sections subjected to a fire.

Apart from normal fire-resisting requirements (including doors, etc.), care must be taken in the selection of finishes which will not contribute too much to the spread or growth of fire. To insist on the use of non-combustible materials in all circumstances would be too onerous and restrictive. For this reason, the surface spread of flame test set out in BS 476-7 was developed to classify the relative risk of various combustible materials, and these can be used in certain positions, though the area may be limited. Building legislation has introduced a further surface spread of flame classification that covers not only non-combustible materials but also materials with a surface finish giving low fire-propagation properties (BS 476-6), which therefore contribute little to the growth of a fire.

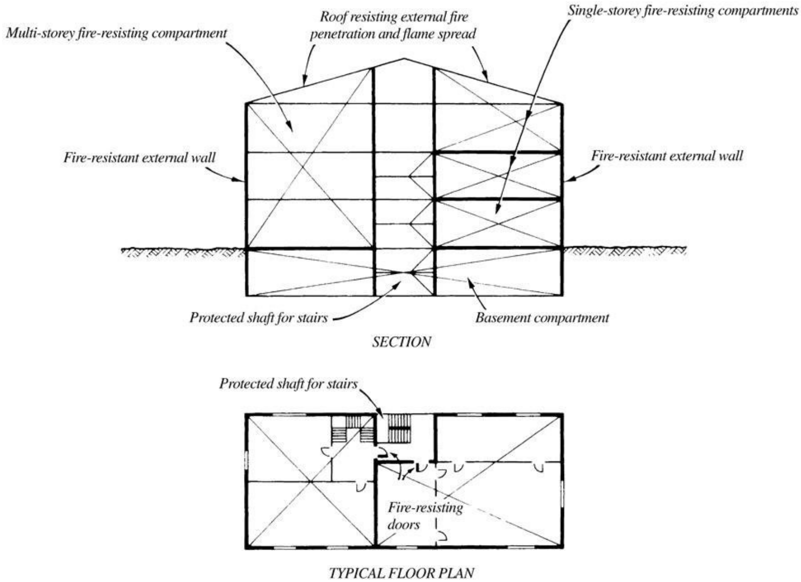


Figure 9.4 Using compartments to limit the spread of fire in a building. (Adapted from material published in the Architects' Journal)

9.4 Means of escape

The occupants of a building must be provided with clearly defined and safe escape routes in the event of a fire. These routes must be kept clear of obstruction, be easy to manoeuvre and, very importantly, should be free of the effects of flames, heat and smoke (Fig. 9.7). For this reason escape routes need special consideration regarding safety from fire; access points must be shielded by lobbies and fire-resisting (and smoke-resisting) doors; walls and floors should have sufficient fire resistance to allow escape and subsequent access for fire-fighters to tackle the fire.

Sometimes it may be necessary to provide positive air pressure in the escape route to ensure smoke is forced back into the body of the building, making exit easier, or an extractor ventilation unit can be provided to remove smoke. Internal surface finishes must not contribute to the fire or provide hazard to people escaping, and escape areas must be adequately lit, sometimes by emergency lights powered from a separate generator.

Tragedies can occur unless means of escape from a building are correctly designed and sited. In the event of a fire it should be possible to evacuate a building in reasonable time ($2^1/2$ minutes is considered normal for everyone to reach a place of safety, except for special premises such as hospitals). Specific fire safety requirements for hospitals are contained in Health Technical Memorandum 05-02: Guidance to support functional provisions in healthcare premises. This document satisfies the objectives set out in the Building Regulations, Approved Document B. The width, the size of treads and risers, and heights of handrails for staircases used for escape purposes must also conform to similar safety requirements. Escape-route planning should therefore be related to the use of the building, the number of occupants, the risks involved, and to the heights of floors above ground and the shapes and dimensions of floors. The risk of persons being trapped or overcome by the effects of a fire is greatest in multi-storey buildings, and access routes and standing positions for fire-brigade appliances are critical factors in the design of escape routes.

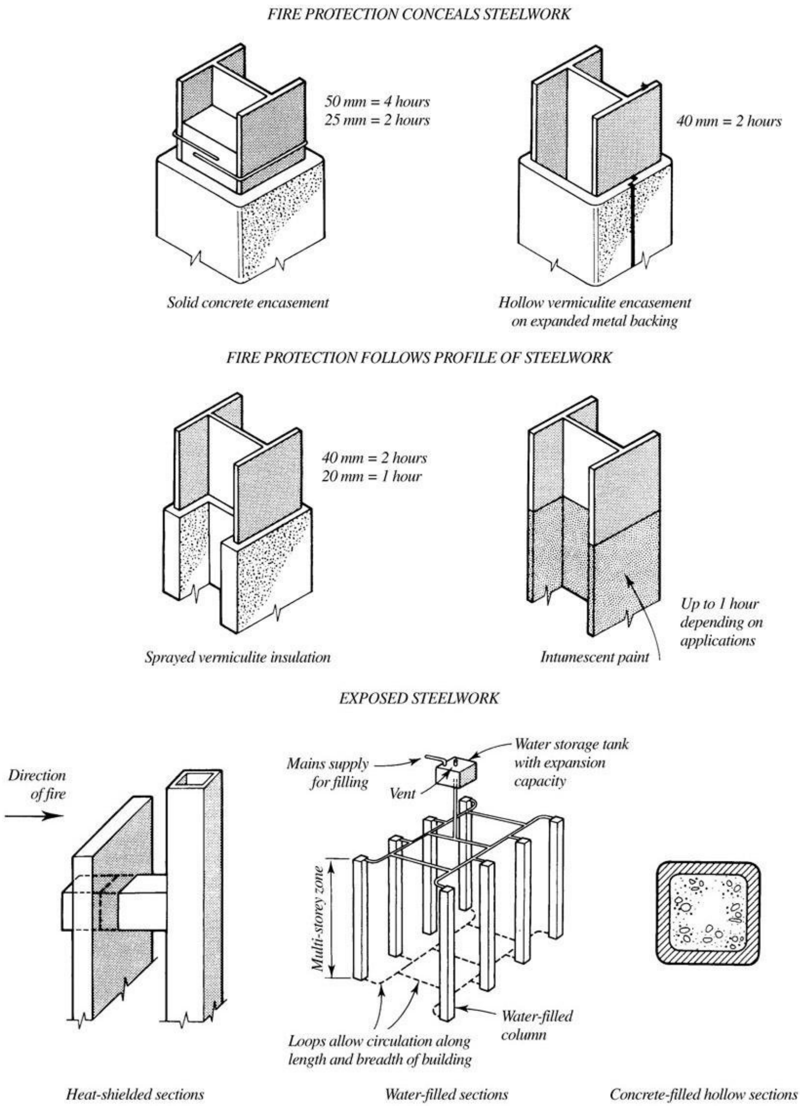


Figure 9.5 Methods of providing fire resistance to steel columns.

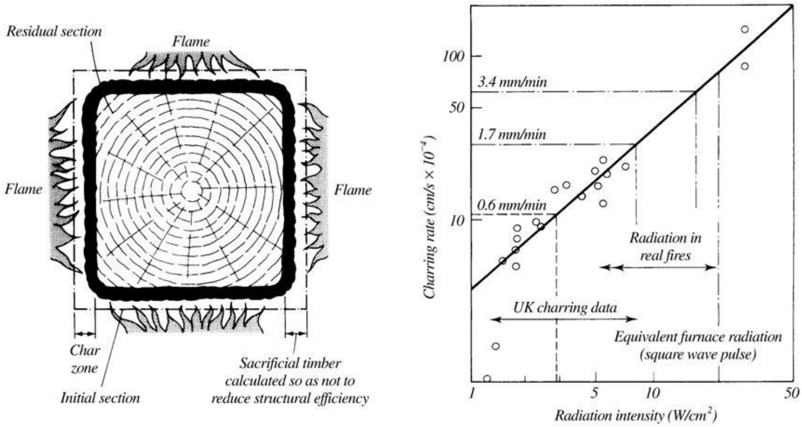


Figure 9.6 Effect of fire on structural timber sections. Once the structural size has been established, extra thickness can provide insulation. The thickness required for a specific period of fire protection for a particular type of timber can be derived from its charring rate. (Adapted from material in Fire Research Note 896 published by the BRE)

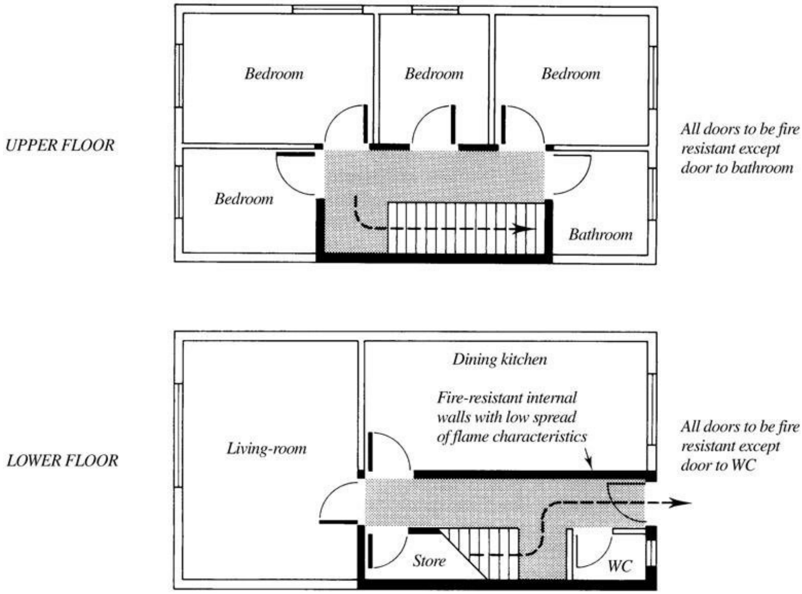


Figure 9.7 Fire-resisting walls and doors assist escape from a burning building.

For an appreciation of the minimum dimensions and location of escape routes in a variety of building types, refer to BS 9999: Code of practice for fire safety in the design, management and use of buildings.

9.5 Fire alarms

New dwellings should be provided with an automatic fire detection and alarm system at least to Grade D Category LD3 standard as recommended in BS 5839: Fire detection and alarm systems for buildings, i.e.

- BS 5839-1: Code of practice for system design, installation, commissioning and maintenance, and
- BS 5839-6: Code of practice for the design, installation and maintenance of fire detection and fire alarm systems in dwellings.

Smoke and heat alarms should be mains-electricity-operated, conforming to BS 5446: Fire detection and fire alarm devices for dwellings. Specifically:

- BS 5446-2: Specification for heat alarms.
- BS 5446-3: Specification for smoke alarm kits for deaf and hard of hearing people.
- BS EN 14604: Smoke alarm devices.

Note that these mains-operated detectors should also have a battery back-up secondary power supply.

A large house, i.e. premises having a floor area greater than 200 m^2 in any one storey, and having three or more storeys (excluding basement), should be fitted with a BS 5839-6 (Grade A Category LD2) system. A large house of no more than two storeys (excluding basement) to be fitted with a BS 5839-6 (Grade B Category LD3) system.

Smoke alarms should be ceiling mounted at least 300 mm from light fittings, with provision of at least one per storey. Specific requirements for loft conversions include an alarm linked to operate the signal in other detectors. Other preferred locations include:

- Circulation spaces between bedrooms.
- Circulation spaces no further than 7.5 m from any door to a habitable room.

- Kitchens.
- Living rooms.

For buildings other than dwellings, consideration must be given to the type of occupancy and purpose of the building. While the basic requirements of BS 5839 alarm systems will suit some buildings, others such as large shopping units may be best cleared by trained staff, rather than an alarm system which could cause panic. Consultation on specific requirements for non-domestic buildings should be undertaken with the local building control authority and the area fire authority, to determine optimum warning systems and procedures in event of a fire. See also:

- Regulatory Reform (Fire Safety) Order.
- BS 5839-8: Code of practice for the design, installation, commissioning and maintenance of voice alarm systems.
- BS 9999: Code of practice for fire safety in the design, management and use of buildings.

9.6 Fire(-resistant) doors

Fire doors have a performance expectation in excess of normal means of access requirements. They are required to have sufficient integrity (see section 9.2) in a fire, for a predetermined period which complements the element of construction in which they are located. BS 476-22: Methods for determination of the fire resistance of non-load-bearing elements of construction categorises door integrity for a period of minutes. For example, an FD 30 classification indicates a Fire Door which can resist fire penetration for 30 minutes. If an S is added to the classification, e.g. FD 30S, this indicates that the door has the added facility to resist smoke leakage. Reference to the Building Regulations, Approved Document B, Appendix B Table B1 provides a listing of fire door locations. These are primarily in compartment walls, escape routes and enclosures.

All fire doors should be fitted with an automatic closing device. Some exception is permitted if self-closing would be considered a hindrance. In these circumstances the door can have a fusible link to hold the door open (unless the doorway is an escape route), an automatic release mechanism actuated by a fire detection system, or a door closure delay device. Hardware and ironmongery should satisfy the requirements of:

- BS 476-31: Methods for measuring smoke penetration through door sets and shutter assemblies. Note that a door set refers to a door and its lining or frame, as an assembly.
- Door and Hardware Federation: Code of practice. Hardware for fire and escape doors.

A colour-coded plastic plug is fitted into the door hanging style to indicate the fire resistance, e.g. a blue core with a white background indicates FD 20 with no intumescent strip in the frame, or FD 30 with an intumescent strip in the frame. An FD 60 door with two intumescent strips in the frame has a colour-coded plug with a red core and blue background. Refer to BS 8214: Code of practice for fire door assemblies.

An intumescent strip can be fitted into a recess in the frame as shown in Figure 9.8. At temperatures of about

150 °C the seal expands to prevent the passage of fire and smoke, but it does not prevent the door being moved physically. An alternative for smoke sealing only is a brush strip seal which also functions as a draught seal.

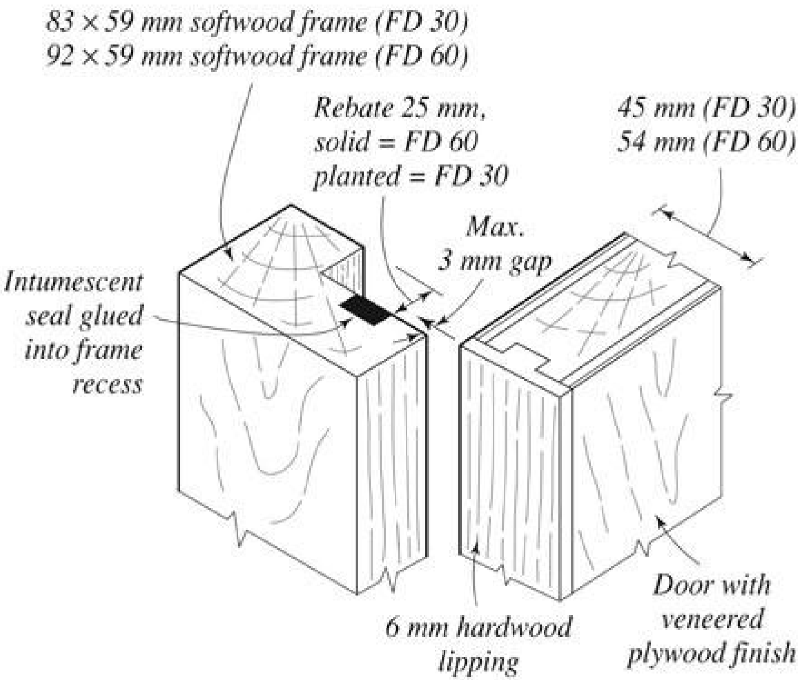


Figure 9.8 Fire door and frame.

9.7 Fire-fighting

The techniques so far described for fire protection can be classified as passive measures as they are an inbuilt feature of a building. Active measures of fire protection incorporate fire-fighting techniques which can be inbuilt (sprinklers, dry/wet risers, alarm systems, fusible links to doors, shutters, fire-fighters' lifts, etc.) or be brought to a building in distress (fire-fighters and appliances). The siting of a building must allow easy access for fire-fighters and their appliances in an emergency. Hard-standing areas must be included in the landscaping and located at prescribed distances from a building to facilitate firefighting activities: see Building Regulations, Approved Document B5.

9.8 Fire insurance

The influences associated with the insurance of a building against damage or loss through the occurrence of a fire are important aspects of initial design considerations. BS 9999: Code of practice for fire safety in the design, construction and use of buildings, provides overall guidance. However, fire insurance companies may require higher or different standards of fire protection, even to that presented in the clauses of fire legislation documents or the recommendations of the fire authority. For this purpose, the fire insurance industry often prefers to apply the Loss Prevention Standards produced by the Loss Prevention Certification Board (formerly Loss Prevention Council, but now part of BRE Certification Ltd). These Loss Prevention Standards complement the Approved Documents and British/European Standards supporting the Building Regulations and generally require higher performance standards. Failure to consider these publications and any other specific insurance requirement at an early stage of design, or during the selection processes for appropriate construction methods, may result in high premiums for fire insurance or the adoption of costly modifications.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 18 Firefighting equipment
Structure & Fabric Part 1	Chapter 5 Walls and piers (functional requirements) Chapter 6 Framed structures (functional requirements) Chapter 7 Roof structures (functional requirements) Chapter 8 Floor structures (functional requirements) Chapter 9 Fireplaces, flues and chimneys (functional requirements) Chapter 10 Stairs (functional requirements)
Structure & Fabric Part 2	Chapter 10 Fire protection

Building Research Establishment

Digest 208	*Increasing the fire resistance of timber floors*
Digest 288	*Dust explosions*
Digest 294	*Fire risk from combustible cavity insulation*
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Digest 458	*Safe as houses?*
Digest 462	*Steel structures supporting composite floor slabs: design for fire*
Digest 484	*Structural fire engineering design: introduction*
Digest 485	*Structural fire engineering design: fire development*
Digest 487	*Structural fire engineering design: materials behaviour* (4 parts)
Digest 488	*Structural fire engineering design: fire and thermal response*
Digest 490	*Structural fire engineering design: aspects of life safety*
Digest 512	*Developments in fire detection and fire alarm systems*
Digest 513	*Fixed gas extinguishing systems for fire protection*
Digest 515	*Lessons learned from real fires*
Digest 516	*Evacuation modelling and human behaviour in fire*
Digest 518	*Sprinkler systems for fire protection of commercial and industrial buildings*
Digest 519	*Residential sprinklers for fire protection* (2 parts)
Information Paper 5/03	*Precast hollowcore slabs in fire*
Information Paper 6/08	*Wireless fire detection systems and European regulations*
Information Paper 11/08	*Self heating and spontaneous combustion*
Information Paper 14/08	*Risks of dust fires and explosions*
Information Paper 12/10	*An introduction to the use of fire modelling*
Information Paper 21/10	*Fire performance of structural insulated panel systems*

Building Regulations

B1 Means of warning and escape
B2 Internal fire spread (linings)
B3 Internal fire spread (structure)
B4 External fire spread
B5 Access and facilities for the fire service

10
Lighting and ventilation

CI/SfB (N) + (L2)

Together with the provision of thermal comfort and sound control, lighting and ventilation provide the initial environmental aspects of a building which ensure the physiological and psychological well-being of its occupants. However, the advancement of technology has led to some degree of complacency on the part of designers concerning the influence which the provision of acceptable lighting and ventilating standards has on the overall appearance and construction method of a building. Apart from purely functional requirements, they provide the principal means of creating aesthetic atmosphere and character. Nevertheless, whereas these functions once derived purely through an interrelationship between architectural form and construction method, it is becoming increasingly possible to design a building where fashion can be made to function by the use of artificial devices.

In all but the simplest form of building, often it may be considered normal to make 'corrections' in the lighting levels not achieved from the designed building by the use of electric light systems. Similarly, air-conditioning apparatus can be made to compensate for the lack of sufficient natural ventilating openings (windows, chimney openings, etc.). Indeed, artificial systems may even be oversized to make the thermal environment acceptable because of ill-considered decisions about siting, orientation or the amount of glazing in a building envelope.

10.1 Standards

Although the size, position and amount of window openings are necessarily controlled by current needs to conserve the use of energy and to ensure safety from the spread of fire or the intrusion of unwanted sound, a sensible balance must be achieved between these aims and acceptable lighting/ ventilating standards. This can be accomplished by detailed analysis of each requirement, careful design decisions and adoption of suitable construction methods. Artificial lighting is required for certain activities to assist concentration without eye strain, and also after natural light periods. A building with a deep plan form required by virtue of optimum function, e.g. large office floor spaces, warrants continuous artificial light sources. In this case a suitably designed system can convert the otherwise wasted heat, generated by the lamp, into useful back-up or supplementary space heating for a building. The residue energy can be similarly used from artificial ventilating systems required by a large building, or a building with the external envelope entirely sealed against noise or extremes of climate.

10.2 Natural lighting

Among its many other vital functions, the sun provides the sources of natural light which create the first psychological connection between the inside and the outside of a building.

The influence of the sun in creating shaded areas affecting the vegetation and human enjoyment of spaces is a critical factor when considering the dimensions and shape of a building and its distance from others. The use of 'natural' coloured daylight to illuminate interior spaces can create interesting effects, caused by variations in intensity during the day influencing the shading of planes and the hue and depth of coloured surfaces.

Daylight is admitted into a building through 'holes' in external fabric (windows, rooflights, etc.), which in adverse climates generally incorporate glass or an alternative transparent material to control the effects of heat loss and/or inclement weather on the interior spaces. The amount of light received inside a building is usually only a small fraction of that received outside – because of modifications
imposed by the size and position of openings – and will also constantly vary, owing to the influences imposed on the 'whole sky' illumination level by clouds, buildings and/or other reflecting planes. Therefore, it is impracticable to express interior daylighting in terms of the illumination actually obtainable inside a building at any one time, for within a few minutes that figure is liable to change with corresponding changes in the luminance of the sky.

Table 10.1 Typical recommended minimum daylight factors for rooms with side lighting only

Building type	Location	Daylight factor* (%)
Dwellings	Living rooms (over 1/2 depth, but for minimum area 8 m^2)	1
	Bedrooms (over 3/4 depth, but for minimum area 6 m^2)	0.5
	Kitchens (over 1/2 depth, but for minimum area 5 m^2)	2
Offices and banks	General offices, counters, accounting book areas, public areas	2
	Typing tables, business machines, manually operated computers	4
Drawing offices	General	2
	Drawing boards	6
Assembly and concert halls	Foyers, auditoriums, stairs (on treads)	1
	Corridors (on floors)	0.5
Churches	Body of church	1
	Chancel, choir, pulpit	1.5
	Altars, communion tables (depending on lighting emphasis required)	3–6
	Vestries	2
Libraries	Shelves (on vertical surfaces of book spines), reading tables (additional lighting on book stacks)	1
Art galleries and museums	General	1
	On pictures (but special provision for conservation where required)	6 (max.)
Schools and colleges	Assembly and teaching areas	2
	Art rooms	4
	Laboratories (benches)	3
	Staff rooms, common rooms	1
Hospitals	Wards	1
	Reception rooms, waiting rooms	2
	Pharmacies	3
Sports halls	General	2
Swimming pools	Pool surfaces	2
	Surrounding floor areas	1

* The minimum daylight factors recommended do not necessarily apply to the whole area of the interior. Unless otherwise stated, the values are for a horizontal reference plane at table or desk height (0.850 m above floor level).

For practical purposes, use is made of the daylight factor. This is a percentage ratio of the instantaneous illumination level at a reference point inside a room to that occurring simultaneously outside in an unobstructed position. Typical daylight factors are indicated in Table 10.1. A simple rule of thumb can also be used to approximate the daylight factor:

$$D = 0.1 \times P$$

where:

- D = Daylight factor
- P = Percentage glazing to floor area

e.g. given a room of 100 m^2 floor area with 20 m^2 of glazing:

$$D = 0.1 \times (20 \div 100) \times (100 \div 1) = 2\%$$

This can be more usefully represented in calculation of the natural illuminance (see section 10.3 and Table 10.2) at the reference point inside a building by applying the following formula:

$$D = (E_i \div E_o) \times 100$$

where:

- D = Daylight factor
- E_i = Illuminance at reference point in building
- E_o = Illuminance at the reference point if the room was unobstructed

Both factors of E are measured in lux (lumens per square metre), with E_o taken as a standard 5 000 lux for un-obstructed sky in the United Kingdom. So, transposing the formula to make E_i the subject:

$$E_i = (D \times E_o) \div 100$$
$$E_i = (2 \times 5\,000) \div 100 = 100 \text{ lux}$$

A comparison of illumination levels is shown in Table 10.2 on page 91.

Daylight reading of a reference point in a room can be made up of three components: sky component, or the light received directly from the sky; externally reflected component, which is the light received after reflection from the ground, building or other external surface; and internally reflected component, which is the light received after being reflected from the surfaces inside a building. Figure 10.1 illustrates how these three combine to make up the daylight factor. The design of a building must take into account these three factors if the 'correct' amount of daylight is an essential factor in its function and if the design and construction method are closely related.

For assessment of daylight and other factors affecting the lighting requirements for interiors, guidance is provided in BS EN 12464-1: Light and lighting. Lighting of work places. Indoor work places. To predict and quantify daylight in a building, numerous methods have been successfully devised. These range from simple modelling and simulation using scaled representations to computer-generated visualisations. A development using scaled grids known as Waldram diagrams applies this principle to assess the amount of visible sky from a window. This also gives an estimate of direct illuminance from the sky at a specific reference point. The Building Research Establishment have established a procedure for measuring the daylight factor using purpose-made protractors that can be applied to design drawings. These are adaptable to rooflights as well as vertical windows and various sky conditions (see BRE Package AP68 and BRE Digest 309). Whatever the methodology, modifications to values should incorporate allowances for type of glazing, glazing materials other than clear glass, dirt on the glass and reductions caused by the window framing. Figure 10.2 indicates various arrangements to achieve acceptable daylight factors within a building for specific visual functions. The arrangement of the windows and other openings in the walls provides the main architectural character of a building, generally called fenestration.

If windows or skylights are within the normal field of vision inside a building, they are likely to be distractingly bright compared with other things occupants may wish to study. To reduce this apparent brightness, or glare, the openings should generally be placed away from interior focal points. Glare can also be reduced by reducing the brightness of the light source (tinted glass, louvres or curtaining) while increasing the brightness of the interior spaces by better light distribution techniques, such as the use of lighter colours for surfaces, or in extreme conditions by supplementary artificial lighting.

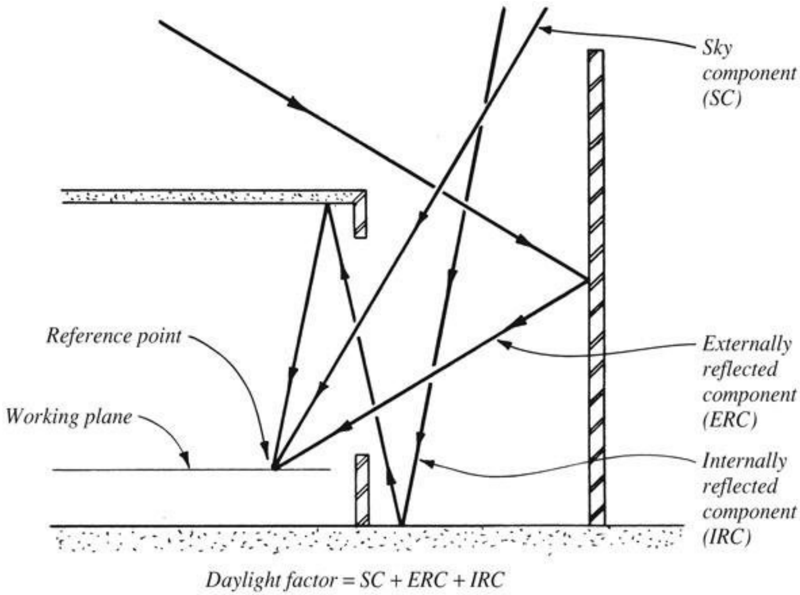


Figure 10.1 Daylight factor components.

Although exerting a very pleasing influence, brightening interior colours and providing both psychological and

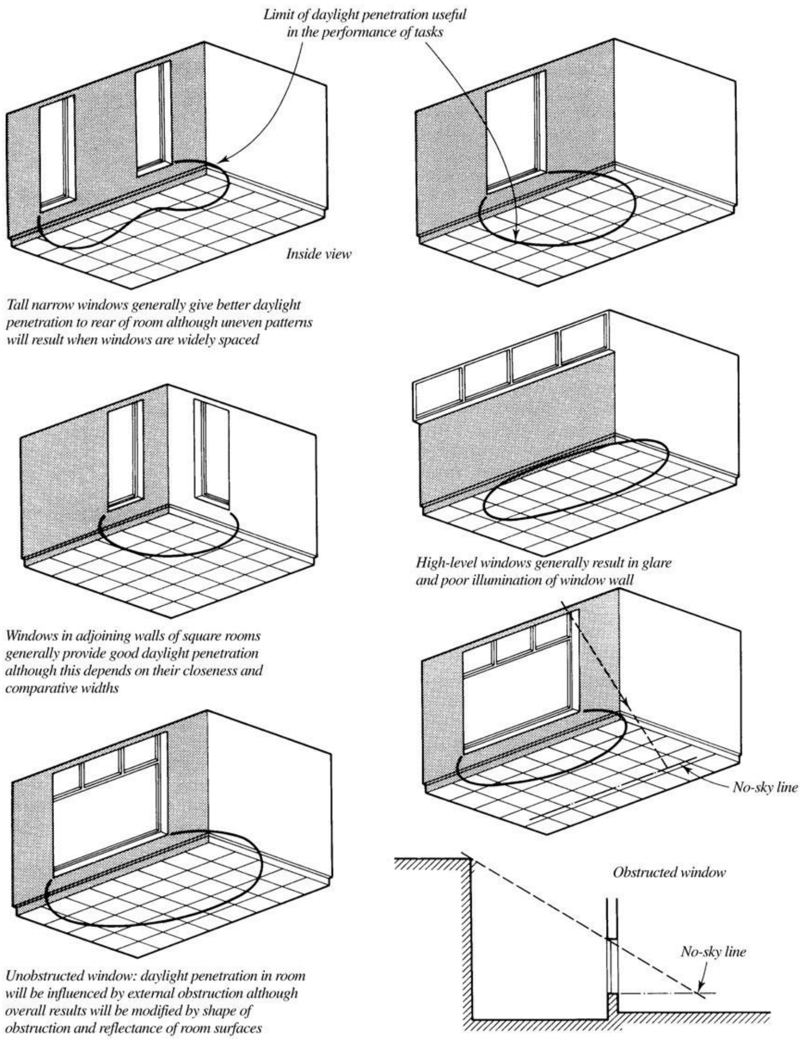


Figure 10.2 Effects of window shape and position on penetration and distribution of daylight. (Adapted from material in Windows: Performance, Design and Installation by Beckett and Godfrey, published by CLS/RIBA)

physical warmth, direct sunlight in a building can cause intensive glare, overheating (see Chapter 8) and fading of surface colours. For this reason, sunlight used to illuminate a building is also often diffused or reflected to reduce its intensity. Shading and reflecting devices include trees, vines, overhangs, awnings, louvres, blinds, shades and curtains. Overhead shading devices (brise soleil) block or filter direct sunlight, allowing only reflected light from the sky and ground to enter a building. Louvres and blinds are capable of converting direct sunlight into a softer, reflected light.

10.3 Artificial lighting

The chief drawback of daylighting is its inconsistency, especially its total unavailability after dusk and before sunrise. Artificial lighting can be instantly and constantly available, is easy to manipulate and can be controlled by the occupants of a building. However, daylighting and artificial lighting should be regarded as complementary. Artificial lighting is used mainly for night-time illumination and as a daytime supplement when daylighting alone is insufficient.

An acceptable balance of brightness within a building can be accomplished by an integration between the design of natural daylight sources and artificial supplementary lighting (Fig. 10.3) to provide the combined level of light appropriate to a specific visual task. During daylight hours natural light should appear dominant wherever possible. However, quite apart from artificial light sources supplementing lighting levels, the use of artificial lighting in a building could lead to more flexible internal planning arrangements and to the incorporation of fewer or smaller windows. Thus daytime supplementary artificial lighting schemes directly affect the appearance of a building and its economy of construction. Against this must be levied the probability of greater energy usage, although reference has already been made to the effects which artificial lighting installations have upon the heating load for a building, and the possible economic advantages obtained by the recycling of heat generated by lamps, etc.

The objective of lighting design is to achieve an appropriate brightness or luminance for a visual task to be performed. When establishing desired luminance levels, account must be taken of the appearance (position, colour, shape and texture) of all wall, ceiling and floor surfaces, as well as the selection of suitable light fittings not only to light the task to be performed, but also to provide appropriate amounts of reflected light. Luminance should not be confused with illuminance. Illuminance is the measure of light falling on a surface (lumens per square metre or lux), whereas luminance refers to light reflected from it or emitted by it (candela per square metre or alternatively apostilb-illuminance × reflection factor).

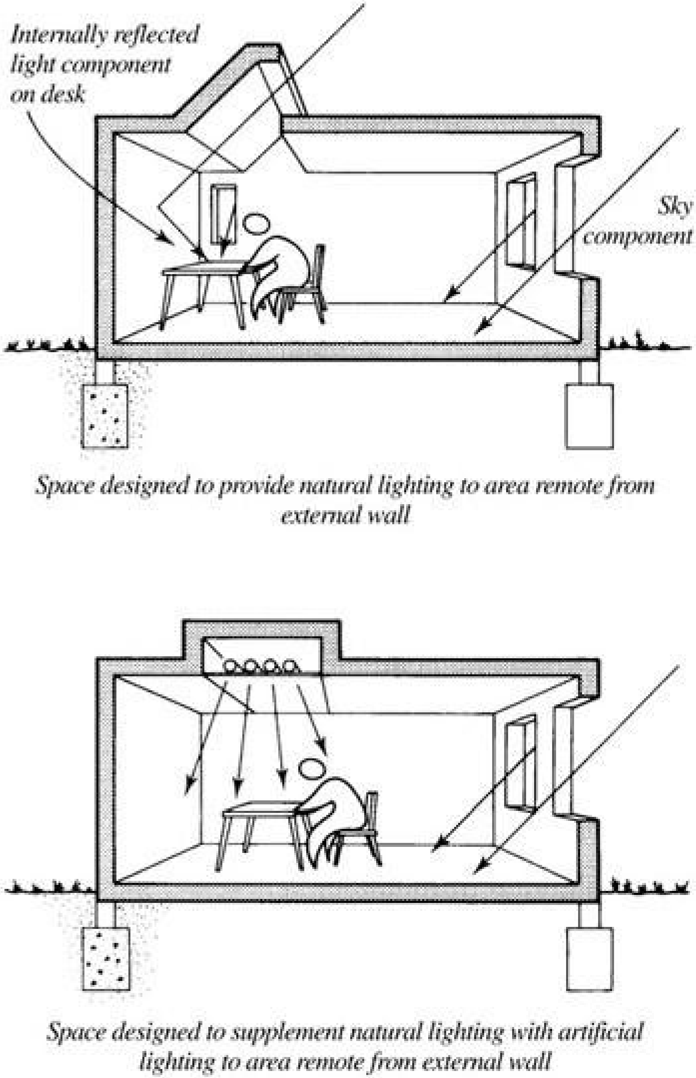


Figure 10.3 Artificial supplementary lighting.

Table 10.2 lists illumination levels suitable for a range of situations: the quality of these levels could be influenced by glare and an acceptable limiting index is also shown. The glare index is calculated by considering the light source location, the luminances of the source, the effect of surroundings and the size of the source. Glare indices for artificial light range from about 10 for a shaded light fitting having low output to about 30 for an unshaded lamp.

As seen from Figure 10.3, various basic decisions have to be made concerning lighting objectives and whether the system involves daylight, electric light or a combined system. With electric or combined systems, further decisions must be taken concerning the way light is distributed by particular fittings, and upon their positions relative to each other as well as in relation to the surface to be illuminated. As with daylighting, light-coloured and highly reflective room surfaces help to provide more illumination from the same amount of energy source.

Table 10.2 Illumination levels and limiting glare indices for various functions

Location	Illuminance (lux or lm/m^2)	Limiting glare index
Entrance hall	150	22
Stairs	150	22
Corridors	100	22
Outdoor entrances	30	22
Casual assembly work	200	25
Rough/heavy work	300	28
Medium assembly work	500	25
Fine assembly work	1 000	22
Precision work	1 500	16
General office work	500	19
Computer room	750	16
Drawing office	750	16
Filing room	300	22
Shop counter	500	22
Supermarket	500	22
Classroom	300	16
Laboratory	500	16
Public house bar	150	22
Restaurant	100	22
Kitchen	500	22
Dwellings		
Living room	50	N/A
Reading room	150	N/A
Study	300	N/A
Kitchen	300	N/A
Bedroom	50	N/A
Hall/landing	150	N/A
Library		
Reading area	200	19
Tables	600	16
Counter	600	16

N/A = not applicable.

For artificial lighting there is also a problem concerning the way the internal colours of a building may be changed depending upon the way they are affected by the light source. Designers must always ensure not only that particular light fittings provide the correct level of illumination in the required direction, but also that the light (energy) source allows the desired colour rendition of the objects to be illuminated. In this respect, the reflectance value of the surrounding surfaces and the contrast created between them also play an important role by reducing the effects of glare. Particular attention should be paid when two or more sources are visible together, such as daylight and supplementary artificial light, or tungsten (incandescent) and fluorescent fittings (see also section 12.6).

The ease with which the maintenance and cleaning of artificial lights can be carried out will depend upon design of fittings and how they are incorporated into a building. Generally, fittings, lamps and auxiliary gear should be readily accessible, and it is an advantage if fittings can be easily removed for replacement and servicing. Access for servicing, whether by reaching, ladders, demountable towers, winches, catwalks or external access from the roof, will depend upon the fixing height, space allocation and the general structural/ constructional design details adopted for a building. However, maintenance of light systems must not be considered in isolation since it generally forms part of similar needs for other services, equipment and perhaps even of window-cleaning procedures (see section 12.6).

A building of special importance is often floodlit for prestige or security. And there is often a need for emergency or safety lighting in public buildings, e.g. theatres, cinemas and department stores. This is generally supplied from an independent energy source and could involve the use of gas, batteries or an automatic-start diesel generator. This type of lighting must again form an essential part of the design of a building and its construction method.

10.4 Natural ventilation

The simplest ventilation system in a building uses external air as its source, the wind as its motive force, and openings in the external enclosure for fresh air intake on the wind-ward side and stale air extraction on the leeward side (Fig. 10.4). In a tightly constructed building, air infiltration is slow, but in a building with loose-fitting components, doors and windows, air movements will be excessive and cause draughts and high heat losses. The idea, therefore, is to create a naturally ventilated building using correctly fitting components of sizes and configurations which provide the optimum amount of air changes for the occupants, according to their activities, and also permit a minimum amount of heat loss. Tables 10.3 and 10.4 indicate the desirable minimum fresh-air requirements for persons taking part in various activities. These figures are also known as ventilation rates or air change rates.

In practice these rates may be very difficult to achieve by natural methods of ventilation because airflow will be governed by areas of openings, the degree to which their use can be controlled by obstruction within a building restricting air movements, and by the pressure differences causing the flow. Also, the recommended quantities of air indicated in Table 10.3 will need some adjustment relative to the possible presence of offensive fumes or smells (including tobacco smoke), as well as for the moisture content of the ventilating air (relative humidity). It is usually considered that relative humidities of 30–70 per cent are acceptable as healthy, and increased ventilation rates will be required to reduce higher levels.

For natural ventilation, windows are used to control the volume, velocity and direction of airflow, and they are designed so as to provide openings capable of adjustment.

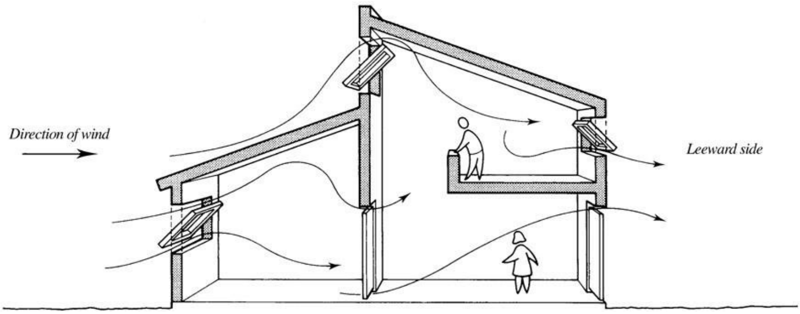


Figure 10.4 Natural ventilation.

Table 10.3 Recommended minimum rates of fresh-air supply to buildings for human habitation

Type of space	Recommended m^3/h per person*
Factory Open-plan office Shops Department store Supermarket Theatre	18–30
Cafeteria Dance hall Hotel bedroom Laboratories Private offices Residential	30–43
Cocktail bar Function room Luxury residential Restaurant/commercial dining room	43–65
Boardroom Executive office Conference room	65–90

Type of space	Recommended m^3/h per m^2 of floor area
Corridors	5
Domestic kitchen	36
Commercial kitchen	72
Sanitary accommodation	36

* To convert to air changes per hour, divide by room volume and multiply by the number of occupants, e.g. a function room of 200 m^3 volume designed to accommodate 20 people requires:

$65/200 \times 20 = 6.5$ air changes per hour

Table 10.4 Approximate air change rates

Accommodation	Air changes per hour
Offices, above ground	2–6
Offices, below ground	10–20
Factories, large and open	1–4
Factories/industrial units	6–8
Workshops with unhealthy fumes	20–30
Fabric manufacturing/processing	10–30
Kitchens, above ground	20–40
Kitchens, below ground	40–60
Public lavatories	6–12
Boiler accommodation/plant rooms	10–15
Foundries	8–15
Laboratories	10–12
Hospital operating theatres	<20
Hospital treatment rooms	<10
Restaurants	10–15
Smoking rooms	10–15
Storage/warehousing	1–2
Assembly halls	3–6
Classrooms	2–4
Domestic habitable rooms	1–4
Lobbies/corridors	3–4
Libraries	2–4

Without wind forces, airflow through a building is simply produced by the migration of air from a high-pressure zone to a low-pressure zone by convection currents created through the difference in density between warmer air and cooler air. Unless employing sealed-duct devices, fuel-burning plant such as fireplaces, boilers or furnaces draw oxygen from the

external air via interior spaces, and produce a stack effect which will also assist ventilation (Fig. 10.5). This technique often avoided the build-up of
air in an interior space containing a large amount of water vapour and thus reduced the possibility of condensation.

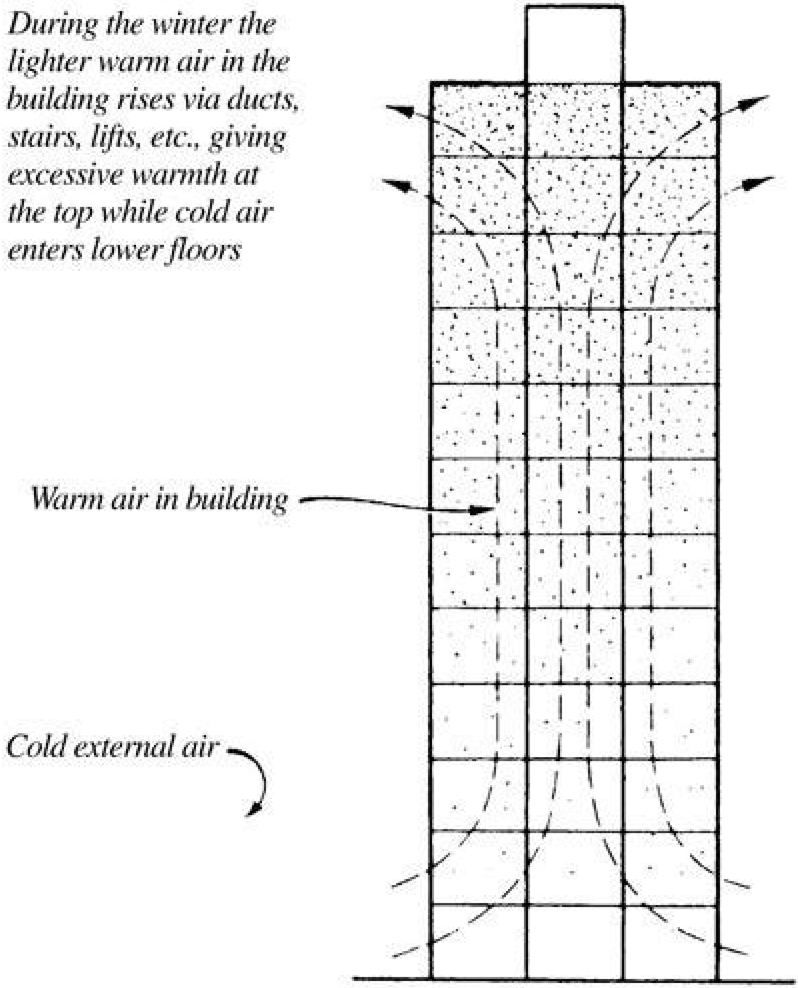


Figure 10.5 Stack effect in a naturally ventilated tall building.

However, the need to conserve energy and reduce room heat losses has given rise to a technology which endeavours to reduce air movements in an interior space to a minimum compatible with the functions to be carried out. The spaces created by joints between components are now reduced, finer tolerances are possible and, where gaps are inevitable, rubber or synthetic seals are used to ensure small amounts of air circulation from the exterior to the interior of a building. This often means that fresh air ducts or grilles now have to be provided to allow sufficient air for both combustion of fuel and the well-being of the occupants in a building.

To satisfy the Building Regulations, Approved Document F, open spaces should be provided outside ventilating openings in domestic buildings to ensure an adequate volume of air for ventilation. Nevertheless, when a building is subjected to high-velocity winds which are likely to cause excessive ventilation or draughts, as well as high heat losses, care should be taken to locate openings in the building exclusively on the leeward side, or to protect them by shielding devices such as fences or trees.

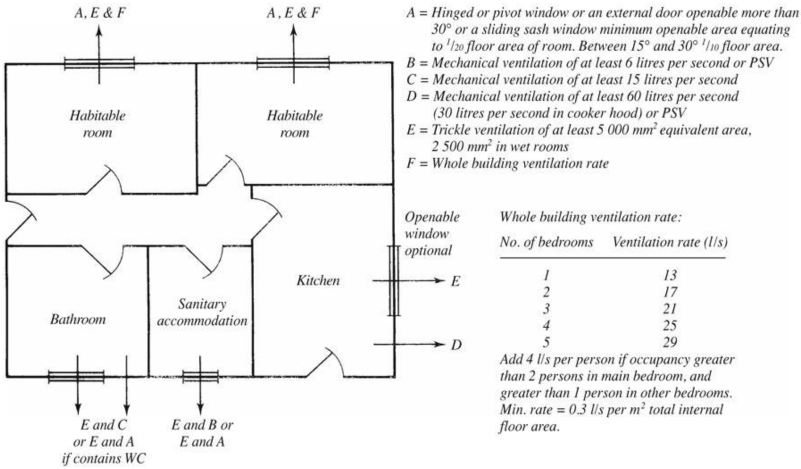


Figure 10.6 Ventilation of dwellings.

With contemporary construction practice, it is essential to provide controlled ventilation in occupied rooms (Fig. 10.6). Table 10.5 indicates rapid and background

means to achieve 0.5–1.0 volume air change per hour, sufficient to complement current high standards of insulation and prevent condensation. This may be by trickle ventilators (Fig. 10.7), fanned extracts or passive stack ventilation (Fig. 10.8). Where kitchens, utility rooms, bathrooms or lavatories are located without an external wall an extract fan is effected with the lighting switch. The fan has a time-delay mechanism to provide for intermittent use with an automatic 15-minute overrun facility. An air inlet of, or equivalent to, a 10 mm gap under the door must also be provided.

Table 10.5 Minimum requirements for domestic ventilation

Accommodation	Ventilation provision		Extract rate (l/s)
	Rapid or purge	Background equivalent area (mm^2)	
Habitable rooms:	Openable window area > 1/20 floor area (see A, Fig. 10.6)	5 000	N/A
Wet rooms:			
Bathroom with or without WC	Intermittent mechanical	2 500	15 or PSV
	Continuous mechanical	2 500	8 or PSV
Kitchen	Intermittent mechanical	2 500	30 in cooker hood 60 elsewhere or PSV
	Continuous mechanical	2 500	13 or PSV
Sanitary accommodation (if separate from bathroom)	Intermittent mechanical	2 500	6 or PSV
	Continuous mechanical	2 500	6 or PSV
Utility room	Intermittent mechanical	2 500	30 or PSV
	Continuous mechanical	2 500	8 or PSV

Note: Background ventilation may be by trickle vents set in window frames, see Fig. 10.7.
PSV = passive stack ventilation (background vents omitted in rooms with PSV extracts). Duct internal diameter 125 mm.
Rapid or purge ventilation up to 4 air changes per hour.
Equivalent area generally relates to unimpeded air flow area, see BS EN 13141-1: *Ventilation for buildings* (Clause 4).

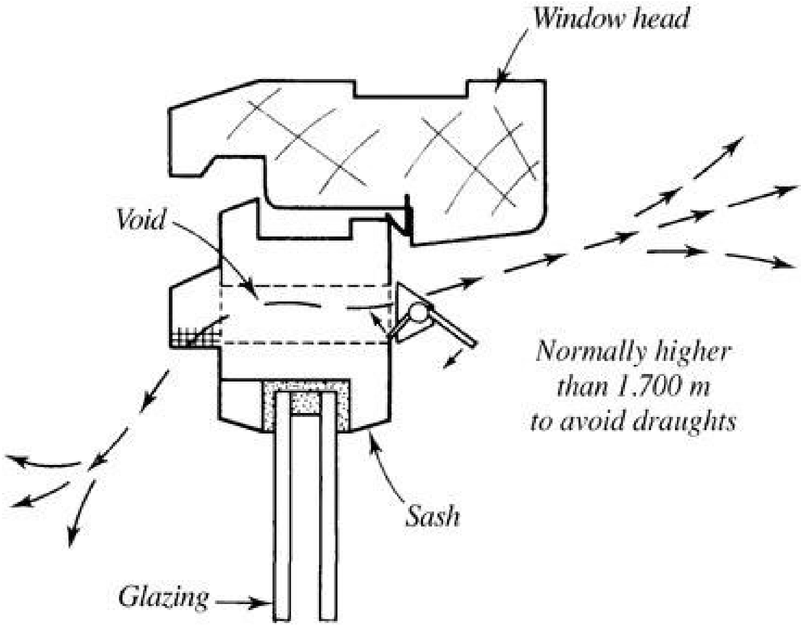


Figure 10.7 Trickle ventilator.

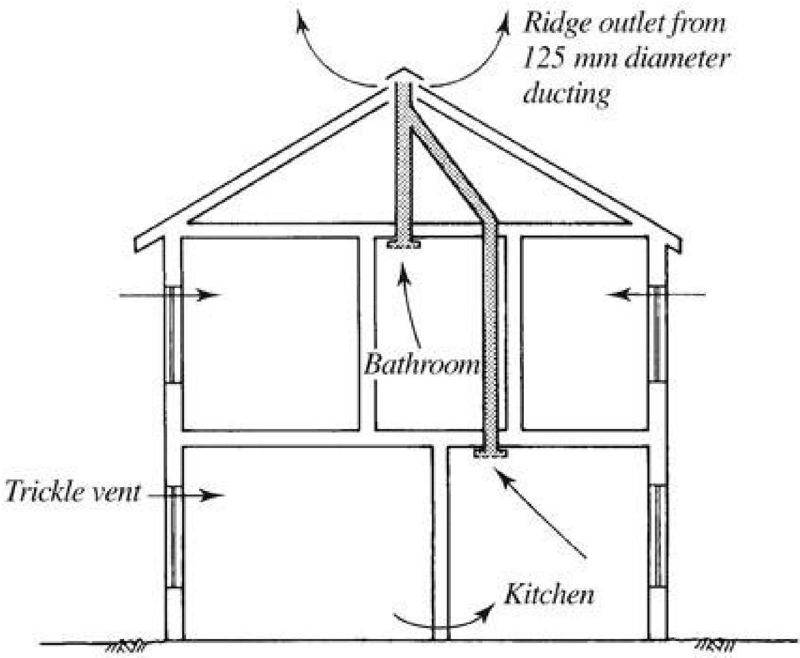


Figure 10.8 Passive stack ventilation.

Passive stack ventilation (PSV) combines with trickle ventilators to create air movement by the stack effect principle (see Fig. 10.5), i.e. warm air rises and gains velocity in the small vertical (or almost vertical) ducts from kitchens and bathrooms, to be replaced by cool fresh air drawn in through ventilation grilles in the window frames of the habitable rooms. Plastic drainpipes or flexible wire reinforced tubes, 125 mm in diameter, are adequate for the application shown in Figure 10.8. A mechanically assisted PSV system may be installed where several internal rooms (no external walls) would otherwise each require an extract fan, e.g. kitchens and bathrooms in a block of flats. The ducted PSV system is linked to each room to provide permanent ventilation and only one extract fan is positioned at the duct outlet. Activation of the fan is from each compartment light switch and inlet air is through a ventilation gap under the door as previously described.

10.5 Artificial ventilation

Where a reliable and positive flow of air for ventilation is required, fans can be installed in a building. This may be to extract stale air, which is immediately replaced by fresh air from the outside flowing through gaps around window and door frames, or through purposely designed grilles. The reverse process of a fanned supply of fresh air into a building may be equally effective as stale air extracts through purpose-made voids. Fans in more elaborate ventilation schemes are connected to systems of ductwork for better air distribution throughout a building. Separate duct systems can be installed to pull away stale air from those used to distribute clean air. Often such systems are coupled with heating and cooling plant enabling the clean air to be distributed at a selected temperature for thermal comfort.

Artificial ventilation systems are usually employed for internally located rooms; crowded rooms where natural ventilation is insufficient; special rooms needing closely controlled humidity and/or freedom from any dust (e.g. computer rooms and operating theatres); and where polluted air is required to be either removed or prevented from entering internal spaces.

Certain high buildings will need artificial air movement control to ensure a balanced thermal environment because of the otherwise exaggerated ‘stack effect’ causing the highest parts to be hot as a result of rapidly rising warm air.

10.5.1 Ventilation systems

Ventilation systems can be categorised as either:

- Mechanical extract/natural supply.
- Mechanical supply/natural extract.

They can also be a combination of the above:

- Mechanical extract and supply.

The simplest form of mechanical extract with a natural supply of air applies to kitchens, bathrooms and sanitary accommodation in domestic premises. Here, fans with the capacity to provide sufficent air change rates as described in the previou section are required to remove unpleasant odours and air contaminated with the residues of cooking or excess moisture from bathrooms. Figure 10.9 shows an application to a small group of flats with shared responsibility for the extract fan.

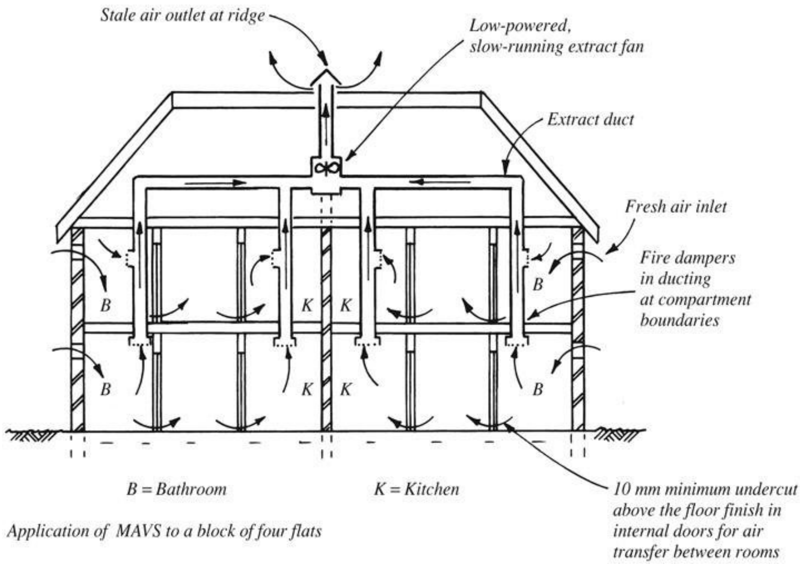


Figure 10.9 Mechanical assisted extract ventilation system (MAVS or MEV).

Mechanical supply and natural extract systems are effectively the reverse of mechanical extract and natural supply systems. By restricting the size of air outlets and locating them strategically, slight pressurisation will give the stale air a defined direction and consistent extract rate. Also, by positioning heat exchangers (radiators) in front of air inlets, incoming cold air will benefit from preheating during the winter months.

While the above two systems will provide a fresh air requirement, heat energy will be discharged in the stale air. The potential to recycle this otherwise wasted energy resource can be achieved with a mechanical extract and supply system incorporating a heat recovery facility. Figure 10.10 shows the use of energy in a warm air recovery unit that combines supply and extract fans with a heat exchanger. The heat energy transfers from the extract air to pre-heat the cold incoming air. The important factor in this arrangement is to understand that it is not the warm stale air being recycled, but the energy within that air. The heat exchanger shown in principle in Figure 10.11 illustrates this concept with a cross-over of steel vanes or plates within the inlet and extract ducts.

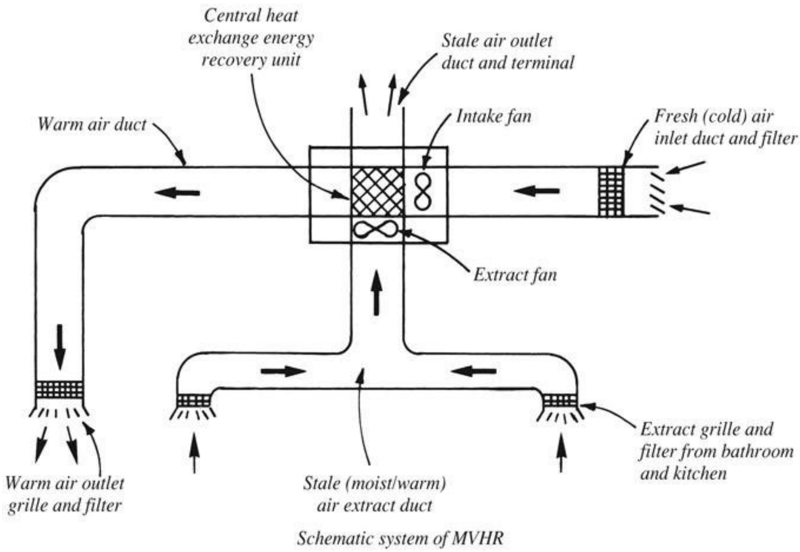


Figure 10.10 Mechanical extract and supply ventilation with heat recovery (MVHR).

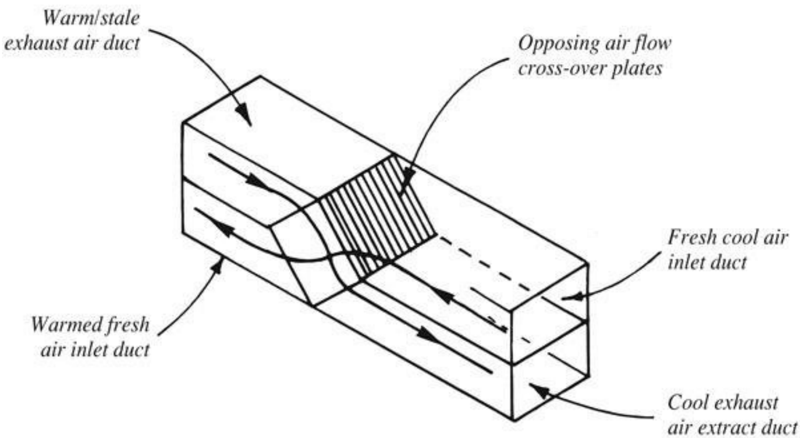


Figure 10.11 Heat energy recovery cross-over duct or plate heat exchanger.

10.5.2 Design implications

The selection, design and integration of artificial ventilation and especially air-conditioning systems into a building require specialist knowledge, techniques and skills. It is essential that the implications of a chosen scheme are realised at a very early stage in the design of a building. The effects of plant, exposed or concealed ductwork, additional fire protection to prevent the spread of fire through ductwork, etc., suspended ceilings, and additional sound control must all be carefully considered as they may have a profound effect on the appearance of the building and other technical aspects, including construction method. The integration of plant and ductwork within the dimensional discipline of the structure of a building requires particular attention as this can take up a considerable amount of space. Figure 10.12 shows an application to a high-rise block with a substantial loss of useful occupancy attributed to the ventilation system. As an approximate guide, the equivalent of one floor in every six can be required to accommodate ducting and its associated services. Raised floors and suspended ceilings account for much of this space, although the air inlet and extract processing unit can often be located on the roof or within the space of a pitched roof.

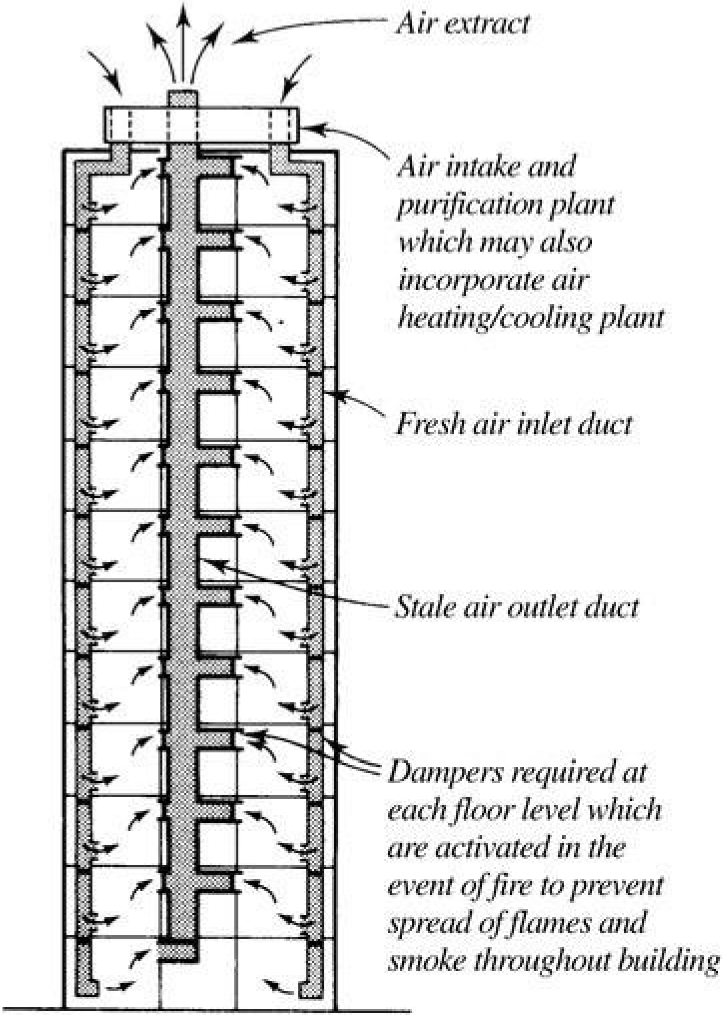


Figure 10.12 Artificial ventilation provides clean air uniformly throughout a building.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 3 Ventilation and air quality Chapter 4 Daylighting Chapter 7 Thermal installations Chapter 8 Electric lighting

Building Research Establishment

Digest 162	*Traffic noise and overheating in offices*
Digest 309	*Estimating daylight in buildings*
Digest 398	*Continuous mechanical ventilation in dwellings: design, installation and operation*
Digest 399	*Natural ventilation in non-domestic buildings*
Digest 498	*Selecting lighting controls*
Report 162	*Background ventilation of dwellings: a review*
Report 288	*Designing buildings for daylight*
Report 345	*Environmental design guide for naturally ventilated and daylit offices*
Report 415	*Office lighting*
Report 430	*Lighting, energy efficiency. Building Regulations*
Report 477	*Ventilation, indoor air quality, air tightness, housing, new build*
Good Building Guide 61	*Lighting* (3 parts)
Good Repair Guide 21	*Improving ventilation in housing*
Information Paper 13/94	*Passive stack ventilation systems: design and installation*
Information Paper 3/98	*Daylight in atrium buildings*
Information Paper 12/98	*Trickle ventilators in offices*
Information Paper 2/99	*Photoelectric control of lighting*
Information Paper 4/99	*Ventilators: ventilation and acoustic effectiveness*
Information Paper 5/99	*Humidistat controlled extract fans: performance in dwellings*
Information Paper 12/00	*Positive input ventilation*
Information Paper 5/02	*Dwellings and energy efficient lighting: new regulation Part L*
Information Paper 2/03	*Background ventilators for dwellings*
Information Paper 6/03	*Improving air quality in homes with supply air windows*
Information Paper 9/04	*Maintaining good air quality in your home*
Information Paper 6/05	*Ventilation and indoor air quality in schools*
Information Paper 15/10	*Specifying LED lighting*

Building Regulations

F1 Means of ventilation

DfE

Building Bulletin 101
Ventilation of School Buildings, TSO

11
Sanitation and drainage

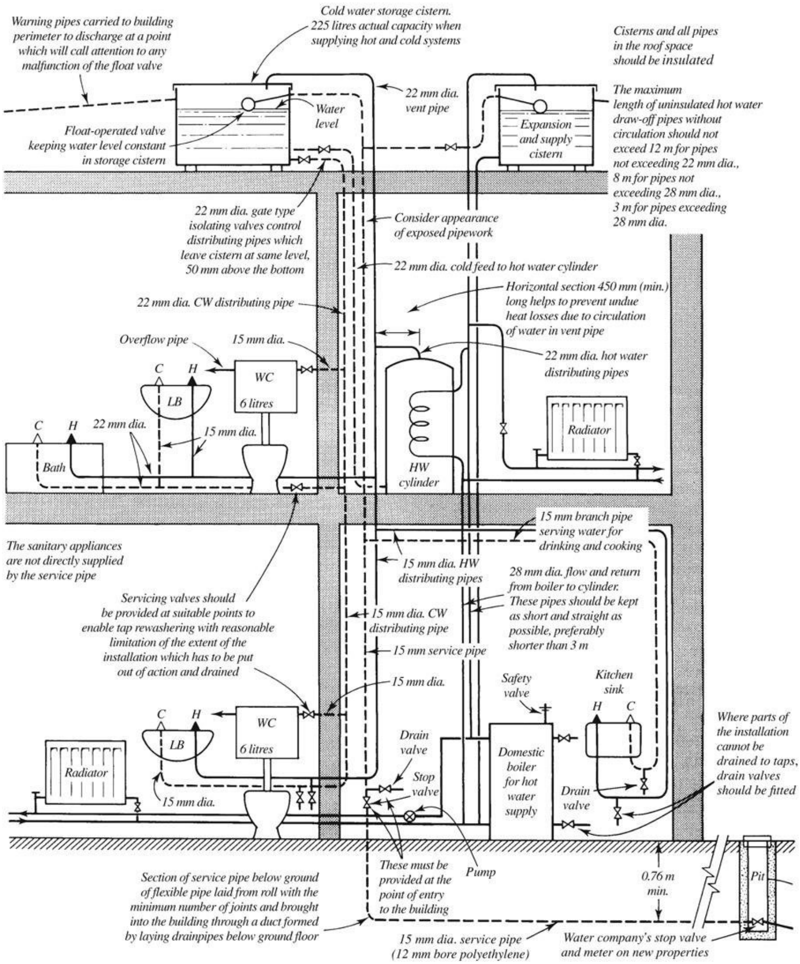
CI/SfB (U46)

Some of the essential activities taking place within and around a building are liable to encourage the growth of bacteria, insects and vermin, which could cause pollution, disease and foul smells. It is therefore necessary to control carefully the conditions most favourable to the development of these unwanted infestations: the provisions for drinking-water, food preparation and washing, and the generation of waste products, refuse and dirt. As far as the building designer is concerned, this involves a careful analysis of suitable water supply and storage systems, and the effective methods of waste and refuse removal. Decisions in these areas must be closely related to the selection of materials least subject to contamination, and the provision in design for efficient cleaning and freedom from deterioration.

11.1 Drinking-water, food preparation and washing

In the United Kingdom, the supply of water to a building is subject to statutory undertakings, mostly controlled by the provisions of the Water Acts, the Water Industry Act in England and Wales, for Scotland a separate Water Industry Act and the Water Scotland Act. These are supplemented by the Water Supply (Water Fittings) Regulations, BS 6700: Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages and BS EN 806-2: Specifications for installations inside buildings conveying water for human consumption, Design. They seek to empower the water authorities to protect drinking-water supplies, effect more efficient use of water, enforce prevention of waste, undue consumption, and misuse or contamination of water. Clean and potable water is therefore generally in ample supply even during times of drought and, as the same source is used for all purposes in a building, installations are of simple design (Fig. 11.1).

The principal physical requirements for the system are that all pipework used should be non-corrodible, capable of being tightly jointed, and resistant to deformation and mechanical damage; the layout of pipework should provide the minimum resistance to water flow and should be protected from freezing; and forming, supporting and connecting techniques to appliances should reduce the possibility of noise generation and transmission. The water supply system or plumbing allows the water not intended for human consumption to be stored in a replenishable cistern, incorporating its own feed system to sanitary appliances such as WCs, bidets, basins, baths, showers and washing appliances. This cistern also supplies cold water to a storage cylinder in which water is heated for distribution to sanitary and washing appliances. The heat source is generally a boiler (may be an electric immersion heater) with a separate water feed and expansion facility. The hot water storage cylinder shown in Figure 11.1 has an internal pipe coil that functions as an indirect heat exchanger connected to the (primary) flow and return pipes from the boiler. This primary and coil circuit contains water that cannot be drawn off (except for maintenance and repairs) although occasional slight water loss due to evaporation will be replenished from the expansion cistern. If the closed coil circuit did not exist and fresh water was frequently introduced, the boiler and associated pipework could ‘furr up’, rendering the system inefficient and potentially dangerous. Furring up of appliances and equipment is most common in hard water areas, characteristic of water sourced from ground comprising chalk or limestone deposits. Water from these sources is most apparent from the build-up of calcium deposits in electric kettles.



Note: Hot water supply to washing facilities, including lavatory basins, baths, showers and sinks must be temperature regulated to prevent scalding. See 11.1.1.

Figure 11.1 Typical traditional domestic water supply system (pipe sizes are for outside diameter copper).

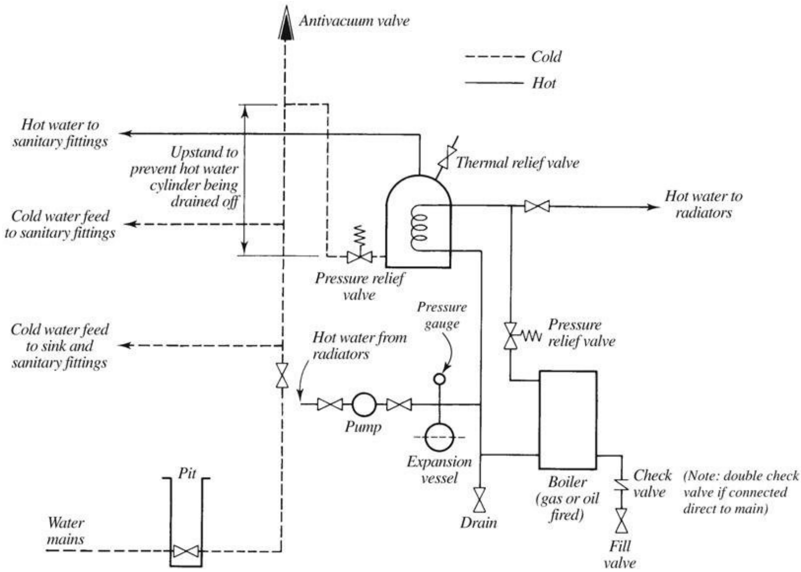


Figure 11.2 Principles of a mains-fed hot water and heating system.

The provision of separate water storage facilities, isolated from the mains, reduces the risk of misuse and contamination of the water within the rising main. Misuse could adversely affect the supply source, as well as the water to be used for direct human consumption (drinking and food preparation) within a building. The storage cistern also ensures a continued supply of water in the event of the mains supply being cut off for a short period due to damage or maintenance work. By installing the storage tank at high level in a building, sufficient supply pressure can be ensured. However, if the pressure of the water in the mains supply is insufficient or likely to fluctuate dramatically owing to demand, the mains water must be pumped to the required level for a building to be adequately serviced.

It is usual to provide a cold water storage cistern as this assists in reducing the size of the pipe used for the mains supply. To avoid the possibility of pollution, there must be a clear gap between the float-valve-controlled water outlet of the supply pipe and the top surface of the stored water; the gap is maintained by siting an overflow pipe at a distance below the supply pipe. Regulation of the flow of water is achieved by a hollow plastic ball attached to the valve mechanism (see Fig. 11.1). A similar air gap must be provided between the outlets on taps supplying water to sanitary fitments, e.g. bath, basin, etc., and the spillover level or rim of these fitments. An overflow will normally control overspill, but this is ignored for provision of an air gap, as it could be obstructed.

As a result of research based on systems in North America and some European countries, most UK local authorities now allow taps to sanitary appliances to be fed directly from the mains without involving water storage cisterns. Figure 11.2 indicates such a plumbing system, and pollution is prevented by using an anti-vacuum valve which maintains a positive pressure in the system to prevent any possibility of water backflow (back syphonage). Sealed hot water heating systems are currently used in the United Kingdom, but the diagram also indicates a sealed system for the hot water supply. The latter is similar to that which is widely employed in other EU countries and has now been introduced in the United Kingdom.

In addition to the mechanical and technical criteria, it is very important that detailed consideration is given to the appearance of a water supply system within a building. Pipework, ancillary devices and appliances must be carefully integrated as an essential part of the design of a building. No plumbing system should 'occur' in a building as an afterthought; if adequately considered during the early stages of design, the system can enhance the appearance of purely practical areas, or be successfully concealed in other areas by incorporation with other services within structural elements, e.g. wall, floor and roof construction.

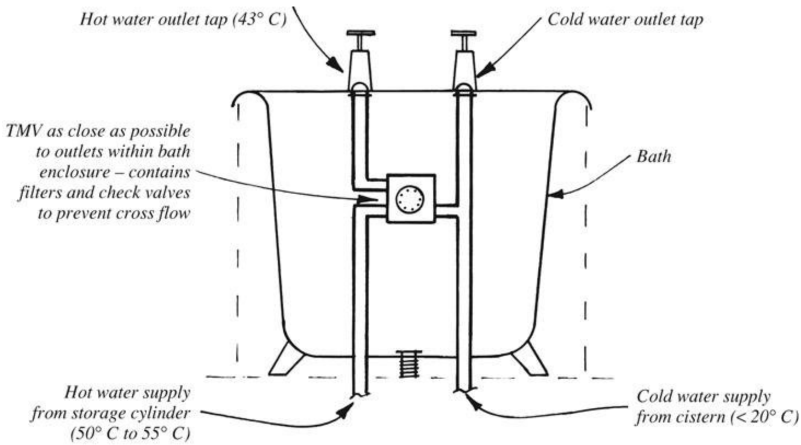


Figure 11.3 Thermostatic mixing valve water temperature regulated installation to a bath.

11.1.1 Hot water installation – prevention of scalding

For health and for safety reasons, the temperature of hot water is thermostatically controlled at the point it is heated (boiler) and the point of storage (hot water storage cylinder). The temperature of water heated in a boiler is slightly above 80° C. Water in the flow and return pipes to the hot water storage cylinder is about 80° C and 70° C respectively. Stored water in the cylinder is between 60° C and 65° C with supply to taps and other draw-offs, 50° C to 55° C.

Hot water in storage must be at least 60° C to destroy bacteria that may thrive at lesser temperatures. The most publicised bacteria is legionella pneumophila, otherwise known as Legionnaire's disease. When contracted by humans the symptons resemble pneumonia and possibly respiratory difficulties. It was identified following the deaths of numerous American military veterans after attending a reunion at a Philadelphia hotel in 1976. Since then, many more outbreaks have occurred worldwide, not least in the UK. Most are related to warm moisture from air-conditioning cooling towers, but hot water storage is also identified as a potential source.

Water above 50° C may cause scalding particularly with children and the elderly or infirm whose sensory responses may be slow. Therefore, the Building Regulations Approved Document G3: Hot water supply and systems requires the following as maximum safe hot water outlet temperatures:

Bath	43° C
Sink	48° C
Shower	40° C
Bidet	37° C
Lavatory/wash basin	40° C

The facility to reduce hot water temperatures supplied from a storage cylinder to safe levels can be achieved by installing a thermostatic mixing valve (TMV) to blend hot water with cold water at a pre-set outlet temperature. TMVs are similar in principle to thermostatic shower mixers and should be located as close as possible to hot water draw-offs as shown for a bath in Figure 11.3.

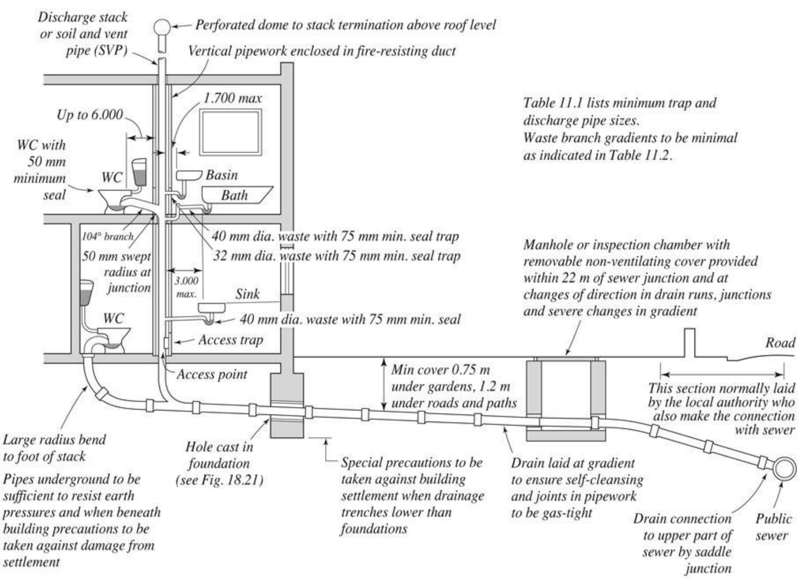
11.2 Waste products, refuse and dirt

Depending upon its precise function, a building usually must also provide installations which facilitate the disposal of water-borne organic waste matter, including human excrement (sewage); permit the collection of rainwater otherwise liable to cause some form of deterioration; and allow other organic and non-organic waste (refuse) to be removed.

Sanitary fittings (WCs, bidets, urinals, baths, showers, basins and sinks) which receive the sewage are designed on the basis of specific anthropometric data for efficient function; they also flush away bacteria, and prevent foul smells. They are manufactured from non-porous, smooth, durable and easily cleaned materials, and they incorporate
a water-filled trap to prevent gases escaping into the building from the pipework beyond. Further precautions against smells and other forms of pollution are provided by building designs which promote good ventilation in rooms used for bathrooms, laboratories, operating theatres, abattoirs, etc., where sanitary appliances are situated; by ensuring adequate space around a building; and by its correct location within a particular environment.

11.3 Drainage systems

The sanitary fittings discharge sewage along a network of gas- and watertight pipes which together form the drainage system of a building. This system conveys both solids and liquids to a treatment plant in the local authority sewage processing works. Above ground drainage discharge pipes which convey liquids only are generally called waste pipes, and those which convey solid matter and liquids are called soil pipes.



See also: BS EN 12056-2: Gravity drainage systems inside buildings. Sanitary pipework, layout and calculation
BS 6465-1: Sanitary installations. Code of practice for scale and provision, selection and installation of saintary appliances

Note: 38 mm water seal traps are acceptable for flat-bottomed appliances with an open outlet, typical of the discharge to a gully. A 50 mm water seal can be used with spray-tapped appliances used without a plug.

Figure 11.4 Typical centralised single stack sanitary installation and drainage for small building.

Efficient and economic design considerations usually mean that the waste and soil pipe system in a building takes one of two forms. The simplest occurs when sanitary appliances can be fairly closely grouped around vertical discharge stacks (soil and waste pipes) which then convey sewage by the most direct route to underground drains (Fig. 11.4). Such installations are found in many types of buildings, including blocks of flats, where the activities to be accommodated allow vertically repetitive planning arrangements. It is now usual to combine the soil and the waste pipe into a centralised single discharge stack system; the overall dimensions of this pipe are dictated by the amount and frequency of solid material it must transfer to the drains. Great care must be taken when designing the system to ensure that the water seals or traps (Fig. 11.5)
in the sanitary fittings are not prevented from reforming after use. Seals may not reform because of induced syphonage, which occurs when the seal is sucked away by the force of water discharging from branch pipes on other floors as it passes down the vertical discharge stack. The rush of water down the stack absorbs air from the branch pipe of the fittings below and this causes the external air pressure on the seal to force the water out of the trap, the most common cause being an undersized branch pipe. Overlong and too steep horizontal lengths of branch pipework may also contribute and these are also likely to cause the discharging water from a sanitary fitting to remove the trap seal by self-syphonage. This occurs when a horizontal pipe flows full, producing a solid ‘plug’ of water that creates a negative pressure or vacuum on the drain side of the trap to draw out the seal. Baths, large flat-bottomed sinks and shower trays rarely suffer self-syphonage because the last of the discharging water moves very slowly allowing the seal to resettle. The discharge

pipe from a WC is unlikely to syphon as it is too large to flow at full bore. Back pressure at the base of the vertical discharge stack is another possible cause of trap water seal loss. This can be caused by an undersized stack and/or an inadequate radiused bend at the stack base. Possible seal loss due to poor system design or installation is shown in Figure 11.6.

Table 11.1 Appliance branch waste and trap size

Appliance	Min. waste outlet and trap diameter (mm)
Bidet	32
Drinking fountain	32
Wash basin	32
Cleaner's sink	40
Kitchen sink	40
Domestic waste disposal unit	40
Bowl urinal	40
Sanitary towel macerator	40
Washing machine	40
Dishwasher	40
Bath	40
Shower tray	40
Industrial waste disposal unit	50
Urinal stall (up to 7)	65
WC	75 to 100*

* Outlet diameter can vary with differing designs but the discharge branch should be at least 100 mm internal diameter.

Table 11.2 Recommended falls or slope of branch pipes

Sink, bath and shower:	18 to 90 mm per metre length
Wash basin and bidet:	18 to 22 mm per metre length up to 1.7 m 18 to 44 mm per metre length up to 1.1 m 18 to 87 mm per metre length up to 0.7 m
WC:	18 to 90 mm per metre length (9 mm min. if more than one WC connected)

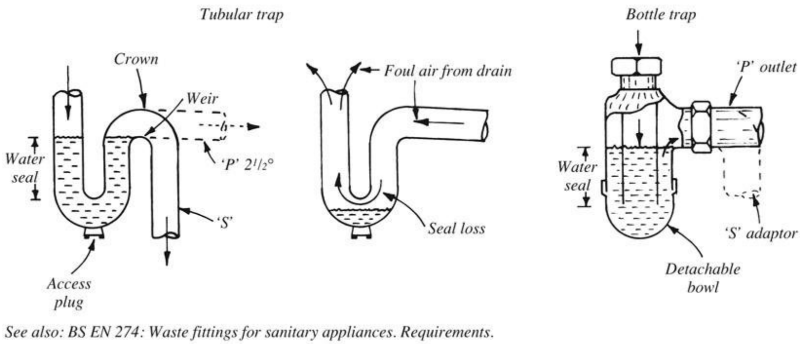


Figure 11.5 Sanitary appliance water seal traps.

When the activities within a building are complex and it is not possible to group sanitary fittings around a centralised discharge stack, e.g. in hospitals, schools and some office layouts, a satisfactory system can be achieved by grouping appliances in 'islands', and by providing extensive horizontal pipework connection to strategically located vertical discharge stacks. This arrangement is expensive and more complicated than a centralised single stack system because the proliferation of horizontal branch pipes requires accommodation in false ceilings and raised floors. The possibility of syphonage of trap water seals due to long pipe lengths must also be considered.

For other sanitary fittings with extensive horizontal lengths of discharge pipework, larger pipe diameters and greater depth of seal must be incorporated and possibly an elaborate system of ventilating the pipes. Alternatively, special anti-syphon resealing traps can be used. These let air into the system without complete loss of seal. However, it is preferable to design the whole sanitation and drainage system with a careful regard for pipe sizes, lengths, slopes and positioning of pipework. Design guidance is based upon empirical and scientific analysis of water flow and air pressure characteristics.

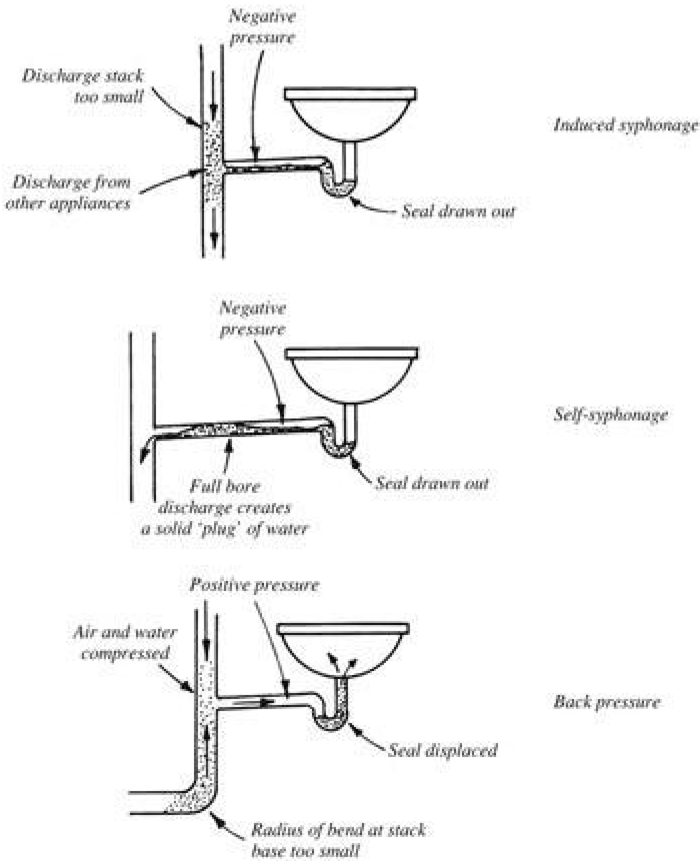


Figure 11.6 Possible causes of water seal loss in traps.

A variation suitable for repetitive development, typical of housing estate sanitation and drainage systems incorporates an air admittance valve at the top of the discharge stack. Unlike a conventional stack, it does not allow foul air to escape from the drain and can be located within the roof space to reduce installation costs. It also eliminates the need for an unsightly stack projecting through the roof slope. However, every fifth dwelling must have a conventional stack to ventilate the drain and sewer as indicated in Figure 11.7.

11.3.1 Sewage treatment

In some rural situations there may not be a public sewer with access to a local authority sewage processing plant. In the absence of a sewer, a cesspool or a septic tank may be considered. Figure 11.8 shows a pre-formed plastic cesspool set in concrete, designed with a suitable capacity for periodic emptying. The plastic septic tank outlined in Figure 11.9, also set in concrete, is a small-scale sewage processing unit for use with a supplementary filter. The reed bed filter shown in Figure 11.10 is an acceptable natural means for final treatment of the effluent.

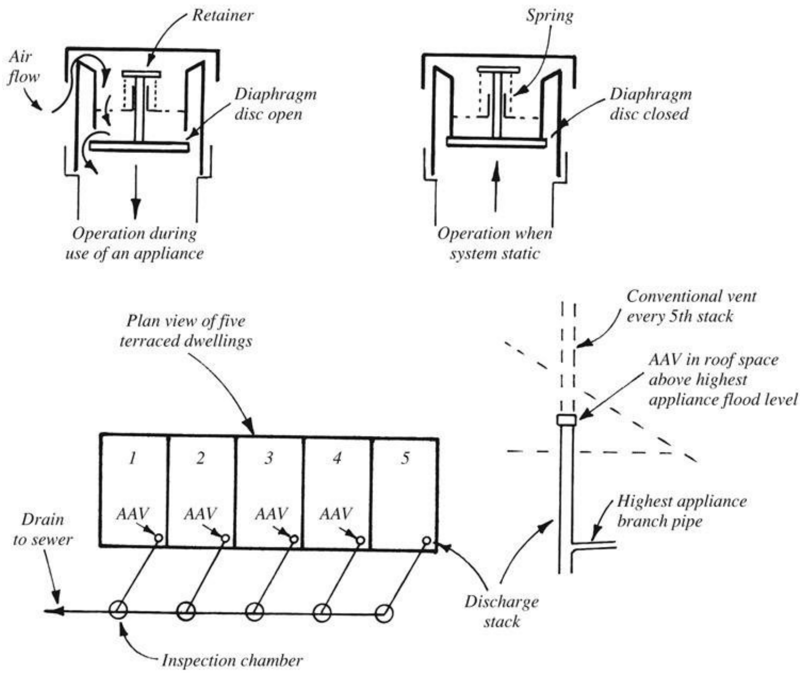


Figure 11.7 Air admittance valve and application.

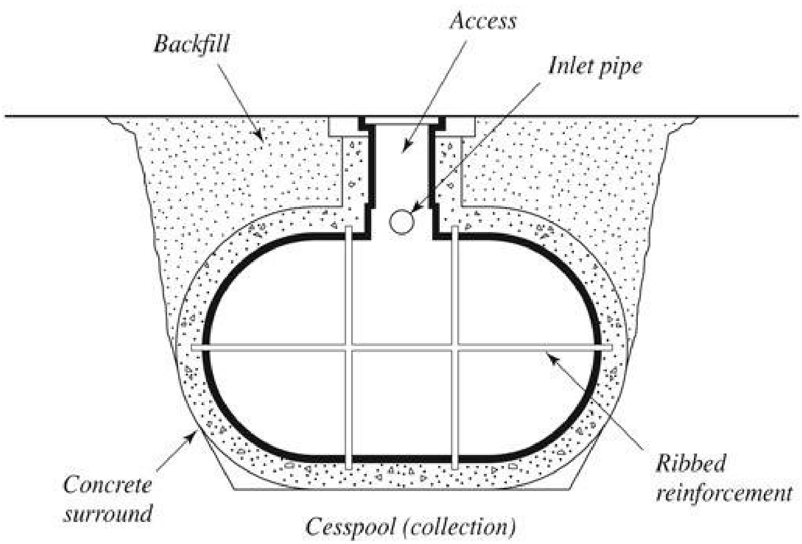


Figure 11.8 Plastic cesspool set below ground in concrete.

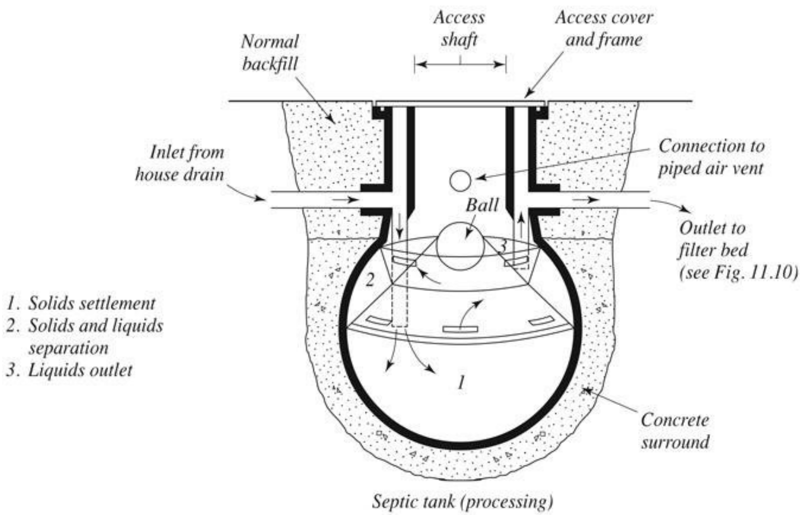


Figure 11.9 Plastic septic tank set below ground in concrete.

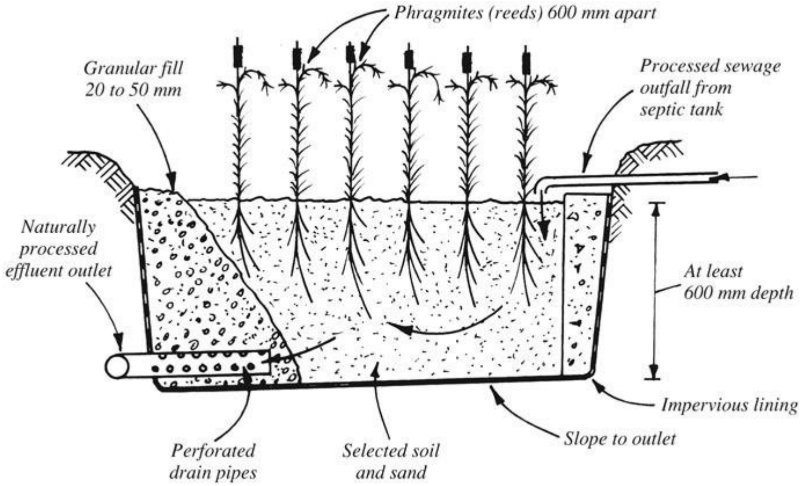


Figure 11.10 Typical reed bed sewage filter.

11.4 Rainwater collection

A drainage system for the removal of waste should be planned in conjunction with the drainage system required for the collection of rainwater. This involves collection of rainwater falling on a building and perhaps around a building. The collected rainwater must then be conveyed in a similar manner as waste water to a local authority surface water drain. If this drain is not available, rainwater can be taken to a purpose-built soakaway situated away from areas likely to be detrimentally affected by excessive amounts of water, or to a conveniently located water course or a storage vessel for subsequent use as a water supply (Fig. 11.11).

The selection of appropriate means of disposing of the rainfall will be determined by the anticipated volume expected and the system for containing it. In recent times of climatic change and extremes of weather, considerable damage has been caused to buildings by flooding. Natural water courses have been unable to cope with the high volume of stormwater. Sustainable Urban Drainage Systems, otherwise known by the acronym SUDS, have become

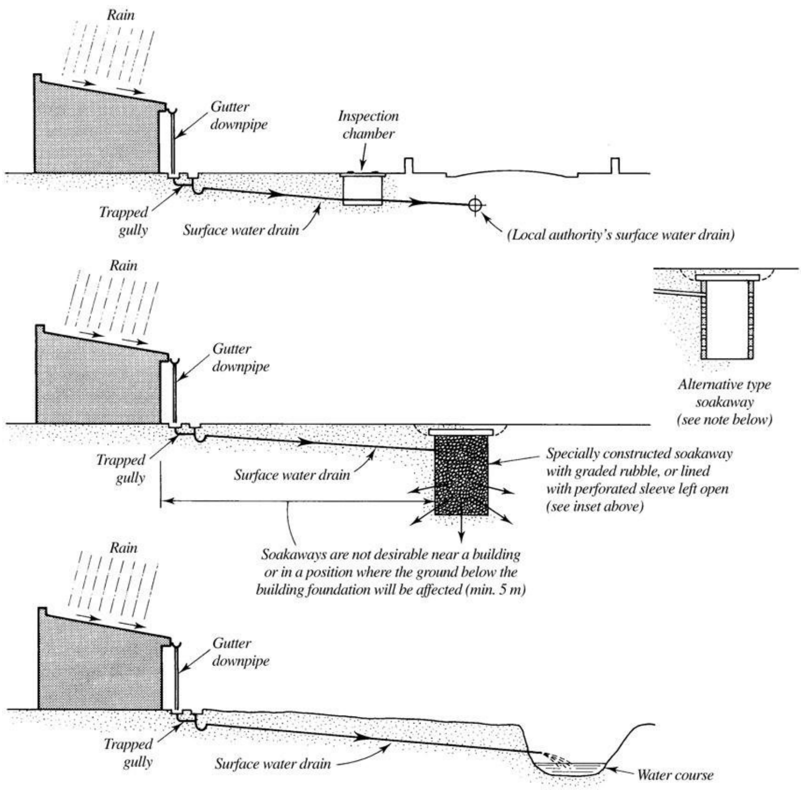


Figure 11.11 Rainwater collection and methods of disposal.

necessary as an intermediate facility between drainage systems and their outfall. The principal objectives of SUDS are to contain the volume of rainwater discharging from a site, to regulate its run-off and to improve the water quality by filtration. SUDS may comprise any of the following, sometimes in combination:

- soakaways
- swales
- infiltration basins
- filter drains
- retention ponds
- reed beds

- Soakaways, as shown in Figure 11.11, may function acceptably for collection and dispersal from individual or small groups of buildings. As a rule of thumb, capacity/volume can be estimated from the following empirical formula:

$$C = A \times R \div 3$$

- where:
  - C= capacity in m^3
  - A = Area of rainfall to be drained in m^2
  - R = Rainfall design factor in m/hour
- e.g. area drained 200 m^2 at a design rainfall of 75 mm/h:

$$C = 200 \times 0.075 \div 3 = 5\ m^3$$

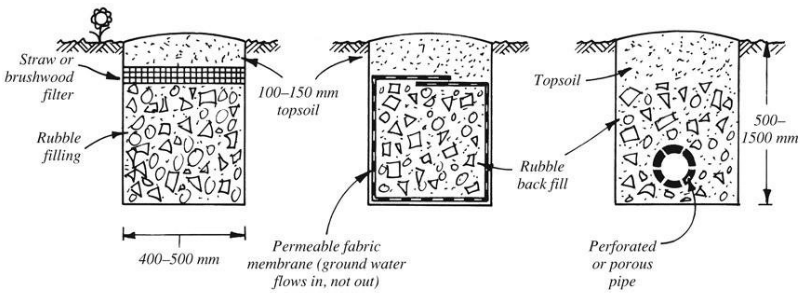


Figure 11.12 Filter, French or rubble drain alternatives.

- Swales are a type of channel or ditch lined with grass. They function by containing and slowing the flow of water while it disperses naturally into the ground, reducing the amount discharging into a water course.
- Infiltration basins, sometimes referred to as reclamation basins. These manage stormwater run-off by capturing it in purpose-made ground depressions lined with a permable membrane and/or grass, through which the water permeates at a steady rate. Alternative permeable surfaces can be porous asphalt or purpose-made paving or brick paviours.
- Filter drains, sometimes called French drains. Generally a series of strategically located trenches filled with loose rubble. These drains are laid to a slight fall and function by attracting surface and ground water into a less restricted flow than the adjacent naturally compacted ground. Final discharge of water is into a swale or a water course. Some variations are shown in Figure 11.12.
- Retention or detention ponds are artificial (man-made) catchment reservoirs designed with a capacity to contain the worst expected volume of stormwater, for controlled release into natural water courses.
- Reed beds, as already described at the end of section 11.3, are a natural means for filtering sewage after initial processing in a septic tank. They can also be useful for filtering surface water by breaking down the suspended pollutants and solids.

Water falling on a building at roof level is collected and discharged into a rainwater pipe system by means of strategically located rainwater outlets. If a building is lower than about five storeys, easier means of access and maintenance generally make a system of collection involving guttering more acceptable. The water is conveyed to the vertical rainwater pipes, which discharge either directly into the drain below ground or over trap-seal gulleys at ground level. Pipe sizes for the design of rainwater drainage systems in the United Kingdom depend upon the expected risk involved: 50 mm/h of rainfall for flat roofs and other open paved areas; 75 mm/h for sloping roofs; or 150 mm/h when very occasional overflowing of rainwater outlets or gutters cannot be tolerated. (This amount is likely to fall only during short periods of heavy storms.)

11.4.1 Rainwater harvesting

Requirements for harvesting (capturing and storing) rainwater for use in situations where processed drinking water is unnecessary is defined in the Department of Communities and Local Government's publication, The Code for Sustainable Homes. See section 14.7.2 of this book for a summary. Additional guidance is provided in BS 8515: Rainwater harvesting systems. Code of practice.

The concept is old technology: simply intercepting rainwater discharge from gutters and downpipes and directing it into storage. Thereafter it is filtered and pumped to useful outlets such as garden taps, flushing cisterns for urinals and WCs, washing machines, dishwashers and other non-drinking-water provisions. Figure 11.13 shows an economical installation for domestic use and Figure 11.14 a more complex arrangement applicable to a group of dwellings, a factory or commercial building. Here rainwater is contained in an underground tank, then pumped into a storage cistern within the building for distribution to suitable outlets.

Pipes and vessels containing harvested water must be clearly marked as such so that there is no opportunity for cross-contamination with drinking water supplies, for example: WATER NOT SUITABLE FOR HUMAN CONSUMPTION.

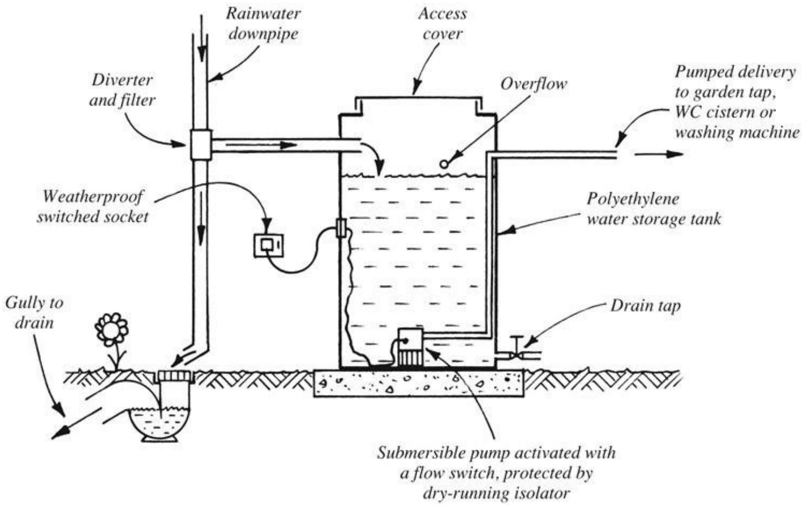


Figure 11.13 Rainwater harvesting – simple domestic garden installation.

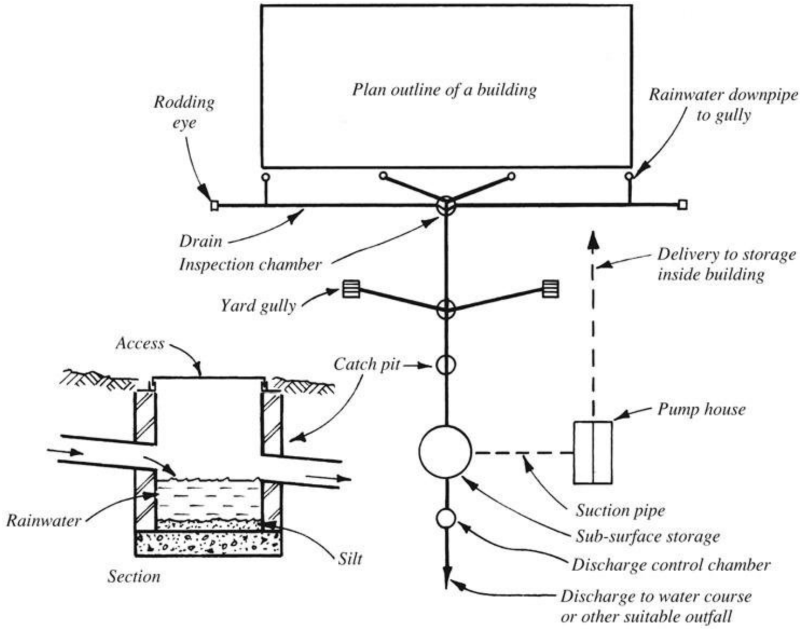


Figure 11.14 Rainwater harvesting – application to a commercial or industrial building.

11.4.2 Drainage systems

The type of drainage system for disposing of rainwater and foul water will vary depending on the processing facilities available to the local authorities. Figure 11.15 shows the principles of three basic applications, namely:

- combined system
- separate system
- partially separate system

- Combined system Both drains discharge into a common sewer. This is a simple and economic system because it involves less pipework and is easy to maintain. However, it has the disadvantage that vast amounts of liquids must pass through the sewage treatment works, particularly after heavy rainfall.
- Separate system Two drains are provided. One of them receives the collected rainwater (or surface water) and conveys it directly to a suitable outfall without treatment, e.g. nearby water course, river or rain-water harvesting facility. The second drain takes the soil and waste discharge and conveys it to the sewage treatment installation. This obviously involves more drainage pipes, but avoids the risk of overcharging the sewage treatment plant during periods following heavy rainfall.
- Partially separate system A combined drain is used for soil, waste and rainfall. However, a second drain is also available to regulate the amount of rain or surface water discharging into the combined drain, according to the capacity of the sewage treatment installation. This may be by connecting some of the rainwater pipes and drains to the foul water drain.

11.5 Means of access to drains

Access to drains is necessary for inspection, testing and maintenance. The following means are acceptable:

- rodding eye
- access fitting
- inspection chamber

- manhole

- Rodding eyes may be used at the head of a drain. They are in effect an extension of the drain up to surface level, terminated with an adaptor to a screw-sealed surface access plate.
- Access fittings are produced in plastic or clayware to suit the drainage system material. They too are limited to rodding, but in both directions. Fittings may be cut or adapted for depths up to 600 mm to invert (invert represents the lowest level that water will flow in a drainage channel).
- Inspection chambers are produced from a range of materials including brickwork, preformed plastic units and precast concrete sections. Each provides the option of a few branch channels in addition to through-flow. Limited bodily access is possible in depths of up to 1 m to invert.
- Manholes are sufficiently spacious at drain level for a person to work in. In depths over 1 m they require step irons or an attached ladder to aid accessibility. They are generally built of concrete (in situ or pre-cast) or dense masonry to provide adequate strengths at depths of several metres.

Note that small surface access plates are secured by screws to prevent unwarranted access, e.g. by children.

Siting of access points should occur:

- at or near to the head of a drain
- at a change of direction
- at a change of gradient

- at a change of drainpipe diameter
- at junctions (unless each drain can be cleared from another access point – maximum distances as in Table 11.3)
- on long straight runs

11.6 Integration of systems

Table 11.3 Maximum spacing (m) of access facilities in drains up to 300 mm in diameter

	Small access fitting	Large access fitting*	Junction	IC	Manhole
Start of drain	12	12	–	22	45
Rodding eye	22	22	22	45	45
Access fitting:					
150 mm ø	–	–	12	22	22
150 × 100 mm	–	–	12	22	22
225 × 100 mm*	–	–	22	45	45
IC < 1 m	22	45	22	45	45
Manhole > 1 m	–	–	–	45	90

Whatever internal drainage arrangements are to be incorporated within a building, it is always important to consider carefully their implication on the precise system to be adopted. Not only can considerable economy be achieved by adopting simple systems, but also the visual impact on a building can be quite considerable; pipework can be exposed, or concealed in service walls, floors or ducts, and false ceilings, etc. When requirements for buildings were much simpler, drainage specialists could arrive

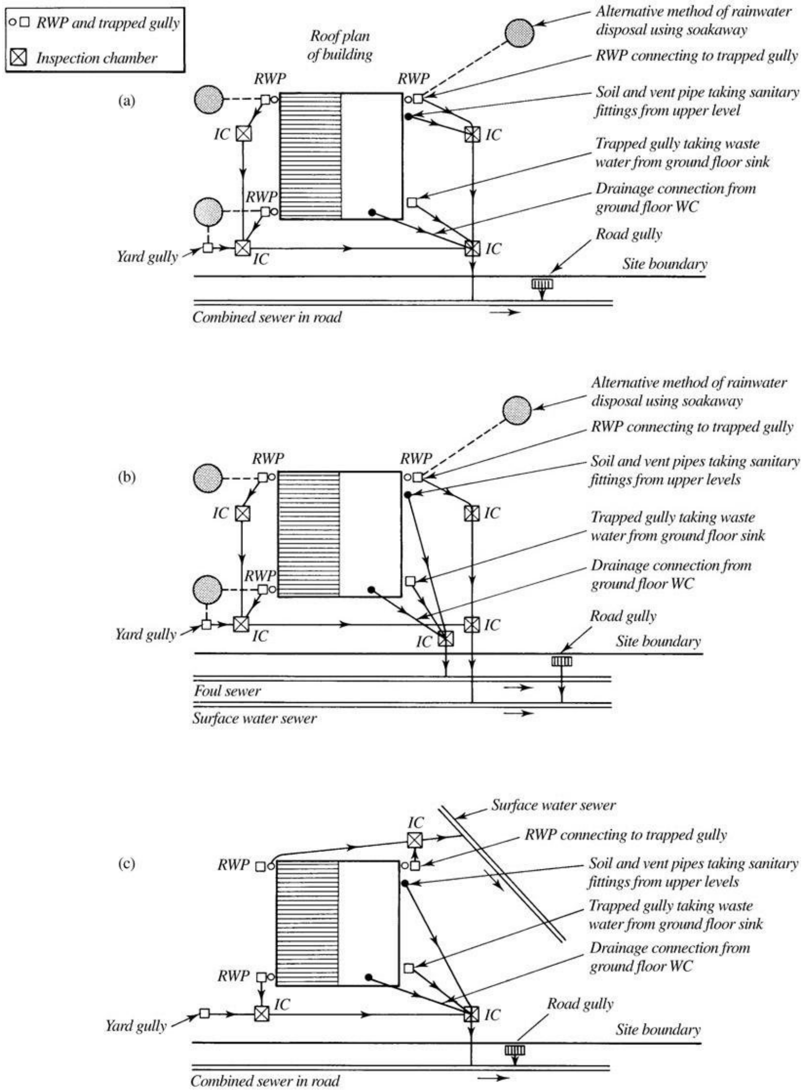


Figure 11.15 Domestic drainage system: (a) combined drainage system; (b) separate drainage system; (c) partially separate drainage system. IC = inspection chamber, RWP = rainwater pipe.

on site and, after initial competition for space with other trades, install their services. The new approach to the design of installation leading from a more sophisticated knowledge, together with the standardisation of components for greater economy, now requires designers to give much greater thought to the incorporation of even simple drainage systems in a building. Indeed, the integration and coordination of services in relation to structures as a whole now becomes a paramount design criterion for such buildings as blocks of flats, offices, hospitals and schools, where all the engineering services (heating, lighting, plumbing, drainage, etc.) could account for 25–50 per cent of the overall capital costs.

Factors relating to the installation of gas, electricity and telecommunications services are discussed in section 18.10.

11.7 Refuse collection and disposal

It is usually necessary for a building to incorporate adequate arrangements in its design for the collection and subsequent disposal of refuse. Methods which can be adopted for this will only operate efficiently if the precise type, form and amount of waste produce has been successfully identified (or anticipated) during the early stages of design investigation. Consideration may then be accurately given to efficient movement patterns of refuse about a proposed building and their influence on required standards of hygiene and safety.

Generally, storage for more than a few hours within a building is undesirable, and the small receptacles in which refuse can conveniently be placed temporarily need frequent emptying.

Unobstructed and direct circulation routes to facilitate refuse collection from a building should also be thoroughly planned, thereby furthering the desire for protection from the pollution caused by unpleasant smells, visual horrors and noise. Refuse which is not destroyed at source is taken to local sites where crude selection may take place to permit incineration, consolidation and/or transportation to centralised tips. Some non-toxic refuse may be used to backfill areas subsequently needed for building sites, or used for other forms of land reclamation.

The design criteria for a building will vary when considering refuse collection and disposal methods applicable to medical, commercial, industrial or domestic activities, for example. A building designed to accommodate complex or multi-purpose activities (hospitals and certain factories) can generate many forms of waste, sometimes toxic, sometimes individually bulky, or sometimes accumulating in vast quantities over relatively short periods. Then different disposal systems, some incorporating incinerators, may have to be adopted within a building, requiring great skill from the designer to ensure maximum operational efficiency. But when convenient to the size and form of refuse, disposal can be satisfactorily accomplished by an independent water-borne pipe system installed within a building. This is very similar to the soil and waste drainage system already described, except that the refuse is conveyed to an external pit, from which it is collected by specialists at convenient time intervals.

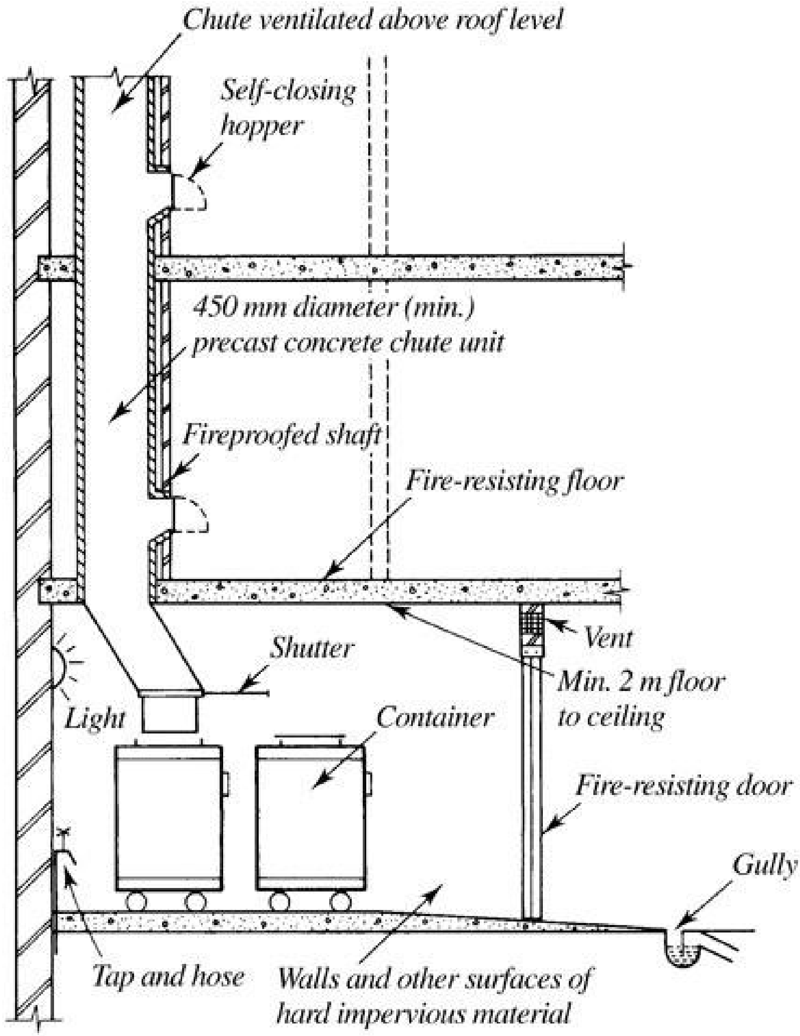


Figure 11.16 Refuse chute.

Less costly methods are available, one of which involves the use of a dry chute, suitable for medium-rise multi-storey flats or maisonettes. The method consists of a vertical arrangement of jointed impervious pipes to provide a tube into which refuse is placed via a chute. The outlet of the tube deposits the refuse into bins conveniently located to facilitate mechanical emptying by the vehicles of the local authority cleansing department (Fig. 11.16).

Small amounts of refuse, such as are generated in houses, can be conveniently stored in dustbins, wheelie bins or plastic bags for eventual collection by the local authority. Some domestic refuse – generally food waste – can be processed in a waste disposal unit below a sink unit, which then allows it to pass through a normal waste pipe and into the drainage system beyond.

Further specific reading

Mitchell's Building Series

Environment and Services	Chapter 9 Water supply
	Chapter 10 Sanitary appliances
	Chapter 11 Pipes
	Chapter 12 Drainage installations
	Chapter 13 Sewage disposal
	Chapter 14 Refuse collection and disposal
Structure and Fabric Part 2	Section 7.3 Ducts for services

Building Research Establishment

Digest 248	*Sanitary pipework* Part 1: Design basis
Digest 249	*Sanitary pipework* Part 2: Design of pipework
Digest 292	*Access to domestic underground drainage systems*
Digest 308	*Unvented domestic hot water systems*
Digest 365	*Soakaway design*
Information Paper 14/03	*Preventing hot water scalding in bathrooms using TMVs*
Information Paper 1/04	*Drainage design for buildings with reduced water use*
Information Paper 8/07	*Self-sealing waste valves for domestic use: an assessment*
Good Building Guide 38	*Disposing of rainwater*
Good Building Guide 40	*Protecting pipes from freezing*
Good Building Guide 42/1	*Reed beds. Application and specification*
Good Building Guide 42/2	*Reed beds. Design, construction and maintenance*
Good Building Guide 76	*Gravity drainage systems for buildings*
Good Building Guide 78	*Below ground drainage systems*
Good Building Guide 79	*Provision of sanitary appliances and their space requirements*
Good Building Guide 80	*Water services for domestic properties*
See also: BRE	*Water supply, drainage and sanitation pack* (AP 266)

Building Regulations

Approved Document G	Sanitation, hot water safety and water efficiency
Approved Document H	Drainage and waste disposal

Department for Communities and Local Government (DCLG)

The Code for Sustainable Homes

Other

The Water Supply (Water Fittings) Regulations (The Stationery Office)

12
Security

CI/SfB (U47)

Like many other performance requirements, the security aspects of a building involve the immediate physiological and psychological well-being of the occupants. The main areas of concern relate to unauthorised entry into a building, vandalism, protection against disasters, lightning, terrorism and the reduction of accidents. The degree of risk associated with a particular building must be established during initial design stages, so that appropriate security measures can be incorporated without hindering the occupants from carrying out their activities. The primary and often most economical defence usually lies in the fabric of a building and therefore involves the use of compatible construction methods (materials and techniques of assembly).

12.1 Unauthorised entry

Unauthorised entry can be achieved either visually or physically. Both involve invasion of the private zones of a building. But whereas the former may be no more than inconvenient, the latter often involves violence towards people, and/or damage and theft of furniture, fabrics, machines, personal belongings and livestock. The defence systems involved for the two areas must therefore be considered separately, although they can be resolved together to provide combined security.

Visual privacy can be achieved through external planning arrangements of a building which provide an acceptable degree of remoteness between observer and observed. When adequate distances for this are not available (see section 18.2), or it is required to augment the remoteness for even greater privacy, the design of a building and its immediate surroundings plays a more important role. The location of the more private zones of a building can be away from the general fields of vision. Alternatively, high perimeter walls, trees and plants, landscaping, projecting wings and outbuildings can be employed as visual barriers.

Although less used today owing to energy conservation requirements, large windows which let in more daylight make room interiors more visible from outside. Cross-lit rooms also reduce privacy levels by silhouetting figures. Although net curtains or slatted blinds may be considered a satisfactory solution by some people, it should still be possible to obtain the levels of daylight the window was designed to provide and for the occupants to enjoy uncurtained views out of a building without loss of visual privacy.

Figure 12.1 illustrates some of the principles involved when trying to provide reasonable visual privacy between dwellings based on the Design Guide for Residential and Mixed Use Areas published by Essex County Council. They involve the interrelationship between acceptable ‘eyeto-eye’ remoteness and the use of screening devices above eye level.

As an initial means of defence against unauthorised physical entry, the approach routes to a building should be carefully organised to prevent, or at least limit, the possibility of uncontrolled usage. This principle is always considered during the initial design stages of a building accommodating strongrooms, security stores, prisons, etc. However, there has been a certain amount of complacency about the planning of a building having less dramatic risks. This has led to the development of the use of numerous elaborate security measures or costly security patrols, often added to a building as an afterthought in an attempt to justify incomplete initial design investigations. Nevertheless, although entrances can be positioned to provide good, well-lit visibility and control, problems may still arise in a building requiring a high degree of security but where easy access by the public is necessary (banks, hotels, offices,
police stations, museums, exhibition halls, etc.). And the final defence against unauthorised entry into a building must rely on some form of locking mechanism.

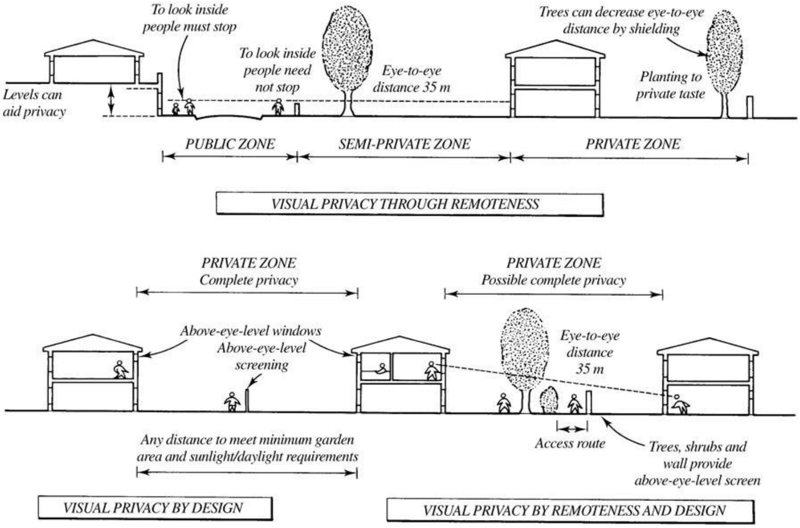


Figure 12.1 Visual privacy provided by building location and design. (Adapted from material in Design Guide for Residential and Mixed Use Areas published by Essex County Council)

However, a conflict often arises between providing doors and windows that are secure but which allow the legal occupants of the building to escape unhindered during a fire. A compromise is sometimes required when selecting locks (ironmongery), particularly for doors, although locks are now available which appear to satisfy both criteria. A similar form of compromise is often required in the design of fitments, which must freely exhibit goods while protecting them from shoplifters.

Methods of construction should augment the initial design considerations which prevent illegal entry. For example, as certain lightweight constructions can be easily dismantled –

boards removed from wall-cladding systems or tiles lifted from roofs – care must be taken in their detail design to ensure their use is compatible with the security risk of a building. Windows and doors, normally regarded as a means of giving access, or light and ventilation, should also be considered as a means of admitting a criminal; they must be carefully designed and protected accordingly.

Once the design of a building fabric has provided the maximum amount of security possible, further protection can be given, if necessary, by electronic devices, alarm bells and surveillance by contracted security patrols. At the planning stage it is advisable to consult the crime prevention officer (CPO) of the local police force for advice about the degrees of risk involved. The building's insurers will also establish their minimum standards for acceptance of risk, and the architect will need to ensure such minimum standards are observed during design and construction.

The building contractor will also be concerned with security during the construction of a building. Fences and hoardings are necessary to prevent unauthorised entry into the site, which could result in theft of materials, equipment, tools, etc., as well as vandalism. This form of protection will also assist in protecting passers-by, who may otherwise be accidentally hurt as a result of certain construction activities. Permanent boundary fences and walls can provide an initial defence against illegal entry into the grounds of a completed building.

The Avon and Somerset Constabulary have established a crime reduction incentive for developers and builders known as Secured by Design. The scheme is specifically aimed at

crime prevention through eliminating trespass and intrusive anti-social behaviour on building sites, by
effecting measures that make sites safer and more secure. Secured by Design encourages developers to recognise the importance of deterring crime by adopting a high standard of physical security, natural surveillance and defensible space as part of their planning strategy. Before site work commences, preferably at a preliminary planning and feasiblity assessment stage, consultation with an appointed Crime Prevention Design Adviser is essential in order that the builder can design out crime. Builders complying and satisfying security precautions receive a Secured by Design award that entitles them to use a distinctive logo for marketing purposes. In addition to being a crime deterrent during construction, it provides potential property buyers with the satisfaction of knowing that building work has been undertaken with a regard for security and safety.

12.2 Vandalism

Vandalism is a continuing social problem which defies complete resolution, although as for unauthorised entry the design of a building can greatly lessen the likelihood of its occurrence. A building and the adjoining spaces need to provide a means of positive identity to owners and normal users as well as the community in general.

The problem ranges from graffiti on accessible surface finishes to physical damage of a building fabric involving defacement, breakage, or complete destruction by demolition or fire. Graffiti can be avoided if not eliminated by the judicious selection of surface finishes; but physical damage is a serious problem which may result in a building employing fortress-like construction methods. Everything must be robust and secure from attack where wilful damage is likely to occur, so the building's appearance and other performance requirements may suffer. The ordinary use of materials will have to be avoided: glazed areas should be of limited size and reinforced; doors of solid construction; walls of dense robust materials which are not easily ignitable, etc. Under certain conditions, suitably selected materials may require further protection by barriers or screens. Accidental damage can also be avoided by these devices.

To some extent the effects of vandalism can be lessened by a building owner through a design which provides conspicuous observation points, allows damage to be promptly repaired, and litter to be minimised and efficiently cleared.

12.3 Disasters

As far as the effects on a building are concerned, disasters can take the form of those which happen accidentally and usually through previous ignorance of a phenomenon, or those which could happen as a direct or indirect result of planned actions. An example of an accidental disaster would be a gas explosion causing collapse of a building. In 1968 this occurred in a newly built, 23-storey block of flats in Newham, East London, called Ronan Point. The explosion in one of the 18th-floor flats blew out part of the outer wall, prompting a progressive collapse of all the precast reinforced concrete wall and floor sections to the south-east corner. Four people died in the incident and numerous others were injured. Although a long time ago, this disaster became established as the basis for a complete review of the design and construction procedures used in high-rise buildings of this type. Legislative measures as shown in Figure 12.2 were introduced to avoid any further progressive collapse incidents. Other examples of learning from disasters with previously unknown causes are, unfortunately, numerous. The use of high-alumina cement (HAC) for the load-bearing reinforced concrete members in a building where warm humid atmospheric conditions exist (swimming pools) produces deterioration of the structure and subsequent collapse. Inadequate bearing for prestressed reinforced concrete beams causes their collapse. A lack of fire barriers in cavity constructions allows the rapid spread of fire from one part of a building to another. Failures such as these and the Ronan Point disaster can cause serious loss of life and cost enormous sums of money to rectify.

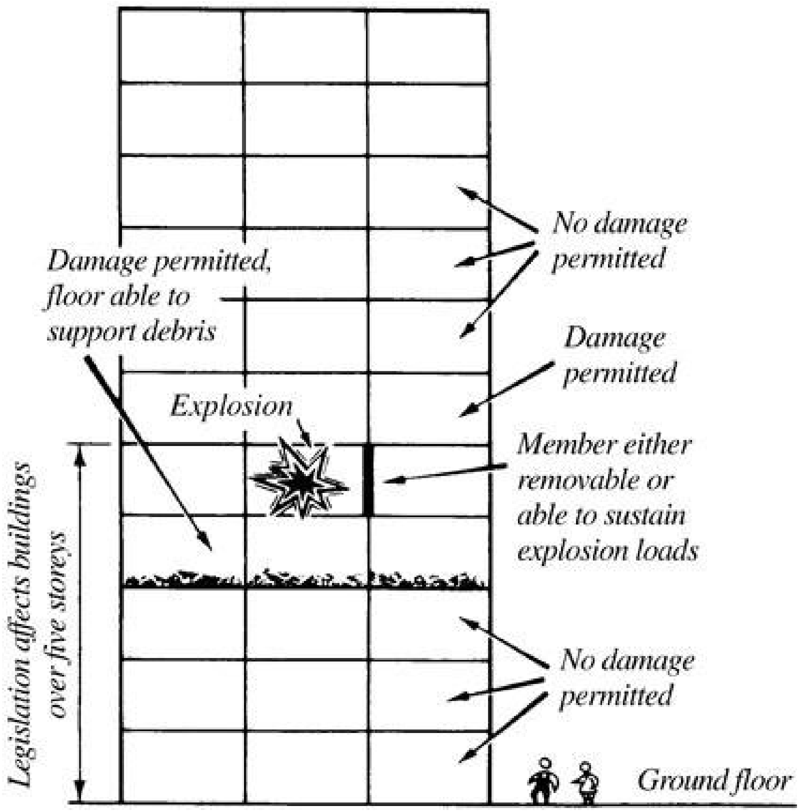


Figure 12.2 Legal requirements to avoid progressive collapse in tall buildings.

Experience of disasters, together with the continuous research by investigative authorities (Building Research Establishment, BRE, Construction Industry Research and Information Association CIRIA, Timber Research and Development Association TRADA Technology Ltd, etc.) and testing organisations (British Board of Agrément)
help to reduce the likelihood of their recurrence. However, there is always need for a designer to proceed cautiously by

seeking out maximum information regarding the performance criteria with new products, materials and untried methods of construction.

Specific forms of construction are also available to lessen the effects of natural disasters resulting from earthquakes, floods, hurricanes, etc.

12.4 Lightning

The risk of lightning striking a particular building is very low. Therefore, provision for lightning protection is a risk assessment by the building owner or, more realistically, the building insurer. Houses are rarely protected, but larger commercial and industrial premises will be assessed on the basis of their size (height and plan area), contents, purpose, construction materials (exposed metalwork), degree of isolation, likelihood of thunderstorms in the locality and general topography.

A lightning protection system is designed to attract a lightning discharge and direct it to earth through a path of low impedance, thereby limiting the amount of damage that would otherwise occur to the more vulnerable parts of a building. BS EN 62305 (4 parts): Protection against Lightning, provides guidance on installation principles for various applications. Generally, air terminations comprise a series of conductor strips interconnected to form a grid, with no part of the roof further than 5 m from the grid. Variations are made to suit roof profile, with prominent features such as apexes and spires suitably protected.

Vertical or down conductors are spaced at one per 20 m of building periphery for buildings up to 20 m height and one per 10 m periphery for buildings in excess of 20 m height. Structural steel and metal pipes are bonded to the down conductor. Conductor metals include aluminium, copper and alloys, phosphor-bronze, galvanised steel and stainless steel in 10 mm diameter rods or 20 × 4 mm strips. Earth terminations are rods driven into the ground to sufficient depth to provide a low electrical resistance. Maximum test resistance is 10 ohms.

12.5 Terrorism

Acts of terrorism or war often involve the use of explosives to cause damage to buildings. For economic reasons there can be few defensive measures taken to avoid complete or even partial destruction of a building constructed using normal techniques. However, when necessary, a building can be specially designed to withstand a certain degree of anticipated damage. Today it seems that the ultimate form of this type of construction is one which must resist the light and heat, blast wave, tremors and fallout from a nuclear explosion. Construction methods can take the form of relatively simple 'do-it-yourself' sealing and containment techniques or those which involve housing large structures almost entirely below ground and which incorporate complicated life-support systems.

Since the events of 11 September 2001, the design and use of high-rise buildings in prime locations has taken on new priorities. By virtue of their prominence and prestige, these buildings are vulnerable to bombing or chemical contamination attack by terrorists. Means for designing in protection have taken on two perspectives, preservation of the structural integrity of the building (passive) and security and safety of the occupants of a building (active). The following sections consider some aspects of these under separate headings, although there is an element of overlap with some items.

12.5.1 Passive protection

- Enhanced specification for fire proofing and insulating materials.
- Over-specification of fire protection to steelwork.
- Increased thickness of concrete structural walls.
- Use of additives in concrete to improve the performance in hydrocarbon fires.
- Design based around a protective central core.
- Glazing – laminated to avoid splintering.
- Over-designing the peripheral steel or reinforced concrete subframing, such that at least two adjacent columns can be lost without the supported substructure failing.
- Strengthening the floor structure and its support interface to prevent progressive structural collapse.
- Widening of escape stairways beyond Building Regulation and British Standard recommendations.
- Fire-escape stairways within a central structural core, in addition to peripheral locations.
- Protection of other escape stairways in a self-contained concrete shell.
- Panic rooms incorporated within a protected central core.

- Ventilation, air-conditioning plant and water tanks sited away from public access. Monitor with CCTV.
- Air intakes located in positions inaccessible to the public.
- Ventilation and air-conditioning systems zoned or separated, instead of traditional centralised systems. Several independent air movement systems reduce the risk of air contamination of the whole building.

12.5.2 Active protection

- Sensors to detect contaminated air located strategically to shut down ventilation and air-conditioning systems and to engage audible and visual alarms.
- Emergency evacuation procedures in place.
- Personal protective equipment (PPE) available to include respirators and protective clothing.
- Monitoring procedures for suspect mail.
- Incidental and subcontracted personnel and support staff security checked and issued with temporary passes.
- Maintenance of a register of personnel entering and leaving the building.
- Fire, smoke and contaminant sensitive alarms installed throughout the building.
- CCTV cameras installed at building access points and at other sensitive areas.
- At entrances in some high-security situations, provision of a personnel screening facility.

12.6 Accidents

A building must be designed to ensure that the human activities it accommodates are carried out with the maximum amount of comfort, safety and efficient enjoyment. It is also important that the construction of a building is carried out with reasonable comfort, a high degree of safety and, hopefully, enjoyment (see section 16.7).

Mention has been made under dimensional suitability (appropriate size) regarding the need to manufacture components to sizes which are sympathetic with building operations and use (see Chapter 4). However, even appropriately sized components must be used wisely because it is not uncommon for people either to cause damage or to be damaged, quite accidentally, as a result of ordinary daily activities (Fig. 12.3). Careful consideration must be given to work surface heights in kitchens, offices or workshops, juxtaposition of conflicting activities within confined spaces, suitable clearances around specific activities, etc. The study of the relationship between people and their environment is known as ergonomics and applies physiological and psychological reasoning to anthropometric data. Figures 12.4 and 12.5 show typical examples.

The design of spaces in and around a building should take into account the appropriately safe features and dimensions for stairflights, treads, risers and landings; slopes of ramps; heights and profiles for handrails and guard-rails, etc. Circulation areas must be planned to give efficient movement patterns which avoid mixing of opposing activities. In this respect, special consideration must be given to the problems associated with the circulation of disabled people through a building, and into the various spaces it accommodates (see section 12.6.1). Gas and water services should be separated from electrical services to avoid risks of explosion, fire and electrocution. For the safety of occupants, the opening parts of a window in a wall above ground level should be not less than 800 mm above the floor finish. This is the minimum guarding height as indicated in Building Regulations, Approved Document K: Protection from falling, collision and impact. Approved Document B: Fire safety provides for a maximum height of 1 100 mm for purposes of an emergency escape. Whenever large areas of clear glass are incorporated in the construction of walls, precautions must be taken to ensure that people are made aware of its presence. Large uninterrupted areas of clear glazing, such as that found between two parts of the same building at the same level or fully glazed doors, must incorporate markings at a height of 1 000 and 1 500 mm to prevent unaware people colliding with them.

12.6.1 Accessibility for disabled people

Estimates of the number of disabled people in the United Kingdom vary. Figures between 8 per cent of the population and 8 million persons provide some scale of the need for building designers, constructors, owners and occupiers to facilitate for the disabled. Legislative measures to ensure that disabled people can access buildings include the Equality Act 2010, the Disability Discrimination Act introduced in 1995 and then in subsequent parts up to 2004, the Disability Discrimination (Employment) Regulations 1996 and Part M of the Building Regulations endorsed by BS 8300: Design of buildings and their approaches to meet the needs of disabled people. Code of practice.

The term ‘disabled’ covers a wide range of incapacities, but it is the wheelchair-dependent person that is of principal concern to the building designer. A person in a wheelchair can occupy about five times the space needed by an ambulant person. Therefore the following should be incorporated into the construction of new dwellings:

- Building entrance minimum 900 mm wide.
- Firm level access to the building – maximum slope 1 in 20.
- Level (or close to level) principal entrance threshold.
- Entrance door minimum 775 mm clear width.
- Corridors/passageways minimum 750 mm width.
- Stair minimum 900 mm width. Handrail both sides.
- Light switches, power, telephone and aerial sockets at 450–1 200 mm above finished floor level.
- WC provision on the entrance or first habitable storey. Door opens outwards. Clear wheelchair space of 750 mm in front of WC with preferably 500 mm each side of the WC measured from its centre.
- Flats to have lifts and stairs which enable disabled residents to access other floors (see Building Regulations, Approved Document M2: Section 9).

Buildings other than dwellings should have the following provisions:

- Ramped and easy access to buildings. Minimum width 1 200 mm, maximum gradient 1 in 20.
- Tactile pavings (profiled).

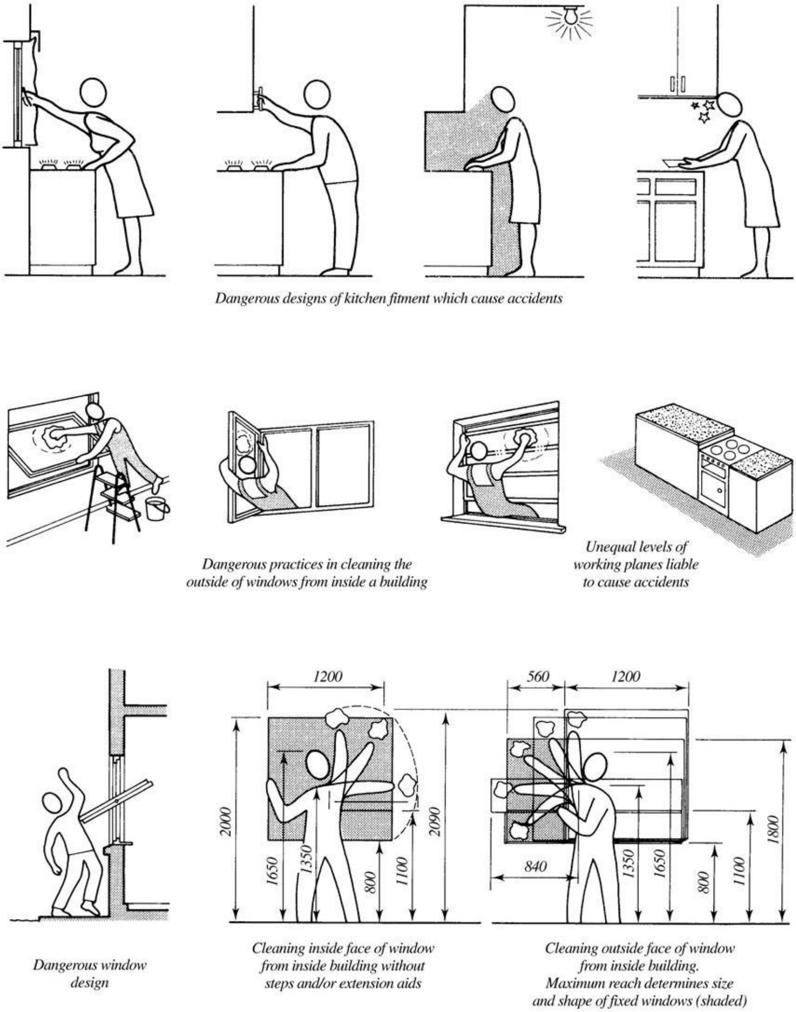


Figure 12.3 Design factors influencing safety in a building.

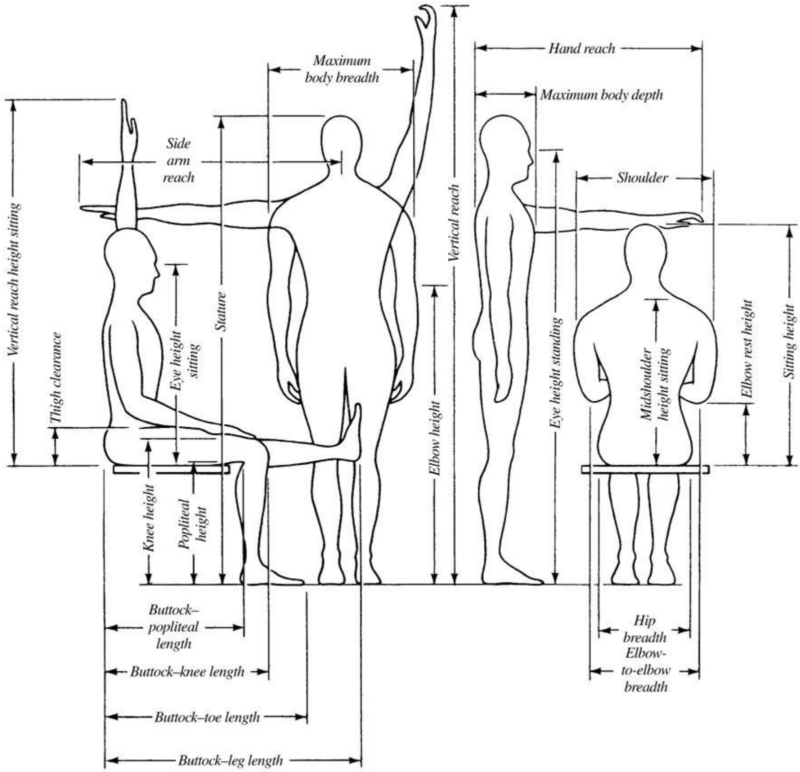


Figure 12.4 Human measurements used by designers (see also Table 12.1).

Table 12.1 Principal average human dimensions

Position from Figure 12.4	Male (mm)	Female (mm)
Maximum body breadth	450	400
Hip breadth	370	400
Hand reach	850	780
Eye height, standing	1 630	1 550
Stature	1 740	1 650
Popliteal height	440	440
Knee height	590	590
Elbow rest height	220	210
Midshoulder height, standing	580	540
Eye height, sitting	780	730
Sitting height	900	840

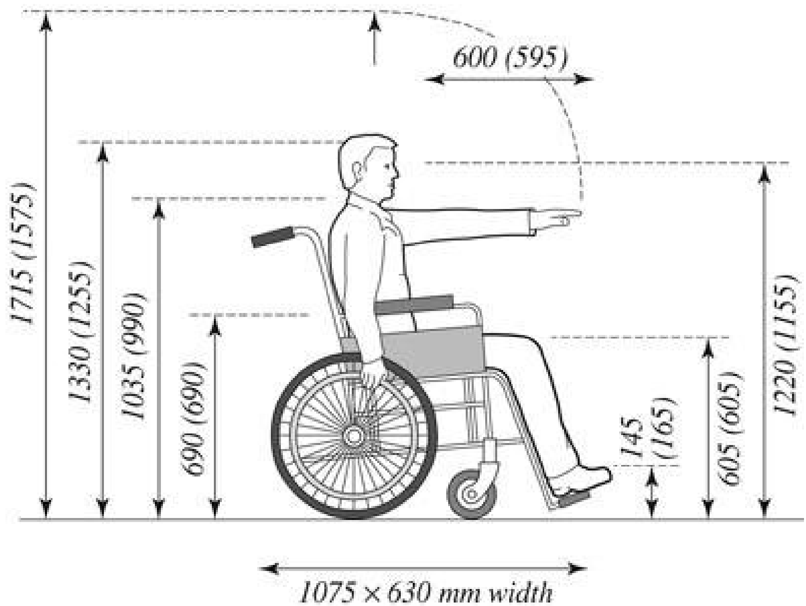


Figure 12.5 Typical wheelchair and occupant dimensions (female dimensions in brackets).

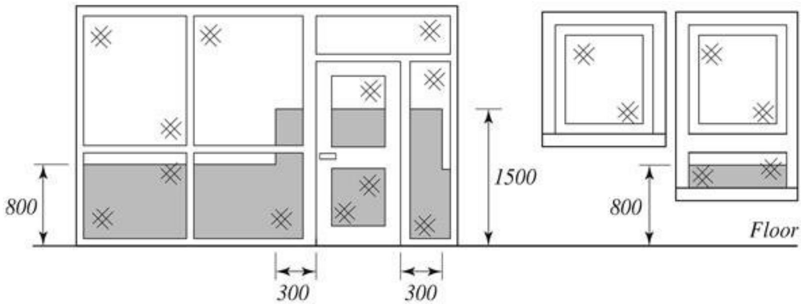


Figure 12.6 Location of safety glass: shaded areas are critical locations for safety glazing; all dimensions are in millimetres.

- Dropped kerbs.
- Handrails at changes in level.
- Guarding around projections and obstructions.
- Wheelchair manoeuvrability in entrances.
- Entrance width minimum 800 mm clear space.
- Internal door openings, minimum 750 mm clear space.
- Corridors/passageways minimum 1 200 mm wide.
- Lift facilities, see Building Regulations, Approved Document M2, BS EN 81-40: Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Stair lifts and inclined lifting platforms intended for persons with impaired mobility and BS 6440: Powered vertical lifting platforms having non-enclosed or partially enclosed lift ways intended for use by persons with impaired mobility. Specification.
- Stairs minimum 1 000 mm wide, rise between landings 1 800 mm maximum, step rise maximum 170 mm, step going minimum 250 mm and a handrail each side.

- Wheelchair-access WC provision on each floor.

12.6.2 Safety glazing regulations

The Building Regulations, Approved Document N details acceptable standards for glazing materials and protection, including the critical areas shown in Figure 12.6 which require safety glazing.

The critical locations are defined as follows:

- glass within 800 mm of the finished floor;
- glass within 1 500 mm of the finished floor and contained in a door or adjacent side panel.

Glazing is accepted as safe if it satisfies one of the following definitions:

- It has 'safe break' characteristics determined in BS 6206: Specification for impact performance requirements for flat safety glass and safety plastics for use in buildings.
- It is robust or in small panes (see below).
- It is permanently protected by a screen (Fig. 12.7).

The terms robust and small panes are defined as follows:

- Robust This term applies to inherently strong materials such as polycarbonates. Annealed glass may also be acceptable as defined in Table 12.2.
- Small panes Small panes can be isolated or in small groups separated by glazing bars. The maximum pane width is 250 mm and the maximum pane area is 0.5

m^2. The nominal thickness should not be less than 6 mm.

Ideas of design safety must be extended to appropriate surface finishes for a specific activity: non-slip floor tiles in swimming pools; non-combustible wall surfaces along fire-escape routes; anti-static finishes in operating theatres.

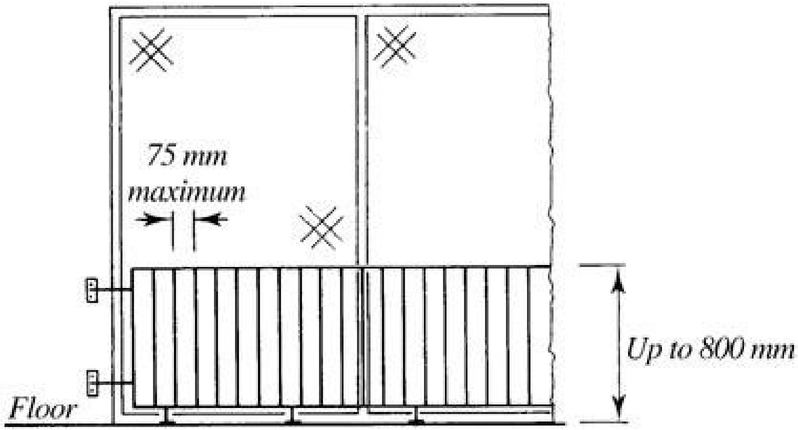


Figure 12.7 Screen protection of glazed areas must prevent the passage of a 75 mm sphere, it must be robust, and it must be difficult to climb (vertical rails).

Table 12.2 Maximum dimensions of annealed glass panels

Annealed glass thickness (mm)	Maximum width (m)	Maximum height (m)
8	1.10	1.10
10	2.25	2.25
12	4.50	3.00
15	any	any

The use of colour can play a very important role in helping to prevent accidents, although it should never be used to justify the safety of a badly designed feature. Apart from adding further dimensions to the shape and form of objects and planes, the addition of colour can act as a form of safety language. For example, because red is universally regarded as a warm and arousing colour, it can be used effectively to highlight equipment required to be used urgently in the event of danger, e.g. outbreak of fire. According to the Young–Helmholtz theory,* human beings use a minimum amount of energy when reacting to red, so their response is relatively rapid. Green requires slightly more energy and blue even more. When the safety precautions for certain areas of a building must be emphasised, the use of varying tones of grey in the colour scheme should be avoided; they produce slow reactions to danger because they tend to camouflage real conditions due to lack of contrast. The reflectance value of certain colours should similarly be investigated to avoid problems from glare, and also the effects which tungsten or fluorescent lights have on certain colours used to indicate safety precautions.

The use of colour as a safety coding device is employed to identify electrical wiring and circuits, hot and cold water services, and various gas supplies, as well as in industrial environments involving machines, steel plants, refineries, cranes and boilers. Some notable designers have used the resulting aesthetic qualities in the production of a building which represents modern hi-tech attitudes towards performance requirements (see Chapter 2).

Section 3.3 mentioned the need for specialised maintenance equipment when the design of a building makes conventional methods difficult. Whatever form is necessary, every effort must be made to ensure that maintenance personnel, such as window-cleaners, electricians, plumbers, can carry out their work in safety (see also Health and Safety at Work, Etc., Act 1974). For example, above the third-storey height of a building (and also below where access for ladders is not convenient), windows should be designed so that they can be cleaned and reglazed from inside, unless there are balconies and special devices incorporated for external maintenance. The maximum human reach is 550 mm for cleaning windows through or across an adjacent opening; side-hung opening windows should have easy-clean hinges which produce a clear gap of 95 mm between frames when the window is open.

Further specific reading

Building Research Establishment

Digest 288	*Dust explosions*
Digest 428	*Protecting buildings against lightning*
Digest 448	*Cleaning buildings: legislation and good practice*
Digest 458	*Safe as houses?*
Information Paper 1/05	*Impact standards for glass*
Information Paper 14/08	*Risks of dust fires and explosions*

Building Regulations

Approved Document M	Access to and use of building

Approved Document N	Glazing – safety in relation to impact, opening and cleaning

Note

* Credited to the English physician Thomas Young (1773–1829) and the German physician Hermann Helmholtz (1821–1894). Their theories of human colour vision defined the colour reception in our eyes. It was not until the latter part of the twentieth century that this was proven biologically.

13
Cost

CI/SfB (Y)

The design of a building must be judged not only by its appearance and the way it performs, but also by how much it costs. However, a true financial value is often difficult to assess because of the complexities of the building industry. The approximate financial value of output from the UK construction industry is £110 billion (one thousand million) per year, see also Fig. 16.3. This figure represents about 9 per cent gross value added (GVA, i.e. the value of construction work) to the UK economy. About 30 per cent of this output is publicly funded, plus 10 per cent by privately financed initiatives (PFI), see page 150. The GVA of all industry sectors and producers combine to provide an estimate of gross domestic product (GDP). GDP is an indicator of the UK's economy in total. The relationship between GDP and GVA can be expressed as follows:

$$\text{GDP} = \text{GVA at basic prices} + \text{tax on products} - \text{product subsidies.}$$

Figure 13.1 shows the approximate apportionment of expenditure. Once most of the other industries know what is to be produced, they can reasonably accurately formulate the precise processes involved in manufacture, and stipulate under what conditions the work will be carried out. The production of a building often does not rely on such entirely rational decisions. The form of a building can be influenced by many interrelated factors (location, planning constraints, soil conditions, availability of resources, etc.), and the balance between appearance, comfort and, inevitably, convenience is finally resolved through subjective criteria. Methods of construction depend upon the knowledge and skill of the designer as well as the availability of materials and specific technical ability. The functional performance can be expressed in terms of the cost of renewing or replacing fittings and fabric, and methods required for adaptation to meet changing needs, including those of heating, lighting and other services; all these factors will be affected by the day-to-day use of a building.

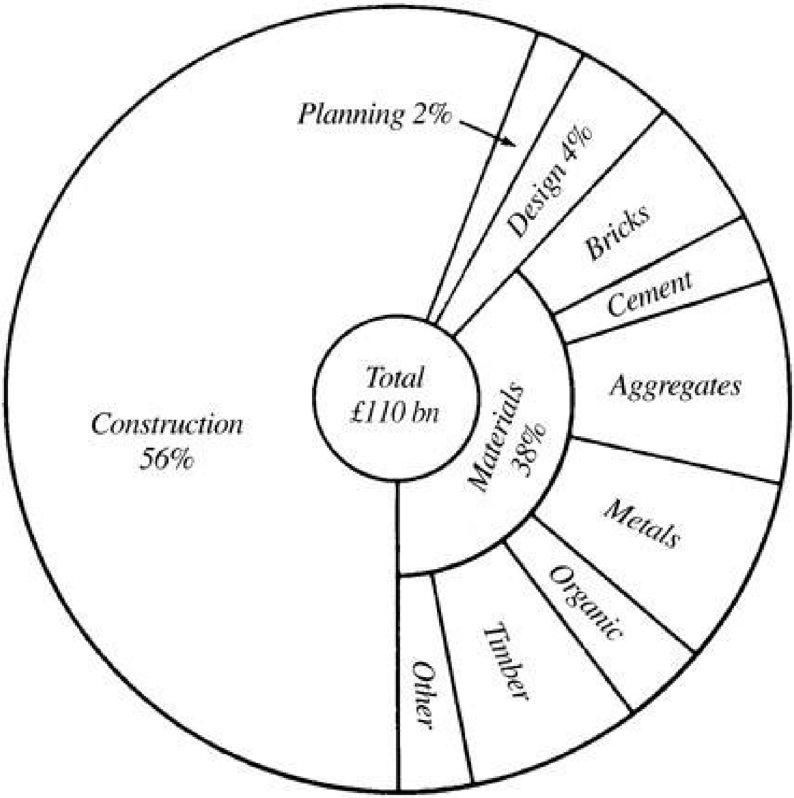
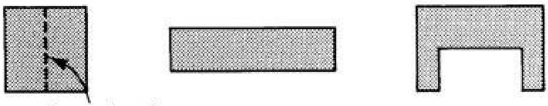


Figure 13.1 A guide to annual UK construction industry output and expenditure.

13.1 Acquisition costs

Acquisition costs cover the financial aspects involved in the creation of a building – investment negotiations, professional fees, cost of land, building design and construction, etc. Further comments regarding most of these are made in Part B and only a few aspects are elaborated here.

Single-storey building with identical plan area



Foundations	100	105	125
External walls	100	125	150
Floor	100	100	100
Flat roof	100	105	120
Overall	100	108.75	123.75

Figure 13.2 Comparison of elemental and overall cost per unit for buildings having the same plan area but different proportions.

The cost of land varies widely according to location, quality, size and its value in terms of suitability for a particular building type, e.g. factory, office, hospital, housing. The consequences of these factors need to be carefully considered so that cost comparisons can be made with alternative sites. The value of the site after a building has been erected on it usually remains in proportion to the value of a particular development unless subsequent political or physical phenomena are likely to result in a change in its original characteristics, e.g. motorway construction, tunnel formation, aircraft flight paths, compulsory purchase, change in planning zone designation, etc. The cost of building land is high and growing faster than the other factors associated with the requirements for a building, and it is therefore essential that the land is used to its maximum efficiency (see section 18.2). A more intensive use of land can be obtained by using a greater number of floors. Usually, however, the cost of suitable construction methods modifies the potential savings, and the necessity to incorporate lifts or mechanical ventilation systems will also add considerably to the subsequent running cost of a building.

There are many financial considerations associated with the design processes of a building. A prime consideration is that government grants and subsidies are available towards the acquisition costs of certain types of building, e.g. buildings accommodating manufacturing activities. Available funds are usually given for initial construction rather than towards subsequent running costs and are usually fixed in relation to the size of the proposed project. Unfortunately, this rarely encourages economic design because large, rather than efficient, forms of building provide better initial investment. Having partly financed such projects, unscrupulous developers or clients often leave their tenant users to run a building as efficiently as they may – any 'improvement' being at their own expense.

The cheapest form for a building is based on a compact cube, with no changes in wall, floor or roof planes. This form is difficult to achieve in truly optimum functional design terms, and may not be practicable or architecturally desirable (Fig. 13.2). Ideally, the spaces which a building provides should be the optimum usage (floor area and room height), and each activity accommodated planned to minimise the areas devoted to circulation as this inevitably contributes towards the time and cost necessary for communication. The siting of a building must give the best relationship with regard to access and public zones, and should also provide the best position for the most pleasing composition. Planning for maximum daylight penetration into a building and minimum exposure to the effects of adverse climatic conditions can effectively reduce the initial and subsequent running costs for sources of artificial lighting and heating. The use of deep or interior spaces will also require mechanically produced environments. Noise, particularly in urban areas, is another important environmental factor related to cost. Tolerable noise levels in city centres can only be obtained by using sealed double glazing or even triple glazing for windows, which again necessitates the use of artificial ventilation and perhaps air-conditioning.

The cost consequences of the construction methods used for each part of a building must be examined in a similar way to the cost consequences associated with the planning. Mention has already been made of the theoretically unlimited availability of material and technical resources for construction, and the limitations imposed by current economic constraints (section 1.3) and other practical considerations (section 3.3).

During very early development stages of a building, the designer must be aware of the constraints that may be imposed by resources upon otherwise economic planning arrangements. Whenever possible, acquaintance should be made with available materials and technical ability, and a building produced which reflects them, rather than construction methods which are beyond economical means. Certain building arrangements are financially viable because they are based on the mobility of cranes and/or gantries. And the lifting capacity of tower cranes having certain radii will limit the size of components which can be placed at the outer edges of a building under construction (Fig. 13.3).

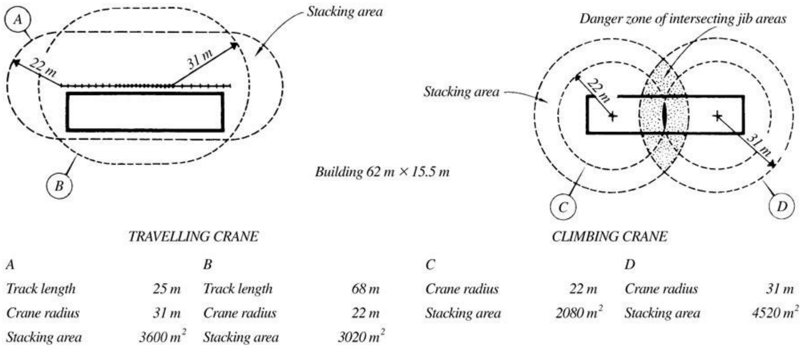


Figure 13.3 Radii of tower cranes and their effects on building shapes.

One aspect that needs amplification concerns the relationship between traditional construction methods which involve the shaping of materials on site by skilled and semi-skilled labour, and industrialised construction involving the erection of large, virtually finished factory-made components on site, usually by semi-skilled labour (see Chapter 4). Both forms of construction use the two basic resources, materials and labour, but the interrelated cost implications associated with each form affect their economic suitability.

In theory the use of factory-made components for a building should generate considerable savings due to the possibility of large production runs. But these savings may not always be available. The cost of basic materials accounts for about 50 per cent of the total cost of materials used in traditional construction methods. After manufacture, the factory-assembled component must be moved for storage, then eventually transported to site, hoisted and fixed in position. These processes often lead to the incorporation of additional construction features (and materials) for handling during transportation and protection against damage during erection. The made component also needs storage or shelter facilities on site, as well as special plant (cranes, etc.) for its manipulation into position in a building. For example, a precast reinforced concrete wall component will need additional reinforcement to withstand the pressures of general handling and transportation; shuttering for in situ concrete connections to the structures of a building, or some form of bolted plate connection device; and a fairly sophisticated jointing system (gasket and sealants) for connection with adjoining components. If the component is delivered in a finished condition, particular care must be taken when it is being positioned, and afterwards while other trades are in close proximity. This adds considerably to the costs of handling and to the cost of site organisation and supervision.

The ultimate cost of a factory-made component, therefore, could be considerably higher than a similar form of traditionally constructed 'on-site' component. On the other hand, traditional methods are subject to weather conditions unless special, and costly, precautions are taken; working conditions are far less congenial than in the factory, amenities poor and safety precautions less easy to manage. A brief comparison is given in Figure 13.4.

13.1.1 Types of building system and components

- Linear
- Planar
- Box
- Linear (skeletal) Although strictly not a prefabricated system, linear components consist of structural units

composed of columns, beams, frames and trusses of steel or concrete, produced or manufactured in a factory. Site assembly is usually by bolting the components together to create repeat modular cells. The infilling construction can be with traditional materials (see section 5.4).

	Traditional construction	*Industrialised construction*
Advantages	Well-tried construction principles Greater possibility for design experimentation Users of building generally familiar with construction methods Generally easily capable of adaptation Flexibility in tolerances during construction Flexibility in design by varying assembly of relatively small components Quality control required but not to factory standards	Standardised specifications/drawings Social conditions in a factory better than on site Elements and/or components fabricated under controlled conditions High degree of accuracy possible Site assembly period likely to be shorter Materials storage on site reduced Large percentage of work performed at one permanent location Repetition and standardisation, therefore less opportunity for error Economies of scale Comparatively stable workforce Coordination of component design, production processes and marketing
Disadvantages	Specifications/drawings vary for each project Work may take longer due to sequential nature of trades Work on site dependent upon material availability and storage Materials and components on site could be damaged Site work often undertaken in poor and harsh conditions Social/welfare facilities relatively poor Work locations dispersed and temporary Several tasks (skilled and unskilled) required to complete a project Relatively high turnover of operatives Varied and dispersed authorities, i.e. local authority, client, designer, main contractor, etc.	System requires production in large quantities and therefore subject to market forces, including government economic policies Designs largely dependent on manufacturing processes; aesthetic appeal often of secondary importance Factory manufacturing processes monotonous to workers Extra cost for transportation of large elements/components Usually 'specialist' site contractor required Accuracy of elements/components requires careful setting out, assembly and site control May not be cheaper than traditional construction method although less labour force employed Building usually costly to adapt Limitations of 'open' and 'closed' systems (see section 16.6)

Figure 13.4 Comparison between traditional construction and industrialised construction.

- Planar (panel) These systems include prefabricated floor and wall panels. They are often used in conjunction with a linear support frame or traditional masonry cross walls. Components may be structural, i.e. load bearing, or for simple division of interior space. Prefabrication may include the first fix of plumbing and electrical services, as well as incorporation of thermal and sound insulation. Popular applications include residential buildings, schools and small hotels (see section 5.5).

- Box (three-dimensional) Units are prefabricated as a box or module, sometimes referred to as a 'pod' or 'mould'. Typical applications are single-storey-height plastic or concrete sanitary units containing WC, bath/shower and basin, or office units all pre-wired, pre-plumbed and pre-decorated for installation and placement by crane. Units can bolt together and stack, but they are usually applied in conjunction with a conventional steel or concrete support frame.

13.2 Running costs

Running costs include expenses incurred for general maintenance, cleaning and servicing of a building, and for renewing or repairing the fabric and fittings, as well as payments for heating, lighting, ventilation and services. Allowances for taxation rates and insurances should also be made to establish total running costs and for management charges where this is contracted out.

Section 1.3 has already commented on how the acquisition costs affect the running costs, and further points are made in each chapter concerned with performance requirements. As

mentioned in Chapter 3, it is generally wisest to select more costly components, construction methods
and servicing systems because they tend to require low maintenance. The alternative use of low-cost components, etc., requiring high maintenance, takes no account of the inconvenience, disruption and loss of earning power which arises with the need for repair or replacement. Techniques and materials which are only of value in minimising construction costs can therefore fall short of what is really required if the designer is to be in a position to provide a building which offers the best value for money. It is also very important that the designer informs prospective users about matters concerning running costs of a building he or she has designed; see section 17.8.

13.3 Operational costs

Operational costs are generally (although not exclusively) associated with non-domestic buildings and include the cost of salaries for employees; provision of amenities which give congenial working conditions (bar, canteen, gymnasium, etc.); machinery, power, and materials used by the processes accommodated in a building; and the costs of adapting a building to meet changing user requirements. These costs must therefore be supplied by, or worked out in close conjunction with, the client and the client's advisers.

Sometimes the layout and design of a building dominates the way certain operations are carried out, the number and type of staff employed, and hence the overall operational costs. The types of activity most affected in this way involve transport systems or product manufacture and handling, but even their efficiency will finally be determined by the calibre (and salaries) of supervision and management staff.

When possible, the prospective building owner must be made aware of the effects which other cost factors of a design have on operational costs. For example, the choice of temperature control in offices can have an effect on the efficiency of employees. During sudden cold spells, a slow room-heating response may produce errors or temporary cessation of clerical performance, giving rise to subsequent financial losses. To ensure continuous internal heating levels in a building, it is possible to increase the acquisition cost of construction (say by double glazing or extra thermal insulation) and/or to increase running costs for fuel (say by using relatively expensive forms of quickly responding temperature controls).

13.4 Cost evaluation

The true cost evaluation of a building should involve a close examination of viable alternative acquisition, running, after care and operational costs. The depth of investigation possible, and therefore the accuracy in achieving the 'true value' of a building, will depend on the information available and skill of interpretation during the inception, preliminary and detail design stages. Although cost analyses (Fig. 13.5) are available through technical publications for numerous schemes which may be similar to one in hand, normally they are not able to supply information regarding operational costs or the effects of solely financial design decisions on building users. When pertinent, this information allows the historical cost analysis data to be used for the future creation of a building specifically oriented towards definable long-term financial goals.

Various techniques exist for the cost analysis of a proposed building. They include a cost-in-use method which analyses the relationship between acquisition and running costs in order to achieve optimum performance requirement criteria; a cost-effectiveness method which analyses the relationship between acquisition, running and operational costs so as to permit adaptation of certain performance requirements to allow for specific user attitudes; and a cost-benefit method (the most difficult) which analyses economic building performance criteria in terms of variable user-benefits.

The evaluation of capital cost of construction and the financial reality of ongoing maintenance is part of terotechnology. This multi-disciplined awareness for the aftercare of new buildings is defined in BS 3811: Glossary of terms used in terotechnology as 'concern with the specification and design for reliability and maintenance of plant, machinery, equipment, buildings and structures; with their installation, commissioning maintenance, modification and replacement; and with feedback of information on design, performance and costs'. In other words, the central idea involves the pursuance of economic life-cycle costs for a building through combined design, technical, financial and managerial skills.

Historically, very few building owners and users calculated the true costs of their building (Fig. 13.6). Now, with the benefits of considerable research into value engineering and life-cycle costing, an analytical approach to the various means of achieving a client's objective, i.e. a building, and its longer term running costs is not only possible but common practice.

Value engineering is an exercise which identifies the optimum means of construction, eliminating unnecessary costs while retaining a high regard for specification, quality and product usefulness. It is a team approach including the building designer, client representative or adviser in construction practice and a quantity surveyor for financial evaluation. Such disparate professional backgrounds should combine to realise the optimum construction process in the client's initial and longer term interests.

Cost analysis

SUBSTRUCTURE

FOUNDATIONS/SLABS **£37.31/m²**
Bored in-situ piles, pile caps and RC slab with service trenches

SUPERSTRUCTURE

FRAME AND UPPER FLOORS **£104.04/m²**
RC frame comprising exposed columns integrated with RC slabs, with a feature exposed soffit finish. Steel column and beam framework at fifth floor

ROOF **£46.47/m²**
A system of flat roofs with a roof garden and paved terraces at fifth floor, in specialist felt roof system. Flat roofs at high level, and to plant areas, in sheet metal with exposed felt systems.

ROOFLIGHTS **£2.82/m²**
Large circular double-glazed aluminium mono-pitch rooflight to north atria with individual small lights to top of escape staircases. Individual polycarbonate rooflights to south atria

STAIRCASES **£31.48/m²**
Steel feature main staircase with mild steel and hardwood balustrade, Jura limestone finish. Five RC secondary access/escape stairs with steel balustrades and handrails. Steel feature balustrades to all atria with glass infill panels and hardwood handrails

EXTERNAL WALLS **£67.96/m²**
Building clad with Jura limestone and Cornish granite. Aluminium rainscreen panelling to stair towers and plantrooms. PPC louvres to plant rooms

WINDOWS **£71.70/m²**
High-quality aluminium flat-panelled/double-glazed window/ walling system. External solar shading to main elevations

EXTERNAL DOORS **£4.03/m²**
Aluminium-framed glazed doors in window walling system generally on ground and fifth floors. Two pairs aluminium-framed electric sliding doors to main entrance; revolving door to south elevation

INTERNAL WALLS AND PARTITIONS **£78.44/m²**
Blockwork walls to cores and plantrooms. Solid and glazed office partitioning with doors. Hardwood single-glazed atria screens and doors

INTERNAL DOORS **£28.22/m²**
Solid-core hardwood-veneered, or painted, flush doors; hardwood frames; stainless-steel ironmongery

INTERNAL FINISHES

WALL FINISHES **£29.87/m²**
Plasterboard dry linings; ceramic tiles to WC areas and kitchen/café; painted blockwork to plantrooms

FLOOR FINISHES **£43.47/m²**
Raised floor, sealed as a plenum; ceramic tiles to WC areas; carpet tiles to office and circulation areas; Jura limestone to atria; hardwood flooring to restaurant, café and boardroom areas

CEILING FINISHES **£14.17/m²**
Painted fairface concrete soffits; plasterboard ceilings to atria and storage areas; metal-pan suspended ceilings to kitchen, gym, print and post rooms

FITTINGS AND FURNISHINGS

FURNITURE **£30.66/m²**
Reception desk, blinds, signage, mirrors, shelving and fittings, café servery and shelving, gym mirrors and cupboards, boardroom cupboards, coffee points, atrium access equipment and safety wires

SERVICES

SANITARY APPLIANCES **£2.92/m²**
Individual WCs with basins; disabled WCs and associated fittings; cleaners' sinks

SERVICES EQUIPMENT **£22.84/m²**
Contractor-designed kitchen and servery installation; specialist-designed audio-visual suite

DISPOSAL INSTALLATIONS **£4.41/m²**
General soil, vent, rainwater and waste installations; copper and cast iron

WATER INSTALLATIONS **£12.02/m²**
Hot and cold water to kitchen, café, WCs, coffee points and sundry basins

SPACE HEATING/AIR TREATMENT **£139.89/m²**
Displacement-air ventilation system. Perimeter LPHW heating to all areas except atria. Fan-coil units to meeting areas, with ice thermal storage. VAV a/c to boardroom and kitchen/ restaurant at fifth floor.

ELECTRICAL SERVICES **£127.89/m²**
Floor-box power arrangement to offices. Lighting control system. Feature lighting and power outlets. UPS computer backup system

LIFT AND CONVEYOR INSTALLATIONS **£14.48/m²**
Two banks of two 13-person passenger lifts to core areas. One goods lift to north core

PROTECTIVE INSTALLATIONS **£34.03/m²**
Internal/external CCTV system, intruder-detection system and an access-control system. Internal fan and window-actuated smoke-control system

COMMUNICATION INSTALLATIONS **£13.37/m²**
Telephone and data-wiring system to floor boxes

BUILDERS' WORK IN CONNECTION **£24.36/m²**

PRELIMINARIES AND INSURANCES

PRELIMINARIES, OVERHEADS & PROFIT **£86.57/m²**
Excludes dayworks

EXTERNAL WORKS

LANDSCAPING, ANCILLARY BUILDINGS **£1,078,387**
Access road with surface parking. Paving, steps and walls. Block of 12 garages, cycle shed and substation. Landscaping and planting. Two copper-roofed, steel-framed, covered walkways. Below-ground drainage, petrol interceptor and holding tank

Cost summary

	Cost per m² (£)	*Per cent of total*
SUBSTRUCTURE	**37.31**	**3.48**
SUPERSTRUCTURE		
Frame/upper floors	104.04	9.96
Roof	46.47	4.33
Rooflights	2.82	0.26
Staircases	31.48	2.93
External walls	67.96	6.33
Windows	71.70	6.68
External doors	4.03	0.38
Internal walls and partitions	78.44	7.31
Internal doors	28.22	2.63
Group element total	***435.16***	***40.54***
INTERNAL FINISHES		
Wall finishes	29.87	2.78
Floor finishes	43.47	4.05
Ceiling finishes	14.17	1.32
Group element total	***87.51***	***8.15***
SERVICES		
Sanitary appliances	2.92	0.27
Services equipment	22.84	2.13
Disposal installations	4.41	0.41
Water installations	12.02	1.12
Space heating/air treatment	139.71	13.02
Electrical services	127.89	11.92
Lift & conveyor installations	14.48	1.35
Protective installations	34.03	3.17
Communication installations	13.37	1.24
Builders' work in connection	24.36	2.27
Group element total	***396.03***	***36.90***
PRELIMINARIES & INSURANCE	**86.37**	**8.07**
Total	***1073.24***	***100.00***

Figure 13.5 Example cost analysis. (Reproduced courtesy of the Architects' Journal)

Clients (and designers) need to be made aware of life-cycle costs so that they apply their minds to the best available data in a structured and systematic way in order to obtain a clearer understanding of the future cost implications for a proposed building. Today the high costs of materials, labour and energy imply that the running costs of buildings are of greater importance relative to acquisition costs.

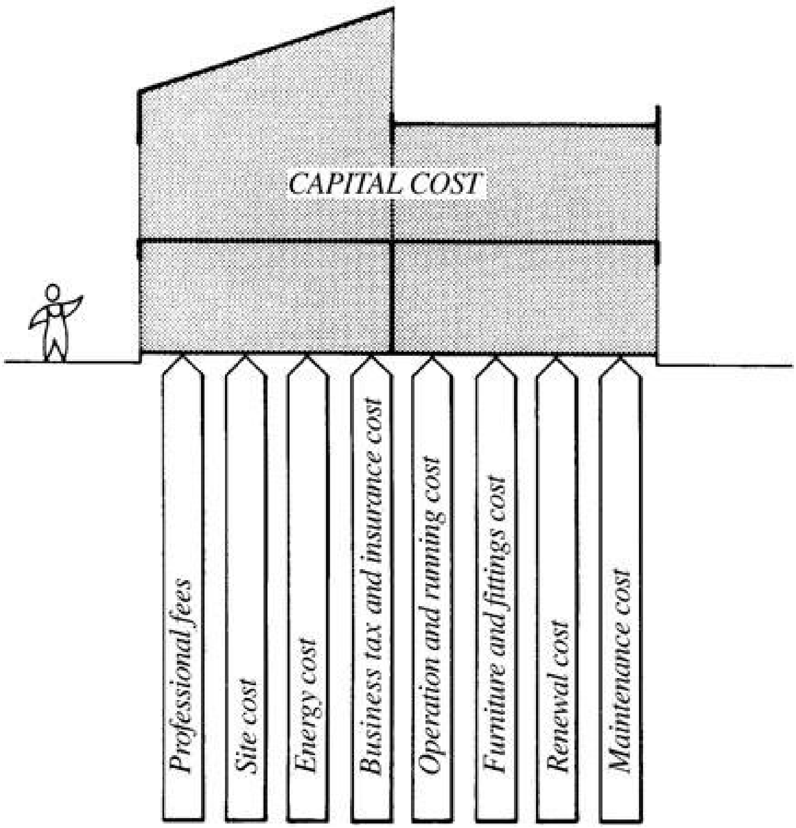


Figure 13.6 Hidden costs of a building.

Despite possible short-term reductions in prices, the long-term trend is likely to continue upwards, and operational costs must be used more fully to buffer the effects of overcostly capital investments. A true understanding of this will facilitate the preparation of estimates to give the realistic cost consequences of building designs against which the more subjective judgements of appearance, comfort and convenience can be set. For this purpose, comparative tables can be prepared which set out the costs and values arising from each design alternative: preferred appearance, comfort and convenience factors can be compared against the monetary figures which sum up the cost consequences of the design.

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Section 2.6 Economic aspects of building construction
Structure and Fabric Part 2	Chapter 1 Contract planning and site organization

Building Research Establishment

Digest 374	*Relocatable buildings: structural design, construction and maintenance*
Digest 423	*The structural use of wood-based panels*
Digest 447	*Waste minimisation on a construction site*
Digest 450	*Better building: Integrating the supply chain; a guide for clients and their consultants*
Digest 452	*Sustainable building design: using whole life costing and life cycle assessment*
Digest 470	*Life cycle impacts of timber: a review of the environmental impacts of wood products in construction*
Information Paper 13/02	*Sustainability lessons from private finance and similar private initiatives*
Information Paper 10/04	*Whole life value: sustainable design in the built environment*

14
Sustainability

CI/SfB (H)

Sustainable construction is an essential criterion for design of buildings. Its purpose is to help protect and preserve the natural environment on which we depend for survival. When considering sustainability it is impossible not to include 'green' issues such as the use of energy, water and material resources. 'Green' issues are a very important component of the process and have an on- and off-site impact on the environment.

14.1 Background

During the 1960s concern was mainly directed at preservation of the Earth's limited and diminishing natural resources. This was in response to world population increases, a corresponding demand for non-replaceable fossil fuels, over-deforestation of timber for building, diminishing drinking water supplies and recognition of the effects of global warming. In the 1970s the situation became more political with disputes occurring in the oil source countries of the Middle East. This resulted in escalating fuel prices and supply limitations. These were to some extent regulated in the UK when North Sea oil resources became commercially viable in the 1980s.

Sustainability is contributory to economic prosperity globally, nationally, locally and for organisations and individuals associated with buildings whether it be in their design, construction or their occupation. The interrelationship is represented in Figure 14.1. In many respects, the purpose of sustainable construction is to satisfy present needs with a responsibility for the needs of future generations. In the 1987 Brundtland Report to the World Commission on Environment and Development (WCED), sustainability is defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. This report addressed international concerns about the accelerating deterioration of the human environment and the decline in natural resources, highlighting the effect on economic and social well-being. Global environmental problems were realised and objective policies for sustainable development became prioritised on the political agenda, not least at the UN Earth Summits in Rio de Janeiro (1992) and Johannesburg (2002). Further initiatives included the UN Framework Convention on Climate Change (UNFCCC) and Worldwide 'Agenda 21' programmes. Around 2005 the European Union and independently the UK government introduced Sustainable Development Strategies as a basis for progression.

Figure 14.1 Sustainability awareness.

Fossil fuel resources are limited and with concerns for atmospheric pollution, more efficient fuel-energy-consuming appliances are now available. Alternative and renewable energy sources e.g. wind power, wave power, solar power and sustainable forest farming techniques with recycling programmes have to a large extent addressed the issue. Public awareness of climate change, global warming, atmospheric pollution and ozone layer
depletion has increased in response to government directives through building regulation legislation applicable to practice requirements.

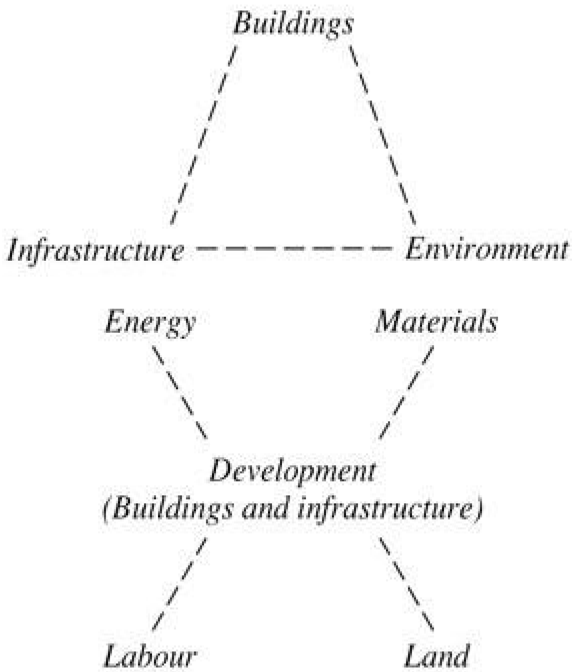


Figure 14.2 Developmental interaction and interdependency.

14.2 Development

Development becomes the environment for living, interacting and working. Therefore, it is important that it is socially, politically, economically and healthily maintained. Design of buildings, their interdependency and interaction through the infrastructure should be environmentally and economically affordable with a perspective for future demand and the possible need for change. Sustainable development represents a social responsibility for protecting and improving the environment in order to enhance economic growth. The interdependency of these factors is shown in Figure 14.2. The principles lie in controlled and prudent use of natural resources and regeneration through material recycling, regulated demolition, redesigning and reuse of redundant buildings, use of brownfield sites, redeployment and training of available workforce.

14.3 Immediate UK Government targets

2012 – 50 per cent reduction of demolition and excavation waste compared with 2008.

- 2016 – New homes to be zero carbon.
- 2016 – New schools to be zero carbon.
- 2018 – Public sector (non-domestic) buildings zero carbon.
- 2019 – Other non-domestic buildings zero carbon.

Note that zero carbon is an expression of zero net emissions of carbon dioxide from all energy use appliances and equipment in a building. Zero net emissions is achieved when the amount of on- or off-site fossil fuel energy used compares with the amount of on-site renewable energy produced. In addition to a well-insulated external building envelope, viable technologies that contribute to achieving zero carbon include solar panels, wind-powered electricity generators, ground-source heat pumps and micro-combined heat and power plant.

14.4 Future UK Government targets

Under the Climate Change Act of Parliament, the UK Government is committed to achieving a 34 per cent reduction in greenhouse gas emissions by 2020 and 80 per cent by 2050, compared to 1990 levels.

(Note that greenhouse gases comprise approximately 85 per cent carbon dioxide (CO_2) from fossil fuel combustion, with methane and nitrous oxide making up the remainder.)

Almost half of CO_2 emissions occur from the day-to-day use of the built environment, principally through fuel combustion for water and space heating. This is a challenge for the building industry to address, particularly in the design and construction of insulated elements that make up the external envelope. Specifically it is for the building services industry to address the manufacture, installation and use of fuel-burning appliances and ancillaries such as thermostatic controls. The objective is a low-carbon construction through application of Building Regulations, the Code for Sustainable Homes, Energy Performance Certification (EPC) and other mandatory and practice guidance. EPCs extend beyond new-build and apply to all buildings that are being altered, extended or marketed for sale or letting. The Joint Contracts Tribunal (JCT) have revised some of their standard contract documents to include provisions for sustainability.

Some examples of initiatives are:

- Lean thinking (based on improvement practices promoted by Toyota Motor Company)

- Value engineering
- Reduction of over-engineering
- Reduction of waste through design
- Resource efficiency
- Collaborative (team) working
- Waste Resource Action Programme (WRAP)

14.5 Achieving sustainability

Emission of greenhouse gases (mainly CO_2) are the prime cause of climate change. With reference to the year 2004 as a benchmark, total UK emissions of CO_2 exceeded 150 million tonnes (MtC). Energy consumption in buildings accounted for about 45 per cent of CO_2 emissions, of which 27 per cent were attributed to housing and 18 per cent to non-domestic buildings. The specific areas responsible for carbon emissions from homes are shown graphically in Figure 14.3. This illustration clearly indicates that the main target area for improvement is the energy consumed by heating the interior. However, other areas also need to be addressed as there is a growing trend in demand for energy-use appliances such as large-screen TVs, airconditioning units, etc.

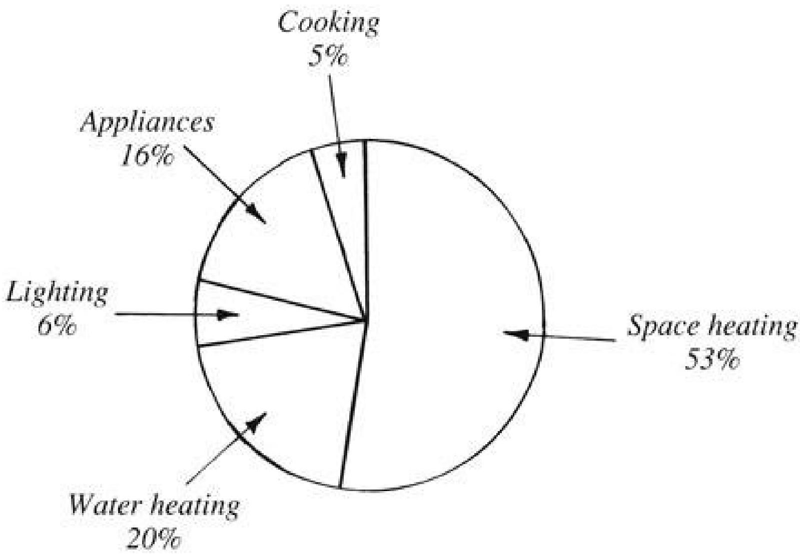


Figure 14.3 Typical carbon emissions from homes by end use.

(Source: Climate Change – The UK Programme 2006 (DEFRA))

Government directives have promoted energy efficiency and conservation through the introduction of several practice guides and legislation, not least the Code for Sustainable Homes, improved building controls to Part L of the Building Regulations, Energy Performance Certificates and Planning Policy Statement 1: Delivering Sustainable Development. PPS 1 is supplemented with further guidance in Planning and Climatic Change. This document describes improvements to the planning system that will encourage sustainable communities through siting and design of new development.

14.6 Renewable energy

Local planning and building control authorities require new building work to include provision for on-site renewable energy. PPS 22: Renewable Energy demands a percentage of a building's primary energy consumption to be provided from a sustainable source, i.e. one or more installations that do not consume hydrocarbon-based fuels. The amount of provision is at least 10 per cent.

Some of the most practical applications include:

- Solar panels. South-facing inclined collectors, preferably with photovoltaic light-powered cells. Can be used to provide stored hot water and to generate electricity.
- Wind turbines. Producers of wind-generated electricity. Large-scale wind farms have the potential to generate sufficient electricity for communities, but micro versions are available for use with individual dwellings. May have aesthetic implications.
- Heat pump. Can be air-, water- or ground-source. Heat energy is extracted from water pipes immersed in a low-temperature source and pumped through the evaporator in a refrigeration cycle. The increased refrigerant temperature at the condenser is used to heat air or water through a heat exchanger.
- Biomass. A solid fuel option for use with micro-combined heat and power or solely as a boiler fuel. Wood pellets are produced from harvested timber sourced from sustainable forest farming. Theoretically carbon neutral, as CO_2 emissions from

pellet combustion are balanced by the natural absorption of CO_2 during the photosynthetic process of plant growth.
- Micro-combined heat and power (CHP) or microgeneration. An engine that generates electricity, from which the heat energy in the cooling system is circulated through a heat exchanger to provide domestic hot water.

14.7 Sustainability rating

The Code for Sustainable Homes provides a system for assessing and rating sustainability based on points awarded for design and completed construction. A post-completion certificate gives the builder/developer a mark of quality. For potential home purchasers the certificate provides an information source and a reference for performance comparison with other dwellings.

14.7.1 Code levels

Ratings range from 1 to 6. Code level 1 (*) represents a 10 per cent improvement over the 2006 edition of the Building Regulations Part L: Conservation of Fuel and Power. Code level 6 (******) is a 100 per cent improvement representing a zero carbon home, the expectation for all new homes by 2016.

14.7.2 Practical measures

The Code in conjunction with the latest edition of Part L to the Building Regulations allows considerable flexibility for attaining the objectives. To enable variation in design, exact construction procedures are not prescribed, but for a high points score and zero carbon rating the following will be needed:

- Thermally efficient external elements, i.e. a high standard of insulation in floors, walls, windows, doors and roof. Insulation continuity to prevent thermal bridging.
- Limited air permeability, but sufficient for a healthy internal environment.
- Appliances with a high energy-efficiency rating. Applies particularly to hot-water-condensing-type boilers and fitments such as white goods.
- Renewable/alternative energy sources as mentioned under 14.6.
- Water-efficient appliances and fittings limiting consumption to about 80 litres per person per day. Provision includes:
    - Metered water supply
    - Low volume 6/4 litre dual flush WCs
    - Flow-limiting aerating taps, combine entrained air with water
    - Limited capacity of 150 litres for baths
    - Aerated shower head/rose
    - Limited capacity of 18 litres maximum for dishwashers
    - Limited capacity of 60 litres maximum for washing machines
    - Flow regulators to tap outlets

- Rainwater harvesting and grey water recycling to provide about 30 per cent of water for non-drinking purposes.

- Management of surface water run-off to prevent an overload of stormwater drains. Soakaways along with porous paving could be considered. Accessible rain-water butts.
- Energy-efficient lighting. Use of fluorescent light bulbs.
- Energy-efficient heating. Use of thermostatic radiator valves and zoned heating controls.
- Waste management storage and processing. Provision of a recycling facility for waste materials and/or on-site treatment.
- Accessible drying space to avoid use of a tumble dryer.
- Environmental impact of materials. Arranged on an elemental basis, i.e. external and internal walls, roofs, ground and upper floors, openings (windows and doors), insulation, finishes and landscaping. Rated in accordance with the BRE Green Guide to Specification. A rating from A and A* down to E. Grade D is the minimum acceptable rating.

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 1 The nature of buildings and building

Building Research Establishment

Report 389 *Ecohomes: The environmental rating for homes*
Report 436 *A sustainability check list for developments: a common framework for developers and local authorities*
Report 498 *Sustainability through planning – local authority use of BREEAM, Ecohomes and the Code for Sustainable Homes*
Report 501 *The green guide to specification*
Report 502 *Sustainability in the built environment: an introduction to its definition and measurement*
Information Paper 13/03 *Sustainable buildings* (4 parts)
Information Paper 3/08 *Delivering sustainability objectives through planning*
Information Paper 15/05 *The scope for reducing carbon emissions from housing*
Information Paper 4/09 *Delivering sustainable development in the built environment*
Information Paper 7/09 *Carbon reduction commitment*
Information Paper 18/10 *Sustainable housing refurbishment*
BRE AP 247 *Sustainability and green issues* (Expert pack)

Note that BREEAM is the BRE's Environmental Assessment Method. It originated in 1990 as a sustainability rating system for any building type, worldwide. Ecohomes is an environmental assessment version of BREEAM, specifically for dwellings. The Code for Sustainable Homes was developed from this.

Department for Communities and Local Government (DCLG)

Planning Policy Statement 1:	Delivering sustainable development
PPS 1 Supplement:	Planning and climate change
Planning Policy Statement 22:	Renewable energy

The Code for Sustainable Homes
Energy Performance Certificates

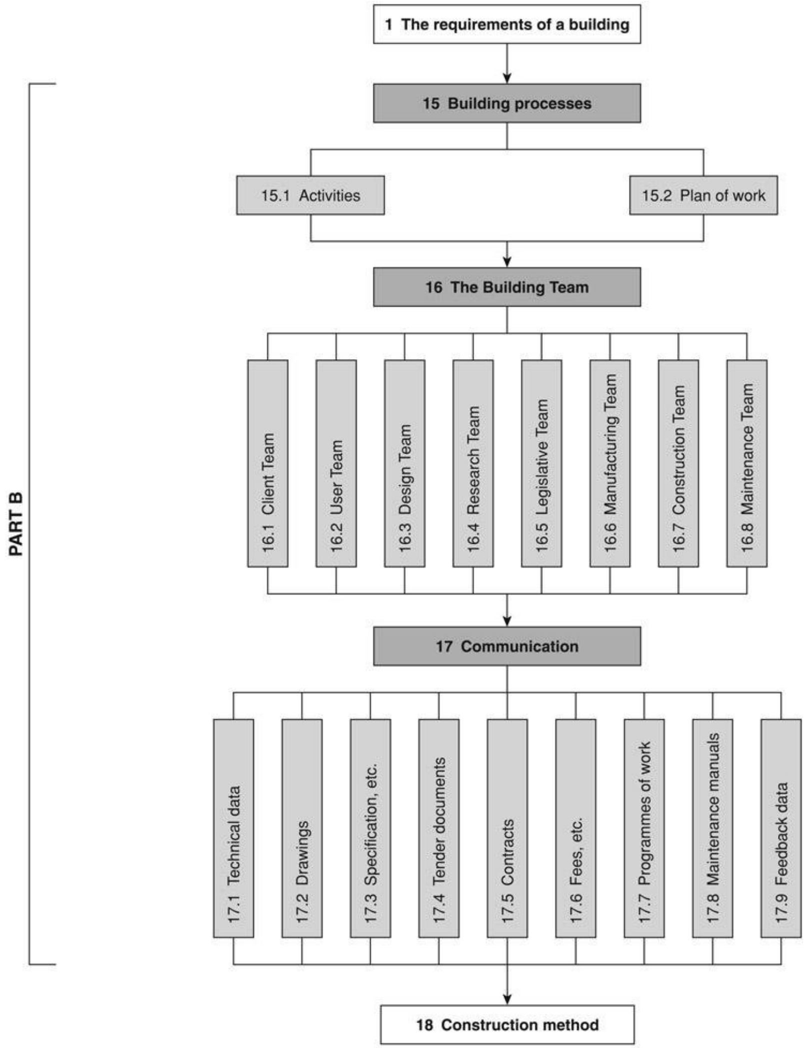
Building Regulations

Part L Conservation of fuel and power
Accredited construction details for Part L

Other references

Brundtland Report: Our Common Future, World Commission on Environment and Development (1987).
Chartered Institution of Building Services Engineers. Guide L, Sustainability.
Stern Review: The Economics of Climate Change, Cambridge University Press (2006).

Part B
An analysis of a building in terms of the processes required, the Building Team which implements them, and the methods used in communicating information


1 The requirements of a building
15 Building processes
15.1 Activities
15.2 Plan of work
16 The Building Team
16.1 Client Team
16.2 User Team
16.3 Design Team
16.4 Research Team
16.5 Legislative Team
16.6 Manufacturing Team
16.7 Construction Team
16.8 Maintenance Team
17 Communication
17.1 Technical data
17.2 Drawings
17.3 Specification, etc.
17.4 Tender documents
17.5 Contracts
17.6 Fees, etc.
17.7 Programmes of work
17.8 Maintenance manuals
17.9 Feedback data
18 Construction method
PART B

15
Building processes

CI/SfB (A1)/(A9)

15.1 Activities

The processes involved in the construction of a building are extensive and complex. This is mainly because it is a labour-intensive non-repetitive industry employing some 2.5 to 3 million personnel in the UK. These are drawn from people with diverse education, skills and qualifications across a range of trades and professions. The organisation, planning and coordination of operatives, administrators and managers from these disparate backgrounds requires extremely competent management. Management of resources both human and material with good communications systems combine with a variety of operational skills in order to effect efficient progression of a building project. Responsibility for specific legislative measures including personal health and safety and that of other personnel on and around the site is for all engaged in the construction process. Successful construction of a building includes the following activities:

- The initial decision to build
- Securing of financial resources
- Selection of appropriate location
- Determination of timescale

- Appointment and briefing of suitable members to be involved with design and construction operations
- Selection of contract type
- Definition of precise functional requirements
- The design process and decisions on how to build
- Implementation of construction plan
- Operations necessary to maintain the building in the state of continuous performance for which it was intended
- Operations necessary to adapt building to new functions

All these activities may be affected by an elaborate system of approvals, controls, checks and cross-checks which involve not only nearly all the members of the entire building team, but also a variety of outside bodies in varying administrative, technical, financial and fiscal capacities. Furthermore, whereas the creation of a building was formerly a leisurely occupation ultimately dependent upon craft-based skills, the whole process is now greatly influenced by the desire to achieve profit on financial investments as soon as possible and the use of simplified assembly techniques using pre-fabricated factory-manufactured components. Therefore, although most buildings of today are far more complex and sometimes much larger, the timescale from the realisation of the need for a building to its use after erection is generally far shorter than at any previous period in the development of building.

In view of these complexities, a great deal of attention has been devoted to methods of achieving clarity of communication between the participants. The difficulty has been bridging the gap between professional activities.

Consultants, designers and builders have stood divided as a result of social and educational background, and contractual relationships which have encouraged apportionment of blame when deficiencies occur, rather than encouraging teamwork.

The need for increased effectiveness – better coordination of effort and control of all the complex operations involved in a building – has been the subject of public and private research for many years. The Tavistock Institute reports, Communications in the Building Industry and Interdependence and Uncertainty, published in the mid-1960s, indicate that this is not a recent area for concern. The Wood Report of 1975 acknowledged some improvement:

The traditional separation between design and construction was found to have diminished with consequent advantages all round … Contractors have much to offer at the design stage, especially by way of advice on constructional implications of design solutions and decisions … yet, methods of procurement are still such that they are brought in too late for their advice and experience to be of practical use … the original problem still exists.

An awareness of the poor correlation between design and construction led to the concept of 'buildability'. In 1979 the Construction Industry Research and Information Association (CIRIA) embarked on several years' research into this subject, endorsing the need for builders' expertise at the design stage. In 1983 CIRIA defined buildability as 'the extent to which the design of the building facilitates ease of construction, subject to the overall requirements for the completed building'.

Emphasis is clearly that design must be with regard to the practicalities of construction, therefore traditional adversarial relationships between architects and builders should be replaced with a good working partnership for the client to obtain value for money. In recent years this has been endorsed with the establishment of many design-and-build practices.

In 1983 the National Economic Development Office (NEDO) produced its findings into construction delays, Faster Building for Industry. Since then the topic has been the subject of many research papers, presentations and professional journal articles. These compounded and eventually encouraged the government to engage Sir Michael Latham to chair a major initiative into improving productivity in the industry. The outcome in 1994 was a 130-page document, Constructing the Team, aimed specifically at providing better value for the client, with the objective of a 30 per cent real cost reduction in productivity targets. In principle the recommendations include formation of a client forum, government commitment to education, training and guidance on practice, consideration of liability and compulsory building user insurance, a research initiative funded by levy and adjudication to be promoted as a means of professional dispute resolution. Overall it places greater emphasis on the professions sharing responsibility for building construction, rather than the traditional practice of ill-defined and segregated interests.

A few years later in 1998, Sir John Egan was appointed to lead another government inquiry into the performance of the construction industry. This resulted in the publication Rethinking Construction, more generally known as the Egan Report. It was highly critical of the industry's efficiency, emphasising the needs for clients to receive value for money rather than price. The report called for cuts of 10 per cent in construction time and costs, with reciprocal gains in profit and turnover. This was to be achieved through cooperation of parties to the project (partnering), further integration of design with construction, increased standardisation, leaner construction techniques to minimise material waste, phasing out of inflexible contracts and less emphasis on competitive tendering for contractor selection.

The Housing Grants, Construction and Regeneration Act of 1996, known as the Construction Act, came into effect in 1998. This aimed to reduce the number of legal claims and acrimony between parties to the building contract, by effecting rules on fair payment and a right to adjudication. It was all-embracing, covering construction contracts between contractors and their subcontractors, and contracts between clients and consultants including architects, engineers and quantity surveyors. In addition to encouraging better contractual relationships, it aimed to reduce the number of long-running disputes, legal bills, personal losses, stress and business failures in the construction industry.

The initiatives of the 1998 Egan Report and the Construction Act, effected that same year, were further defined in 2002 by another report called Accelerating Change. This was produced by the Strategic Forum for Construction (SFfC) and was chaired initially by Sir John Egan. The SFfC comprises key members from industry, government, unions and professional bodies. Like previous initiatives, Accelerating Change has been about promoting the various parties to a contract to work closer together in pursuit of modernising the industry. A mission statement for Accelerating Change states, ‘Our vision is for the UK construction industry to realise maximum value for all clients, end users and stakeholders and exceed their expectations through consistent delivery of world class products.’ The SFfC has identified four key areas for change and improvement:

- Client engagement (contractual arrangements)
- Integration and management of teams, including design, construction and material supplies
- People issues (education and training, and minority groups)
- End product and facility enhancement

To improve these four key areas, the SFfC also produced six headline targets through which they would coordinate, monitor, measure and formally report on the progress. These were:

1.
    - (a) By 2004, 20 per cent of construction projects by value undertaken by integrated teams and supply chains.
    - (b) By the end of 2007, the figure to rise to 50 per cent.
2.
    - (a) By 2004, 20 per cent of client activity to embrace the principles of a Clients’ Charter (client involvement in design, project and construction planning).
    - (b) By the end of 2007, the figure to rise to 50 per cent.
3. Recruitment, training and education to ensure that by 2006, 300 000 people are appropriately trained, qualified and retained to fulfil the various functions within the industry.

4. In support of target 3, by 2007, 50 per cent more applications are required for construction-related further and higher education courses. By 2010, trade apprenticeship completions to show an increase of 13 500.
5. By 2010, all projects to have a fully trained and competent workforce.
6. Design Quality Indicators (DQIs) established as a measure of efficiency by 2004. By 2004, 500 projects to be measured in this way and by the end of 2007, 20 per cent of all projects having a value greater than £1 million to use DQIs.

The Government has been concerned that some developers' business and financial interests differ from public interest in value, affordability, high-quality standards and sustainable home building. Numerous reviews and reports have been commissioned and in 2007 the Callcutt Review of Housebuilding Delivery consolidated the findings and produced many new recommendations, while considering the potential to deliver an increased number of dwellings in a low/zero carbon environment. The principal factors were the business models and structure of the house-building industry, its supply chain encompassing the resources of land, materials and personnel.

In common with previous reports the review identified the industry's traditional independence from the professions and the need for closer integration and partnering, in particular between local planning authorities and developers where there was a relationship of 'mutual suspicion and distrust'. To achieve the Government's target of 240 000 new homes per year by 2016 and to construct them to zero carbon standards, the review recommended that the industry and local planning authorities find new ways of working. This could possibly be by sharing in the financial and commercial benefits of investment in building houses and infrastructure.

There were five propositions:

- Partnership between public and private sectors to promote low-value sites for new homes
- Public commitment to regeneration of existing infrastructure and facilities, e.g. schools, roads, leisure and recreation spaces and health services
- Existing regulatory frameworks substituted for market disciplines that promote high standards with penalties for developers that fail customer satisfaction surveys
- Government and LPAs to give strong leadership and directives to attain zero carbon objectives
- Community management objectives prioritised towards permanent regeneration and to provide confidence in commercial development as a long-term asset growth

From these propositions evolved a considerable number of recommendations, some of the most significant being:

- Curtailment of urban sprawl in favour of brownfield site development
- Concept of LPAs working with ‘preferred partner’ developers (generally housing associations or registered social landlords) to promote building on lower-value sites attracting private finance

- Present community management as a stimulus for regeneration through the Homes and Communities Agency (HCA). (The HCA is a national housing and regeneration agency for England. It has the remit to contribute to economic growth by helping communities to deliver high-quality sustainable and affordable housing (see Housing and Regeneration Act 2008))
- Establish customer satisfaction standards as a measure against which failing developers are prevented from bidding for public land and from claiming public funding
- Review of design processes to simplify planning requirements. Government to consider the Commission for Architecture and the Built Environment's (CABE) role in this. (CABE is a government advisory body on architectural urban design and public space)
- Government's zero carbon targets to be reinforced with establishment of a methodology, for example, the Code for Sustainable Homes and Part L to the Building Regulations
- Status of developers' land holdings to be more transparent
- Government's Planning and Policy Statement (PP3) (underpins the delivery of its strategic housing policy objectives, including affordable housing) to be amended to stipulate that at least 10 per cent of the five-year supply of housing land to be for small sites up to 15 homes. Larger sites to be divided for separate development
- Review existing building inspection procedures and requirements, in particular building control, private

company warranties and planning conditions to promote uniformity of quality standards

Note that affordable housing can be defined as the housing costs for rented or purchased dwellings that are financially manageable by occupants with a median household income (low- to middle-income families) not costing so much as to prevent them meeting other basic financial needs. LPA requirements vary regionally. As a guide, some 35 per cent of units on new development
sites may be required to fulfil this criterion. Of this, typically 85 per cent may be available at social rents.

The work of these committees and their subsequent reports builds on initiatives established some 50 years ago as outlined in the preceding pages. It is not an easy task to modernise an industry with traditions steeped in the depths of history and particularly one so influenced on such a huge financial and economic scale.

It is often stated that the only common factor underlying the whole process is the economic one, and this should therefore provide the basis of organisational procedures. Economics are significant in assessing the nature of the individual contributions of the members of the building team and often explain the reasons for the elaborate system of mutual controls, checks and doubts usually blamed for delays and 'inefficiency' within the building process. Perhaps the future will provide greater professional cooperation, and mutual distrust will no longer interfere with progress.

15.2 Plan of work

Figure 15.1 indicates a plan of work which was originally published in the first edition of the Royal Institute of British Architects' Handbook in 1964. Its intention was to provide a model procedure for methodical working of the design team employed on projects which have sufficient common factors to make it widely relevant. The plan of work (since revised) has subsequently become widely known among other professions concerned with the design and construction of buildings as it is capable of being used in a variety of ways. It can assist the planning of projects and be adapted to form the basis for control of organisational procedures. In developing the model, certain assumptions were made:

- It related to a building costing £300 000 (1964 price) which used a full design team.
- An architect is principal designer and leader of the design team.
- The architect is appointed at an early stage of the building process.
- Each stage follows sequentially.
- The cycle of work in each stage involves the following items:
    - – stating objective and assimilation of relevant facts
    - – assessment of resources required and setting up of appropriate organisations
    - – planning the work and setting timetables
    - – carrying out work
    - – making proposals
    - – making decisions

- – setting out objectives for the next stage.

Figure 15.2 shows in outline the 1998 revision which incorporates some changes in practice and procedures. It is intended for application to works exceeding £150 000 (1998 price). Some variations exist for design and build procurement, client requirements and contractor's proposals.

In 2007 the RIBA plan of work was again updated, with some amendment in 2008, to maintain its relevance to changes in contractual procedures, planning processes and patterns of working. Its format of work stages and key task descriptions for procurement of buildings is outlined in Figure 15.3. For historical reference the earlier 'plans' from which it evolved are retained and shown in Figures 15.1 and 15.2. In 2011 the 'plan' was supplemented with a green overlay of sustainable design and activity checkpoints, see www.ribabookshops.com/green-overlay.

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 2 The production of buildings
Structure and Fabric Part 2	Chapter 1 Contract planning and site organization

Government Reports

Latham, M. Constructing the Team (The Latham Report), The Stationery Office (1994).

Egan, J. Rethinking Construction (The Egan Report), The Stationery Office (1998).

Accelerating Change, Strategic Forum for Construction (2002).

Callcutt, J. The Callcutt Review of housebuilding delivery, DCLG (2007).

Stage	Purpose of work and decisions to be reached	Tasks to be done	People directly involved	Commonly used terminology
A Inception	To prepare general outline of requirements and plan future action.	Set up client organisation for briefing. Consider requirements, appoint architect.	All client interests, architect.	**Briefing**
B Feasibility	To provide the client with an appraisal and recommendation in order that he may determine the form in which the project is to proceed, ensuring that it is feasible, functionally, technically and financially.	Carry out studies of user requirements, site conditions, planning, design, and cost, etc., as necessary to reach decisions.	Clients' representatives, architects, engineers and QS according to nature of project.	
Stage C begins when the architect's brief has been determined in sufficient detail.				
C Outline Proposals	To determine general approach to layout, design and construction in order to obtain authoritative approval of the client on the outline proposals and accompanying report.	Develop the brief further. Carry out studies on user requirements, technical problems, planning, design and costs, as necessary to reach decisions.	All client interests, architects, engineers, QS and specialists as required.	**Sketch plans**
D Scheme Design	To complete the brief and decide on particular proposals, including planning arrangement appearance, constructional method, outline specification, and cost, and to obtain all approvals.	Final development of the brief, full design of the project by architect, preliminary design by engineers, preparation of cost plan and full explanatory report. Submission of proposals for all approvals.	All client interests, architects, engineers, QS and specialists and all statutory and other approving authorities.	
Brief should not be modified after this point.				
E Detail Design	To obtain final decision on every matter related to design, specification, construction and cost.	Full design of every part and component of the building by collaboration of all concerned. Complete cost checking of designs.	Architects, QS, engineers and specialists, contractor (if appointed).	**Working drawings**
Any further change in location, size, shape, or cost after this time will result in abortive work.				
F Production Information	To prepare production information and make final detailed decisions to carry out work.	Preparation of final production information i.e. drawings, schedules, and specifications.	Architects, engineers and specialists, contractor (if appointed).	
G Bills of Quantities	To prepare and complete all information and arrangements for obtaining tender.	Preparation of Bills of Quantities and tender documents.	Architects, QS, contractor (if appointed).	
H Tender Action	Action as recommended in relevant NJCC *Code of Procedure for Selective Tendering.*	Action as recommended in relevant NJCC *Code of Procedure for Selective Tendering.*	Architects, QS, engineers, contractor, client.	
J Project Planning	To enable the contractor to programme the work in accordance with contract conditions; brief site inspectorate, and make arrangements to commence work on site.	Action in accordance with RIBA Plan of Work.	Contractor, sub-contractors.	**Site operations**
K Operations on Site	To follow plans through to practical completion of the building.	Action in accordance with RIBA Plan of Work.	Architects, engineers, contractors, sub-contractors, QS, client.	
L Completion	To hand over the building to the client for occupation, remedy any defects, settle the final account, and complete all work in accordance with the contract.	Action in accordance with RIBA Plan of Work.	Architects, engineers, contractor, QS, client.	
M Feedback	To analyse the management, construction and performance of the project.	Analysis of job records. Inspections of completed building. Studies of building in use.	Architect, engineers, QS contractor, client.	**Feedback**

Figure 15.1 Original RIBA plan of work. Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com

Stage		Procedures
A	Appraisal	Identification of client's requirements and of possible constraints on development. Preparation of studies to enable the client to decide whether to proceed and to select the probable procurement method.
B	Strategic Briefing	Preparation of Strategic Brief by or on behalf of the client confirming key requirements and constraints. Identification of procedures, organisational structure and range of consultants and others to be engaged for the project.
C	Outline Proposals	Commence development of Strategic Brief into full Project Brief. Preparation of Outline Proposals and estimate of cost. Review of procurement route.
D	Detailed Proposals	Complete development of the Project Brief. Preparation of Detailed Proposals. Application for full Development Control Approval.
E	Final Proposals	Preparation of Final Proposals for the project sufficient for co-ordination of all components and elements of the project.
F	Production Information	F1 – Preparation of production information in sufficient detail to enable a tender or tenders to be obtained. Application for statutory approvals. F2 – Preparation of further production information required under the building contract. (Not required for design and build).
G	Tender Documentation	Preparation and collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the construction of the project.
H	Tender Action	Identification and evaluation of potential contractors and/or specialists for the construction of the project.
J	Mobilisation	Letting the building contract, appointing the contractor. Issuing of production information to the contractor. Arranging site handover to the contractor.
K	Construction to Practical Completion	Administration of the building contract up to and including practical completion. Provision to the contractor of further information as and when reasonably required.
L	After Practical Completion	Administration of the building contract after practical completion. Making final inspections and settling the final account.

Note: A & B = Feasibility.
C,D,E,F,G & H = Pre-construction period.
J,K & L = Construction period.

Figure 15.2 Revised (1998) RIBA plan of work. Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com

Work stage	Description of key tasks
A Appraisal	Identification of client's needs and objectives, business case and possible constraints on development. Preparation of feasibility studies and assessment of options to enable the client to decide whether to proceed.
B Design Brief	Development of initial statement of requirements into the Design Brief by or on behalf of the client confirming key requirements and constraints. Identification of procurement method, procedures, organisational structure and range of consultants and others to be engaged for the project.
C Concept	Implementation of Design Brief and preparation of additional data. Preparation of concept design including outline proposals for structural and building services systems, outline specifications, preliminary cost plan. Review of procurement route.
D Design Development	Development of concept design to include structural and building services systems, updated outline specifications and cost plan. Completion of final (project) brief. *Application for detailed planning permission*.
E Technical Design	Preparation of technical design(s) and specifications, sufficient to coordinate components and elements of the project and information for *statutory standards and construction safety*.
F Production Information	Preparation of production information in sufficient detail to enable a tender or tenders to be obtained. *Application for statutory approvals. Preparation of further information for construction required under the building contract*.
G Tender Documentation	*Preparation and/or collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project.*
H Tender Action	*Identification and evaluation of potential contractors and/or specialists for the project. Obtaining and appraising tenders; submission of recommendations to the client.*
J Mobilisation	Letting the building contract, appointing the contractor. Issuing information to the contractor. Arranging site handover to the contractor.
K Construction to Practical Completion	Administration of the building contract to Practical Completion. Provision to the contractor of further information as and when reasonably required. Review of information provided by contractors and specialists.
L Post Practical Completion	Administration of the building contract after Practical Completion and making final inspections. Assisting building user during initial occupation period. Review of project performance in use.

Notes: Activities shown in italics may be moved to suit project.
A & B = Preparation
C,D & E = Design
F,G & H = Pre-construction
J & K = Construction
L = Use.

Figure 15.3 Revised (2007/8) RIBA plan of work. Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com

16
The Building Team

CI/SfB (A1m)

Building is a group activity and its success depends on a good understanding and cooperation between a large number of people. The participants involved can be conveniently arranged into groups or teams according to their particular interest and/or involvement as follows:

- Client Team
- User Team
- Design Team
- Research Team
- Legislative Team
- Manufacturing Team
- Construction Team
- Maintenance Team

Figure 16.1 relates the stages of design and construction and activities of the various teams with the RIBA Plan of Work. This is a form of sequential timetabling and also indicates the principal designer of a building to be the leader of the building process. Various permutations can be adopted involving different 'leaders', or no 'leaders' at all, as well as employment of teams at different stages according to the precise circumstances. Figure 16.2 indicates the interrelationship of the various teams in the sequence to be considered in this chapter.

16.1 Client Team

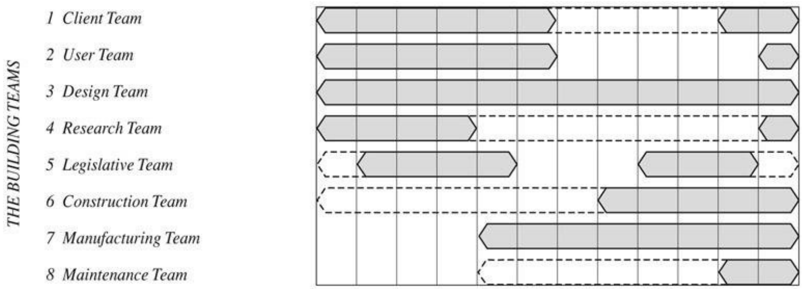
The client, or prospective building owner, has the responsibility for defining the building to suit needs, establishing and providing the necessary finances, agreeing design and construction phases, timetabling and, of course, fulfilling the management and running of the completed project. This implies that, besides producing a clear and accurate brief (or list of requirements) for a building and maintaining a strategic knowledge throughout the building process, the client should be able to make prompt decisions when requested. But the client usually resolves many of them helped by professional advisers.

The type of client varies from a house owner requiring nominal changes, e.g. a loft conversion, to a multi-national organisation redeveloping industrial premises or constructing new prestigious offices. Large organisations very often incorporate a committee of laypersons backed by consultants, such as exist in government administrative departments. Nevertheless, whatever the combination or form of the client organisation, its responsibility is always to provide clear and concise instructions to the building professionals.

The British Property Federation is an association devoted to the interests of property owners, investors and others with a major concern for property. Their main objective is to promote a better understanding between property owners (ranging from large development companies to owner–occupiers of single dwellings) and the public, government and local authorities. The Federation provides general advice on all matters relating to the law, management and administration of property, and on taxation, housing and rating problems.

16.1.1 The necessity to build

A potential client must establish whether to build or not to build, and it is first necessary to carry out a comprehensive appraisal of needs. Having decided that a new building is necessary to provide additional or alternative space, it is important that consideration is then given to when the space will be needed. For people who are not connected with the building industry, the timescale for building often seems surprisingly (and unnecessarily) long. A minimum of six months will be required between making an appraisal and the start of even a quite modest



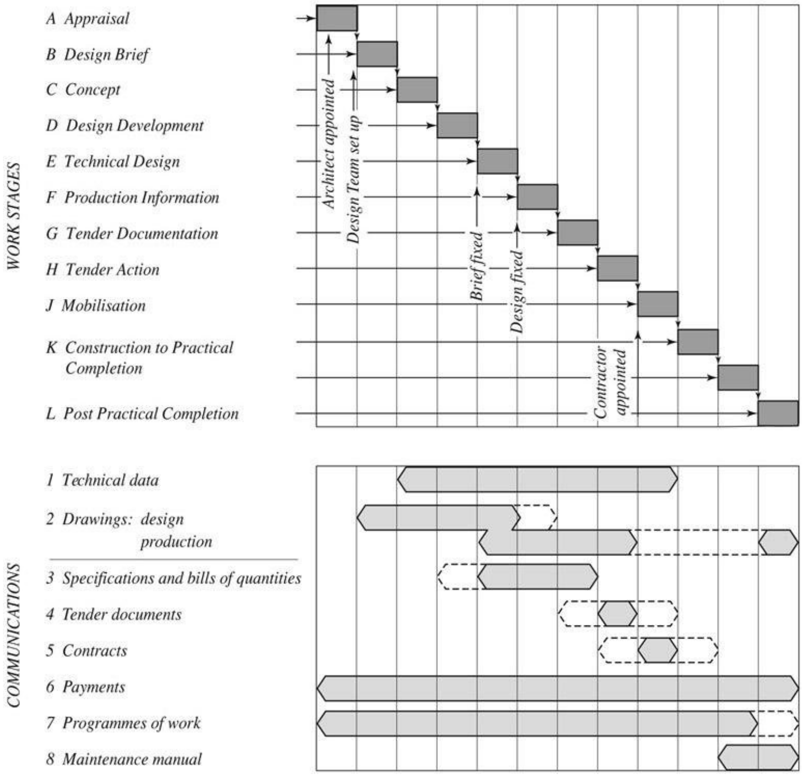


Figure 16.1 Function of the building team relative to activities in the RIBA Plan of Work.

building. Larger buildings can take several years in resolving the problems associated with land acquisition, establishment of rights, development permits, planning permission, building approval, contractor selection and subsequent erection. Initial delays may also be encountered while seeking out and appointing a suitable team of professionals (lawyers, financiers, designers, etc.) to advise on these activities.

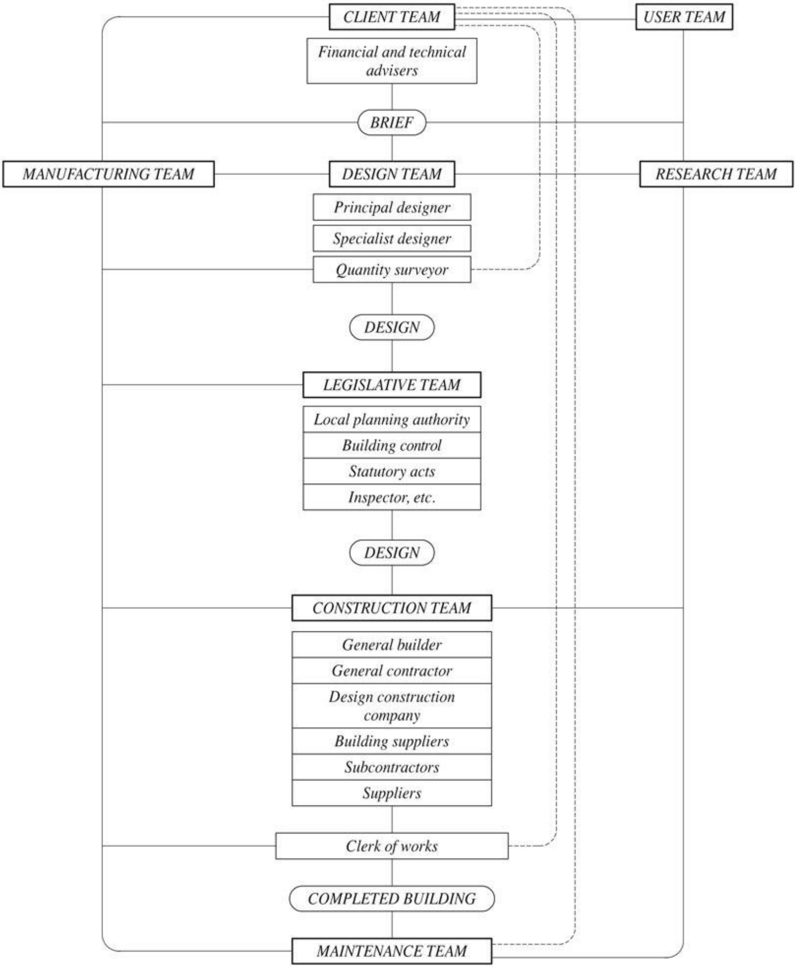


Figure 16.2 Sequential relationships within the Building Team.

There are various options open to a person or organisation requiring more space other than commissioning a new building. For example, there may be the possibility of the purchase or lease of existing property which can be altered,

adapted, extended or renovated in a suitable manner. Alternatively, there is the possibility of the purchase or leasing of a precisely suitable building. Developers will often build office blocks and shopping areas speculatively,
and many town councils will build factory units for sale or lease. These buildings usually, however, require fitting out to greater or lesser amounts by the eventual owner or lessee. Clients wishing to investigate the potential use of an existing building, or one which is under construction having been commissioned by others, should seek the advice of the estate agents dealing with the particular interest. These are professionally qualified people involved with the buying, selling and managing of property generally. They may belong to the Royal Institution of Chartered Surveyors (RICS) or to the National Association of Estate Agents (NAEA).

16.1.2 Construction Design and Management (CDM) Regulations

All building, civil engineering or engineering construction projects involving more than 500 employee days or lasting more than 30 days with the exception of domestic work are subject to compliance with the CDM Regulations. The Health and Safety Executive must be informed using a standard F10 notification form.

The purpose of the CDM Regulations is to improve standards of site safety, reduce risks and promote the practice of risk assessment and management by all on site, thus encouraging effective project administration, planning and progress. The Regulations identify the following key positions of responsibility known as duty holders:

- Client
- Designer
- CDM coordinator
- Principal contractor
- Contractors
- Everyone, i.e. workers, operatives, etc.

Summary of main duties:

- Client
    - Appoint CDM coordinator and principal contractor (can be the same person depending on the extent of work).
    - Ensure provision of adequate welfare facilities (note that Workplace (Health, Safety and Welfare) Regulations are now part of the CDM Regulations.)
    - Allow sufficient time and resources to be available for all stages of design and construction and for a construction phase plan to be in place.
    - Ensure health and safety information file and plan is in place.
    - Check competence of all appointees.
    - Provide pre-construction information to designers and contractors.
- Designer
    - Identify and eliminate potential hazards and risks.
    - Check client is aware of duties and responsibilities outlined above.
    - Provide any information required for health and safety file.

    - Ensure workspaces and facilities are adequate as determined by the Workplace Regulations.
- CDM coordinator
    - Notify the project to the HSE.
    - Advise, assist and support the client in their duties.
    - Ensure competence of client's appointees and advise accordingly.
    - Process and convey pre-construction information.
    - Ensure measures are in place to maintain health and safety and coordinate with others involved.
    - Facilitate effective communication between client, designers and contractors.
    - Liaise with principal contractor regarding work progress and ongoing design information.
    - Maintain and update health and safety file.
- Principal contractor
    - Manage health and safety on site with prescriptive duties.
    - Identify hazards and assess risks.
    - Develop and administer construction phase plan relative to health and safety arrangements, site rules and any special measures.
    - Convey relevant parts of plan to other contracted parties.
    - Check competence of all appointees.

    - Ensure site operatives are suitably inducted and informed of specific issues pertaining to the site.
    - Liaise with site operatives through their line management.
    - Effect site security measures.
- Contractors
    - Plan and manage their work without risk to health and safety.
    - Inform appointees/employees/operatives of site health and safety details.
    - Ensure adequate provision of welfare facilities.
    - Check appointment of CDM coordinator and that HSE are notified.
    - Cooperate with principal contractor in planning and managing work.
    - Provide any information requested for health and safety file.
    - Identify any foreseeable problems with construction phase plan.
    - Inform principal contractor of all accidents, hazards and risk identifications.
- Everyone/workers/operatives
    - Verify own competence and ability to do the work.
    - Cooperate with others and coordinate work especially with regard to health and safety issues.
    - Identify and report potential hazards and risks.

A construction phase plan is a plan for managing health and safety procedures during the construction phase of a building project. It must be in place before site work commences. It includes developing information from the client and the CDM coordinator. A construction phase plan determines:

- Specific responsibilities
- Personnel with these responsibilities
- Identification of anticipated hazards and risks
- Manner in which the works are controlled

16.1.3 Financial resources

Most building is undertaken from money made available in the form of a loan, so interest rates (loan charges) are important. In this respect, the government has direct influence and can use the building industry as a regulator for the economy of the country. Taxation and/or adjustment to the bank rate on loans can cause boom or slump periods. Funds for a public building are made available from local or national taxation, and there is concern to spend as little as possible with due regard to the value for money. Financial control is implemented by the use of the ‘cost yardstick’ in housing, cost per place in schools, or cost per bed in hospitals, etc. In the private sector there is a little more flexibility in that the client will spend in proportion to stated aims, which may be as diverse as a temporary-use building or a prestige building. Private funds arise from the profits of industrial undertakings or the savings from individuals which again are closely linked with investment and borrowing potential, mortgage rates and grants to charities, etc.

Privately financed initiatives (PFI) are a combination of public and private interests for public sector building such as prisons, schools, hospitals and roads. This has become known as public–private partnership (PPP). The financing objectives can take on a variety of forms. At its simplest, a business may seek to invest in a public sector project for publicity and/or a profit share of its success. More complex is the idea of bonding and sharing, where all team members including designer and main contractor participate financially in their client's project. Some of their costs are deferred until the business is established, with the possibility of a profit share thereafter.

For the year 2011, main contract awards totalled approximately £110 billion. About 30 per cent of this is publicly funded and 10 per cent through PFI schemes. Figure 16.3 indicates how that money was variously apportioned.

Some building types which the government in power considers should be encouraged for the benefit of a particular region or the country in general may be eligible for financial support from national taxation. Former industrial and commercial premises such as hotels have been supported in this manner. Indeed, building work is often only implemented as a result of this financial aid or grant, but designers must always confirm the opportunities which may exist for the client. For smaller-scale work, involving the domestic sector, the Housing Acts specify grants which are available for the provision of adequate sanitary appliances where they do not exist, and for essential repairs such as rewiring, provision of adequate heating, replacing lead water pipes, installing insulation, adapting a house to the needs of a disabled person, and even for converting other building types into housing, joining two or more houses into one, or dividing an existing dwelling into smaller independent living units. Grants are administered through the local borough or district councils. Each authority has its own local policy and criteria which applicants must satisfy to qualify for financial assistance. The councils can also serve enforcement on building owners to undertake improvements to buildings in a serious state of disrepair. These are effected under a Repairs Notice and Improvement Orders.

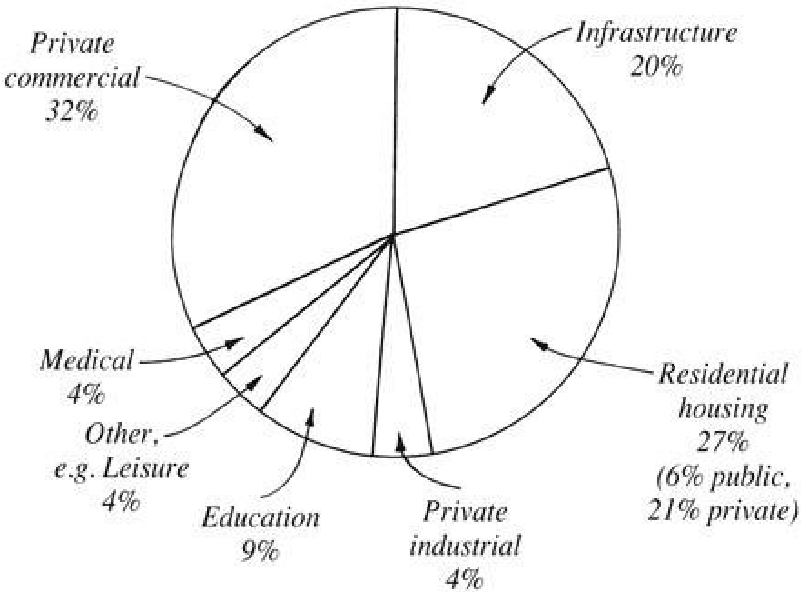


Figure 16.3 Main UK contract awards for 2011: by percentage of £110 bn output.

Once money becomes available for a building, the client will require speedy action for its design, construction and subsequent use, so that the lost interest, which would have been gained through alternative financial investments, may be speedily recouped. Indeed, today, speed of use is even more essential to ensure that the value of the original sum is not extensively reduced by the effects of monetary inflation in the cost of labour and materials. The total cost of a building must include the professional fees of the Design Team which the client appoints. In conventional terms the contractor's 'fees' and those associated with initial local authority services (planning, bylaws, utilities, etc.) are included in the costs for the building (see Chapter 13).

16.2 User Team

As the majority of building is for the direct employment of people or involves people for its continued function, i.e. maintenance, a building User Team forms a vital link between design concepts and built reality. Formulating user requirements may be simplified when client and occupants are the same. However, this is not always the case, and it is the initial responsibility of a non-user Client Team to establish user requirements when formulating a brief with its professional advisers.

Typical User Teams which can supply information are tenants' associations, medical associations, consumer associations, tourist boards, unions, etc., and their membership may include professional advisers as well as laypersons. The Design Team often has to draw independently upon the expertise, experience and research of these bodies when advising on a client's own interpretation of user requirements for a proposed building. In this way the designer can modify certain views and provide for the psychological and physiological well-being of future occupants.

The performance requirements for a building are sometimes derived from feedback information supplied by the users of similar existing designs. This applies particularly to experience gained from designs which resulted in loss of security or accidents (see Chapter 12). Where a novel project is being contemplated, detailed research must be carried out to ascertain the effects which certain designs or construction methods are likely to have on potential occupants; if necessary, a life-size prototype of the proposed enclosure must be made for users to experience and test.

16.3 Design Team

The design of a building can no longer be the total responsibility of one person. There are a great many people concerned with supplying the design expertise which will make a building possible, and these people are known collectively as the Design Team.

Within this team there are two types of building designers: principal designers with the responsibility for the overall design of the project, and specialist designers who provide expertise concerning certain aspects of a building and whose requirements are often coordinated by the principal designer. The principal designer may also be appointed as project CDM coordinator – see section 16.1.2. Cost control and financial advice to client, principal and specialist designers is generally provided by a quantity surveyor. The fees for the professional services of principal designers, specialist designers and the quantity surveyor are paid by the client (see section 17.6).

16.3.1 Principal designers

Professional principal designers generally include architects, interior designers and building surveyors. Each is capable of fulfilling the function of a building designer, but their training means they may provide different emphases in the approach to the problems associated with the production of a building.

Architects design and prepare the production information for most building projects, and on small general-purpose buildings their expertise permits them to be the sole designer. They will also inspect the construction work on site and may function as project CDM coordinator. The title ‘architect’ is protected under the Architects’ Registration Board (ARB), and only persons appropriately qualified and registered can use it.

Most architects are also members of the Royal Institute of British Architects (RIBA) and are governed by its mission and vision statements, bylaws, regulations and code of professional conduct under, and in addition to, the general law. The purpose of the RIBA as described in its mission statement is ‘to advance architecture by demonstrating benefit to society and promoting excellence in the profession’, through its vision to ‘champion for architecture and for a better environment’. The object of the code is to promote the standards of professional conduct in the interest of the public and consists of three principles:

1. Integrity
Members shall act with honesty and integrity at all times.
2. Competence
In the performance of their work Members shall act competently, conscientiously and responsibly. Members must be able to provide the knowledge, the ability and the financial and technical resources appropriate for their work.
3. Relationships
Members shall respect the relevant rights and interests of others.

Each of these principles contains a number of rules with guidance about specific aspects of practice. Under Principle 1 architects must act impartially, responsibly and truthfully with regard to their business and professional activities. Under Principle 2 architects are expected to apply high standards of skill, care and knowledge in their work, should only undertake work within their ability and should maintain a comprehensive means for documentation of procedures. Under Principle 3 architects must have regard for fairness and concern for individuals, the community and the environment. They must comply with good employment practice, act fairly and equitably in competitive practice and have in place effective procedures for dispute resolution.

A full version of the RIBA's Code of Professional Conduct can be accessed through its website, www.riba.org.

Interior designers can also prepare design and production information for a building, and provide supervision of work, but, as their title implies, they may be specifically concerned with the interior of a building and need additional advisers in order to deal with all the design and construction processes involved in a total building. Interior designers can be members of the Chartered Society of Designers (CSD). This organisation has codes of professional conduct which reflect ideals equivalent to those of the RIBA.

Building surveyors are sometimes responsible for the design and supervision of certain building work, although they more usually carry out surveys of structural soundness, condition of dilapidation or repair, alterations/extensions to existing buildings and market value of existing buildings. However, it must be borne in mind that the emphasis of their training lies in the technical aspects of building rather than the aesthetic aspects. They may be members of the Royal Institution of Chartered Surveyors (RICS) and will therefore be governed by its code of conduct.

Some architects and surveyors have also been members of the Architects and Surveyors Institute (ASI). This is now a specific faculty within the Chartered Institute of Building (CIOB).

16.3.2 Specialist designers

These include civil and structural engineers, services engineers, and those concerned with specific aspects of architecture, including landscape, interiors, office planning, etc. Civil and structural engineers are employed to assist principal designers on building projects which contain appreciable quantities of structural work, such as reinforced concrete, complex steel or timber work, or foundations which are either complex or abnormal.

Civil engineering can be defined as the construction of roads, bridges, tunnelling, motorways, etc. There is often a certain amount of building work in civil engineering construction and, likewise, many building projects contain civil engineering construction. Structural engineering deals especially with the calculation of the structural parts in a building. When projects consist mainly of structural work, the civil or structural engineer will be the principal designer. They can be members of the Institution of Civil Engineers (ICE) or the Institution of Structural Engineers (IStructE). The Association of Consulting Engineers (ACE) represents the business of consultant engineering companies associated with the built environment. Its provisions include training, professional guidance, legal advice and specialised contracts.

Services engineers work with other designers and are concerned with environmental control: lighting, heating, air-conditioning and sound modulation; electrical installations, plumbing and waste-disposal systems; and mechanical services, such as lift installations and electrical conductors. The Chartered Institution of Building Services Engineers (CIBSE) was formed from an amalgamation of the Institute of Heating and Ventilating Engineers (IHVE) and the Illuminating Engineering Society (IES) with the object of promoting the science and practice of services engineering, as well as advancement of education and research in the field. Electrical engineers are governed by the regulations of the Institution of Electrical Engineers (IEE), and mechanical engineers by the Institution of Mechanical Engineers (IMechE). Table 16.1 indicates some of the services engineers involved in the design of buildings.

Table 16.1 Some services engineers as specialist designers for the environmental control aspects of buildings

Services engineer	Environmental control aspect
Acoustical	Modulation and audio
Air-conditioning	Heating and refrigeration
Communications	Lifts, hoists, escalators, paternosters and conveyors
Catering	Food preparation and service
Drainage	Above and below ground, and water-borne refuse
Electrical	Heating, air-conditioning, refrigeration and lighting
Gas supply	Heating, including industrial applications
Heating	Gas, electric, oil, solid fuel, solar and ambient
Fire protection	Escape and fire-fighting equipment
Lighting	Natural and artificial
Plumbing	Hot and cold water services
Refrigeration	Preservation and installations
Refuse disposal	Storage, chutes, water-borne and disposal
Sanitation	Pest control, appliances and drainage
Security systems	Protective, anti-theft and pilfering devices
Telecommunications	Telephone, security, cable and TV
Thermal insulation	Fabric design and installation
Ventilation	Natural and artificial
Water supply	Availability and storage

Other specialist designers such as landscape architects, interior designers, graphic designers, space planners, acoustical and production engineers are employed according to the type and complexity of the building project. Each discipline is represented by a professional institute or association.

16.3.3 Quantity surveyor

An essential part of any design process involves cost control. The costing services for smaller, less complex building projects are generally provided by the principal designer working in conjunction with the client and specialist designers. However, for larger or more complex projects it is usual that a quantity surveyor is employed to give cost advice and sometimes a cost control service (see Chapter 13). Chartered quantity surveyors are governed by the codes of professional conduct issued by the RICS and, like other members of the Design Team, their fees are paid by the client. The RICS is also the professional body for certain other members of the building profession (e.g. building surveyors, estate agents).

Until recently, no country, other than the United Kingdom, regularly employed a quantity surveyor for building projects. The quantity surveyor's primary role is to prepare a bill of quantities from the drawings and specifications supplied by the Design Team. This itemises the type, form and amount of materials to be used in the construction project. The bill (see section 17.3) will also define the legal requirements for the project, including the form of contract to be adopted between the client and the contractor. The whole document, together with relevant drawings and specifications supplied by the Design Team, will therefore provide a good basis for obtaining prices for the project from a number of interested contractors (competitive tendering).

Prior to the work on the bills of quantities, the quantity surveyor may be expected to give cost advice on any alternative solutions that may be considered during the various stages of the design of a building. Also, during the actual construction period for a project, the quantity surveyor must measure and value the work carried out at regular (monthly) intervals, and submit details to the overall financial administrator (usually the principal designer) for interim payments from client to contractor. The quantity surveyor also advises on the use of sums of money listed in the bill of quantities for contingency or provisional items, the cost of making variations in areas originally described in the bills or indicated on the drawings, and settlement of the final account for the finished project.

16.3.4 Student assistants, technicians and technologists

Principal and specialist designers, as well as quantity surveyors, often employ students of their individual profession to assist them in their work. The students are mostly post first-degree standard and, as such, their work will require close supervision by suitably qualified staff within an organisation. If a part-time or sandwich mode of professional education is not available, the use of this type of assistant may be limited to university vacation times, or the periods designated as 'time out' for practical training such as is required by the RIBA and CSD examining boards.

Greater continuity of assistance may, however, be provided by technicians and technologists that are specially experienced in a number of areas concerned with the design features of a building and the subsequent inspection of construction or installation work. According to qualifications and experience, they may be responsible for carrying out surveys, technical feasibility studies, as well as the preparation of designs, working drawings and models. They can also be involved in cost analysis, obtaining legal approvals, contract administration and assisting with site inspections. The Chartered Institute of Architectural Technologists (CIAT) represents specially qualified and trained architectural, structural engineering and quantity surveying personnel. Nevertheless, as far as architecture is concerned, it is important to recognise that technical performance and production are skills that differ from those of architectural design.

16.3.5 Methods of operation

Principal designers, specialist designers and quantity surveyors can work in private practice either as part of a single-discipline firm, or as part of a larger multi-discipline firm. They can also be employed by public bodies such as central or local government, by major and industrial firms, and by building contractors. The fees of the designers and quantity surveyors are paid by the client at prescribed intervals related to the stage of development in a project. But where they are employed as part of a large organisation, these fees will be absorbed as part of the overall charges and paid to the consultants as a regular salary. Depending on the precise nature of a project, and as a rough guide, the combined cost of these professional fees, including cost-planning advice, will vary from 12 per cent to 20 per cent of the final construction costs (see section 17.6).

Table 16.2 briefly summarises the sequence of events for a building project, where the principal designer is the team leader. For small uncomplicated contracts, say less than 500 m^2 floor area, principal designers may perform all the functions of the Design Team. They will establish the brief, appraise the building requirements, obtain approvals, provide sketch schemes, develop them in detail, present them for evaluation to the client, provide drawings and provisional assessments, compile the production information and supervise the job on site. A shortlist of builders will price from detailed specifications and key drawings, and the successful builder will provide a breakdown of the price and the schedule of rates for the main activities. For medium-sized contracts, say 500–2000 m^2 floor area, the principal designer will probably work in conjunction with the quantity surveyor. The principal designer is normally selected first and is responsible for the design and management of the project. The quantity surveyor can be appointed on the recommendation of the designer or chosen separately. The designer and quantity surveyor together

Table 16.2 Sequence of events for small building projects adapted to the format of the RIBA plan of work

Plan of work stage	Principal designer	Specialist designer	Quantity surveyor (QS)
A Appraisal	Agree extent of work to be done, financial arrangements and appointment with client	–	–
B Design brief	Elicit all information by questionnaire, etc., from client Carry out studies on site-user information, e.g. boundaries, rights of way, rights of light, easements, services, etc. Make particular enquiries to local authority regarding planning approvals, preservation orders, site lines, availability of services, etc. Prepare feasibility report and present to and discuss with client	Provide initial guide about possible factors influencing design and cost of proposals Assist in preparation of feasibility report and if required help in presentation to client Agree fee for services	Agree extent of work to be done, financial arrangements and appointments with client Produce cost area guides, i.e. cost per m^2 or m^3 Advise on alternative cost factors Discussions on financial aspects of specialist designer's discipline
C Concept	Study circulation and space problems for site and proposed building Try planning/massing solution and investigate alternative costs Produce diagrammatic analysis and discuss problems Try out various general solutions indicating critical dimensions and mean-space allocation Contribute to, prepare and present report to client	If not already done, agree condition of appointment with client Provide more detailed information on design and cost problems Assist in preparation of outline proposal	Estimate cost of project based on outline plans and brief specification Provide cost evaluation of elements for designs as they develop Provide comparative cost information relative to possible alternative materials and construction techniques Prepare elemental cost at sketch design stage and estimate of building cash flow
D Design development	Complete outstanding user studies Consult other members of design team Prepare full scheme design, taking individual and group advice Receive and discuss proposals of specialist designers and QS Prepare presentation drawings and obtain client and other members of Design Team approval Prepare more detailed drawings for local/central government approvals	Formulation of accurate information regarding space and dimensional requirements Detailed negotiations with principal designer, other specialist designers and QS Preparation of preliminary drawings, specification and schedules indicating proposals; assist with presentation to client Negotiations for local/central government approvals	Evaluate design within cost plan limits Prepare preliminary measures of quantities Advise on alternative cost factors Discussions on financial aspects with specialist designers Advise on running cost for proposed building
E Technical design	Complete user studies Complete final design Close cooperation with specialist designers and QS	Finalise drawings, specification and schedules Close cooperation with principal designer, other specialist designers and QS	Detail consultation with principal and specialist designer
F Production information	Prepare drawings, specifications and schedules Agree drawings, specifications and schedules of specialist designers Close consultation with QS, agree subcontractors and suppliers	Assist with incorporating requirements into principal designer's documents Advise on suitable subcontractor, etc.	Assist with cost information for principal and specialist designer's drawings, specification and schedules Checks on cost factors, agree subcontractors and suppliers

G	Tender documentation	Complete all information for QS including contractual arrangements Assist in completion of bills of quantities	Assist with preparation of bills of quantities Advise on form of contract, methods of payment, etc.	Preparation of specification and bills of quantities Advise on forms of contract, methods of payments, etc.
H	Tender action	Agree list of suitable contractors with client and other interested parties In conjunction with QS issue tender documents and answer queries arising Receive tenders and consider with QS If necessary, interview short-listed contractors Report to client with recommendation of appointment of contractor, adjustment or retendering Draw up and arrange for client and contractor to sign contract documents	When appropriate, advise on selection of contractor and/or subcontractors Assist with recommendation for appointment of contractor	Assistance with list of suitable contractors and issue of tender documents Check arithmetic and content of tenders from contractor Prepare detailed report on tenders for principal designer and give recommendations regarding acceptance, adjustment or retendering Assist in drawing up contract documents
J	Mobilisation	Prepare list of critical dates for contractor's programming and pass on sets of contract and construction information documents to contractor for use on site Arrange start of work and inform site inspectorate	Assist in preparation of critical dates for contractor's programming and supply all necessary information for contractor through principal designer Brief contractor when necessary	Supply cost information relative to site organisation Agree programme of certification with contractor Advise on contract interpretation
K	Construction to practical completion	Hold regular site meetings using agenda and minutes Give general supervision and negotiate with subcontractors Issue instructions and certificates for payment in consultation with QS Keep client informed of progress and financial reports Obtain approvals for increased costs and time for completion Agree completion of work with QS and contractor Agree final costs and prepare statement Arrange for any defects to be rectified Arrange for final payments	Attend regular site meetings Provide general supervision and negotiate with subcontractors Issue instruction and certificates for payment through QS and principal designer Prepare progress reports Obtain approvals for increased costs and delays in contract Agree completion of work with contractor, principal designer and QS Agree final costs for their work and prepare statement Arrange for any defects to be rectified Notify principal designer and agree final payments	Attend regular site meetings Measure and value work in progress for interim payments Provide cost advice on and measure and value instructions and variations Agree costs involved in delays in building programme Agree completion of work with contractor, principal and specialist designer Prepare final account in agreement with contractor Agree final payment following rectification of any defects Prepare elemental cost of finalised building based on final account
L	Post practical completion	Prepare building owner's manual Arrange for storage of contract documents	Assist in preparation of building owner's manual Arrange for storage of contract documents	Assist in preparation of building owner's manual Advise on running costs of building

undertake a general appraisal of the building requirements. For large projects, say over 2000 m^2 floor area, the Design Team will comprise the principal designer(s), quantity surveyor(s) and specialist designers; the skills of the specialist designers are related to the particular complexity of the projects. Where circumstances are such that the principal designer is not the leader of the team in so far as management function is concerned, then various divisions of responsibility should be made to all members of the team at the outset of a project (see pages 163–167).

16.3.6 Professional liability

Principal designers are the conventional leaders of the Design Team because, following the client's instruction, they normally produce the design of a building. In this case it is also their responsibility to supervise and coordinate the production of all drawings, schedules and specifications, thereby ensuring the project is carried out in accordance with their aims for the design. Principal designers should make certain that adequate information is available to other members of the Design Team, so decisions relative to the continuity of work can be made at the right time. They must also try to foresee, as far as is practicable, the problems likely to arise and take action on unplanned eventualities. Being leader of the team, therefore, the principal designer must take the ultimate responsibility for the project. Accordingly, any deficiencies which may occur as a result of any design and construction decision, or mismanagement of associated contracts, often make the designers liable to legal claims for negligence. This may appear to be perfectly reasonable, but must be considered with some caution depending upon current legal interpretations of what constitutes the reasonable 'skill and care' which should be exercised by designers in the performance of their duties. Certain claims for negligence are just, but it must be remembered that design and construction processes involve innumerable value judgements when balancing the demands imposed by various performance requirements for a modern building. Each demand can only be satisfied at some expense to others. Also, the liability of principal designers often extends into the work of others, in that there is a responsibility for inspection and therefore acceptance.

The Civil Liabilities (Contribution) Act makes provision for a writ to name all and any party who might conceivably have any degree of liability for negligence in connection with a claim. Furthermore, the designers are currently liable for life for the cost implications (including inflation costs) arising from the errors in decisions made. In the event of a belated claim, the identifiable personal estate of the principal designer may even be penalised after his or her death. It is therefore necessary to take out professional indemnity insurance against possible claims, and when unlimited liability periods are required the premiums are very high. Furthermore, it is recommended that designers retiring from private practice continue this insurance cover, although once they are no longer practising it will be given at a slightly lower premium year by year.

16.4 Research Team

Any synopsis of the Building Team, however brief, must include reference to those members who make understanding and development of current construction methods (materials and technical ability) possible, i.e. the researchers. The process of building has moved from a craft-based art towards a science-based technology over a period of about 100 years. Latterly this is particularly true in the environmental science areas of energy usage, thermal comfort, sound control and lighting, where quantifiable criteria have found application in the design of the external envelope of a building.

The function of building research through government agency was begun in the United Kingdom in 1921 when the Building Research Station was founded, now known as the Building Research Establishment (BRE). The aim of the research is to discover facts by means of scientific study and, in matters concerning building, it covers a very wide area of knowledge requiring controlled programming of critical investigation of chosen subjects. The BRE regularly publishes information, current papers and monthly digests (Building Research Establishment Digest) about its work.

The BRE has numerous fields of study and provides an advisory service to the Building Team providing information which includes the following:

- Building materials Research into old materials and new materials to produce an advanced scientific knowledge of their structure and behavioural characteristics so as to produce economic advantage in use.
- Structural engineering Concern with the problems of design, serviceability and safety related to cost.
- Geotechnics Provision of a rational set of principles and analysis to help structural engineers to design a wide range of structures in and on the ground with a calculated risk and with economy.

- Mechanical engineering Investigations into the mechanisation of the building process and the development of new production equipment, and methods and study of new building plant.
- Environmental design Study of the physical environment in and around a building, including research on human needs, the physics of building, and design and development of engineering services, bearing in mind the relevant cost implications.
- Building production Concern with the use of resources of capital, materials and labour for new building, the maintenance of old buildings, and life-cycle costs.
- Urban growth Study of problems associated with urban growth, either in new and expanded towns or in sectors of existing towns.

Separate bodies associated within the BRE also make special studies:

- Fire The Loss Prevention Certification Board (LPCB) undertakes studies concerning the behaviour of people subjected to the effects of a building fire and smoke; evaluation of fire statistics; undertaking fire tests; identifying and quantifying fire and explosion hazards, and methods of reducing them; evaluating the performance of structures in fires in relation to future design guidance and the compilation of legislation.
- Timber technology Investigation into the properties and performance of wood, wood-based products and similar materials used in lightweight components; problems relating to the processing of home-grown

timbers and jointing components; understanding of the causes of deterioration of wood and wood products with the aim of reducing loss by the evaluation of preventative, remedial and preservative treatments; timber grading by quantifiable stress criteria and the effective design of timber structures.

There are many other advisory bodies allied to the construction industry which are prepared to supply informed opinions on specific problems. Like the BRE Technical Advisory Service, they charge a fee and include the Construction Industry Research and Information Association (CIRIA) which often helps to finance research into aspects of construction by allocating funds to universities, other research bodies and industrial organisations. The Building Cost Information Service (BCIS) provides a cost analysis service and issues reviews of building costs; the RIBA Enterprises provide subscribers with access to a wide range of technical and practice documentation; and the Society for the Protection of Ancient Buildings (SPAB) advises (without charge) on possible listing of old buildings, as well as giving recommendations concerning technical aspects of conservation.

Research and development organisations also exist which are sponsored by industries to promote the scientific and aesthetic use of particular materials. These organisations include the Brick Development Association (BDA); Clay Roofing Tile Council (CRTC); Timber Research and Development Association (TRADA Technology Ltd); British Woodworking Federation (BWF); Constructional Steel Research and Development Organization (CONSTRADO – Steel Construction Institute); British Cement Association

(BCA); and Gypsum Products Development Association (GPDA). Other organisations promote the use of data concerning the use and specification of suitable and tried construction methods as well as many other aspects, including documentation methods, testing procedures and the legal requirements associated with the building process. These include the National House Building Council; National Building Specification; Concrete Society; Fire Protection Association; Chartered Institution of Building Services Engineers and the Chartered Institute of Building. These and many other organisations, too numerous to mention here, can supply information which assists in making critical decisions during design and construction processes.

More detailed reference must be made to the importance of the British Standards Institution (BSI) and the British Board of Agrément. The basic function of the BSI lies in the preparation and promulgation of British Standards covering nearly all aspects of productive industry. These standards represent the recommendations made by specialist committees of interested parties in a particular subject and, for the building industry, cover dimensions, quality, performance, safety, testing, analysis, etc., of materials, components and methods of assembly or construction. Standards relating to materials and components are known as specifications, standards for methods of assembly as codes of practice. More and more products carry the now familiar Kitemark, the registered BSI symbol, which implies that the product concerned has been tested and found to meet the appropriate requirements. Furthermore, British Standards recommendations regarding appropriate methods of construction frequently form the basis of the mandatory minimum requirements contained in the Building Regulations.

The United Kingdom is part of the European Union, and many British Standards have been harmonised with the Comité Européen de Normalisation (CEN) requirements for European standardisation, e.g. BS 65 on vitrified clay pipes for drains and sewers is replaced by BS EN 295. Many European products carry a CE mark, which signifies safety, durability and energy efficiency. This should not be treated as a mark of performance and is not intended to substitute for the BS Kitemark. International standards are also available. They are prepared by the International Organization for Standardization and are prefixed ISO followed by a reference number, e.g. ISO 2808: Paints and varnishes. It is also possible that British, European and International Standards have comparable objectives, e.g. BS EN ISO 9288: Thermal insulation.

The principal objective of the British Board of Agrément, which employs the resources of the BRE and other organisations, is to help to bring into general use in the building industry new materials, products, components and processes. Accordingly, the Board offers an assessment
service based on examination, testing and other forms of investigation. The reports include details of the methods of assessment and testing. The aim is to provide the best technical opinion possible within the knowledge available, and those innovations satisfying critical analysis relative to their intended performance are issued with an Agrément certificate. Products or processes already covered by a British Standard do not normally fall within the scope of the

Agrément Board; items to be covered by a British Standard will be issued with a certificate renewable after three years.

Agrément certificates, therefore, not only supply a critical analysis of new materials, products, components and processes for members of the Design Team, but also further the production of new British Standards and often provide proof that certain innovations suit the requirements of the Building Regulations.

16.5 Legislative Team

16.5.1 The planning process

Modern planning for development originates from 1947 legislation which required all local planning authorities to determine development plans for their specific areas. It also required formal applications for permission to build. Procedures are now effected by the Town and Country Planning Act of 1990, through central government, county planning authority and district planning authority (the local authority).

- Central government is represented by the Department for Communities and Local Government (DCLG). Administration of government town and country planning policy is under The Planning and Compulsory Purchase Act 2004 and The Planning Act 2008 through departmental circulars or Planning Policy Statements (PPS’s). These refer to such issues as housing policy, green belts, telecommunications,

recreation facilities, highways, transportation and industrial, retail and commercial development.
- Subdivision of government planning policy has been administered and effected through strategic regions. In England the nine regions are shown in Figure 16.4. However, the government are seeking to revise regional planning strategies in favour of a 'Localism Bill' devolving greater powers to councils and communities.

Regional planning bodies prepare a regional strategy for submission to the Secretary of State for public consultation. Subject to amendments, the strategy is finalised for presentation to sub-regional district (local) planning authorities. Their main responsibility is to produce a Local Development Framework (LDF) for the area and to process all but the most complex of planning applications, as detailed in Planning Policy Statement 12: Local Spatial Planning. The LDF comprises a portfolio of Local Development Documents that set out a strategy for land use and development. The documents include draft plans for development and use of land. These are available for public consultation before modifications are submitted and approved by the government office for the area. Prior to final acceptance, a public inquiry is held in the presence of an inspector appointed by the DCLG. Subject to the inspector's report and modifications, the plan becomes mandatory.

Figure 16.4 Regional subdivisions for England.

LDFs and planning applications may be referred to the Secretary of State where matters remain unresolved at a lower level. Where a planning authority is found to have acted unreasonably, the Secretary of State can award costs against the authority.

16.5.2 Application to build

After the client's brief for a building has been established, it will be necessary for the Design Team to start negotiation with the local authority in which it is to be situated in order to clarify certain legal requirements. The location and design of a building are controlled by the planning authority, and the construction by the building control department. These are supported by many other legal
requirements concerning fire precautions, clean air, highways, factories, offices, shops, railways, etc.

Although in theory a designer must be conversant with all the legal requirements affecting a building, this can be an impossible task. There are probably more than a thousand Acts of Parliament which make reference to the building process and at any time during the course of construction (and even after occupation) a building is liable to be inspected by such diverse officials as factory inspectors, health and safety inspectors, water inspectors, petroleum officers, planning and building control officers, fire-fighters and police officers. Although not necessarily guaranteeing the avoidance of demands being made during a late stage of construction, demands which cause additional expense and loss of building time, it is the responsibility of a designer to be aware of the relevant legislation influencing the design of a particular building. At least this awareness means that contact can be made with the appropriate controlling person or organisation for specific advice during the various design stages of a building.

Town and Country Planning Acts are administered through the local authority by professional planners who are members of the Royal Town Planning Institute (RTPI) and perhaps the RIBA. In dealing with the creative, environmental, social and administrative aspects of planning, the planning officers frequently employ specialist advisers, e.g. sociologists, ecologists, statisticians, economists, planning technicians, geographers, architects, graphic designers and landscape architects.

Initial advice will be given on the suitable location of a building in a selected area, zoning; amount of building permitted on a particular site (plot ratios and densities); the influence of previous planning decisions affecting the site; tree preservation; car parking; building lines; general public circulation; road widths and proposed widenings; and changes of use from one activity to another. Advice will also be given when work is to be carried out on existing buildings of special architectural or historic interest. Under the Planning (Listed Buildings and Conservation Areas) Act, such buildings will have become listed by the local planning authority in an effort to safeguard heritage, and any proposed demolition, extensions, alterations or modifications require special consent through the Listed Building Consent procedure. Listing places a responsibility on owners to ensure that their buildings are maintained properly and not altered or demolished. Selection may be for architectural or historic reasons, constructional style or as a valued part of an attractive grouping. Most listed buildings are Grade II, but where they have exceptional features may be II*. Grade I listings include buildings of exceptional interest which could be town halls, churches and country houses.

A building preservation notice can also be served on any individual when a building of special interest is pro posed for demolition. Indeed, whole areas of countryside and urban development can be designated or zoned as a conservation area, and either no development permitted or only that permitted which is necessary for overall maintenance of features required to be preserved. Local authorities have a statutory responsibility to designate areas of conservation. Within these, even the smallest scale of works will require planning permission, i.e. Conservation Area Consent. This includes building a porch, replacing windows or minor alterations which outside of conservation areas may be allowed without planning permission (permitted development). Some planning authorities also issue guidelines about the appearance of a proposed building in an attempt to control the general character of a neighbourhood. (See DOE Circular 8/87 Historic Buildings in Conservation Areas: Policy & Procedures and DCLG Planning Policy Statement [PPS 5]: Planning for the Historic Environment.)

Having incorporated the requirements of the planning officer (or negotiated compromises), a formal application can be made, which consists of a set of drawings indicating proposals and documentation giving details of ownership (certificate of ownership, under Article 7 of the Town and Country Planning Act), land usage, densities, etc. If the application is successful, permission will be granted for the proposals to commence construction as far as the provisions of the Town and Country Planning Act are concerned. Planning applications can be made in two consecutive stages, a fee being paid to the local authority for each according to the size of the proposed projects. Outline planning consent gives permission to the principle that a building, as yet not designed in detail, may be erected in a certain locality, e.g. a shop or office in an area or zone of an urban area designated for commercial usage; full planning consent gives permission for a specific building to be erected when precise details are finalised and proposals are known.

Particular applications for industrial and office buildings have been accompanied by government-issued development certificates and permits, respectively. This procedure was devised to regulate the effects of industrial development and to focus this type of occupational facility to areas of high unemployment. Currently, the Industrial Development Advisory Board consider such plans and proposals in a consultancy role and as advisers to the Department for Business, Innovation and Skills (BIS).

The Town and Country Planning Act stipulates that a decision of approval or rejection of a project should be given within eight weeks of receipt of application, but most authorities currently request an extension of this period rather than formally rejecting a proposal owing to the lack of sufficient time for detailed consideration. Appeals against rejections, or any conditions imposed on a consent, can be made to the Secretary of State.

16.5.3 Building control

Building control legislation in England and Wales (Scotland and Northern Ireland have separate systems) is covered by the Building Act 1984 and the Building Regulations 2010. The

Act is a consolidating statute drawing together requirements previously found in such documents as the Public Health Acts 1936 to 1961, the Health and Safety at Work, Etc., Act 1974, the Fire Precautions Act 1971 and the Housing and Building Control Act 1984. The Building Act calls for a series of Approved Documents (see Table 16.3) to give practical guidance on some of the ways of meeting building control requirements and these combine to form the basis of the Building Regulations. The main purpose of the regulations is to ensure the health and safety of people in or about a building, although the regulations are also concerned with energy conservation and access to buildings for the disabled.

Building work controlled by the regulations includes new buildings, extensions and material alterations to existing buildings, as well as the provision, extension or material alteration of controlled services or fittings and the work required for a change of use. Certain small buildings and extensions (normally under 30 m^2 floor area), and buildings used for special purposes, may, subject to local requirements, be exempt from the regulations. These can include conservatories, sheds, greenhouses, carports and porches.

Table 16.3 Approved Documents to the Building Regulations

Approved Document	Application
A	Structure
B	Fire safety
C	Site preparation and resistance to contaminates and moisture
D	Toxic substances
E	Resistance to the passage of sound
F	Ventilation
G	Sanitation, hot water safety and water efficiency
H	Drainage and waste disposal
J	Combustion appliances and fuel storage systems
K	Protection from falling, collision and impact
L	Conservation of fuel and power
M	Access to and use of buildings
N	Glazing – safety in relation to impact, opening and cleaning
P	Electrical safety – dwellings

Also:
Approved Document to support Regulation 7 – Materials and workmanship.
Thermal insulation: avoiding risks, 3rd edition, BRE Report 262.

To ensure compliance with the provision of the regulations, the Client Team (acting on the advice of the Design Team) can have the work approved and supervised under construction by the local authority or by a privately employed approved inspector acting with the local authority. The two methods are independent and affect the way in which initial building control approval is sought.

Under local authority building control, two main options are available. One is full plans procedure requiring the deposit of working drawings for approval, to be given conditionally or in stages within five weeks, or, by agreement, within eight weeks. Although having the drawings passed gives some protection in the event of subsequent problems, there is no need to wait this long before starting work. The alternative option involves giving a building notice to the local authority who may then ask for drawings such as a location plan or structural calculations to help it when inspecting the work. This procedure is generally used for small domestic works. It is not permitted for the construction of shops, offices, where fire certification is required (Regulatory Reform [Fire Safety] Order 2005) and when building over or near to (within 3m) a public sewer. For both options, 48 hours' notice must be given before work commences and, if the local authority considers that the regulations are contravened at any stage, it must serve a notice requiring rectification, unless it has approved the drawings. There are procedures for challenging the views of the local authority. A certificate is issued on satisfactory completion of the work.

When the local authority is fully involved in this way, building control officers, inspectors or district surveyors (term used for building control personnel in London) will inspect the work during the various stages of construction to ensure compliance with the regulations. These stages are shown in Figure 16.9. Inspectors are usually members of the RICS, the CIOB, the Association of Building Engineers (ABE) or have qualifications recognised by other professional bodies concerned with the construction of buildings. Some building designers may wish to discuss proposals for use of materials or certain constructional strategies with these officials prior to the submission of drawings. A fee is payable to the local authority for this whole approval process as prescribed in the Building (Prescribed Fees) Regulations. Instead of seeking local authority approval, which involves checking calculations, etc., certificates of compliance can be supplied instead. These are prepared by approved persons, who are professionals in those areas of design (members of CIBSE or IStructE).

The alternative method of obtaining approval under the Building Regulations, using the privately employed approved inspector, requires the submission of an initial notice to the local authority. This notice must be accompanied by certain drawings and evidence of insurance. The local authority must accept or reject the initial notice within 10 working days, and once accepted, its powers to enforce the regulations are suspended. It becomes the duty of the inspector to notify the Client Team if the work contravenes the regulations. If the defective work is not remedied within three months, the initial notice must be cancelled. On satisfactory completion of work, the inspector issues a certificate to the local authority and the Client Team.

The fee payable to an approved private inspector is a matter of negotiation with the Client Team. Currently most approved inspectors come from the National House Building Council (NHBC). However, there is increased interest from many professional bodies, including the ABE, CIOB as well as RIBA, ICE, IStructE and RICS.

In addition to the Building Act and Building Regulations, a designer may need to consult the inspectors who administer the many other acts directly affecting the building process.

These include the Office, Shops and Railway Premises Act; Factories Act; Clean Air Act; Chronically Sick and Disabled Act; Civil Amenities Act; Noise Abatement Act; Licensing Act; Housing Acts; and the Health and Welfare Acts, etc. There are also peripheral 'laws' in respect of cost, dimensional coordination of certain building types and costs allowances (yardsticks). Account must also be taken of the recommendation and requirements of the utilities suppliers: gas, water, electricity, telecommunications, drainage, and public services such as fire and police. The rights of the building owners or landowners adjoining the site of a proposed building are also protected by legislation and require attention from a designer: rights of light, rights of way, trespass during construction, etc.

A building site can be a place of danger if care is not taken or there is a lack of experience at the management level. There is a vast amount of legislation related to this problem, but currently the principal acts are the Factories Act 1961; the Office, Shops and Railway Premises Act 1963; and the Health and Safety at Work, Etc., Act 1974. These statutes incorporate many other significant regulations, known as Statutory Instruments. These include:

- Management of Health and Safety at Work Regulations.
- The Construction (Design and Management) Regulations.
- The Construction (Head Protection) Regulations.
- Lifting Operations and Lifting Equipment Regulations.
- The Construction (Health, Safety and Welfare) Regulations.

- The Work at Height Regulations.
- The Manual Handling Operations Regulations.
- The Personal Protective Equipment at Work Regulations.

These acts and their subsidiary regulations require the builder and client to ensure that the building site maintains safe and healthy conditions for employees. Emphasis is on an assessment of risks by all involved in the construction process. Specific work situations are defined in the regulations, in addition to provision of adequate air quality, safe use of transport and traffic facilities and site accommodation sufficient to include first aid and other welfare installations. Further emphasis is on good site management, documentation of proceedings and organised planning. The general public should be adequately protected from dangers resulting from site operation. The regulations should be on display for employees to read, and adequate instruction must be given to ensure safety consciousness. The Health and Safety Executive (HSE) has inspectors empowered to enter, inspect and examine a building site at all reasonable hours and to make examinations and enquiries to ensure compliance with the regulations. Inspectors must be informed when serious accidents occur, or when disasters happen such as when cranes or lifting appliances collapse, or if there is any fire or explosion.

The client is required to appoint a competent CDM coordinator to inspect and supervise certain construction activities (see section 15.1.2). Most of the larger building organisations will also have a safety officer, either employed or under contract from a group safety scheme. This officer will visit site offices, workshops and site works, liaise with site personnel and, where necessary, report to the organisation's safety committee and to the local authority factory inspector.

The Design Team also has legal responsibilities under the Health and Safety at Work, Etc., Act 1974 because its projects must not create hazards for building operatives during construction. Although this may influence a change between initial concepts and the final design, the safety requirements are entirely reasonable. A building organisation has the right to refuse to allow its employees to become involved in its construction methods which are liable to be dangerous.

16.6 Manufacturing Team

The Manufacturing Team supplies the materials, components and equipment which are used during the construction processes of a building, and therefore incorporates many organisations and interests. Traditionally, construction processes relied on the supply of readily available materials easily converted into manoeuvrable forms or sizes which could be adapted further by skilled workers on site to suit a particular design. With the need to economise in labour and reduce costs, building procedures became more rationalised. Materials were formed into readily usable components during manufacturing processes, and were assembled with few adaptations after delivery to site. This rationalised traditional construction procedure reduced the number of separate operations and saved time on site.

However, the continual advancement of technology and increases in complexity and size of buildings has generated ever more complex construction processes. Manufacturers must extend their services from the supply of single components to the supply of much larger parts of a building (elements), and indeed whole buildings. Site operations are reduced to a minimum using mechanical plant, and methods of building become largely concerned with the organisation of the systematic supply and assembly of prefabricated items, i.e. system building (see also section 13.1).

Some manufacturers produce items which will not normally fit with the components of other manufacturers, and the resulting method of building is commonly known as closed-system building. When component design is coordinated between the manufacturers of different products so that they can be used together without alterations, or become interchangeable, the building method is called open-system building.

The purpose of this brief account of an aspect of the evolution of building processes is to indicate the vital role which the Manufacturing Team has on the design and development of a building (see Fig. 16.2). In many respects, its members should be members of the Design Team. Generally, however, manufacturers are often only concerned with the entire suitability of their particular product as it leaves the factory, and it is up to the Design Team to assess its performance relative to other criteria. (Mention has already been made of the influence of the Research Team and construction specialist in assisting the work of the Design Team in this area.) Whether producing materials, equipment, components or building systems, Manufacturing Teams often incorporate their own research and development organisation to test products. Manufacturing Teams will also employ public relations organisations to produce information about their products for circulation to members of Client, Design, Research, Legislative and Construction Teams.

16.7 Construction Team

A study of building workers carried out by the Building Research Establishment lists over 50 separate occupations associated with construction. Therefore, the erection of a building depends on an industry where total reliance is placed on the diverse attitudes, abilities and adaptability of its workers. Conventionally, these workers were grouped under 'trade' headings according to their skills (Table 16.4), and 30–40 years ago most were employed by a main contractor managing and directing all works on a site using a general supervisor to coordinate the work of each trade or subcontractor supervisor. Today most specialist trades are employed as nominated subcontractors by the client or principal designer on behalf of the client; relatively few key trades are employed directly by the main contractor as ordinary subcontractors (known also as non-nominated subcontractors or domestic subcontractors).

Table 16.4 Basic list of trades required for erection of a simple building

Trade	Job
Asphalter	Roof, floor and wall (basement) finishes
Bricklayer	Laying brick and blockwork
Carpenter	Structural and carcassing timber work
Concretor	Placing concrete
Drainlayer	Providing below-ground drainage
Electrician	Electrical installation, inc. telecommunications (interior)
Floor/wall tiler	Internal floor and wall finishes
Gas-fitter	Gas installation
Glazier	Fixing glass
Groundworker	Levelling site and digging drain/foundation trenches
Joiner	Timber work to finished components
Metalworker	Sheet metal applications (roofing)
Painter and decorator	Finishing components
Paver	External paths/road finishes
Plasterer	Plastering walls/ceilings, screeding and rendering
Plumber/heating engineer	Plumbing installation, flashing and gas pipes (interior)/central heating
Scaffolder	Erecting scaffolding and working platforms
Steel erector	Erecting steel columns and beams
Steel fixer	Cutting, shaping and positioning steel reinforcement
Tiler and slater	Roof finishes

Nominated subcontractors may be required to design and provide specialist elements within a building from a statement of performance requirements, but the main contractor is still entirely responsible for the satisfactory completion of the work involved. It is also quite common for the client or principal designer on behalf of the client to employ nominated suppliers for certain specialist materials, components or equipment which are to be used or fixed into position by the main contractor.

Although this system of site organisation remains normal with most small and many medium-size building firms, there is an increasing tendency for the larger main contractors to become building managers, responsible for the coordination of the erection of a building using only nominated subcontractors or suppliers. Perhaps the main reason for this is the fact that the continuous employment of their own trade operatives cannot be guaranteed during periods of economic recession. Enforced redundancies are sometimes contractually difficult and likely to prove expensive.

16.7.1 Available skills

The training of skilled building workers has traditionally been very much a matter for employers and unions. The City & Guilds of London Institute has a long history of examining for skilled building workers. It now joins others to provide syllabuses and training courses for National Vocational Qualifications (NVQs), which form the basis for college and employment assessment. In order to compete with the other employment areas in terms of time-related earning power, the basic apprenticeship period for skilled building workers was reduced and has resulted in a gradual but continuous 'deskilling' of traditional crafts. Furthermore, the greater emphasis now being placed on academic subjects in secondary schools, together with the unattractiveness of adverse climatic conditions on exposed UK construction sites, has resulted in far fewer recruits than previously. Government attempts through the Construction Industry Training Board (CITB) and the Training Services Agency (TSA) have endeavoured to boost training of skilled staff. So has the trend towards providing an artificial climate around a building site by transparent protective sheeting, or moving most processes into a factory producing preformed units for final and speedy erection on site. Nevertheless, the reduction of practical tests in favour of the theoretical assessments of craft skills and technical knowledge has produced building managers rather than craft operatives.

The importance of the move away from the traditional skilled building workers on site lies in the need for building designers to concentrate earnestly upon the selection (or implementation) of suitable construction methods which are known to be realistic, relative to the depth of practical expertise likely to be available at the time when a project is to be erected. There is therefore an even greater need than before for close consultation between Design Team (including quantity surveyor) and Construction Team, especially if hitherto untried materials and/or techniques are being contemplated. If this is not possible, the Design Team must include sufficient expertise (perhaps through specialist designers) to be able to supply a potential main contractor with more detailed specifications and drawings of the chosen construction method than perhaps was necessary for corresponding innovations in the past.

Notwithstanding the above comments concerning the role of trade skills, it is important to realise that mechanisation based on the development of petrol, diesel and electric engines, pneumatic and hydraulic engineering, has influenced building methods considerably. In recent years mechanisation has become universal on site: excavators have replaced hand-digging of foundation trenches; mechanical hoists have largely replaced the necessity to carry materials up ladders by hand; pumping techniques make concrete more manoeuvrable without the need for wheelbarrows; cranes transport large building components; hand-held power tools have replaced hammer and chisel; mobile heaters have been introduced for drying out, etc. Indeed, certain building techniques rely on the use of equipment specially designed to carry them out. The increased use of plant or machines means that semi-skilled operatives are often in the majority on a building site. However, completely unskilled activities still remain, mainly to service skilled and semi-skilled workers; they are fulfilled by labourers.

There are many organisations and associations that collectively represent the business interests of contractors and the trades. These include the following:

- National Federation of Builders
- Civil Engineering Contractors Association
- Major Contractors Group
- National Contractors Federation
- British Woodworking Federation Scottish
- Building Federation
- UK Contractors Group

The benefits of membership include help and advice, business solutions, publications, bookshop, workshops, seminars and an opportunity to advise the government and represent the industry on policy.

The Confederation of British Industry (CBI) represents the interests of about 250 000 UK-based businesses, including many construction companies. As a joint industry organisation, the CBI has considerable resources and is representative in matters relating to local and national government policy.

Professional qualification for individuals in the building industry is through membership of the CIOB. The CIOB concerns itself with promoting education and management training for a diversity of disciplines within the construction industry. It is UK based, but its 40 000 members are represented worldwide. Membership benefits are extensive, including activities at local and national level.

16.7.2 Types of building organisation

The term 'main contractor' used earlier will now be investigated in greater detail since, for the efficient and economic construction of a building, it is imperative that the right type of organisation is selected. Criteria generally relate to size and complexity of the project in hand, although the speed with which it can be erected and the special resources which may be provided by a particular builder play an important role in selection.

The sometimes loose separation between a simple and complex project relates more to the intended purpose (design) of the building rather than actual size. Single or predominantly single-storey projects are not necessarily simple buildings, and multi-storey or large-span projects not necessarily complex. The general configuration of a building, the amount and degree of complication of the services it accommodates, the characteristics of the site, and the complexity or otherwise of the construction method are more accurate divisions between simple and complex. The selection of a suitable builder may additionally be influenced by members of either the Client Team or the Design Team who may have preference for a builder with whom they are familiar. Generally, however, the available range of suitable builders can be narrowed by their ability to build a particular project to suit the intended financial outlay allocated to it.

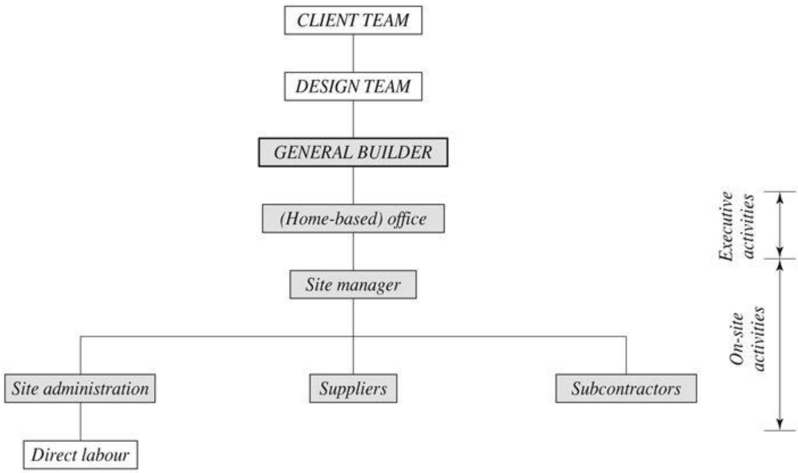


Figure 16.5 General builders.

Although it may be more complicated, as just explained, main contractors can be divided into three basic groups: general builders, general contractors and design and construction companies. Currently, each could be coordinated by building managers, but this role is mostly associated with the larger organisations of the latter two groups. All could therefore employ trade operatives as part of their regular staff, and use subcontractors to deal with the specialist construction areas necessary for a particular project.

General builders General builders will take on a wide range of work, but most concentrate on particular types and sizes of projects which are seldom in excess of £1 million (Fig. 16.5). The smallest firms will be the ‘jobbing builders’ concerned with minor repairs of existing buildings. Proprietors are usually trade operatives (bricklayers or carpenters) who may employ subcontractors for other skills such as plastering, electrical and plumbing installations, etc. The larger firms will tend to be management organisations, employing administrative staff, including site managers, quantity surveyors, site engineers and safety personnel, perhaps with a few skilled and other operatives. They normally operate in a particular area and therefore avoid excessive commuting distances. When their own building staff, plant and/or material resources are insufficient to carry out a particular trade or specialism, subcontractors will be employed.

Some organisations with continuous building programmes undertake part or even all of the construction processes themselves through the agency of capital works departments which directly employ all the personnel concerned. These capital works departments are usually associated with maintenance and the building of small general-purpose works, or sometimes housing under the control of local government.

General contractors General contractors will range in size and include multi-national organisations having international, national and regional headquarters (Fig. 16.6). These firms will probably carry out both building and civil engineering projects of a very large size, e.g. multi-million pounds, but will also carry out much smaller projects requiring a special expertise they may have developed. For example, many general contractors specialise in particular types of work based on local traditions or availability of workers: shopfitting; specialist joinery work; special expertise in bricklaying, or concrete work resulting from particular skills in shuttering and form-work. Some include research and development divisions,

and have evolved individualistic construction methods based on the exploitation of certain materials such as precast concrete units, steel frame components or load-bearing timber panels.

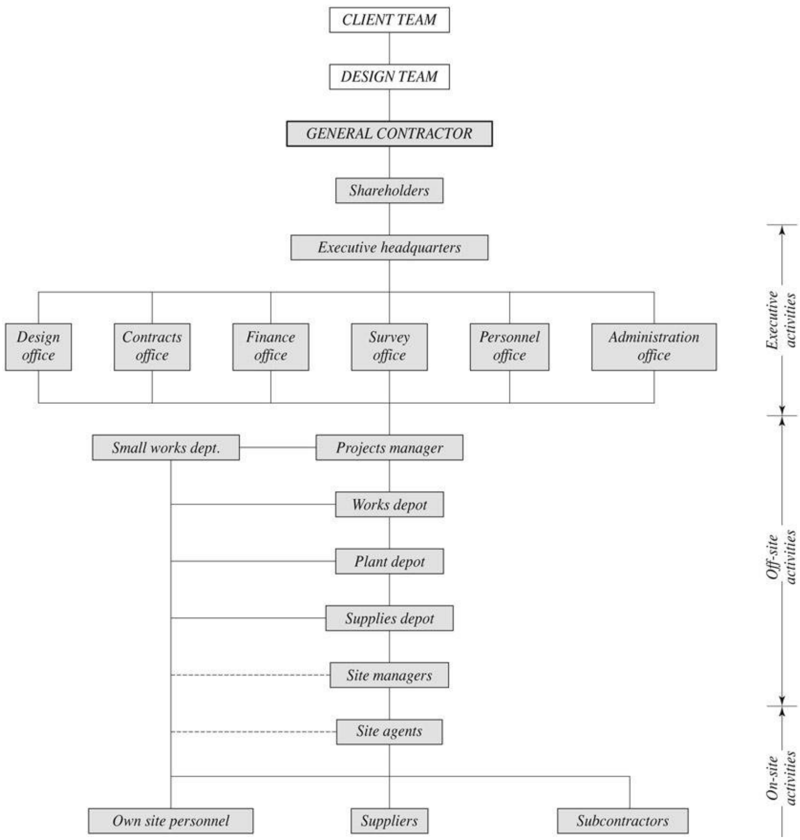


Figure 16.6 General contractors.

The general contractor's organisation must necessarily be divided between office and site activities. Offices will often be concerned with estimating, tendering, site planning, construction process and planning, quantity surveying, cost control, and the bulk purchasing of materials and hire of plant. In large firms there will be separate transport, personnel and employee welfare sections.

The work on site will be under the control of a site or project manager, who may coordinate many other projects on different sites. The resident contact on a particular site will be the general supervisor or agent who will be responsible for the contractor’s own employees and hired subcontractors.

A site office will employ staff to keep careful records of the work in progress, and assist in effective control and costing. These staff will also be concerned with time sheets, delivery and store records, weather records and details of work progress.

Drawing-office staff may also be employed, either at the main headquarters or on a particular site. Their function is to make larger and more detailed working drawings when it is felt special information is required, such as the temporary work for shoring up excavations or methods of constructing shuttering for in situ concrete work required by a particular building design. It may also be necessary for drawing-office staff to confer with a designer regarding alternative methods of construction when greater efficiency can be achieved as a result of a general contractor’s special resources.

A great deal of contracting work is carried out for and by government agencies, and runs into several millions of pounds of work each year. This is true of both local government and the privatised industries, such as transport, gas and electricity, which have their own building works departments known as direct labour organisations.

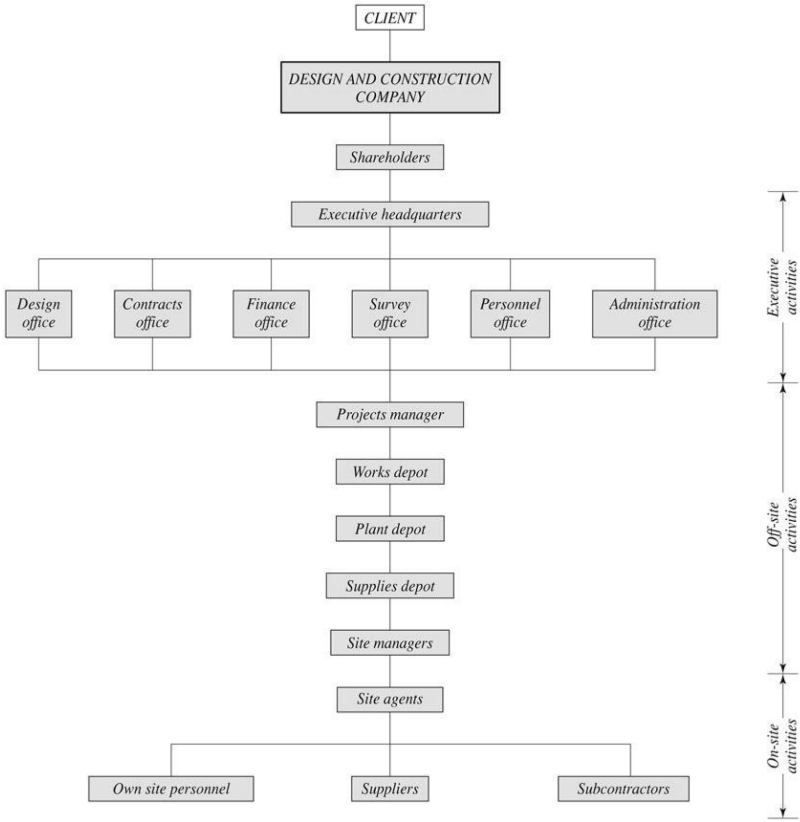


Figure 16.7 Design and construction companies.

Design and construction companies These provide a service which is more elaborate than the previous two, as they will undertake the responsibility for both design and construction of a building project (Fig. 16.7). This type of contractor is usually a specialist in one form of building, such as housing, factories or offices, using a particular form of construction.

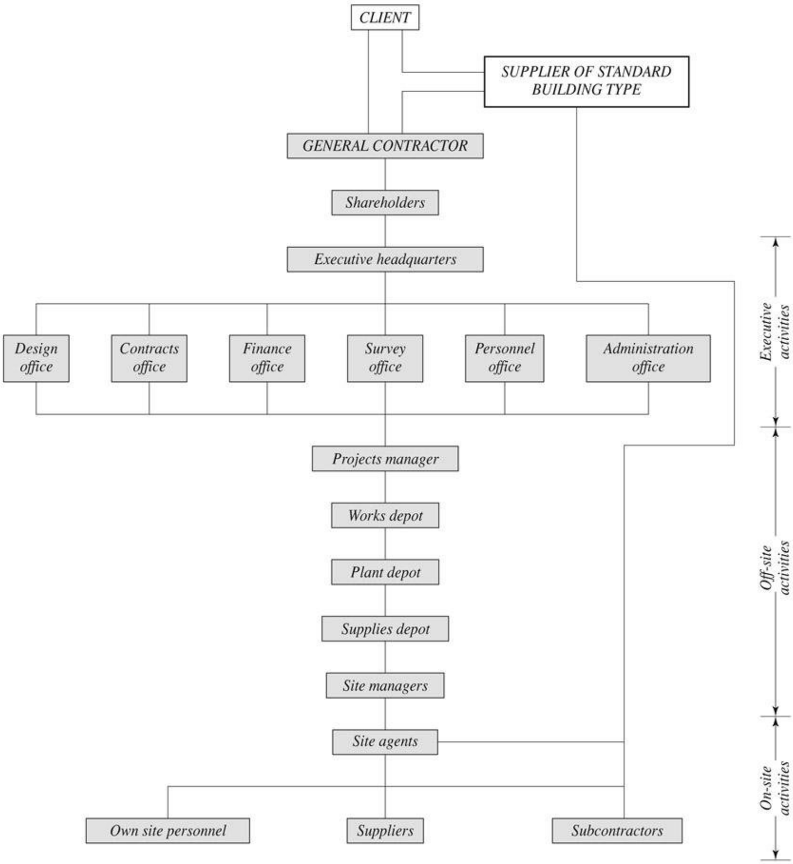


Figure 16.8 Package-deal contractors.

Design and construction companies therefore combine the services of the Design Team with those of general contracting, and are employed directly by a client for a particular project. In effect, the company provides a 'package deal' in which a contractor is responsible for all the major decisions on design and technical matters, prepares plans and specifications, obtains approvals and carries out the

construction. Contractors either employ salaried designers to prepare the design for projects, or pay a fee to independent principal designers and specialist designers. Arrangements are also made with building specialists and subcontract staff. There is an area of free enterprise building in which contracting firms will seek out and acquire land, negotiate planning permission and develop a project to their own specification before setting out to find a customer for the project (Fig. 16.8). Conversely, with many overseas projects, fee-paid consultant designers may work
as a team with contractors to make an all-in offer for design and construction supervision.

16.7.3 Other personnel on site

During the construction period of a building site, other personnel who may not be directly involved with the practical work of a building organisation will also be present, and the coordinating role of the site supervisor, agent or manager must also include responsibility for making sure their needs are recognised. This includes consideration for their safety and welfare while they are on site. Appropriate and adequate insurance must be taken out, to compensate for accidents and the possible financial loss caused by delays resulting from any accidental damage they may cause while on site. Among those covered are the following personnel.

Client Team Visits may be made, but it is important that they only observe and not, for example, issue instructions. This will only confuse channels of communication and eventually cause the Design Team to lose control of the running of the project.

Nevertheless, when a client requires a regular check on the quality of the work, a clerk of works can be employed with responsibility for ensuring that the building organisation strictly adheres to the documentation and instructions supplied by the Design Team (and agreed by the client). On small projects the clerk of works would visit the site at regular intervals to inspect critical work, but on larger projects the clerk would probably be resident on site and have an office there. Although paid for by the client, the employment of a clerk of works usually follows the recommendation of the principal designer, especially when it is considered that a particular building project requires a fairly high degree of supervision. For similar reasons, specialist designers may also recommend that a clerk of works specialising in their discipline should be employed when a building organisation is lacking the necessary coordinating expertise.

Records will be kept by a clerk of works of all events, such as delay periods caused by inclement weather, strikes or unavailability of materials, components and labour. This information is invaluable in assisting the Client and Design Teams to establish the need for extensions of construction time for a project which are requested by a builder or contractor.

Clerks of works will have been trained in all aspects of construction and contract management, and are often those of craft background who have decided to turn their acquired experience of building into an overall supervisory skill. The professional body representing clerks of works, examining and issuing their code of professional conduct, is the Institute of Clerks of Works and Construction Inspectorate of Great Britain Incorporated (ICWCI).

Design Team This includes the quantity surveyor. Visits will be made to deal with queries, supply information, issue additional instructions, establish financial criteria and monitor progress. For this purpose the principal designer usually organises site meetings at regular and frequent intervals, the first one or two taking place before any work commences. All members of the Design and Construction Teams may not necessarily have to attend every meeting, but it is essential that individual members are present when issues are to be raised concerning their expertise. The agendas for site meetings must therefore be carefully planned in advance. Other meetings, probably less formal, will take place as necessary to ensure the smooth running of a project.

For large or complicated projects it may be desirable to have a member of the Design Team permanently resident on site during construction activities. Depending on the nature of the project involved, he or she may be a representative of the principal designer, quantity surveyor or any of the specialist designers. In certain cases a member from each may be necessary. The function of this resident designer or quantity surveyor is to answer and authorise action on any day-to-day queries a contractor may have, and to supply detailed information about areas of the project when the drawings, schedules and specifications issued by his or her office require further clarification or amendment. In fulfilling these duties, the resident designer or quantity surveyor liaises with his or her office, which will provide the overall communication links between other members of the Building Team.

Research Team Visits may be made to monitor any work it has recommended, or to give advice concerning special problems which have arisen during the course of construction. Information gathered during these visits may form the basis of future useful research.

Legislative Team Members are likely to visit the site by direct invitation or often to carry out spot checks on parts of the work relevant to their delegated power. The building control officer or district surveyor will regularly visit the site, usually by invitation of the builder, to inspect aspects of construction required by the provision of the Building Regulations (Fig. 16.9). When approved inspectors have been commissioned to ensure compliance with regulations, they will also be visiting the site. Highway engineers, public health inspectors and planning officers will check compliance with approvals and investigate
complaints made by the public concerning such matters as the builder's access into a site, mud on roads, noise obstruction, and other nuisances or infringements.

LONDON BOROUGH OF ENFIELD	FOR OFFICIAL USE ONLY
For the attention of the Chief Building Surveyor Date .... **BUILDING CONTROL STATUTORY NOTICE** (Building Regulation 16) Plan No. BC .... Nature of Works .... Address .... I hereby give notice that:– (a) the above works will commence on .... at .... a.m/p.m (b) the under-mentioned work or building will be ready for inspection on .... Name and Address of Builder .... Tel. No. .... Signature of Builder .... 1. Excavations 2. Foundations 3. Damp Proof Course 4. Hardcore/Concrete Oversite 5. Drains (before covering) 6. Drains testing (after surrounding and backfilling) 7. Occupation of Building 8. Completion Note:– (a) delete items not applicable (b) 48 hours' notice required under Building Regulations for item (a) (c) 24 hours' notice required under Building Regulations for items (b) 1,2,3,4 and 5 (d) not less than 7 days' notice required for item 7 (e) not more than 7 days' notice required for items 6 and 8 BC/15	FEE PAID £.......... TO PAY AREA

Figure 16.9 Typical notification card used to inform a local authority of progress in building work on site and to request an official inspection for compliance with the Building Regulations.

Although not strictly members of the Legislative Team, the public utility services organisations (gas, water, electricity, telecommunications, etc.) will periodically check for possible damage to existing installations and/or organised work to new installations. Police may wish to inspect the site during the day or night to discuss security measures or to resolve problems concerning road obstruction caused by unloading lorries, etc.; the fire officer will check for fire hazards and to establish that recommendations have been incorporated as the work proceeds; the safety officer and a representative from the Health and Safety Executive will examine the way that safety, health and welfare facilities are maintained on site.

Construction Team Members, either permanent or visiting, are not all involved in practical work. They include contract administration staff, health officials, draughting technicians, secretaries, canteen staff and union officials. On larger projects, subcontractors may have a similar range of staff on site and will have regular visits from their management staff. Suppliers will deliver materials and components to designated storage areas.

Apart from a building site being inspected by members of the above teams, special visitors often make applications or are permitted by a building organisation to observe the construction work during progress. These visitors include interested professional institutions, user teams, councillors, foreign visitors and students of the building design and construction professions. With this type of visitor the site agent or manager must be quite certain that proper insurance cover exists, in case the visitors injure themselves or cause damage to the site, perhaps delaying a project's completion.

16.8 Maintenance Team

The chosen design and construction method of a building must take into account the effects which time will have on their performance (see Chapters 3 and 13). Because of the complicated requirements, their interrelationships and the multiplicity of stylistic conventions which influence the selection of design and construction methods used today, it is sometimes necessary for the Design Team to consult
certain specialists who, during the investigatory phases of design, can offer advice which goes towards the assurance of satisfactory performance standards for the intended life span

of a building. These specialists collectively form a consultative Maintenance Team who, although they may not necessarily become involved with the physical processes, can use their acquired experience and research to advise a designer on a suitable solution to a particular problem, especially where the more normal procedures of maintenance are impracticable. For example, very tall tower blocks often present external cleaning problems which could be solved by incorporation of one of several special items of equipment: cantilevered gantry devices and specially profiled curtain wall mullions to allow safety clips to be inserted for external manual cleaning; or strategically positioned sparge pipes which allow water to be sprayed on façades, thereby eliminating the need for external manual cleaning altogether. Inevitably, the appearance of the building will be affected by such devices and it is therefore very important that the Design Team and consultative Maintenance Team work in close harmony (Fig. 16.10). The precise methods adopted for subsequent maintenance and cleaning will also be influenced by the attitude of the Client Team towards the running costs of a building. The Maintenance Team will therefore give valuable advice which affects the ultimate cost evaluation of a particular project. Three-dimensionally profiled glass façades often present particular financial problems associated with both maintenance and cleaning. Additional costs can be incurred in the design, manufacture and installation of special climbing gantries to facilitate accessibility, and additional costs are sometimes involved in special training programmes for maintenance and cleaning personnel. Nevertheless, for certain prestige building types the aesthetic desirability of three-dimensional glass façades may more than offset additional costs.

Normal maintenance procedures can usually be formulated using the expertise of the Design Team without the need for special consultation, e.g. methods of access to services; dimensions of ductwork and crawlways within ducts to permit space for repair or alterations; the routines necessary for continued or adjustable service supply (heating, lighting, ventilating, drainage, etc.); and the care needed to maintain finishes, furniture and fitments. On completion of a project, the Client Team must be presented with a maintenance manual compiled by the Design Team which incorporates the advice of the consultative Maintenance Team. This manual describes how a building can be expected to perform, what measures have been taken to ensure that it does, and what action must be taken in the future (see section 17.8).

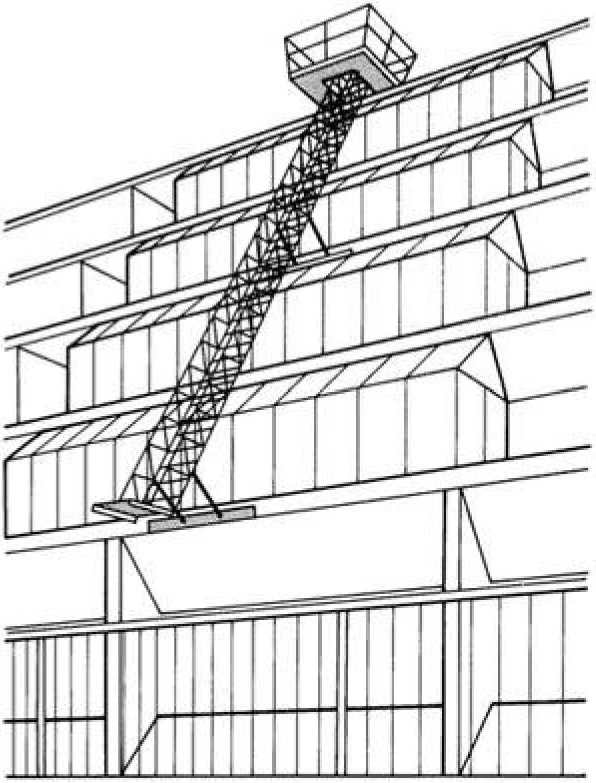


Figure 16.10 Window-cleaning apparatus necessary for complicated façades may become a permanent feature, affecting the appearance of the whole building.

The aftercare or continued maintenance of a building following its completion will often be contracted out to a facilities management company. This simplifies the building owner's responsibility for engaging caretaking staff. For an agreed fee, many facilities management contractors provide a full package of building maintenance, repairs, replacements, security, car parking attendance, catering, and so on. The

British Institute of Facilities Management (BIFM) represents the professional interests of facilities management organisations.

Further specific reading

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 2 The production of buildings
Structure and Fabric Part 2	Chapter 1 Contract planning and site organization Chapter 2 Contractors‘ mechanical plant

Building Research Establishment

Digest 448	Cleaning buildings: Legislation and good practice
Digest 450	Better building: Integrating the supply chain; a guide for clients and their consultants
Digest 452	Whole life costing and life-cycle assessment for sustainable building design
Good Building Guide GG54	Construction site communication (2 parts)
Good Building Guide GG56	Offsite construction: an introduction

17 Communication

CI/SfB (A3/A8)

The operational procedures and other management activities associated with the design, construction and subsequent performance of a building rely a great deal upon quite complex information being transferred between the various participants of the Building Team. Ideas and technical data must be dispersed to a wide range of people at both professional and non-professional, skilled and unskilled levels. For this reason, methods used for communication should not only clarify issues, but also attempt to bring harmony to the work processes involved in the creation of a building, and foster the cooperation which ensures maximum contributions from all those with tasks to perform.

Communication methods have developed in type and sophistication to meet the needs of the disparate parties increasingly becoming involved with the creation of a building. Traditional methods such as memos, letters, reports, minutes, schedules, diagrams and drawings are gradually becoming universally standardised in format to simplify understanding and to speed up production. Computers, telecommunication systems, recording tapes and closed-circuit television make it easier to achieve instant communication.

The introduction of microchip technology has changed attitudes towards efficiency and communication within today's building industry. Design aims, methods of communicating design information and technical data can be instantly dispersed between designer, specialist designer, client and contractor by electronic mailing through the desktop personal computer. This process raises possibilities of absolute understanding and, in the face of ever-increasing building costs, the concept of keeping options open until the last minute. For example with a school project that at one time would have taken several weeks, it is now possible to design and produce all the drawings, schedules, specifications and other contract documents in a few days when using computer-aided design (CAD) technology. This process obviously involves a modification in the way the various teams operate when creating a building and how they deal with design and construction problems. The designer will no longer have to ponder over a drawing board in search of a solution to a problem through reliance on his or her intuitive skills and ability to interpret technical facts through memory or prolonged research. Instead, he or she will receive multifarious solutions from a computer, all with equal technical and economic competency; the problem becomes one of selection. Any selection process must include a realisation of aesthetic ideals, and although the computer can incorporate ergonomic and other data about physical comfort, it has limitations on the design of a building to give full psychological delight to a human being. A virtual reality visit via the monitor, through and around a visualisation is about as close to actuality as we can get. The techniques applicable to computer technology involve the production and manipulation of information, information storage and information transmission. The extent to which these activities can be carried out depends upon the capacity of the computer: its size and cost, its programming capability and complexity. Information technology computers range from pocketsize multifunction dictaphones, telephones, calculators and e-mailers to larger but fully portable laptop equipment; from desktop equipment to large processors, including 'intelligent' machines networked with similar computers at remote locations. Needless to say, the competence of the operator is of paramount importance.

Figure 16.1 illustrates the RIBA plan of work for a building of moderate cost and which involves the activities of a full team of designers with a principal designer as leader, as described in Chapter 16.

The following areas of communication complement the progress of the work:

- Technical data
- Drawings
- Specification of works and bills of quantities
- Contracts
- Tender documents
- Fee accounts and certificates of payments
- Programmes of work
- Maintenance manual

17.1 Technical data

The time has long passed when members of the Building Team were able to rely only on the technical data contained in a few textbooks for the design and construction of a building.

The development of new uses for materials and of new techniques of construction, together with continual research into all aspects of building, has undoubtedly led to an information explosion in the building industry. Technical data is now readily available from research organisations in the form of research bulletins and papers, and from manufacturers of materials, equipment, components and building systems in the form of trade literature and/or actual samples of products, mostly distributed by travelling sales representatives and as seen at the many exhibitions and seminars held throughout the United Kingdom.

Computer websites have been produced by manufacturers, commercial organisations and research institutes. These give ready access to a wealth of information on products, services and new developments. Listings of websites are found in trade and professional directories. Agencies produce, under licence, computer-compatible compact discs containing regulations, legislative documents, standards and a variety of technical data. Some of these can be directly downloaded at no cost; others require an annual fee or subscription, to include updates.

But the vast amount of new and important information supplied through these organisations makes accumulation and categorisation of the knowledge difficult, and thorough assimilation virtually impossible. The industry therefore needed to establish suitable methods of presenting technical data to the Building Team, and to recommend a method of cataloguing documents, etc., so they could be readily found when required. The International Council for Building Research (CIB, now the Council for Research and Innovation in Building and Construction) published a list of headings for the guidance of authors of technical literature which classified a method of giving information based on sequential performance criteria. From 1961 onwards, a method of classification for technical information began to be adopted which developed into the currently used CI/SfB system.

This system was first created in Sweden by what was then known as Samarbetskommittën for Byggnadsfrågor (the Coordinating Committee for Building) and related more to the specific requirements of the building industry than the universal decimal classification (UDC) system employed in UK libraries. However, in order to make the SfB system relate precisely to the UK building industry, the RIBA initiated modifications that led to the adoption of the CI/SfB system (CI stands for Construction Index). Figure 17.1 gives the four tables of this modified system (Tables 1–3 constitute the original SfB system), and each table represents a major group of subjects or concepts now available in the building industry. Broadly speaking, the tables represent the design process for a building as it proceeds through levels of increasing detail. The construction work proceeds through these same levels but in reverse order. Therefore, CI/SfB is a common language for communicating information to all members of the Building Team. Figure 17.2 illustrates how the system may be used.

Whether the CI/SfB system is used totally or only partially depends on the size of the organisation requiring to classify information, or the degree of cataloguing necessary for easy retrieval by an individual. For example, members of the Client Team may only require information relating to Table 0 (physical environment); or a manufacturer to Tables 1, 2 and 3 (elements, construction form and materials); whereas

Design and Construction Teams may need to make use of all four tables.

Other systems of indexing are Uniclass and EPIC. See pages 191–193 for information on these. A selection of critical technical data can be obtained from a Building Centre located in one of many areas in the United Kingdom, and which forms the recognised meeting places for manufacturers, users and designers. The Building Centre, London, published a short but useful guide to manufacturers of trade literature for the building industry; it stated:

Trade literature may be defined as information which enables the user to select, specify and utilize a product in service. This information also helps him to compare similar products and services. He may thus elect the ones that best suit his requirements. The fully informative piece of trade literature is a great aid in the preparation of drawings, specifications and bills of quantities.

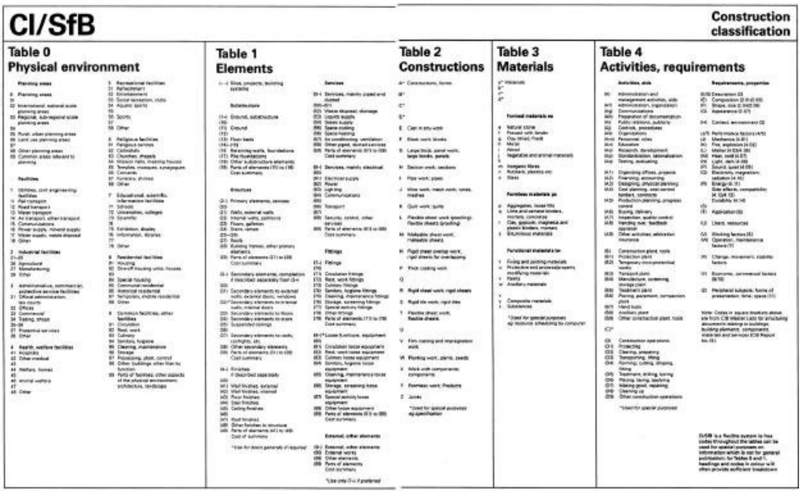
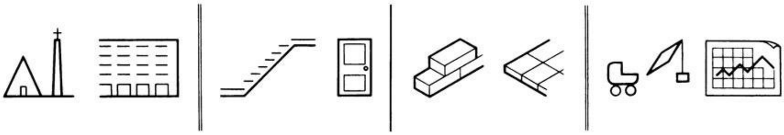


Figure 17.1 CI/SfB construction classification. Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com

CI/SfB How to use it

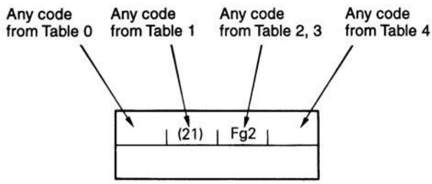
1 CI/SfB is a common language for communicating information in the building industry. Like any other language it has to be learnt. After a time (quicker than most languages) the key words and codes which make it up can be used without conscious effort.
2 It consists of four 'tables'. Each of these represents a major group of subjects (concepts) about which information is passed in the building industry:



3 Each table consists of key words and codes to go with them:

Numbers		(Numbers in brackets)		Letters		(Letters in brackets)	
RELIGIOUS	6	SERVICES	(5–)	BLCKWK/BLOCKS	F	OPERATIONS	(D)
Cathedrals	62	Drainage	(52)	Concrete	Ff	Storing	(D1)
Churches	63	Gas	(54)	Clay	Fg	Transporting	(D3)

4 The tables are shown in more detail in the Construction indexing manual, and on the RIBA wall chart.
5 Classification (numbering for filing) is done in three stages:
1 Decide what the document is about, in terms of CI/SfB (difficulty arises when it is about several subjects).
2 Select most appropriate key word(s) or code(s) (or both).
3 Write these down, sometimes in a classification 'box':



or without any classification box:

(21) Fg2

or without any classification box, using words only:

external walls – bricks, blocks – clay

6 When classifying, make a careful decision as to whether or not any code is required from each of these tables – 0, 1, 2, 3, 4, in that order. Any other 'citation order' may be adopted if there is a good reason for it. The order, once decided upon, should be used consistently.
7 File in a 'filing order' which may also be – 0, 1, 2, 3, 4 – or any other order used consistently.

Project information
8 In the case of project information the principal designer, specialist designer or quantity surveyor is the originator of the document, whether drawn or written and is therefore able to use the classification as a set of definitions to decide what should go on each drawing or in each section of the specification etc. The classification is used *before* the document is produced and *not, as in library classification, after it has been produced.*

Figure 17.2 Using the CI/SfB classification system. Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com

Building Centres incorporate libraries of building and engineering product literature (including samples) classified under CI/SfB, Uniclass and EPIC. They provide an information service which includes a computer link to European sources of reference. But specifiers of non-UK products must ascertain that testing data complies with BSI Standards, Comité Européen de Normalisation (CEN) for European Standards, International Organization for Standardization (ISO) for international standards or have an appropriate Agrément certificate or its equivalent.

Some Building Centres may provide contact offices for professional and research bodies such as the RIBA, ICE, BRE and TRADA Technology Ltd. Whereas Building Centres primarily provide permanent information resources, manufacturers and trade organisations also frequently sponsor temporary national building exhibitions. Well-designed UK products may be exhibited at a Design Centre run by the Design Council whose chief purpose is the promotion of British design.

Instead of collecting and classifying technical information, or in order to supplement an established technical library, some organisations prefer to employ the services of companies specialising in the dissemination of information. As far as the building industry is concerned, in addition to Building Centres and exhibitions, technical information is also available through trade and professional journals. Other easily accessible resources include:

- Barbour Index/Product Search
- Building Products Index
- Technical Indexes: Construction Information Service
- RIBA:
    - Information Centre
    - Product Selector
    - British Architectural Library
- Sweet's Network
- ESI Information
- IHS Engineering, Construction and Government Solutions
- Green Book Live
- Green Specification

These organisations provide a basic library of literature, some available as hard copy or on compact discs (CDROM) or as data downloads accessed through their web-sites. Many of these library resources can be used to access legislative documents, national standards and design information, some requiring a fee or annual subscription. Product and equipment data is linked to a product selector, lists of manufacturers and service providers. Most manufacturers of commercial products supplement their traditional hard copy trade catalogues with direct telephone consultancy, CD-ROMs, DVDs, video packages and downloadable information accessed through their websites.

17.2 Drawings

Drawings of many types provide the main method of communication between all the members of the Building Team. As the information required at any one stage of the implementation of a building will vary, and also be at different levels of complexity according to user requirements, the different types of drawing are divided for convenience into two broad categories.

Design drawings communicate the form of a building in terms of shape, colour and texture; production or working drawings communicate the technical, physical and economic aspects of a building which are associated with its construction, subsequent use and maintenance. The information conveyed on both types of drawing is generally supplemented by reports, schedules, samples, specifications, models, discussions, etc. In reality, there should be no firm division between design and production or working drawings, just as in reality there should be no division between design ideas and construction. However, certain drawings need to convey more about appearance to less technically minded parties, whereas other drawings are needed to convey technical information to parties which have priorities besides the overall appearance and function of a project. Though all the Building Team would undoubtedly benefit from studying a comprehensive range of drawings for a particular project, such a need is of most value to the principal designer, who is concerned with the all-embracing quality of the project. It is the responsibility of the overall coordinator of the project (whether principal designer, contractor or some other party) to ensure that the most useful drawings are distributed to the appropriate members of the Building Team at the precise time they are required.

17.2.1 Design drawings

There are two types of design drawings: those concerned with the preliminary investigation processes for a design, and those concerned with the presentation of a design solution. Both are produced during the ‘design’ stages of a project.

Design drawings for investigation purposes communicate information between designers, quantity surveyors, etc. (Design Team), and, if involved during early stages of negotiations, the builder or contractor (Construction Team). In addition, this information about the project will also be passed to the client, and eventually form the basic information necessary to produce a preliminary visualisation or sketch design.

The earliest form of investigation drawing is that which provides information about the site (and existing building if a conversion is involved) and the immediate environment, including adjoining structures, roads, services, etc., likely to influence a project. This is known as a site survey and will enable the Design Team to begin the design. Ordnance Survey maps are useful initial references (Fig. 17.3).

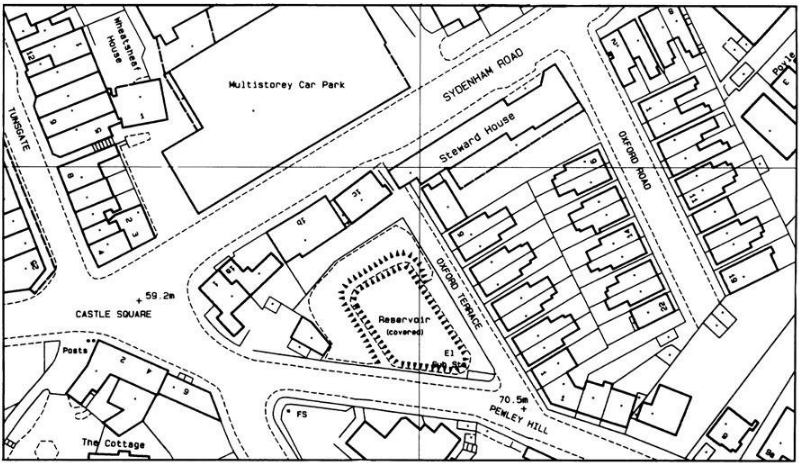


Figure 17.3 Section of an Ordnance Survey 'Superplan' map. (© Crown copyright (399582))

As the design process continues, the Design Team may require specific information about the cost of different solutions for a potential scheme, and may supply sketch drawings to a quantity surveyor for comment. A contractor may also be able to help in establishing economic and efficient construction methods by suggesting the suitable type and availability of labour and mechanical plant for a particular design. Specialist designers usually prepare sketch drawings of their proposals for similar reasons and communicate vital information which enables the principal designer to incorporate them in the design. Drawings for these purposes need not be elaborate when information is being communicated between parties having a common aesthetic and/or technical language.

Computer printouts are increasingly used for the production of technical data (Fig. 17.4) to develop concepts outlined by sketch design decisions. Using this method, speedy and accurate information is made available for assessing various aspects of design, including lighting levels created by different shapes and sizes of window, heat losses for different constructions, and economic spanning methods for alternative structural solutions.

WALL CONSTRUCTION

MATERIAL	RESISTIVITY	THICK	RESISTANCE
SURF. RES. IN	0	0	0.13
GYP. PLASTER	2	15	0.03
LTWT. CONC. BLK.	5.3	100	0.53
EXP. POLY.	27.2	30	0.83
CAVITY	0	25	0.18
BRICKWORK	1.78	102	0.18
SURF. RES. OUT	0	0	0.05

TOTAL RESISTANCE = 1.93

'U' VALUE = 0.52 W/m^2 K

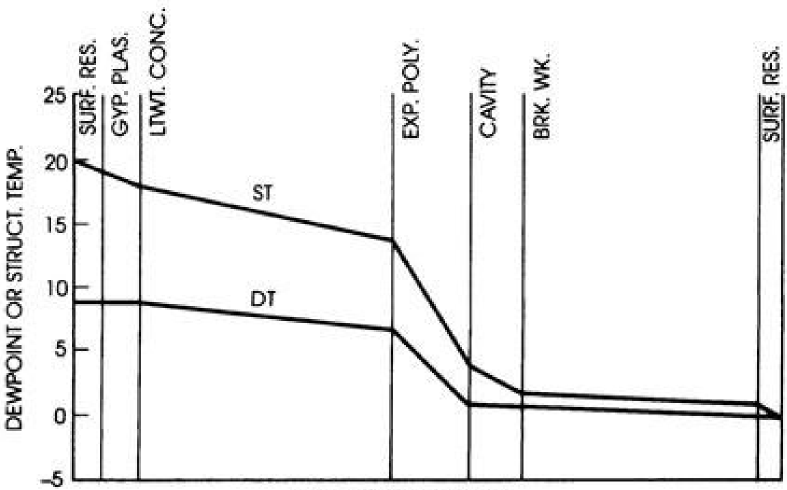
STEADY STATE CONDENSATION ANALYSIS

CONDITIONS:

OUT. TEMP. = 0°C OUT. VP = 6 mb

IN. TEMP. = 20° C IN. VP = 11.3 mb

STEADY STATE TEMPERATURE PROFILE



NO CONDENSATION

Figure 17.4 Brick/block cavity: computer analysis.

Design drawings for presentation purposes are prepared by the designer to illustrate to the client the appearance of a project, the general disposition of the accommodation
to be provided, and the effects the overall scheme has on the environment, including details of landscaping and the immediate physical surroundings. Drawings should use techniques which are readily understood, preferably three-dimensional representations such as perspectives (Figs 17.5 and 17.6), axonometrics or isometrics. And two-dimensional representations (orthographic – see Fig. 17.12) should be clear and provide easily identifiable features, e.g. people, furniture and trees. The drawings range from simple pencil sketches to highly finished, fully coloured and mounted drawings. Very little technical information is usually given, although this depends on the expertise and requirements of a particular client. Clients having technical expertise influencing the design will probably need information to show how their interests have been incorporated.

Figure 17.5 Typical perspective drawing.

Whenever possible, information about the design should be supplemented by scale models and/or sample boards of materials to be employed. Some principal designers prefer to use the skills of visualisers, who specialise in artistic techniques so that a design is most effectively presented. Line perspectives can be produced by computers (Fig. 17.6). After being programmed accordingly, computers are also capable of producing a video/virtual reality presentation of a walkabout within a proposed building. This preview can also assist a designer during sketch design stages.

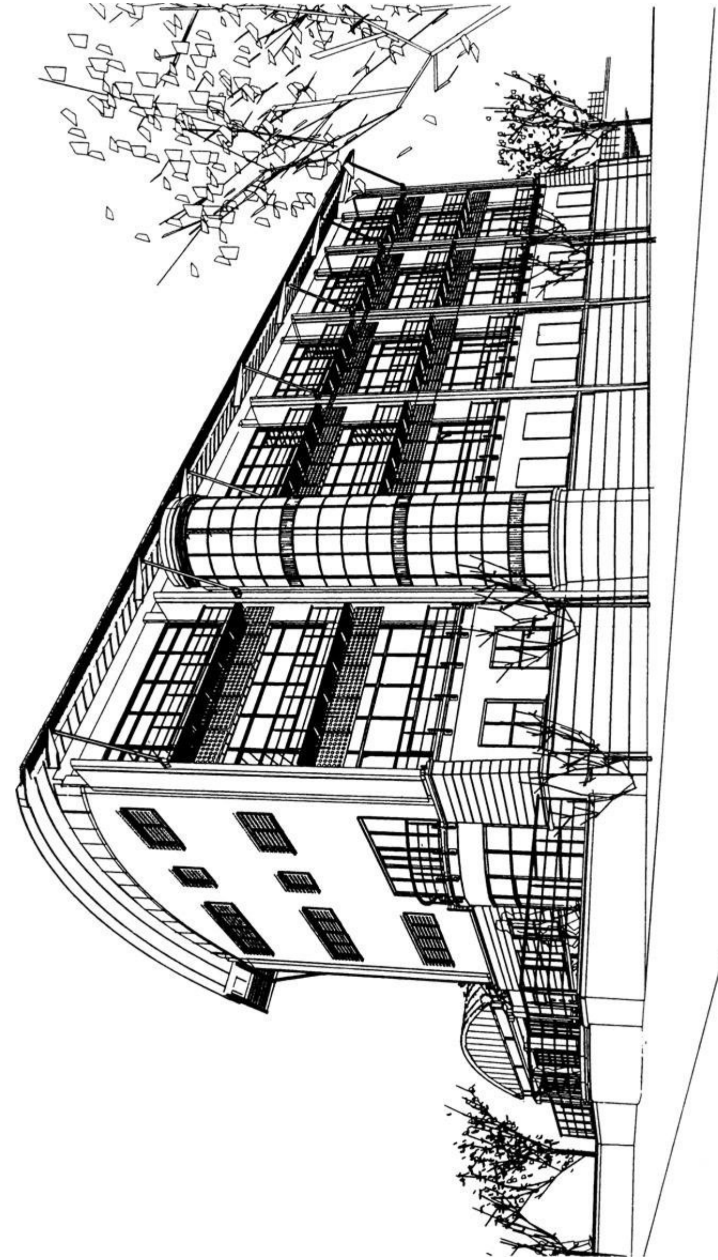
With a few minor additions, design drawings can form a suitable submission to the local authority for planning approval, although generally for this they need not be as elaborately presented.

17.2.2 Production or working drawings

Production drawings are often called working drawings, and are produced by designers in order to communicate technical information throughout the Building Team. According to the nineteenth-century architect Sir Edwin Lutyens, 'a working drawing is merely a letter to a builder telling him precisely what is required of him – and not a picture to charm an idiotic client'. The building process has become much more complex since; the following list describes the uses of production drawings:

- Obtaining official consents and statutory approvals
- Analysing cost factors
- Establishing use of materials

- Informing extent of subcontractors' work
- Providing source of information for other contract documents
- Providing details for tendering
- Indicating contractual commitments
- Providing basis for ordering materials and components
- Establishing type and amount of labour required
- Demonstrating construction detailing
- Forming part of documentation during site meetings
- Indicating degree of supervision
- Providing check for variations from the contract
- Assisting the measurement of progress
- Providing guidance on interim financial payments to contractor



CELTEL HEADQUARTERS, KAMPALA
NORMAN + DAWBARN LIMITED

Figure 17.6 Computer drawings: three-dimensional representation of different aspects of a building complex. (Reproduced courtesy of the architects, Norman + Dawbarn Limited)

- Agreeing completed works and final payment
- Checking on defects in site construction method
- Recording work completed
- Indicating factors to put in maintenance manual
- Analysing factors affecting health and safety
- Providing an information base for structural calculations

Generally, the principal designer of a project prepares information and incorporates the data supplied by others (including specialist designers) to produce a master set of production drawings. For larger projects, certain specialist designers (structural and mechanical services engineers, etc.) prepare independent production drawings, but this must be done in close collaboration with the principal designer in order to ensure unified intentions and maintenance of professional responsibility.

Together with the written descriptions of a project (e.g. bills of quantities, schedules and specifications of works), production drawings are a vital part of the legal documentation upon which contractual arrangements are based. It is important that any alterations which are necessary after the formal issuing of production drawings are communicated to all members of the Building Team as they could result in changes in legal arrangements. Amendments influencing cost and/or uses of materials and labour need particular attention.

A typical basic list of items to be incorporated on production drawings for a small project is indicated in Appendix I. From this it will be realised that they must provide an accurate record of the principal designer's intentions at all stages of the construction process, and the information must be interpreted by many people with different sets of priorities, e.g. building control officers, quantity surveyors, sales staff, supervisors, site operatives and labourers. It is important, therefore, that production drawings are clearly representative and easily understood; are comprehensive and sufficiently detailed for their purpose; and are produced in a format which enables them to be easily collated so that specific drawings can be found by particular users when required.

For this reason, a great deal of work has been carried out, initially by the British Standards Institution, in order to establish a system of coordinating production drawings and the information they communicate so as to avoid errors, inadequate data and omissions. Various standards contain recommendations for the optimum arrangement of production drawings for communication of information, e.g.:

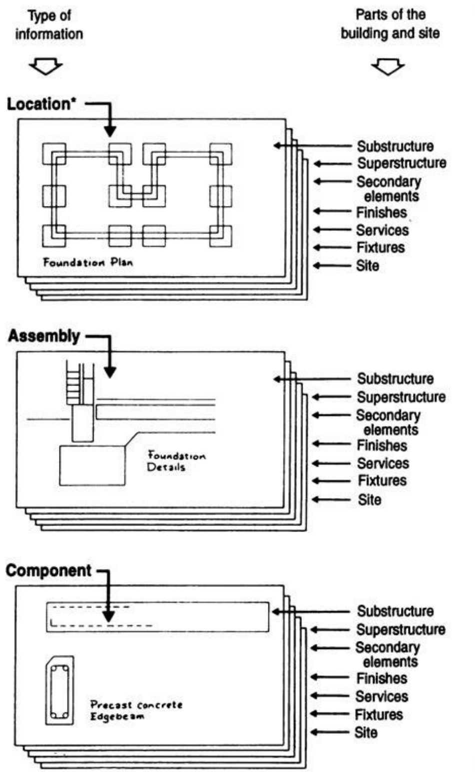
- BS 1192: Collaborative production of architectural engineering and construction information. Code of practice.
- BS EN ISO 3766: Construction drawings, simplified representation of concrete reinforcement.
- BS EN ISO 4157–1: Building and parts of buildings; 4157–2: Room names and numbers; 4157–3: Room identifiers.
- BS EN ISO 6284: Construction drawings, indication of limit deviations.

- BS EN ISO 7518: Construction drawings, simplified representation of demolition and rebuilding.
- BS EN ISO 7519: Technical drawings – construction drawings – general principles of presentation for general arrangement and assembly drawings.
- BS EN ISO 8560: Construction drawings, representation of modular sizes, lines and grids.
- BS EN ISO 9431: Construction drawings, spaces for drawing and for text and title blocks on drawing sheets.
- BS EN ISO 11091: Construction drawings, landscape drawing practice.

Members of the Building Team first need to know the shape, size and location of the building to be constructed and its constituent parts; then about the methods to be adopted for the assembly of the parts (type of material and labour required); and finally about details of components to be used. Figure 17.7 indicates in greater detail the type and purpose for each category of drawing together with the scales which are recommended for each. Schedules provide more detailed specialised information and are a collection of mostly written information about the repetitive parts of a building, such as doors, windows and finishes (Fig. 17.8).

This method of structuring information greatly assists individuals of the Building Team in identifying the group of production drawings which are able to give the particular information they require. However, consideration must also be given to how this information is presented to assist easy reference and understanding. Drawing sheets should be used which conform to a uniform series of sizes to facilitate handling or storage and the international A series of paper sizes (Fig. 17.9) should be adopted for all drawings and written material, including trade literature. Secondly, consideration must be given to one of the standard methods of graphically representing materials, components and dimensions so that a common grammar is established between the members of the Building Team, thus reducing ambiguity and speeding understanding. Figure 17.10 indicates the British Standard recommendations for dimensions on drawings. Some typical conventions are illustrated in Figure 17.11.

In addition to the above factors it is important that the layout of drawing sheets should be done in a systematic manner; particular attention should be given to the title panel of the drawings, as ambiguity can cause a considerable waste of time when seeking out particular information. Figure 17.10 illustrates a typical title panel.



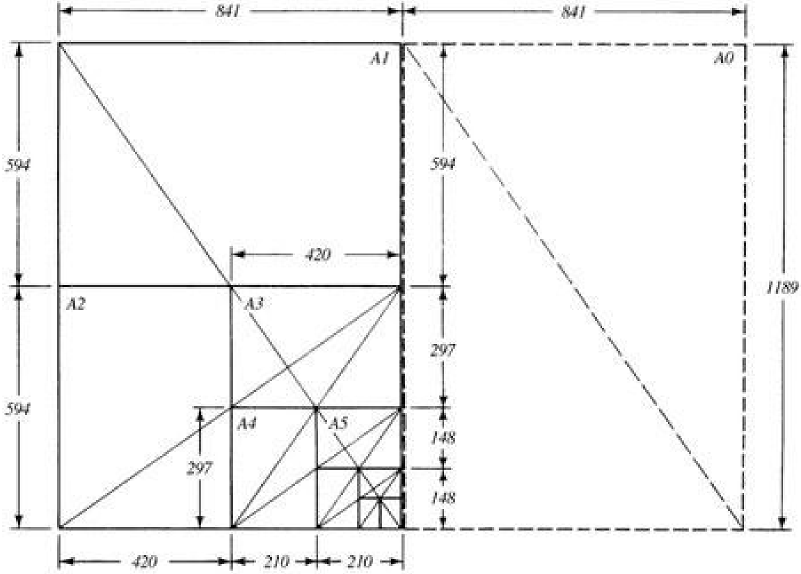
* There will be additional location drawings dealing with the project as a whole

Type of drawing and purpose			*Approximate scale*
Location	Site and external works	General site plan	1 : 2500 1 : 1250
		To identify, locate and dimension the site and external works	1 : 100 1 : 200 1 : 500
	Building	To identify, locate and dimension parts and spaces within the building and to show overall shapes by plan, elevation and section	1 : 50
		To locate grids, datums and key reference planes	1 : 100
		To convey dimensions for setting out	1 : 200
		To give other information of a general nature for which a small scale is appropriate (e.g. door swings)	
	Element	To give location and setting-out information about one element, or a group of related elements	1 : 100 1 : 200
	Cross-references	To show cross-references to schedules, assembly and component drawings	1 : 100 1 : 50
Schedule	Element	To collect repetitive information about elements or products which occur in variety	
		To collect cross-references to assembly and component drawings	
Assembly	Element	To show assembly of parts of one element, including their shapes and sizes	1 : 5
		To show an element at its junction with another element	1 : 10
		To show cross-references to other assembly and component drawings	1 : 20
Component	Element or sub-elements	To show shape, dimensions and assembly (and possibly composition) of a component to be made away from the building	1 : 1 1 : 5 1 : 10
		To show component parts of an *in situ* assembly which cannot be defined adequately on the assembly drawing	1 : 20 1 : 50

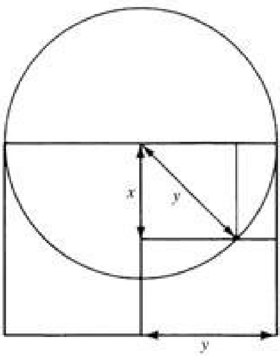
Figure 17.7 Production of working drawings.

DOOR GROUP PREFIX LETTERS			INTERNAL DOORS														EXTERNAL DOORS coded XD												
DOOR NUMBERS			1.	2	3	4	5	6	7	8	9	10	11	12	13		1	2	3	4	5	6	7	8	9	10	11	12	13
COMMON SUITING MASTER KEYING.	REFERENCE NUMBERS	AZA								DOUBLE							DOUBLE				DOUBLE		DOUBLE		DOUBLE				
UPRIGHT LOCKS	WITH ONE KEY	100																											
	LOCKS TO PASS	101	1	1	1		1					1	1	1															
	WITH TWO KEYS	102																											
	REBATED COMPONENTS	103																											
	ROLLER BOLT, ONE KEY	104																											
	ROLLER BOLT, LOCKS TO PASS	105																											
	ROLLER BOLT, TWO KEYS	106																											
	ROLLER BOLT REBATED COMP'S	107																											
UPRIGHT DEADLOCK	WITH ONE KEY	112																											
	LOCKS TO PASS	113								1.							1.		1	1	1		1		1		1	1	1
	WITH TWO KEYS	114																											
	REBATED COMPONENTS	115															1		1	1	1		1		1		1	1	1
LEVER HANDLES	PAIR ON ROSE	130																											
	PAIR ON BACKPLATE, KEYHOLE	131	1	1	1		1					1	1	1															
	PAIR ON BACKPLATE, NO KEYHOLE	132																											
	ESCUTCHEONS	133								2							2		2	2	2		2		2		2	2	2
PULL HANDLES	150 mm CENTRES FIXING	134																											
	225 mm CENTRES	135						1	1	1	1				1		1	1	1	1	1	1	1	1	1	1	1	1	1
	300 mm CENTRES	136																											
FINGER PLATES	300 x 75	140				1		1	1	1	1				1		1	1	1	1	1	1	1	1	1	1	1	1	1
KICKING PLATES	625 mm WIDE	141													1.														
	725 mm	142				1	1	1	1	2	2		1																
	775 mm	143	1	1	2							2		2							1	1					1	1	
	825 mm	144															1	1	1	1			1	1	1	1			1
	875 mm.	145																											
FLUSH AND BARREL BOLTS	PAIR FLUSH BOLTS	150								1							1				1		1		1				
	SOCKET FOR WOOD	151																											
	SOCKET FOR CONCRETE	152																											
	PAIR BARREL BOLTS	153																											
OVERHEAD CLOSERS	FOR EXTERNAL DOORS OPEN OUT	160																											
	FOR INTERNAL DOORS	161				1		1	1					1	1														
	DOOR SELECTOR	162																											
	OVERHEAD LIMITING STAY	163															1	1	1	1	1	1	1	1	1	1	1	1	
DOOR STOPS	FOR TIMBER	170																											
	FOR CONCRETE	171				1						1	1	1	1														
	POST MOUNTED DOOR HOLDER	172																											
	CABIN HOOK	173																											
LETTER BOX	LETTER BOX.	174																										1	
HAT AND COAT HOOKS	ALUMINIUM	180																											
	NYLON COATED SECRET FIX.	181																											
	PAIR NYLON COATED SECRET FIX	182																											
	NYLON COATED SCREW FIX.	183																											

Figure 17.8 Ironmongery schedule.



A sizes retain identical proportions (1:√2), each sheet size being half the size next above



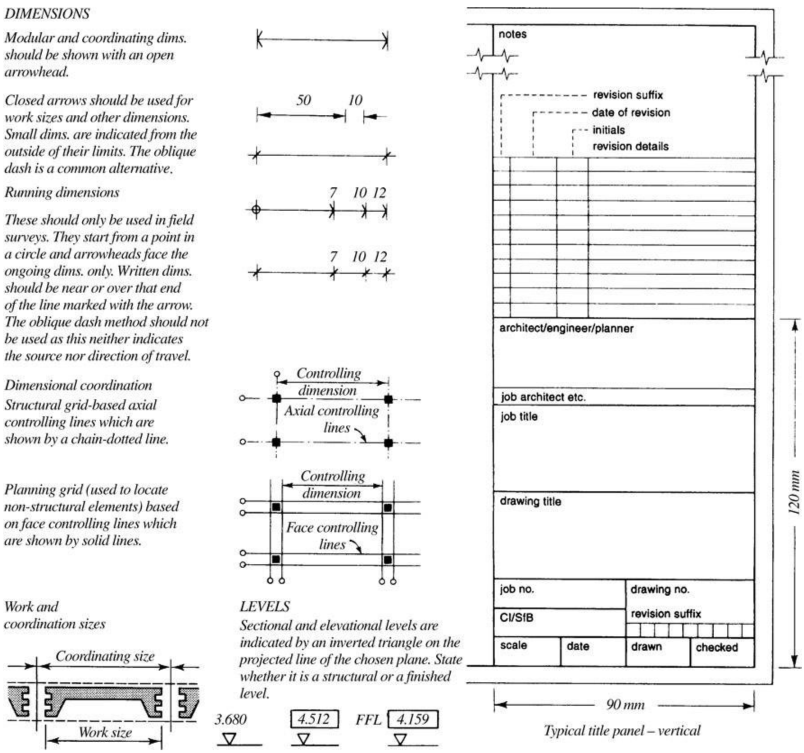
The rectangle x × y has a surface area of 1 m² for sheet size A0

A size	mm
A0	841 × 1189
A1	594 × 841
A2	420 × 594
A3	297 × 420
A4	210 × 297
A5	148 × 210
A6	105 × 148
A7	74 × 105
A8	52 × 74
A9	37 × 52
A10	26 × 37

Measurements represent trimmed sizes

Figure 17.9 Paper sizes: the internationally agreed A series for all written documents, drawings and trade literature.

The messages conveyed by the production drawings are really a translation of the three-dimensional ideas of a designer, so perhaps the best form of graphical presentation should also be three-dimensional, i.e. isometric or axonometric. This form is particularly useful when new construction methods or difficult junctions between several components need amplification (see Fig. 6.8). However, three-dimensional representations are very time-consuming to prepare unless computer generated, and, for the majority of building work, are not normally necessary. There are two basic methods of communicating information on production drawings. The conventional method



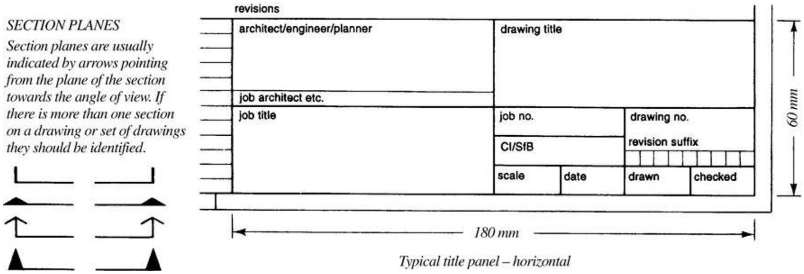


Figure 17.10 Dimension symbols and title boxes on working drawings.

1 ORIENTATION, CI/SfB Table 0

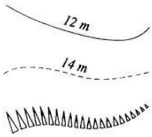
North points
All drawings which relate plans to the site should have a North point. Ideally, plans should be drawn to face North on the sheet, but this is often impractical. It is bad practice to change the orientation of drawings within a set (although this is sometimes unavoidable)

2 SURFACE CONTOURS, CI/SfB Table 0

Existing contour

Proposed contour

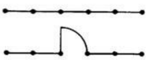
Bank (sharp edge of the wedge is lowest)



3 BOUNDARY FEATURES, CI/SfB Table 0

Fence

Fence with gate



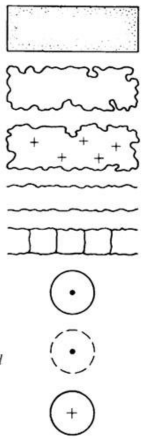
4 PLANTING, CI/SfB Table 0

Grass

Woodland — *Existing*; *Proposed*

Hedge — *Existing*; *Proposed*

Tree — *Existing*; *Existing, to be removed*; *New*



5 MATERIALS, CI/SfB Table 3

Soil

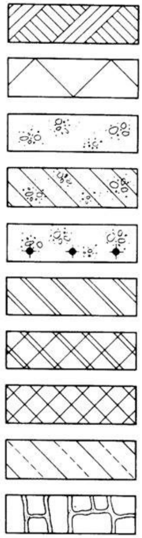
Hardcore

Concrete — *General*; *Precast*; *Reinforced*

Brick — *General*; *Facing*

Block

Stone — *General e.g. ashlar*; *Rubble*

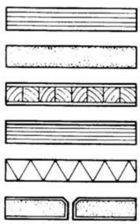


Timber

Unwrot

One face wrot — *Softwood wrot* — *Hardwood wrot*

Boards and linings — *Plywood*; *Particle board e.g. chipboard*; *Blockboard*; *Insulation board*; *Woodwool*; *Plasterboard*

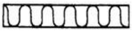


Steel and metal work 

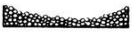
Clay products 

Plaster — *General* 

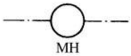
Decorative render 

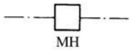
Insulation — *General* 

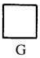
Quilt 

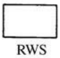
Loose insulation 

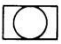
6 DRAINAGE, CI/SfB (U46)

Manhole — *Surface water* 

Foul water 

Gully 

Rainwater shoe 

Rainwater head 

Rainwater pipe 

Discharge (soil) pipe 

Vent pipe 

7 FIXTURES AND FITTINGS

Kitchen fixtures and equipment, CI/SfB (73)

Refrigerator 

Sink 

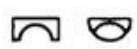
Sanitation, CI/SfB (74)

Bath 

Bidet 

Wash basin 

Shower unit 

Urinal 

WC 

Laundry fixtures and equipment, CI/SfB (75)

Washing-machine 

Furniture, CI/SfB (82)

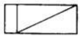
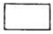
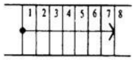
Bed 

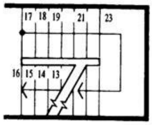
Table 

Chair 

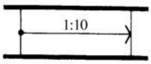
8 STAIRS AND RAMPS, CI/SfB (24)



Stairs and steps
Arrows always point up.
Tread numbered from lowest step to highest floor level



Ramp
Arrow indicates direction of rise; give gradient and levels at both floor levels



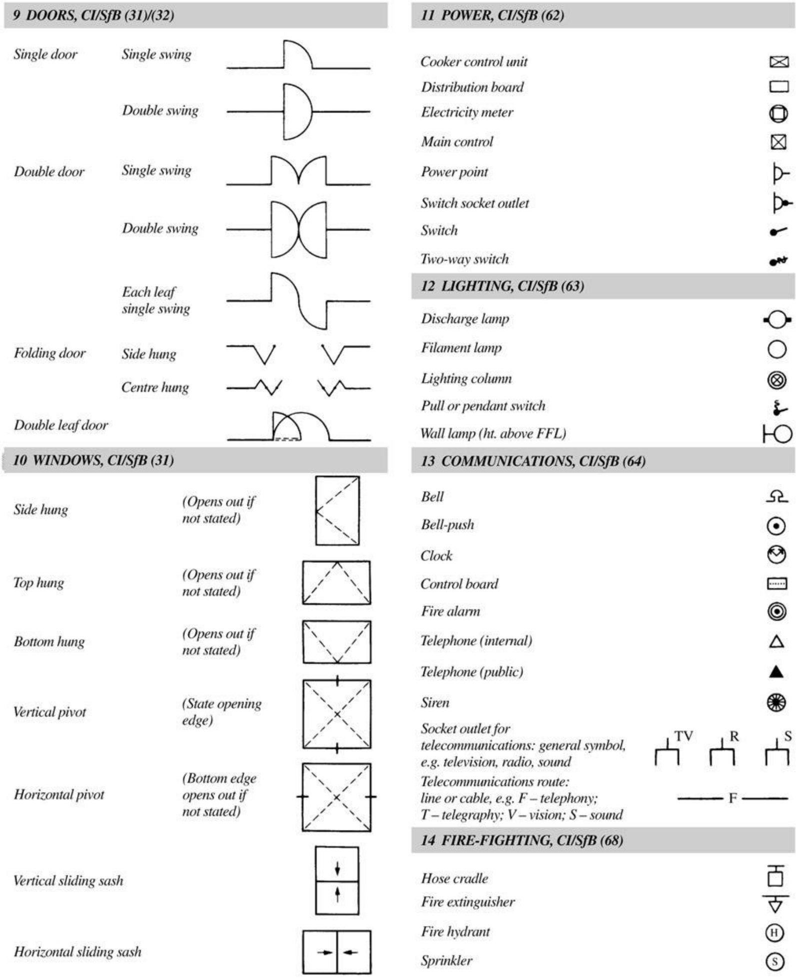


Figure 17.11 Typical graphic symbols used on working drawings.

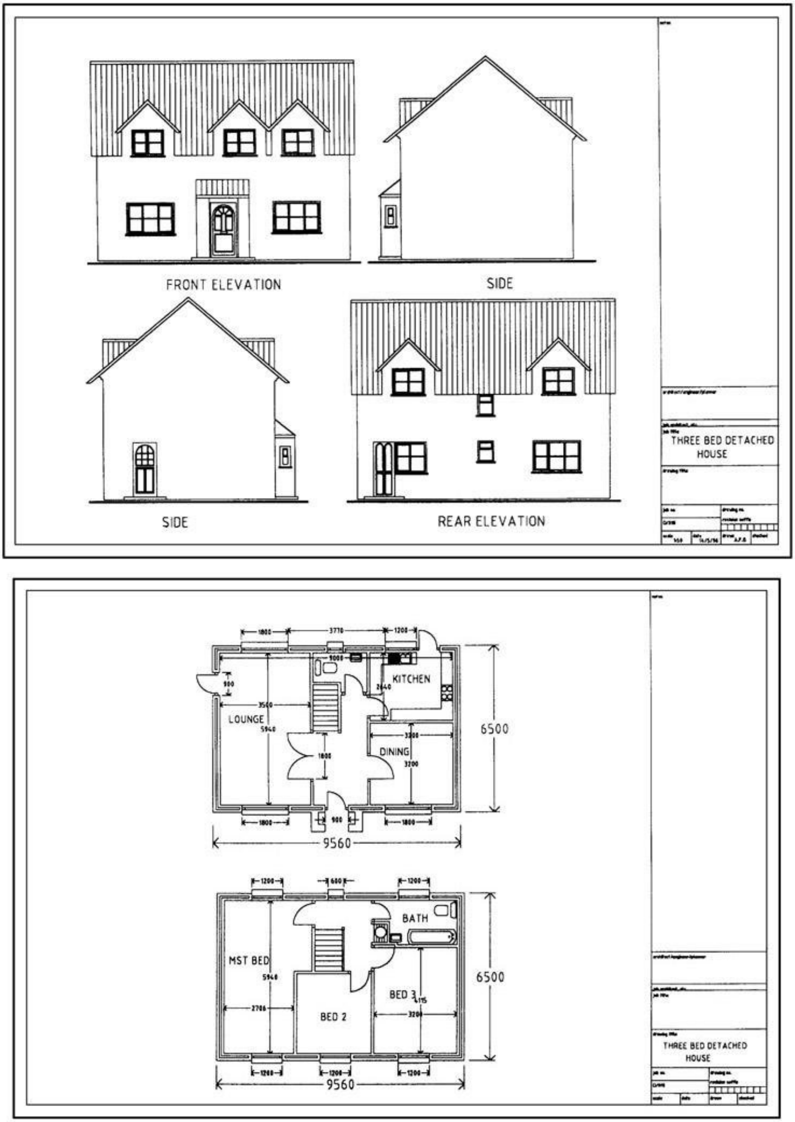


Figure 17.12 Working drawings produced on a computer.

consists of drawings containing many notes about the construction methods to be employed which are further developed by the clauses of specifications and/or bills of quantities. There is also the systematic method, which consists only of outline drawings but makes frequent direct cross-reference (using the CI/SfB system) to supplementary documents such as standard details, schedules, specification clauses and bills of quantities. These forms are illustrated in Figures 17.12 and 17.13.

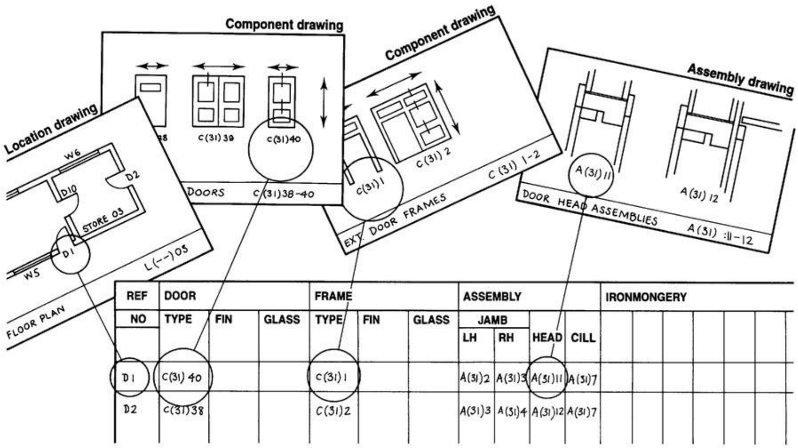


Figure 17.13 Systematic method for producing working drawings. (Based on material in BRE Digest 172.)

In 1987 the Building Project Information Committee (BPIC) created the Common Arrangement of Work Sections (CAWS) classification system to simplify specification and referencing. BPIC sponsors included RIBA, RICS, BEC and ACE, the latter representing CIBSE and ICE. CAWS simplifies conventions and applies a letter- and number-coded notation common to the standard method of measurement

(SMM), a code of procedure for project specification and drawings code, the national building specification (NBS) and the national engineering specification (NES). Work sections are coded A to Z (I and O omitted), as listed in Figure 17.14. Each section is subdivided, as shown in Figure 17.15, for masonry, and further subdivided for detailed descriptions. New innovations and products are easily added, e.g. F4. Confusion over section entries is avoided by definition of work sections. So for F10, brick/block walling (Fig. 17.16), inclusions and exclusions are clearly indicated, with exclusions referenced to alternative sections.

A	Preliminaries/general conditions
B	Complete buildings
C	Demolition/alteration/renovation
D	Groundwork
E	In situ concrete/large precast concrete
F	Masonry
G	Structural/carcassing metal/timber
H	Cladding/covering
J	Waterproofing
K	Linings/sheathing/dry partitioning
L	Windows/doors/stairs
M	Surface finishes
N	Furniture/equipment
P	Building fabric sundries
Q	Paving/planting/fencing/site furniture
R	Disposal systems
S	Piped supply systems
T	Mechanical heating/cooling/refrigeration systems
U	Ventilation/air-conditioning systems
V	Electrical supply/power/lighting systems
W	Communications/security/control systems
X	Transport systems
Y	Services reference specification
Z	Building fabric reference specification

Figure 17.14 Common Arrangement of Work Sections.

BPIC evolved into Construction Project Information (CPI) committee and in 1997, then represented by RIBA, RICS, CIBSE, ICE and CIAT (later CIOB), produced a unified classification for structuring product literature and information into library format known as Uniclass. Uniclass comprises 16 groups of tables as shown in Figure 17.17 with further subgrouping, as example in Figure 17.18. Uniclass incorporates the established European technical literature product coding system known as EPIC for product identification where marketed across Europe. Product literature can be coded/indexed with all three systems as shown in Figure 17.19.

F	**Masonry**		
F1	Brick/block walling	F10	Brick/block walling
		F11	Glass block walling
F2	Stone walling	F20	Natural stone rubble walling
		F21	Natural stone/ashlar walling/dressings
		F22	Cast stone walling/dressings
F3	Masonry accessories	F30	Accessories and sundry items for brick/block/stone walling
		F31	Precast concrete sills/lintels/copings/features

Figure 17.15 Organisation of CAWS workgroups.

The selection of the most suitable classification system for a particular project depends upon the organisation of the Building Team, and on the complexity of the building work involved. The conventional form of production or working drawing shown in Figure 17.12 has been produced by a computer; the hand-drawn equivalent, which still forms the major technique of presentation today, is similar to most of the illustrations in this book.

The use of a ‘systematic method’ for production drawings has developed with the use of computers, which are able to supply drawings for particular design and construction problems, e.g. repetitive details relating to columns and beams on structural grids.

17.3 Specification of works and bill of quantities

These, together with the production drawings, combine to form the legal documents describing the totality of the construction process. A specification is a written document prepared by members of the Design Team and provides fundamental information which, for various reasons, cannot be incorporated on the production drawings for a proposed project. It is an integral part of the design process because it describes the quality of work which is considered necessary during construction. Information for a specification therefore evolves during the preparation of the production drawings, and is subsequently issued in two main parts:

- Preliminaries describe the legal contract through which the construction work is controlled, including insurances; the facilities to be provided by members of the Building Team on site; the general conditions of the site and/or existing building to be converted, including details of access routes, roads and local restrictions; and other details concerning the general running of a project, including information about the quality of work required, nominated subcontractor and suppliers, hours of working, generation of noise, dust, etc.
- Trade clauses describe the actual construction methods (materials and techniques) to be adopted and may be done in the following ways:
    - – precisely describing the materials to be used and the work to be executed under each trade (see page 162);

- – describing the materials and work required for each separate part or element;
- – giving a performance specification (statement of requirement) which accurately details the quality of work expected in terms of performance criteria for each part involved, without describing a method of achieving it, e.g. Concrete in foundations, C15 (15 N/mm^2). BS EN 206-1: Concrete. Specification, performance, production and conformity.

The purpose of a specification is to provide information to the potential builder or contractor of a proposed project which, together with the drawings, will enable a reasonably accurate price to be submitted or tendered for the work involved. The detailed information it provides could not be adequately indicated on the production drawings because these would become far too complicated, and extremely difficult to read. In order to avoid unnecessary confusion, it is important that notes on a drawing should not duplicate clauses of specification. Drawing notes should only provide a general comment necessary for an overall understanding, and which leads to the more detailed description in the specification. Only for very simple projects involving few trades will drawing notation suffice for describing the work; the legal arrangements are left to the clauses of the formal building contract.

F10

Brick/block walling

Laying bricks and blocks of clay, concrete and calcium silicate in courses on a mortar bed to form walls, chimneys, partitions, plinths, boiler seatings, etc.

Included

Brickwork of clay, concrete and calcium silicate
Blockwork of clay and concrete
Special shape bricks and blocks
Specially faced bricks and blocks
Brick facing slips
Brick DPCs
Firebrick work
Brick bands, copings, sills, arches, etc.
Holes, chases, grooves, mortices, cutting, bonding, pointing other than for engineering services
Forming key for asphalt and other applied finishes
Centring
Mortar (Z21)

Excluded

Concrete cavity fill and concrete fill for hollow blocks or reinforced brickwork/blockwork (In situ concrete, E10)
Bar reinforcement for reinforced brickwork/blockwork (Reinforcement for in situ concrete, E30)
Natural stone rubble walling, F20
Natural stone ashlar/dressings, F21

Figure 17.16 Contents of a CAWS workgroup.

A	Form of information (7)
B	Subject disciplines (7)
C	Management (5)
D	Facilities (9)
E	Construction entities (9)
F	Spaces (9)
G	Elements for building (7)
H	Elements for civil engineering works (8)
J	Work sections for buildings (24)
K	Work sections for civil engineering works (26)
L	Construction products (8)
M	Construction aids (9)
N	Properties and characteristics (9)
P	Materials (8)
Q	Universal Decimal Classification (10)
Z	Computer-Aided Draughting (8)

Figure 17.17 Uniclass group listing. Note: Sub-group numbers in brackets, see example in Fig. 17.18.

C1	Management theory, systems and activities
C2	Management personnel
C3	Type of business/organisation
C4	Specialist areas of management
C5	Management of construction activities/project management

Figure 17.18 Uniclass sub-group.

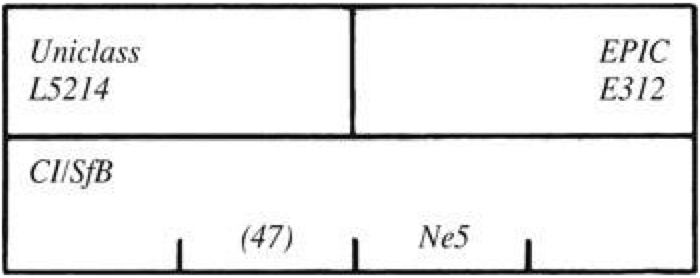


Figure 17.19 Combined CI/SfB, Uniclass and EPIC product coding.

Writing specifications is often thought to be tedious and time-consuming. Over the years attempts have been made to standardise phraseology, rationalise descriptions and provide a structure to the clauses in order to speed production while still providing an adequate means of communication. The latest version of the standard method of measurement (SMM), written to comply with CPI (section 17.2.2), provides a system advocating the structuring of specification clauses to follow the construction process, starting with excavations and structure, proceeding through all the services to finishing trades and external works. This logic is complemented by the National Building Specification (NBS) in CPI format. NBS Create is a commercially available specification facility linked to building information modelling (BIM), the industry terminology for collating, organising and managing technical data (Fig 17.20).

CAWS – Comprises a framework of defined work sections, groups and sub-groups as an arrangement for coordinating specifications and bills of quantities. See pages 190 and 191.

CI/SfB – An indexing system introduced to the UK in 1961, subsequently revised in 1968 and 1976. Obtained universal acceptance in the industry, but by contemporary digital standards, its alpha-numeric bracketed combinations limit its use to libraries of manufactured products. See section 17.1.

BPIC/CPIC – Committee responsible for providing best practice guidance on construction production information. See page 190.

BS ISO 12006-2: Building construction. Organisation of information about construction works. Framework for classification of information.

COBie – Construction Operations Building information exchange. A data management system for use over the life cycle of a building. Comprises a series of spread sheets used as a data exchange facility.

EPIC – Established as a European system for coding manufacturer's product information. Less popular in the UK, but used by some architectural and engineering practices for data presentation. See pages 191 and 192.

NBS – Established as the UK industry standard for specifications of elements of building work and as a resource for information solutions, products and services. Maintained and updated by RIBA Enterprises Ltd.

NBS Create – A web delivered system of pre-written clauses with options. It also includes data from product manufacturers. Automatically updated and functions as a specification writing tool produced specifically for building information modelling.

NES – National Engineering Specification. Standard specifications facility for building services endorsed by CIBSE and BSRIA.

RIBA Plan of Work – A model procedure introduced by the RIBA in 1964 as a means of methodically applying design to the construction process. It was subsequently revised in 1998 and 2007 and is now used by many in the industry as guidance to overall planning of a project. See section 15.2.

Standard Method of Measurement – Originated in 1922, currently the revised 1998 version SMM7 provides rules for QS's in producing bills of quantities. Maintained by the RICS. See page 192.

Uniclass – Incorporates CAWs and EPIC systems of structuring project literature and information. See pages 191 and 192.

Figure 17.20 Building Information Modelling (BIM) systems and associated terminology.

A bill of quantities or contract bills is also a written document providing fundamental information about a proposed project, but varies from a specification in that it arranges the information into a form more suitable for direct pricing by a builder or contractor. Bills of quantities are used for larger and more complicated contracts, and are prepared within the organisation of a Design Team by a quantity surveyor using the information supplied by production drawings and specification notes. A currently acceptable method of presentation for bills of quantities consists of three main parts:

- Preliminaries: as described for specifications.
- Preambles to trades: a general specification and description of materials and standards of work.
- The quantities: a description of the individual items to be priced and also the numbers, amounts or quantities of each required for the project.

The Construction Team's or building contractor's quantity surveyors or estimators generally prepare their own list of quantities, when they are not supplied, from information indicated on the production drawings and in the specification. But as the bills of quantities prepared by the Design Team describe the work to be done and the conditions relating to the work and measure the materials and components required (and therefore the type and amount of labour), it is easier for a contractor's quantity surveyors or estimators to prepare a more accurate price for a project. (Furthermore, an individual contractor's estimated price is based upon standardised information, and this facilitates the Design Team when comparing it with the prices of any other contractor who may wish to do the work; see the next section.)

17.4 Tender documents

The production drawings, specification and/or bills of quantities together form the initial contract documents which are submitted to the Construction Team for pricing. The principal designer may agree with the client to submit these documents to a builder or contractor who is known to be capable of executing the particular work involved. This will produce a negotiated tender, where a price for the work is prepared on the basis of discussion around the contents of the contract documents. This method of tendering has the advantage that a considerable amount of time is saved by not involving other builders or contractors, and the selected organisation may well be able to make cost-saving suggestions.

As an alternative, the principal designer may advise the client to obtain competitive tenders from a suitable range of Construction Teams (building contractors). Bills of quantities are particularly useful for this purpose as they permit individual Construction Teams/builders to submit tenders on a uniform basis. Equally, the Design Team is able to check and compare the figures of each competitor efficiently before making recommendations to the Client Team. Before this recommendation is given, however, the Design Team must also ascertain the suitability of resources and quality of work available from each competitor. The period of time required for the construction work is also an important consideration. It is not uncommon for the organisation submitting the lowest tender price to be rejected because of doubt in these areas.

Work which is being undertaken by competitive tender is often advertised in professional journals such as Building. On receiving the contract documents, contractors should visit the site of the proposed project in order to base their economic assessments on the actual conditions likely to affect construction work. Each competitor will prepare their estimate for the work and submit a tender, which gives prices for the individual items in the bill of quantities (now often described as contract bills).

Matters to be considered when pricing work include the current cost of materials, machinery and transport, fluctuations in wage rates, and the overhead expenses involved in maintaining an administrative organisation. To this must be added an allowance for waste of materials, depreciation of equipment, labour on non-productive work and a reasonable margin for profit. The profit objective is a corporate decision. It may be determined by the amount of work currently in progress and that anticipated in the near future. Factors such as the possibility of repeat and continuous work from the client/architect will have an influence, as will the anticipation of a continuing aftercare/ maintenance contract for the completed building.

A building contractor's profit is not only realised through good organisation of site work, but involves the efficient costing ability of its quantity surveyor or estimator at the time of tendering. Consideration must be given to how much work is to be done within the organisation and how much is to be subcontracted. Prices must be obtained for materials and labour from subcontractors and suppliers. The management personnel within the organisation must discuss the estimate to establish a figure for contingency items, resulting from likely increases in materials and labour, before the contract ends. When the cost of certain items indicated in the contract documents cannot be predicted i.e. it is work which cannot be properly valued by measurement, e.g. the extent of excavation, provisional allowances are made on a daywork basis. This incorporates the cost of material and equipment required and a unit rate for the time taken for the work, which includes the hourly sum paid to the workers, as well as insurance, holiday pay, grants, travel and overtime expenses, and adverse weather payments, etc.

The absence of information caused by poorly prepared, or the non-existence of, specifications or bills of quantities could mean that much of the work indicated on drawings will be priced by using this method, but with additional sums added to cover uncertainties. The lack of information concerning some constructional aspects of a project could result in massive extra costs once the work has proceeded and can therefore lead to serious repercussions.

If the price for the construction work is considered acceptable and the project proceeds, it is quite usual for the quantity surveyor of the builder or contractor to continue with the financial management for the construction work. This entails agreement of interim work, measurement or accurate assessment of completed work and materials on site, and negotiation of payments with the client's quantity surveyor at intervals agreed in the building contract. Details are submitted to the principal designer for confirmation and payment by the client. Similarly, at the completion of the project, the measurement and valuation of all variations leading to the final account must be agreed.
These variations will usually be calculated in relation to the itemised prices which have been given in the bills of quantities. These negotiations are considered in section 17.6.

It sometimes happens that the initial contract documents are not fully completed, but it is still desirable to negotiate a price for the intended work or obtain competitive tenders from a builder or contractor. This will enable an early start on site preparation and construction, as well as permitting close cooperation with a builder or contractor during the preparation of production information, of particular advantage when specific construction skills or resources have to be taken into account.

One method of involving specialised construction skills early in the design process is for the principal designer to prepare a 'shortlist' of potential contractors, and then interview each to establish their methods of management, construction policy, the possible form and content of their pre-contract input, and their current contractual commitments. The contractor having the best potential suited to the particular project can then be appointed. However, the criteria to be used to calculate the price of the project must be agreed before the contractor's appointment so that a sum can be developed as the design process continues. This method of negotiation requires a high level of trust between the parties involved, specific costing expertise and a thorough knowledge of current building costs.

Alternative methods include a cost reimbursement scheme, where the selected contractor is paid for the work executed on the basis of audited accounts to which is added an agreed percentage for overheads and profit. Sometimes an estimated lump-sum price for a project is agreed prior to the commencement of construction work and any discrepancies, savings or extras are shared equally between client and contractor. This is known as a target contract.

When it is necessary to obtain fully competitive tenders for a project without completed tender documents, one of the following techniques may be more appropriate. These methods of tendering can also be used when negotiating a price with a preferred builder or contractor without adopting competitive techniques.

A list of the major items of work is prepared and a selection of suitable builders or contractors are invited to submit a schedule of rates for each. Once the work on site starts, the successful competitor will be paid for particular construction work at the agreed rates listed in the schedule, unless there are major changes. Work which the final design requires, and which has not been given a price rate, will be subject to negotiation.

A notional bill of approximate quantities can be prepared by the quantity surveyor, which lists the approximate quantities measured from preliminary design drawings, or the quantities given in a full bill of a similar project. This notional bill will be submitted for tenders and the successful contractor, once appointed, will be paid at the unit price rate agreed for the actual quantity of work measured on site. If there are any items not included in the notional bill, their cost must be negotiated separately.

A two-stage tendering procedure may be adopted. The first stage is based on a notional bill of approximate quantities, as described. Once appointed, the successful contractor helps to develop the design and prepares the second-stage tender based on contract documents which include a full bill of quantities. Rather than appoint a contractor after the first-stage tender, the client may prefer (or be recommended by the principal designer) to delay appointment until after the second-stage tender, in order to obtain more favourable prices. In this case the pre-contract contractor may be paid a fee for advice and services during the design process stage. Whichever stage of appointment is adopted, construction time can be shortened if the contractor is authorised to prepare the site, or to order long-term delivery of materials during the period between obtaining first and second tenders.

A serial tendering procedure may be appropriate when a number of projects of a similar nature are to be constructed over a considerable period of time. This has the advantage of engaging the same Design and Construction Teams for each project, encouraging a familiarity with procedures to produce time and other cost savings. The type of work could be repetitive housing for the public sector or possibly industrial units for the private sector. The full bill of quantities for the project first constructed can be progressively updated for subsequent projects.

17.5 Contracts

It is preferable that building operations, like any other activity involving human and material resources, have a formalised set of rules based on a legal contract. This will ensure the rights and responsibilities of each party, and help in the successful production of a building. Various types of agreement can be drawn up, but it is usually advisable to adopt a standard form of contract because the individual provisions of non-standard forms will most likely not have been tested in the courts of law, which means the accountability of each party is not always clear. Even though standard forms of contract result from the joint consultations of interested professional bodies and may have been well tested in practice, matters often arise which cause dissatisfaction between various parties, as indicated by the legal sections of most current building trade journals. For this reason, a continuous process of reassessment is necessary; revisions are issued from time to time, particularly in the face of the increasing complexity within the building industry.

17.5.1 Contracts between Client Team and Design Team

Standard forms of contracts are available which stipulate the rights and responsibilities between a client and the principal designer, or specialist designer, or quantity surveyor. They are available from the professional body which represents each consultant, and state the role played by them during the design and construction periods of a project, the fees payable and the liability taken. Although these formal agreements are perhaps the least used (most clients employ consultants through personal recommendation), the increased tendency towards costly litigation to solve disputes makes them almost mandatory in the interest of both parties.

Standard forms of contract between client and building designer have been drawn up by the RIBA. The principal appointing practice documents are:

- Standard Agreement for the Appointment of an Architect (S-Con-A).
- Standard Agreement for the Appointment of a Consultant (S-Con-C).
- Concise Agreement for the Appointment of an Architect (C-Con-A).
- Concise Agreement for the Appointment of a Consultant (C-Con-C).

- Agreement for the Appointment of a Sub-Consultant (SubCon).
- Supplementary Schedule for Contractor's Design Services (SupCD).
- Form of Appointment for Interior Design Services (ID).
- Domestic Project Agreement for the Appointment of an Architect (D-Con-A).
- Domestic Project Agreement for the Appointment of a Consultant (D-Con-C).

17.5.2 Contracts between Client Team and Construction Team

The most important standard form of contract for the building industry exists between a client requiring construction activities and the builder or contractor who is prepared to execute them. The first modern type of formal contract was drafted during the late nineteenth century. It was prepared by the RIBA and it became known as the RIBA Standard Form of Building Contract. In 1931 the RIBA was joined by the National Federation of Building Trades Employers (later known as Building Employers Confederation and now Construction Confederation) to review forms of contract, and this combination became known as the Joint Contracts Tribunal (JCT). In 1939 the RIBA Form of Contract was completely revised and replaced by the JCT Standard Form of Building Contract. However, the term 'RIBA Form' is still common parlance, probably because RIBA Publications produce the JCT forms.

Further revisions and editions to the JCT Form followed in 1963 and 1977, by which time the constituent bodies of the JCT had increased to include:

- Royal Institute of British Architects
- Building Employers Confederation
- Royal Institution of Chartered Surveyors
- Association of County Councils
- Association of Metropolitan Authorities
- Association of District Councils
- Specialist Engineering Contractors Group
- National Specialist Contractors Council
- Association of Consulting Engineers
- British Property Federation
- Scottish Building Contract Committee

In 1980 a substantially new edition was produced. This became known as JCT 80 and it was published in various contract versions, including standard administration forms available for private sector and local authority clients as follows:

- Private edition with quantities
- Private edition without quantities
- Private edition with approximate quantities
- Local authority edition with quantities
- Local authority edition without quantities
- Local authority edition with approximate quantities

Between 1983 and 1998, JCT 80 received a considerable number of amendments, culminating in the need to accommodate the requirements of the Housing Grants Construction and Regeneration Act – the Construction Act 1998. The volume of changes to JCT 80 then made it extremely difficult to use, so it was rationalised into an amalgamated edition published by the JCT Ltd under the title Standard Form of Building Contract 1998, i.e. JCT 98. The constituent bodies at this time were:

- Royal Institute of British Architects
- Construction Confederation
- Royal Institution of Chartered Surveyors
- National Specialist Contractors Council
- Association of Consulting Engineers
- British Property Federation
- Scottish Building Contract Committee
- Local Government Association

Other styles of the JCT 98 Standard Form of Building Contract included:

- With contractor's design – with or without quantities for use where no architect or supervising officer is engaged by the employer.
- Intermediate form of building contract – for use where works are of a simple nature.
- Fluctuation clauses – for use with all versions of the local authorities and private editions.
- Management contract – prescribes all work to be conducted on a standard contractual base.
- Subcontract documents:
    - – invitation to tender;
    - – tender and agreement;
    - – particular conditions;
    - – standard form of employer/nominated subcontractor agreement;

  - – standard form of nomination for subcontractor;
  - – employer/specialist agreement, a warranty for named subcontractors who provide a design element;
  - – standard conditions of nominated subcontract;
  - – articles of agreement between contractor and nominated subcontractor.

- Sectional completion supplement – with quantities, approximate quantities and without quantities.
- Prime cost contract – replaces the former fixed fee contract. Used where the employer agrees to work commencing where only a price indication is given and the employer agrees to pay labour and material costs, plus a 'fixed fee' for the contractor's overheads and profit.
- Standard form of building works of a jobbing character – used by employers that place a number of small contracts (generally < £20 000) with various contractors.
- Measured term contract – used by employers who need regular maintenance and/or minor works to be carried out in a defined area over a specific time by one contractor.
- Minor building works – used where small-scale work is carried out for an agreed lump sum and an architect/supervisor has been appointed to represent the employer. Not suitable where a bill of quantities is used or the employer nominates subcontractors or suppliers.

- Formula rules for use with all standard forms of contract and subcontract. These are adjustments to accommodate for index changes in national wages and prices.
- Building contract for the homeowner or occupier – comprehensive document specifically for home improvements and domestic building work. Designed to enhance the professional relationship between house owners and reputable builders.

After 1998, the JCT continued to revise existing contracts and to produce new ones, with the objective of achieving a consistent and uniform format. In 2005 this materialised as a new suite of contracts known collectively as JCT 05. In addition to the standardised layout, Sweet and Maxwell have published these colour-coded contracts in the following ‘contract families’:

- Standard Building Contract – with or without quantities, or with approximate quantities. Suitable for larger works designed and/or detailed by or on behalf of the employer.
- Intermediate Building Contract – for use where works are of a normal and simple content.
- Minor Works Building Contract – with or without contractor’s design.
- Design and Build Contract – where the employer requires detailed contract provisions and the contractor is required to complete the design and the works.
- Major Project Construction Contract – where the employer requirements are for large-scale construction work and the contractor is sufficiently

experienced to take greater initiatives and risks than would arise in other JCT contracts.

- Construction Management – required where separate contractual responsibilities exist for management, design and the construction of a project.
- Management Building Contract – used where commencement of work precedes the full design information, or works are carried out in different sections.
- Prime Cost Building Contract – may also be used where an early start is required for site work. Work is initially based on a specification and cost estimates.
- Measured Term Contract – regular maintenance and ongoing type of minor works over a specified period of time.
- Housing Grant Works Building Contract – works of a relatively simple nature, based on employers providing drawings and specification re Housing Grants, Construction and Regeneration Act.
- Adjudication Agreement – appointment of adjudicators where a dispute has arisen under other JCT contracts or subcontracts.
- Framework Agreement – used for procurement of construction/engineering work over a period of time. Used as a supplement to other forms of contract.
- Generic Contracts – subcontractor forms of engagement where the main contract is a JCT contract.
- Collateral Warranties – used where a contractor (or sub-contractor) gives a warranty to a company providing finance for a project.

- Home Owner Contracts – a consumer contract for residential occupiers and owners. Can also apply where the owner engages a consultant, e.g. architect.

The Local Democracy, Economic Development and Construction Act 2009 – the Construction Act – became effective from 2011. It amended the previous Act of 1998 by introducing significant changes to the ways that construction main and subcontracts had previously operated, requiring the JCT 05 suite of contracts to be revised and updated as JCT 11. Engagement and terms of professional appointments changed to improve payment practice with new provision for retentions, adjudication procedures and inclusion of further provision for appointment of principal contractor under the CDM Regulations. Sweet and Maxwell publish the JCT contracts in the established format of 'contract families' as previously listed with the following additions:

- Constructing Excellence – used for collaborative and integrative working of construction project partnerships or multi-party agreements.
- Consultancy Agreement – used by the client where they consider the nature of construction work justifies engagement of specialist consultants.
- Pre-Construction Services Agreement – a supplementary contract to other main contracts, e.g. Standard Building Contract or Design and Build Contract, where the contractor has a specialist input such as consultancy or design work.
- Repair and Maintenance Contract – generally work of a relatively small scale in terms of cost and time.

Periodic scheduled maintenance may be better with a Measured Term Contract.
- Tracked Change Documents – to help with the transition from JCT 05 to JCT 11 contracts.

Work that was previously undertaken with the Housing Grant Works Building Contract can be effected through either the Minor Works Building Contract or the Home Owner Contract. The CIOB have also produced two contracts that are appropriate to relatively simple works:

- CIOB Mini Form of Contract (General Use) – suitable for small refurbishment projects not CDM-notifiable up to about £20 000 in value and less than 12 weeks' duration, e.g. replacement bathrooms, kitchens, extensions and loft conversions.
- CIOB Small Works Contract – a straightforward, easy-to-understand contract suitable for small building projects up to £250 000 with a duration of less than six months.

The Association of Consultant Architects (ACA), which represents over 400 private sector architectural practices, has also prepared a number of building contracts. These contracts are generally shorter than the JCT contracts and do not attempt to duplicate those areas of building legislation covered by common law. These contracts, listed below, should be used in conjunction with the ACA's own version of architect's instructions, interim certificates, final certificates, conciliation agreement and taking over certificates:

- A Form of Building Agreement.
- Standard Forms of Contract for Project Partnering.
- Standard Forms of Contract for Term Partnering.

- Form of Sub-Contract.
- The Appointment of a Consultant Architect for Small Works, Works of a Simple Content and Specialist Services.
- Standard Form of Agreement for Appointment of an Architect.

Civil engineering work is contracted under the New Engineering Contracts (NEC) produced by the Thomas Telford organisation or the Civil Engineering Contractors Association (CECA) and the Institution of Civil Engineers (ICE) Conditions of Contract. The Chartered Institute of Building (CIOB), in partnership with Cameron McKenna, has produced the first Standard Form of Facilities Management Contract for application to all categories of private and public sector works. Government contracts (GC/Works), published by the Stationery Office, are widely used for government building and engineering works. Various forms exist within the following categories:

- GC/WKS/1 – Contract for building and civil engineering major works.
- GC/WKS/2 – Contract for building and civil engineering minor works.
- GC/WKS/3 – Contract for mechanical and electrical engineering works.
- GC/WKS/4 – Contract for building, civil engineering, mechanical and electrical small works.
- GC/WKS/5 to 9 – General conditions for a variety of situations.
- GC/WKS/10 – Facilities management contract.
- GC/WKS/11 – Minor works term contract.

17.6 Fee accounts and certificates for payment

One important area of concern in most standard forms of contract involves payments for the services connected with the design and construction processes.

17.6.1 Fee accounts

Fees paid by the client to various members of the Design Team are usually governed by the conditions of engagement issued by the professional body which represents a particular design discipline. For example, the RIBA's practice documentation described earlier lists those services normally offered by an architect in accordance with the plan of work. Indicative fees for administering traditional competitive tendered contracts are shown in Figure 17.21. These are negotiable with the client and represent

a percentage of the construction cost, depending on the type of building as shown in Table 17.1. Where the construction follows normal established procedures and the design is simple in concept, this approach as a fee basis is generally acceptable. However, where client expectations are for more varied and complex designs, in addition to the designer taking on more responsibilities in project management, traditional fee appraisal by percentages is unlikely to represent a fair deal for either client or architect. Fees can be agreed by a number of means, not least a percentage of the construction cost. For some work a simple lump sum or an agreed fee per timescale may be appropriate. More likely, a fee will be calculated or negotiated relative to the range of services offered by the

Design Team, the means for procurement, the schedule and programme of work, the construction method and the degree of complexity of design and build. For the large projects, which occupy long periods of time, it is becoming usual for designers' fees to be paid by instalments in accordance with a scheduled programme agreed with the client at the outset of negotiations. This programme can incorporate more frequent intervals between payments than provided by the work patterns given in the plan of work, and thereby enable the designer to receive more or less regular sums during a project's design and construction processes (see section 16.3). There is also a 'Fees Toolkit' introduced by the RIBA as a comprehensive method for preparing fee proposals on the basis of services provided. (Source: A Client's Guide to Engaging an Architect, RIBA Publishing.)

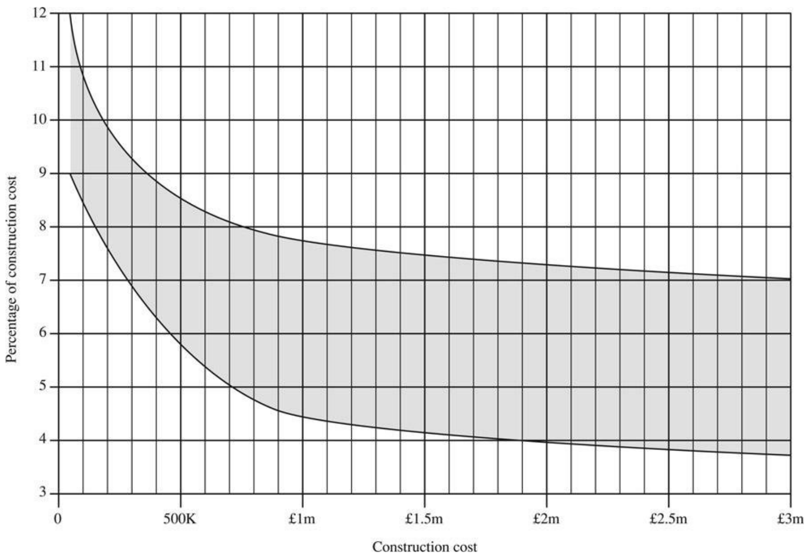


Figure 17.21 Indicative range of average fees for new works – traditional contract. Reproduced courtesy of RIBA Enterprises Ltd., www.ribabookshops.com

17.6.2 Certificates for payment

Depending on which standard form of building contract governs the construction of a particular project, it is also usual for payments by the client to the builder or contractor to be made at regular intervals. Normally the client's quantity surveyor prepares valuations (see page 152) at the periods stated in the contract (28 days or 14 days for large projects) in accordance with the given terms and conditions. Reports are made to the principal designer for guidance in preparing interim certificates for payment. These certificates give valuations of the work executed on site; materials delivered to the site but not used; nominated subcontractors' and suppliers' invoices; and other

substantiating evidence of expenditure such as may result from daywork rates (see page 194) to cover designers' instructions not already included in the contract documents. Thereafter, each interim certificate must contain an itemised statement of the principal sum due to the builder or contractor as well as the sums to be paid to subcontractors for their work. With most forms of contract there is provision for the retention of a small percentage of the total sum given in each certificate. This is normally 5 per cent (or 3 per cent where the estimated contract sum is £500 000 or more), and acts as a safety retainer in the event of subsequent default by the builder or contractor, subcontractor or supplier.

Table 17.1 Building types - range of complexity

Building Type	Simple	Average	Complex
Offices	Multi-storey and underground car parks	Banks Office developments	Telecom and computer buildings Research and development laboratories Radio, TV and recording studios
Industrial	Barns and sheds Speculative factories and warehouses Transport garages	Purpose-built factories and warehouses Animal breeding units	Food processing units Breweries High risk processes
Retail	Speculative retail	Food retail Non-food retail Garages/showrooms	Department stores Shopping centres
Community buildings		Community centres Branch libraries Schools Ambulance and fire stations Police stations Prisons Postal buildings Bus and railway stations Airports	Civic centres Specialist libraries Universities Churches and crematoria Museums and art galleries Courts Theatres, opera houses, concert halls and cinemas
Medical		Health centres GP surgeries	Hospitals Dental surgeries
Public housing		Social housing Sheltered housing Housing for single people	Special needs housing Residential care homes
Private housing		Apartment blocks	Individual houses/flats
Leisure		Sports halls Squash courts Swimming pools	Leisure complexes Restaurants Public houses Hotels

(Reproduced courtesy of RIBA Publications)

Once the construction work has been completed, a certificate of practical completion can be issued to cover the agreed costs of the project. At this stage, usually only half of (or one moiety) the retention sum previously withheld is paid; the rest is kept for a period agreed in the contract during which it is assumed any defects will become apparent which are the sole liability of the builder or contractor, subcontractor or supplier. After this agreed defects liability period has elapsed (generally 3 months for small works and 6–12 months for larger works), the final certificate of payment, or certificate of making good defects is issued and the residue retention sum can be released in total, or in part, according to the expenditure necessary to correct any faults. The retention sum does not cover faults in design, or any work executed by the builder or contractor in total accordance with the instructions

from the Design Team (i.e. as given in the contract documents). Failures arising from the content of the contract documents are subject to separate negotiations between client and designer, although the experience of the builder or contractor may be used in the event of a dispute. Where no quantity surveyor
is employed to prepare financial statements, the builder or contractor submits a claim directly to the principal designer, who will then prepare the certificates for payment as already described.

After preparation by the principal designer, certificates of payment are issued initially to the builder or contractor, who will then submit them to the client for payment. This procedure arises because the contract is between client and builder; members of the Design Team are only acting as agents who administer the rules of agreement. Nevertheless, when the principal designer issues the certificate to the builder or contractor, the client and quantity surveyor (if involved) are automatically informed with a copy of the certificate. Under the conditions of the building contract, the client must pay the contractor within a stipulated period, normally 14 days.

17.7 Programmes of work

Programmes of work for the design and construction of a building project involve the coordination of many complex human and material resources to ensure economy and efficiency. The more detailed the programme, the less likely will unforeseen circumstances upset either the intentions or the timetabling of a project, thereby reducing the chances of frustration and delays.

The three main areas requiring detailed programmes are as follows:

- Design programmes (Fig. 17.22) These can take the form of a bar chart and are often called pre-contract programmes. They are prepared by the Design Team in order to establish how long it will take from the beginning of the design process to start of construction work on site. Apart from providing valuable information to the client – particularly when complicated negotiations are required for the release of capital for building – they allow the Design Team to accurately assess the demands on staff and the effects which the new project may have on other work running concurrently.

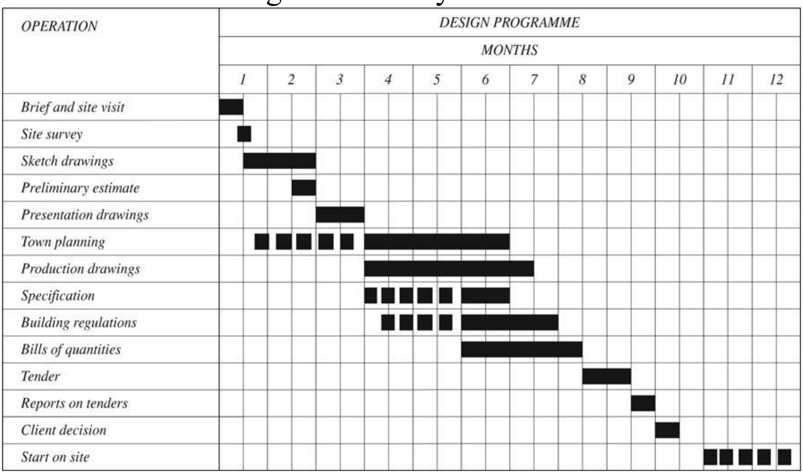


Figure 17.22 Design programme.

- Tendering programmes (Fig. 17.23) Sometimes, on behalf of a client, the principal designer will request builders or contractors who are tendering for a project to submit an outline, or tender programme. This can also consist of a bar chart which indicates the approximate periods of time required for each major construction activity and, together with the total period indicated for the proposed project, provides a method of assessment concerning the organisational ability of the builder or contractor. The total period required for construction is very often the critical factor used when making a choice from a selection of tenders which have been priced competitively. Generally speaking, time delays are dearer for the client after work has commenced on site.

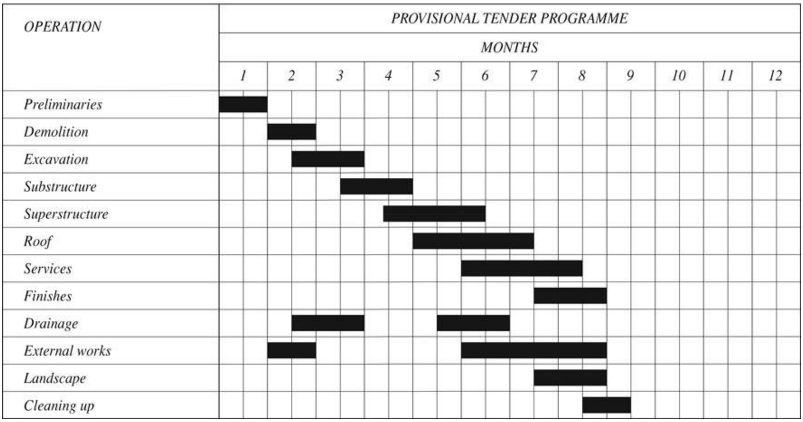


Figure 17.23 Tender programme.

- Contract programmes (Fig. 17.24) Once the successful builder or contractor has signed the building contract, he or she must plan the project in great detail. Whereas the Design Team specifies the work to be done, the order in which it is executed is usually the responsibility of the contractor, and even the smallest project demands a close examination of available resources, assessments of time and the influences of subcontracted work.

A method statement should be prepared from information given by the contract documents. This takes the form of a schedule breaking down the intended construction work into operations, then labour and plant requirements (or availability) for each (Fig. 17.25). The information can then be converted into a draft programme which should be issued prior to a general meeting between the management members of all the parties concerned with construction activities. Having had time to consider the proposals, this meeting will be able to confirm working methods and agree amendments as necessary. The contractor can then prepare a 'final' contract programme.

If the contract stipulates a monetary penalty, liquidated and ascertained damages, for delays beyond the completion date required by the client, a prudent builder or contractor will ensure the work is finished earlier than the programmed finish. This potential time difference allows for the unforeseen eventualities which usually result in longer time periods for certain building operations. A contractor may find that the initial timetable determined by the programme soon becomes unrealistic because of delays caused by bad weather conditions, late delivery of materials, subcontractors not being nominated quickly, client's variations or instructions not being given on time by the designers. If such problems develop, the contract programme should be updated to indicate a revised plan of action, and allowance made to cover the builder or contractor against unjust claims for delay.

Highly sophisticated programmes can be produced to provide a visual representation of the interrelationship between material and component deliveries, subcontractor and trade work. These can provide a more accurate programme and are based on a network diagram known as the critical path method (CPM) or critical path analysis (CPA) (Fig. 17.26). This method is sometimes considered too complicated for practical use in small to medium-size projects because of the frequent reconstruction which may be necessary as a result of updating. Nevertheless, the critical path method reflects actual site techniques more accurately than bar charts; this is because the tasks performed on site do not divide naturally into 'design element' parts, or the sequential use of trades. Each task has its own

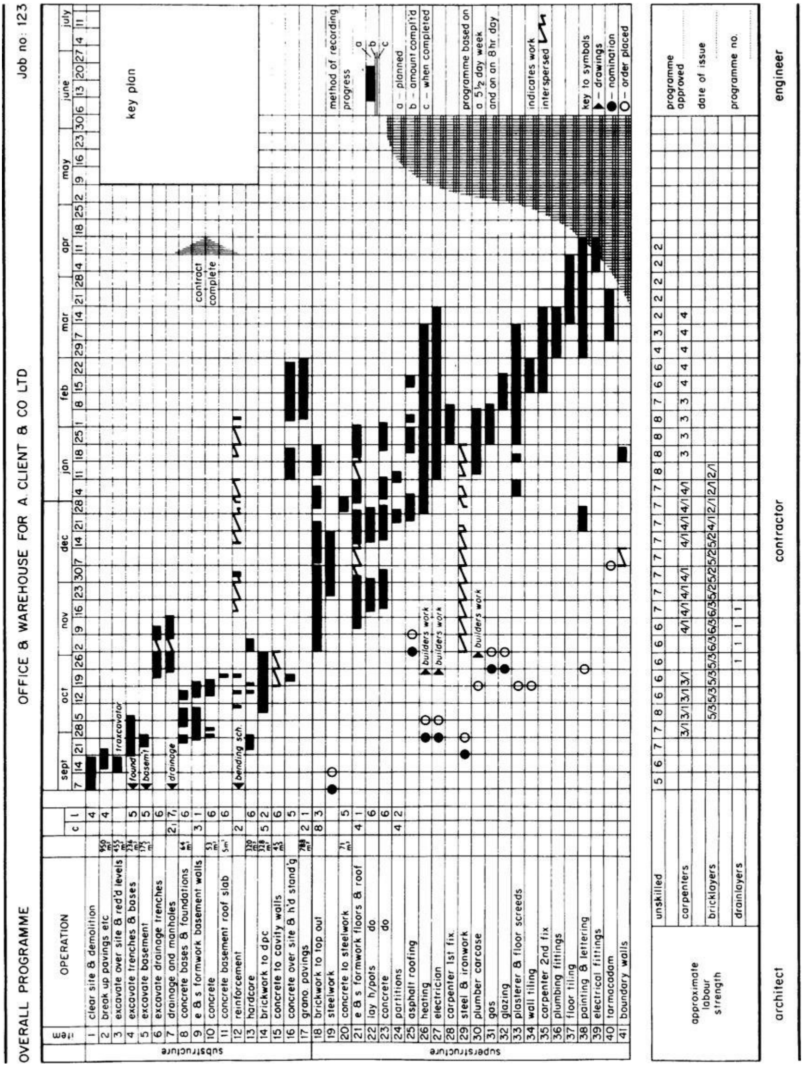


Figure 17.24 Contract programme.

breaks determined by the technology of production often peculiar to the particular site concerned, and a programme oriented towards reality should greatly improve the effective use of resources and progress of building work. The use of computer-produced programmes with the associated ease of updating data make network planning methods easily adaptable to ongoing changes to work in progress in the building programme.

Ref.	Item	Quantity	Method	Output	Labour	Plant	Time

Figure 17.25 Method statement.

17.8 Maintenance manuals

A completed modern building is often complicated to operate and maintain. Therefore, it is to the advantage of all those directly concerned with its eventual use that a maintenance manual is produced. This manual should be prepared by members of the Design Team, and perform a similar function to the operation and maintenance book for a car or any other machine.

For building, the maintenance manual can be conveniently divided into three parts:

- Statement of the designers' intentions This includes key drawings, schedules and photographs of the newly completed building; a description of its function; details of specialist designers; contract information; consents, licences and approvals obtained; details of Building Team; floor areas and permitted loadings; fire-fighting methods, precautions taken and means of escape; and a list of those maintenance contracts which are absolutely necessary as well as those considered desirable.

- Statement of the general maintenance required This includes regular cleaning instructions and methods when applicable; general maintenance log sheets; and a schedule of fittings and components which require regular attention and/or replacement.
- Statement of the mechanical services provided This includes a maintenance guide giving timing and frequency of required operations; fittings requiring periodic replacement; and drawings which are required for an understanding of facilities provided.

17.9 Feedback data

It is important that those concerned with the design and construction processes of a building also prepare data which will prove invaluable in the event that they will be concerned with a similar building in the future. This information should include a complete set of contract documents; an appraisal of the contract procedures between designer, client, builder or contractor, and subcontractors; a detailed cost analysis; and an appraisal of design and technical criteria which incorporates details of operational procedures associated with the subsequent use of the building.

This information may also prove invaluable in the event of legal claims arising as a result of disputes concerning responsibility for subsequent faults in the performance of a building. Claims of this nature could arise many years after the completion of a building when, perhaps, most of the original Design and Construction Teams have dispersed.

Organisations requiring to retain this information for all or most of the projects for which they have been responsible will face a serious problem of storage, and even of retrieval when required for subsequent research. Large projects may have several thousands of large drawings and schedules, as well as other documentation. Storage problems can be overcome by one of the many microcopying techniques ranging from simple reduction to 35 mm slide transparencies, to 35 mm or 16 mm micro-film or microfiche processes and storage on computer disks or CD-ROMs. The microfiche process has been effectively superseded by the compact nature and increased memory capability of CDs and computer hard disks. Where it is retained, it uses the principle of photographic reduction of documents on transparent cards usually 150 mm ´ 100 mm in size. Each card carries up to 60 micro-images set in rows which can be displayed on an enlarging screen for easy reading.

The use of micro-reproduction techniques is inseparable from the systematic information storage method mentioned in section 17.1; it can provide a total package of information on a particular project in a very small storage area. The CI/SfB system could be used for classification and ease of retrieval (see Table 0 in Fig. 17.1).

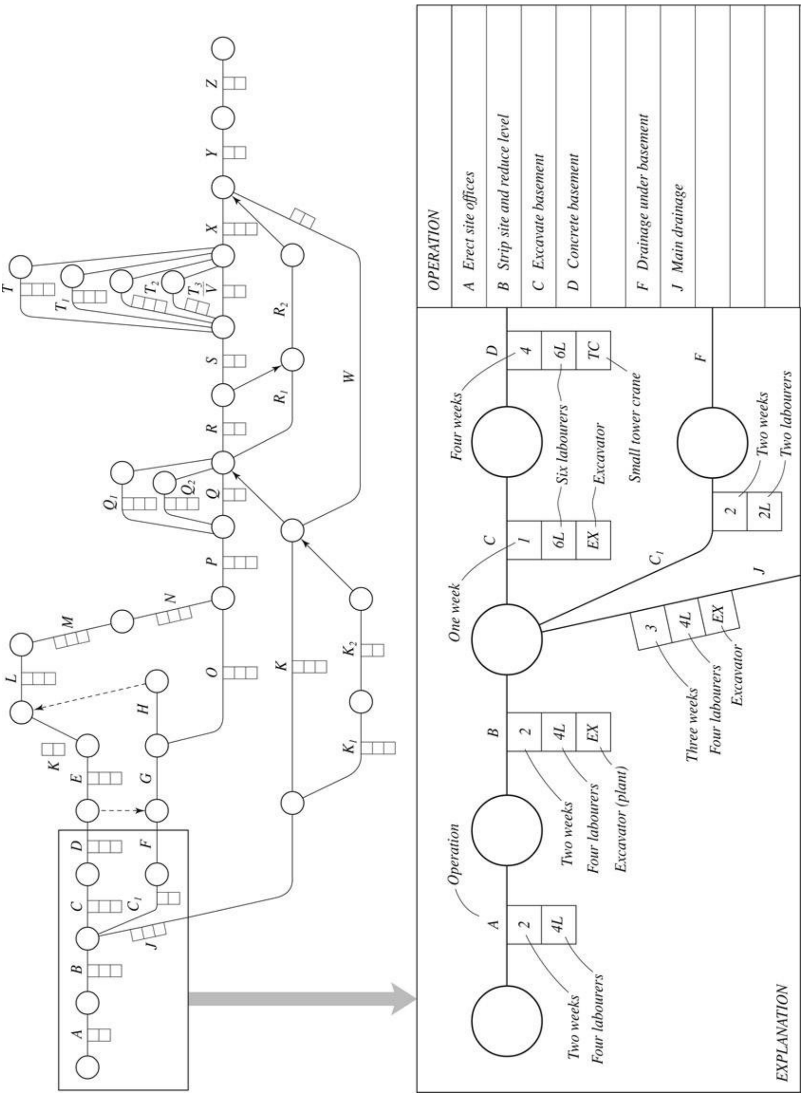


Figure 17.26 Critical path programme.

Further specific reading

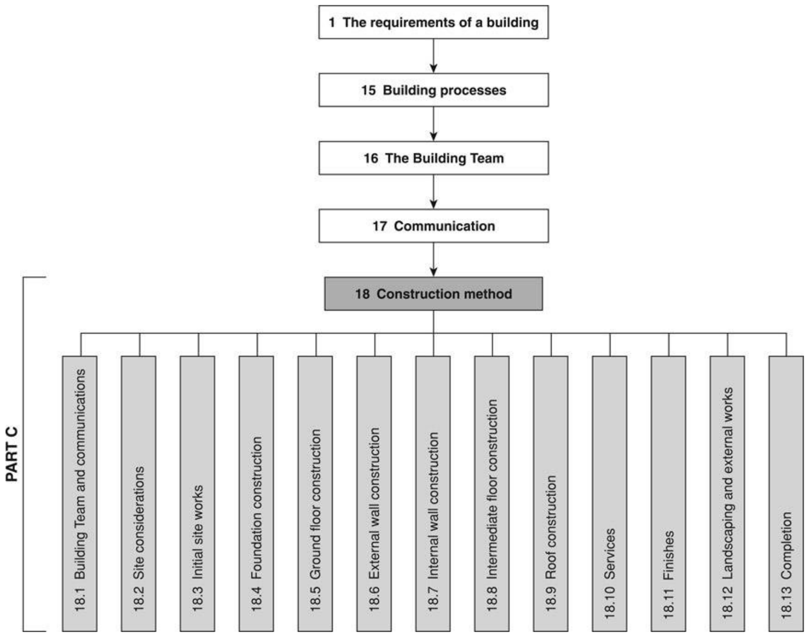
Mitchell's Building Series

Structure and Fabric Part 1	Chapter 2 The production of buildings
Structure and Fabric Part 2	Chapter 1 Contract planning and site organization Chapter 2 Contractors' mechanical plant

Building Research Establishment

Digest 335	*Electrical interference in buildings*
Digest 424	*Installing BMS to meet electromagnetic compatibility requirements*
Digest 448	*Cleaning buildings: legislation and good practice*
Digest 450	*Better building/Integrating the supply chain: a guide for clients and their consultants*
Digest 459	*Construction logistics: an introduction*
Digest 474	*Handover of office building operations protocol*
Digest 478	*Building performance feedback: getting started*
Good Building Guide GG 54	*Construction site communication* (2 parts)
Information Paper IP 8/04	*Whole building commissioning* (4 parts)
Information Paper IP 14/05	*Achieving cost effective responsive maintenance*
Information Paper IP 6/06	*Balanced value for sustainable procurement*
Information Paper IP 4/10	*Delivering a sustainable masterplan*

Part C
An analysis of a building in terms of typical construction methods, the interaction of components and the processes for assembly



18
Construction method

CI/SfB (A5)

The following description will give an outline of some of the various considerations, activities and processes which result in the erection of a simple building. A two-storey house has been chosen primarily because it is likely to be the form of building most familiar to those with limited experience of the construction industry. And a house is now the most common form of building in the United Kingdom which continues to be erected using conventional techniques derived from traditional craft skills. This creates a particular kind of 'domestic' aesthetic.

This is not to say that house-building techniques have not changed over the years. Indeed, the standards of performance requirements are continually being upgraded to provide increasingly sophisticated enclosures which reflect ideas of comfort, stability, aesthetic appeal and sustainability as indicated in Part A. It should also be borne in mind that the techniques to be described represent only one method of erection; there are many others. Furthermore, this chapter is not an exhaustive study on a particular construction method and should be regarded as a brief basic indication only. Further information can be obtained from the Structure and Fabric (Parts 1 and 2) volumes of the Mitchell's Building Series.

In order to help the designer to assess the effects of design decisions it is often useful for a sequence diagram to be prepared which shows the relationship of the activities involved. Figure 18.1 is a typical example where individual boxes define activities and circles contain the sequential operation number. Operations are usually sequential, but with good site management, organisation and coordination of trades, some activity overlap may be possible. This ensures continuity of work and an efficient construction process. A timescale can be applied to the diagram so that progress of construction is carefully monitored (see also section 17.7).

18.1 Building Team and communications CI/SfB (A1g)

The Building Team and method of communication adopted for the creation of a two-storey house could in certain areas be less extensive than those described in Part B. Also, the number and type of personnel involved, and the resulting degree of communication, will obviously vary according to the problems to be solved. A large house with unusual, complicated or elaborate structural and/or environmental requirements may involve a correspondingly elaborate Building Team. The Client Team for the two-storey house to be considered here will most likely be a single individual or a couple who employ the services of a single principal designer (e.g. architect) from the Design Team. He or she may recommend the services of a quantity surveyor, although his or her skills should be sufficient to control expenditure accurately for such a small project. The designer’s skills should also encompass sufficient expert knowledge of the drainage, plumbing, heating and electrical installation required, although he or she can recommend the services of subcontractors who will give recommendations and submit competitive estimates for these specialised areas.

The building work is best carried out by a general builder whose standard of work is familiar to the designer. Alternatively, contract documents in the form of working drawings, specification of works (and bills of quantities, if a quantity surveyor is employed) and the contract can be prepared by the designer in order that competitive tenders can be submitted by a number of general builders situated in the locality of the site for the proposed building.

It is important that the designer maintains overall control over the standard of work and materials used for the

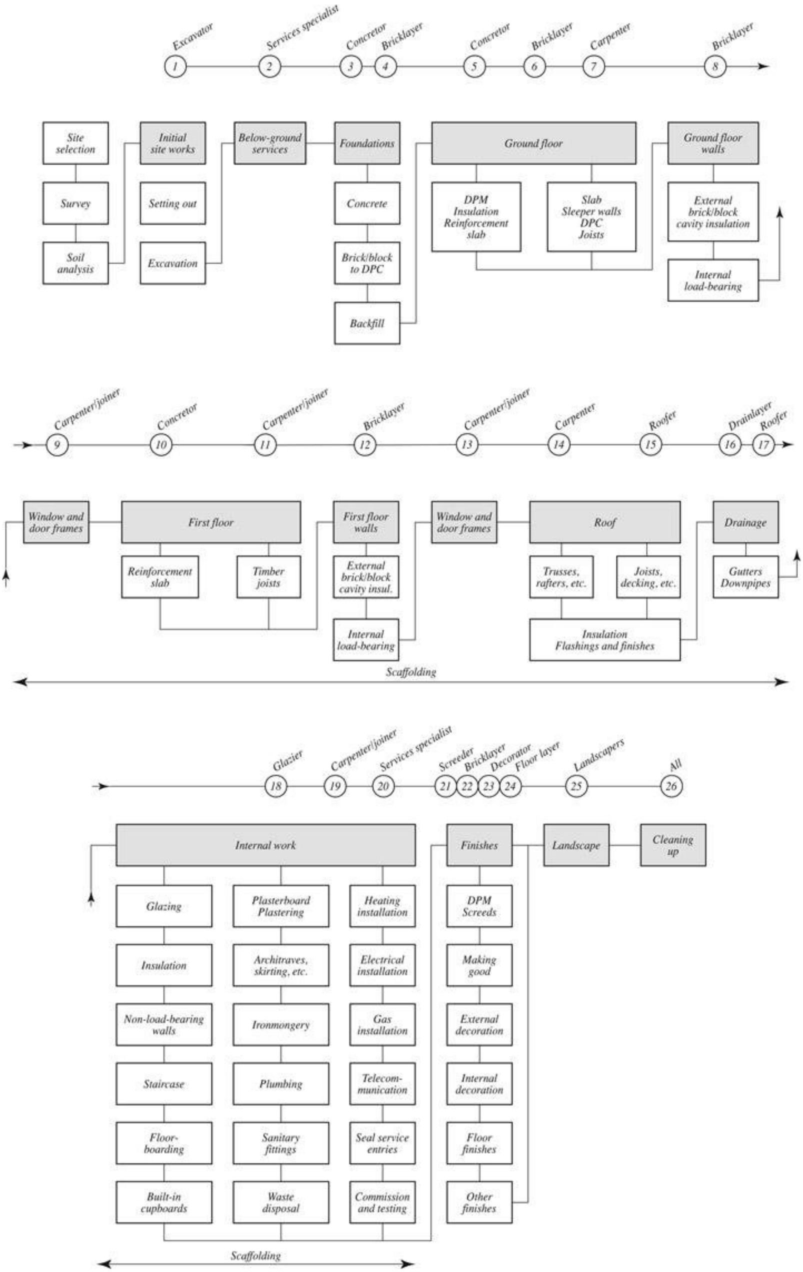

Excavator
Services specialist
Concretor
Bricklayer
Concretor
Bricklayer
Carpenter
Bricklayer
Site selection
Survey
Soil analysis
Initial site works
Setting out
Excavation
Below-ground services
Foundations
Concrete
Brick/block to DPC
Backfill
Ground floor
DPM Insulation Reinforcement slab
Slab Sleeper walls DPC Joists
Ground floor walls
External brick/block cavity insulation
Internal load-bearing
Carpenter/joiner
Concretor
Carpenter/joiner
Bricklayer
Carpenter/joiner
Carpenter
Roofer
Drainlayer
Roofer
Window and door frames
First floor
Reinforcement slab
Timber joists
First floor walls
External brick/block cavity insul.
Internal load-bearing
Window and door frames
Roof
Trusses, rafters, etc.
Joists, decking, etc.
Insulation Flashings and finishes
Drainage
Gutters Downpipes
Scaffolding
Glazier
Carpenter/joiner
Services specialist
Screeder
Bricklayer
Decorator
Floor layer
Landscapers
All
Internal work
Glazing
Insulation
Non-load-bearing walls
Staircase
Floor-boarding
Built-in cupboards
Plasterboard Plastering
Architraves, skirting, etc.
Ironmongery
Plumbing
Sanitary fittings
Waste disposal
Heating installation
Electrical installation
Gas installation
Telecom-munication
Seal service entries
Commission and testing
Finishes
DPM Screeds
Making good
External decoration
Internal decoration
Floor finishes
Other finishes
Landscape
Cleaning up
Scaffolding

Figure 18.1 Sequence of activities for a two-storey house of conventional construction.

building work, especially when the builder employs a large number of subcontractors rather than his or her own workers. A form of contract which would be applicable for this project would be the JCT Standard Building Contract, Without Quantities.

The designer will be required to seek approval for the proposed scheme from the local authority's planning department, highways department, engineer's office and building control section. The house construction to be described will be governed by the Building Act 1984, the Building Regulations 2010, the associated Approved Documents and subsequent amendments.

18.2 Site considerations CI/SfB (A3s)

18.2.1 Selection

The characteristics of a site (Fig. 18.2) are likely to have an important influence on the way a building is designed and it is therefore important that the designer is employed as soon as the desire for a house has been established by the client. As many sites as possible should then be inspected, and the relative merits compared before final selection. A badly chosen site can be one which offers few amenities, or few aesthetic advantages, and also one which involves the client in considerable additional building expenses arising from physical properties requiring special constructional solutions. It is also important that the local planning authority is consulted regarding any problems which may arise in connection with suitable zoning.

The early involvement of the designer is particularly important today, since those sites which provide highly suitable facilities are becoming scarce and land is increasingly having to be used which was previously avoided. For example, it may be necessary to select more remote sites than normal and, as outlined in Chapter 6, it will be essential to investigate the full range of climatic conditions as these will affect the final form and appearance of the building fabric. Special consideration will influence the final form of building to be erected on a site which has poor subsoil or suffers from waterlogging, or a site to be reused following the demolition of existing structures where its physical properties may well have been altered during the life of the previous building.

18.2.2 Survey

An Ordnance Survey map (see Fig. 17.3) may give an initial guide to site features, but a detailed and accurate survey must be made to obtain more specific data. This should be done by a member of the Design Team; it will ascertain the precise shape and size of land involved, and the shape and position of any obstacles such as ponds, trees or buildings that exist within and around the boundaries of the site. It is also important to establish the exact path of the sun across the site, the prevailing direction of wind and rain, etc., and the way the site slopes.

Details will also be required about the privatised utilities (gas, electricity, telecommunications, water, drainage, etc.) and other services (cable television, refuse collection, maintenance contractors, etc.) as well as the transport routes. Greater details of these can probably be obtained from the local authority, which may also be able to supply information about desirable access points to the site, future road-widening schemes in the locality, preservation orders affecting buildings and/or views, rights of way and light, etc. Some planning authorities issue guidelines about the appearance of buildings to be erected in their locality. It may also be useful to make contact with the building control officer or approved inspector at this stage and discuss any general factors which may influence the construction methods applicable to a building to be erected on that particular site.

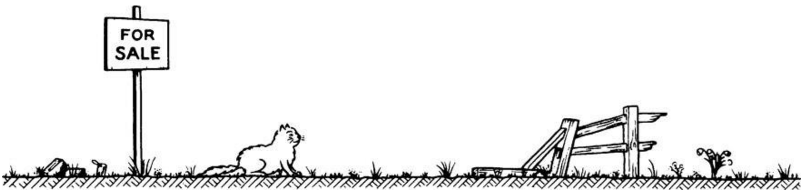


Figure 18.2 Site selection.

This preliminary site research can be defined under the following three categories:

- Desktop study.
- Field or walk-over survey.
- Laboratory analysis/soil investigation (see section 18.2.3).

Desktop (office based) study:

- OS maps, digital imagery and aerial photographs show the current situation. Historical maps are useful to determine former uses of the site, i.e. greenfield or brownfield.

- Previous planning applications, approvals, referrals and rejections. Conditions applied and reasons for referrals and rejections.
- Other nearby planning applications. LPA local development plans.
- Restrictions on development, conservation areas and conservation/preservation orders.
- Protection orders, trees and wildlife.
- Utilities. Availability and location. Relevant authorities/contacts.
- Local knowledge and information centres, libraries, parish councils, regarding rights of way and established use and accesses.
- Boundaries, footpaths and roadways.
- Other topographical details, e.g. relative levels and heights (Ordnance Datum).

Field or walk-over survey (visual and physical site examination):

- Establish site characteristics from desktop study.
- Locate proximity of existing structures on site if relevant and others close by.
- Trees, hedges, boundaries and other established and natural features.
- Topographical detail with regard to prominent surface features.
- Bore holes to determine depth of water table.
- Bore holes to extract soil samples for laboratory analysis with regard to bearing capacity, chemical composition and contaminants (methane/radon?).

- Consider need for further and deeper bore holes.
- Flood potential, proximity of water courses/springs.
- Appraise potential of any existing on-site structures.
- Extent of demolition, cost, disposal, health issues (asbestos?) and impact on locality.
- Transport links and accessibility.
- Overhead obstructions, telephone lines and electricity pylons.
- Underground utilities, location of drains, water mains, gas, telephone and electricity. Obstructions, consider possibility of redirecting services and provision for new connections.

18.2.3 Soil investigation

Apart from the above-ground conditions, a survey must also include data about the below-ground conditions of the site. These include characteristics of the soil because this information influences the selection and design of an appropriate structural form for the proposed building.

The subsoil must safely support the combined building loads indicated in Figure 18.3 (explained in Chapter 5) and also ensure that unreasonable movements of the building do not occur. If the supporting soil is sufficiently resistant and its characteristics under load are likely to remain satisfactory, the problems of support and movement will be easily resolved. However, few soils other than rock can resist these concentrated loads and it is usually necessary to collect the resolved loads at their lowest point and transfer them to adequate bearing soil known to be available on a particular site (Fig. 18.4).

Building loads can be fairly easily calculated from known data, but the strength or resistance of the soil to them requires expert understanding and very careful analysis. Underneath the top layer of soil, which consists of decaying vegetable matter and has little strength, lie bearing soils varying in strength according to type and consistency. Consideration must be given to the soil, including the particle sizes from which it is formed; moisture and chemical content; behaviour under loads; the presence of inherent or induced peculiarities; and the likely effects of variations in its normal undisturbed condition.

There are several methods employed to assess soil conditions; they can be used singly or in combination, depending upon the precise circumstances. Investigation can be done by reference to geological and topographical references or empirical knowledge from local residents, building inspectors, etc., and/or by physical exploration of the site. Physical exploration may be accomplished by trial holes dug into the ground or by taking test cores of the soil. Both techniques can provide a reliable source of information which costs as little as 1–2 per cent of the total building expenditure. It is important that trial holes are taken as near as possible to, but not on the actual line of, a proposed foundation in order to avoid the subsequent excessive consolidation of the relatively loosely backfilled soil by the constructed foundation (Fig. 18.5). Trial holes need to be formed to sufficient depth to expose the likely soil which will support the foundation. Most of this lies in the volume of soil beneath the foundation known as the bulb of pressure (Fig. 18.6). For lightly loaded buildings with simple foundations, this generally lies within 2 m below ground level. When necessary, investigations can be carried out beyond this depth by taking sample cores of soils, 150– 200 mm in diameter, using special equipment, see BS 1377: Methods of test for soils for civil engineering purposes.

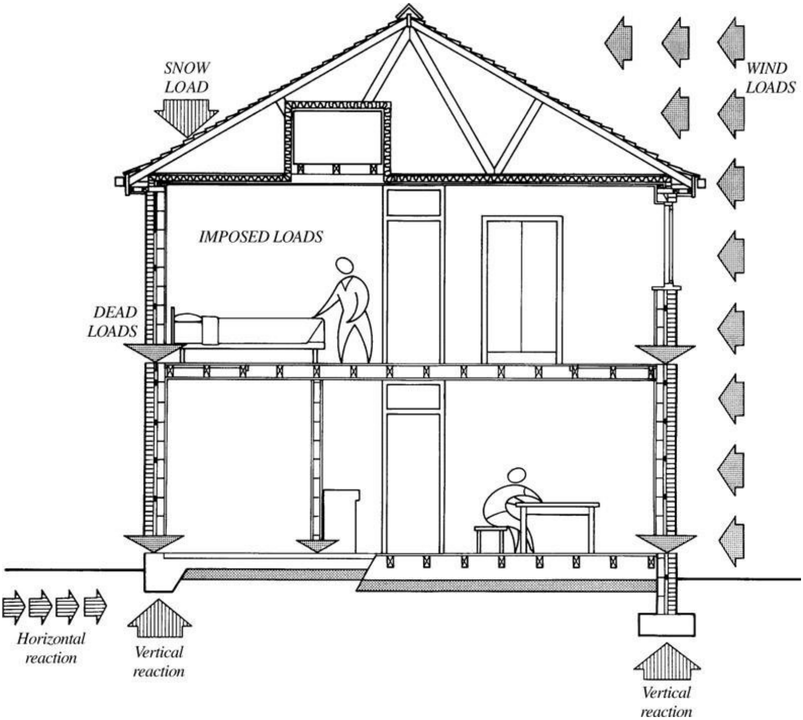


Figure 18.3 Combined building loads. (See also Figs 5.1, 5.2 and 5.3)

The general distribution of soil types in the United Kingdom is indicated in Figure 18.7; the soils include peat, clay, silt, sand and gravel. Corresponding safe bearing pressures are also given.

The steady increase in loads resulting from the construction of a building causes initial consolidation of the soil beneath the foundation. The amount of this movement varies with the soil conditions and, in a correctly designed and formed foundation, causes little disturbance in the building fabric above. Unreasonable movements of foundations (Figs 18.8 and 18.9) can be caused by the use of poor materials (inadequate concrete mixes) and formation techniques, or commonly they are caused by earlier soil movements. These movements derive from either excessive consolidation of the soil particles under load or by other factors independent of building loads:

- Swelling and shrinkage Clay soils are likely to swell or shrink with variations in moisture content caused by seasonal fluctuations in rainfall and the water-table, drought conditions, and the proximity of tree roots, boilers, kilns and furnaces.
- Frost heave Ice lenses may form between the soil particles of chalks and silts, causing swelling.
- Swallow- or sink-holes Chalk and limestones may contain pockets of weaker soil.
- Slopes and landslips Clay soils may exhibit movement on sloping ground with a gradient steeper than 1:10.
- Mining subsidence May occur when temporary supports in old or uncharted mines decay, causing the void to collapse.
- Shock and vibration Soils near railways, motorways or active industrial plant may experience shock and vibration.

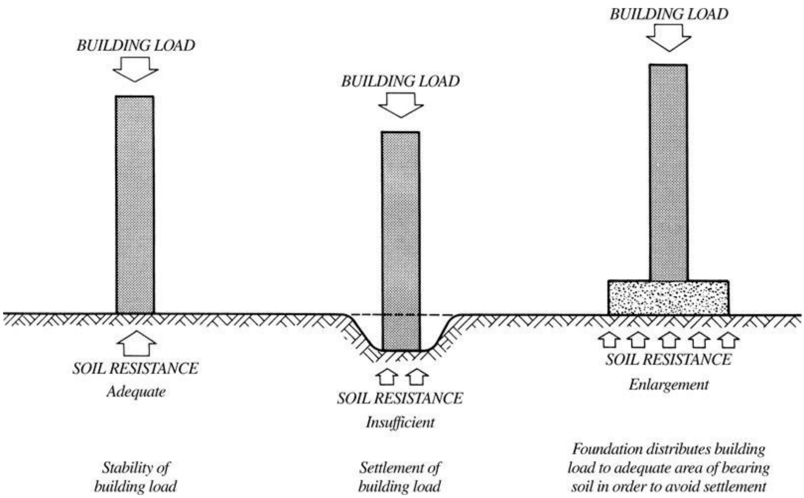


Figure 18.4 Method of transferring combined building loads to supporting soil.

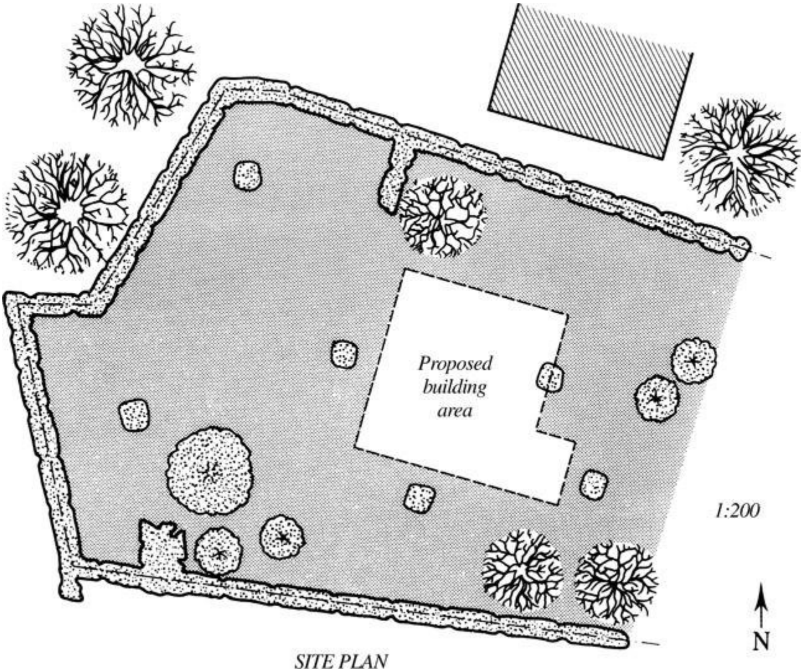


Figure 18.5 Suitable position for digging trial holes for soil investigation.

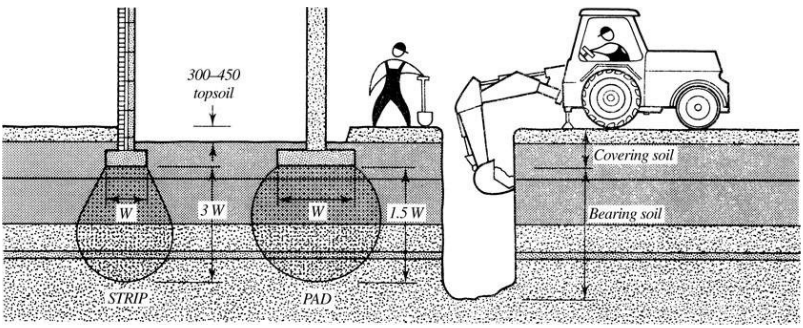
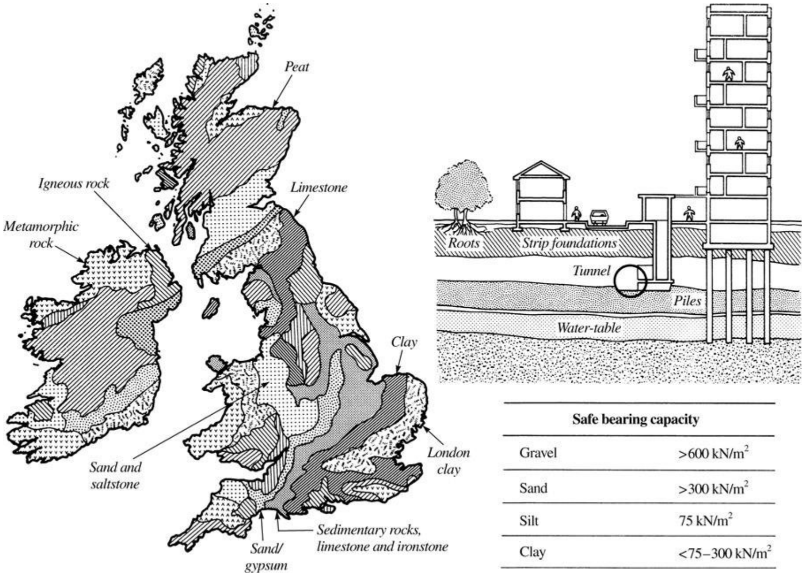


Figure 18.6 Influence of 'bulb pressure' on supporting soils.



Safe bearing capacity	
Gravel	>600 kN/m^2
Sand	>300 kN/m^2
Silt	75 kN/m^2
Clay	<75–300 kN/m^2

Figure 18.7 Much simplified distribution of various types of supporting soils in the United Kingdom (see geological survey maps for greater detail). The quality of bearing soils will also vary with depth and various uses. Metamorphic rock – marble, limestone, sandstone and slate. Igneous rock – granite, pumice, basalt and volcanic ash (tuff). Sedimentary rock – sandstone, mudstone, clay, chalk and gypsum.

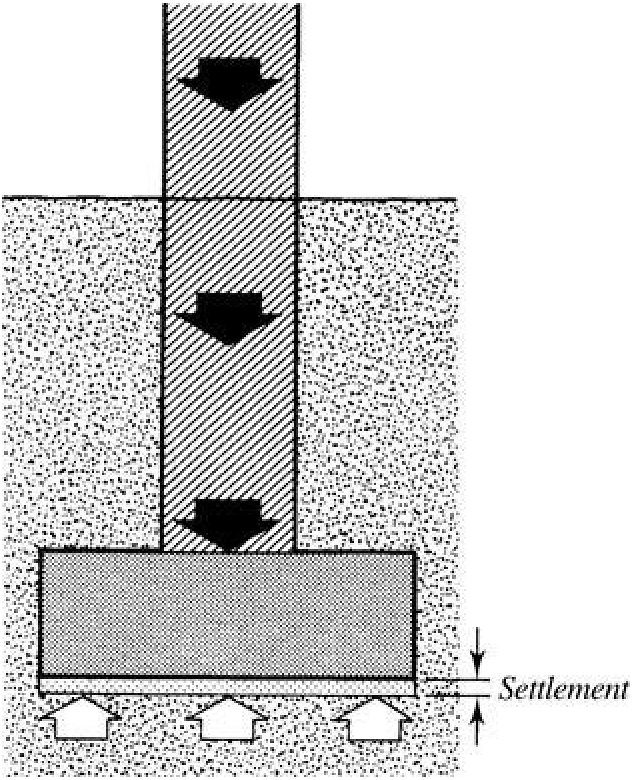


Figure 18.8 Initial consolidation of the supporting soil occurs during construction. Consolidation produces settlement and its effects are anticipated in the design.

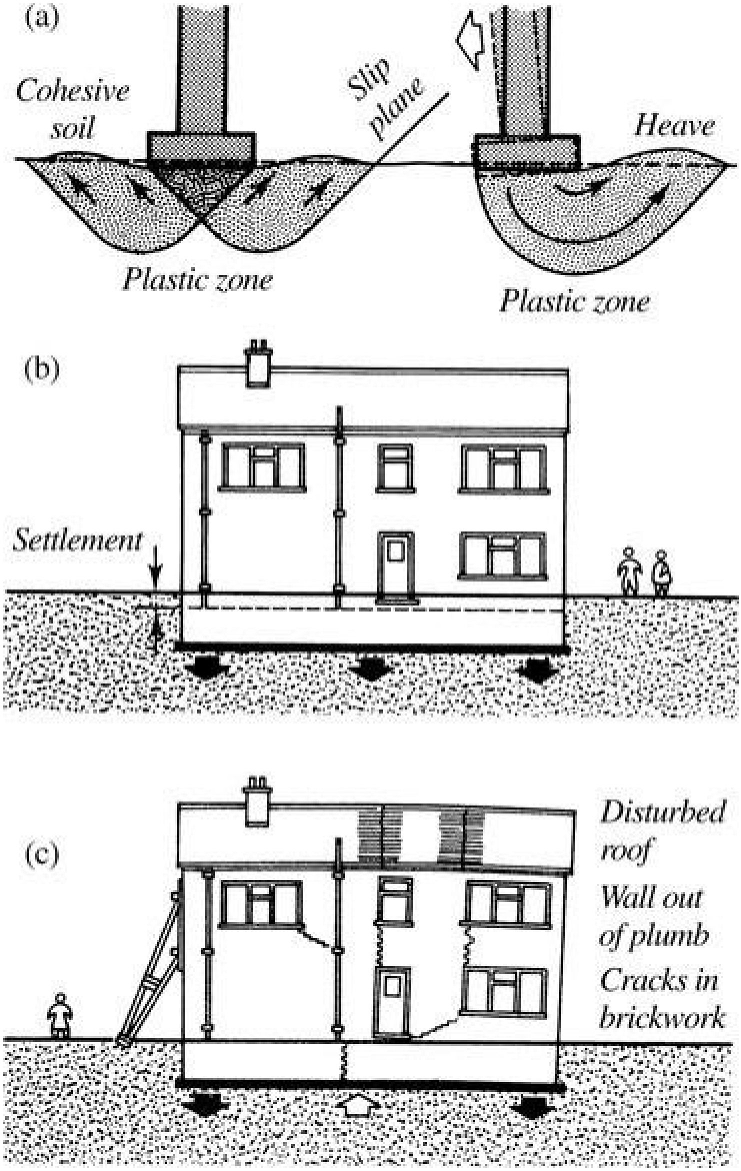

(a)
Cohesive soil
Slip plane
Heave
Plastic zone
Plastic zone
(b)
Settlement
(c)
Disturbed roof
Wall out of plumb
Cracks in brickwork

Figure 18.9 Foundations must be designed to prevent damage caused by unreasonable movements: (a) plastic failure of soil; (b) excessive settlement; (c) differential settlement.

18.3 Initial site works CI/SfB (11)

18.3.1 Selection of plant

One of the first decisions the selected builder must make is whether it will be more economical to employ mechanical equipment (plant) or hand-excavation techniques for site work (Fig. 18.10). Plant should normally be used where it can be kept fully occupied, the ground is not too boggy, the excavation is not too 'fussy', there is room to manoeuvre, and the transport costs of plant (mechanical equipment) to and from the site can be paid from the savings over the cost of hand excavation. Regardless of whether the builder owns certain items of plant or hires it for certain periods, the choice whether it should be used or not is a matter for expert consideration. It is possible, however, for a designer to take the use of plant into consideration (perhaps in consultation with the builder) when designing a building so that maximum time saving can be obtained, which could cut costs.

18.3.2 Setting out

Having cleared the site of debris, unwanted shrubs, etc., by using information from the designer's site plan, the builder can erect temporary accommodation for workers (sanitary facilities, canteen, site office, etc.) and for storage of materials and components. These should be located in a position which will be unaffected by access points, circulation about the site and the subsequent building processes. The builder can then begin to set out the areas of the site which are required to be excavated. This is done by using a steel measuring-tape to establish the exact position and perimeter dimension of the building or other excavated area, then by providing profiles to give guidance during substructure operations. Profiles consist of timber pegs driven into the ground with timber crossbars fixed to them on which points are marked by nails to indicate lines of foundation and the walls above (Fig. 18.11).

The crossbar of the profile is fixed at a predetermined height or datum such as finished floor level (ffl) or damp proof course (dpc) level which is established by a measuring-staff and an optical instrument known as a level. By periodically stretching a thin string or line between the tops of the crossbars during excavation and using a boning rod of known length, the amount of soil to be removed can be established (Fig. 18.12). An optical instrument known as a theodolite can be used to set right angles and accurately range along the string lines. It is always necessary to set up profiles away from the actual region of excavation to allow for working room. The setting out of trenches for drainage can be accomplished in a similar manner, but as
the bottom of these excavations should be laid to a fall, to ensure the pipes they support are self-cleansing, measurements down from the temporary line stretched between profiles need to be taken at frequent intervals.

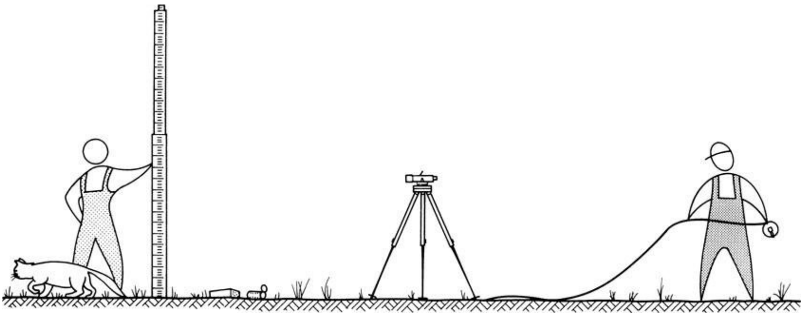


Figure 18.10 Initial site work: above-ground survey.

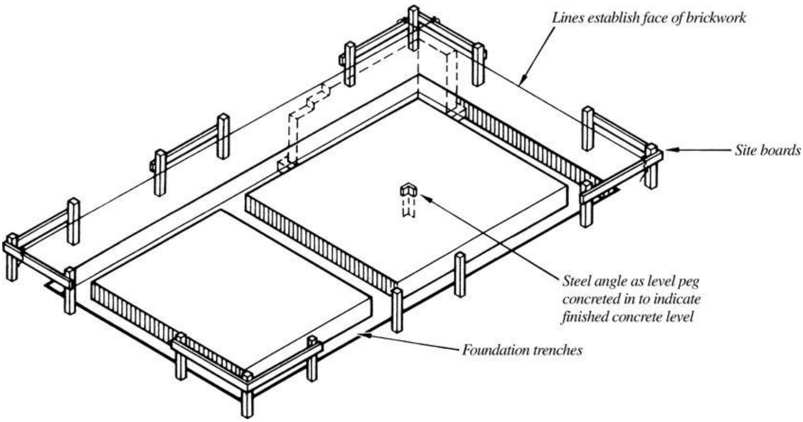


Figure 18.11 Setting out trenches and brickwork.

18.3.3 Excavation

Excavation will consist of removing the topsoil from the area of the proposed building, then forming the trenches for the foundations (Fig. 18.13).

Topsoil exists on most sites to a depth of about 300 mm and is of considerable value for landscaping. But topsoil is highly water retentive, propagates plant life and is highly compressible, so it must be carefully removed from areas where it is not required and stored clear of building operations, ready to be reused. If the quantity involved is not all wanted for its site of origin, arrangements will have to be made for it to be removed and perhaps sold.

The type of excavation needed for the foundations depends on their category, chosen according to subsoil
type and characteristics. Further details about the influence of these factors are given in section 18.4.3.

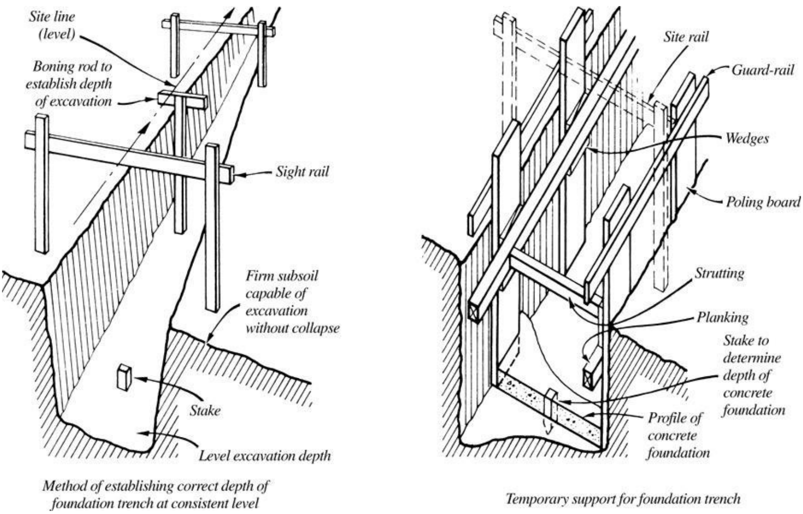


Figure 18.12 Setting out and casting foundations.

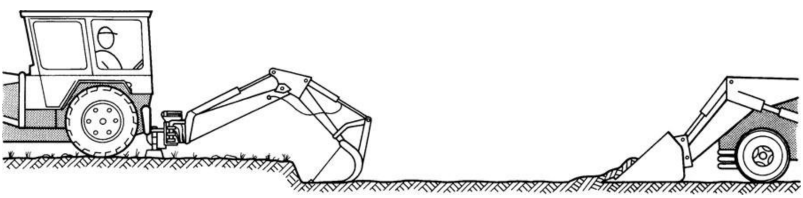


Figure 18.13 Clearance of topsoil over area of building before the foundations are excavated.

18.4 Foundation construction CI/SfB (16)

18.4.1 Function

The resolved dead, imposed and wind loads (Part A, section 5.1) may be transferred through the building by continuous walls, or through isolated piers, by columns or piers, or by combinations of these techniques. Because each of these structural systems results in foundation types which transfer the loads to the supporting soil in different manners, the selection of a foundation category (Fig. 18.14) should reflect the optimum relationship between building structure and the characteristics of the soil used as support. In other words, the aesthetic and technical factors resolving into a particular building form above ground are interdependent with the technical requirements of the foundation design below ground.

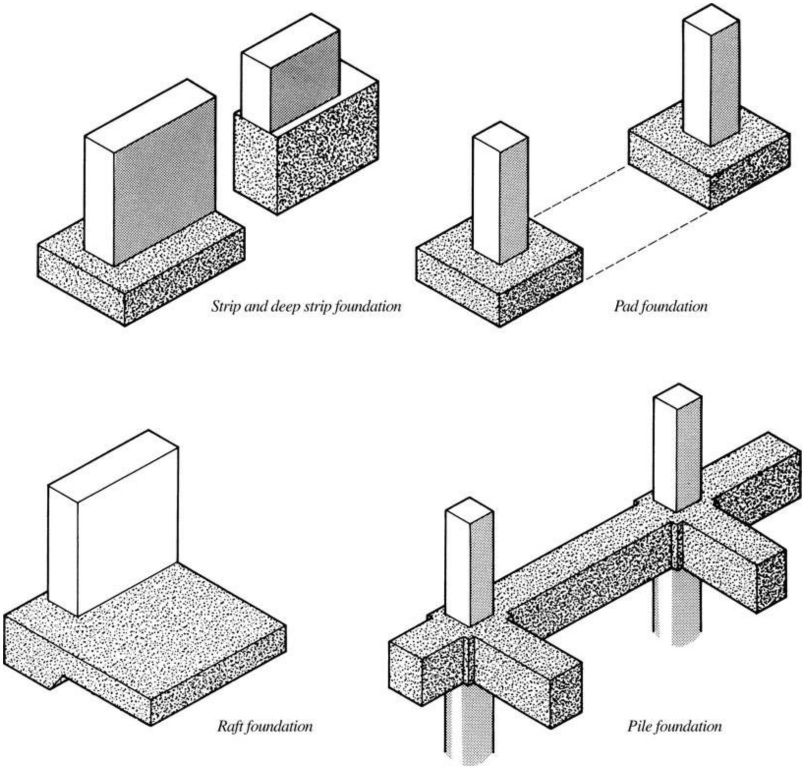


Figure 18.14 Different types of foundation are used according to subsoil conditions and the form of building to be supported.

18.4.2 Design

The following steps are necessary to arrive at a correctly designed foundation which takes into account the relationship between soil conditions and building loads.

1. Assess soil conditions by suitable investigation (see section 18.2.3).

2. From investigations decide the permissible soil loading.
3. Determine the combined building loads (dead, imposed and wind) and allow for the self-weight of the foundation. Typical loads for a single- and two-storey house are indicated in Figure 18.15.
4. Establish the form and size of the foundation to suit loadings and correct for the self-weight allowances.
5. Check soil resistances against permitted stresses and estimate permissible movements.
6. Allow for necessary movement joints for differentially loaded parts of the building or other structural effects on the foundation.

18.4.3 Choice

For a two-storey house using continuous load-bearing masonry walls (brick, block or stone), a form of strip foundation will probably be most appropriate, and can consist of a horizontal strip or a vertical strip of mass concrete located beneath ground level. The choice between these two forms can be made during discussion between designer and builder as their structural significance is
closely related to site conditions, plan shape of the building and the availability of appropriate resources. In both cases the depth of the foundation will depend upon the depth of adequate bearing soil, and the avoidance of certain phenomena which detrimentally affect the upper layers of the bearing soil: seasonal variations in moisture content, tree roots, etc. The Building Regulations, Approved Document A: Structure, specifies a minimum depth of 0.45 m to the underside of a strip foundation to avoid the action of frost

(frost heave), and a minimum depth of 0.75 m to the underside of strip foundations in clay subsoils. Generally, a depth of 1.0–1.2 m is adequate when a suitable subsoil is available. The width of excavation and hence the proposed strip foundation can be determined by calculation. Figure 18.16 shows a simple example, given analysis of the subsoil to indicate a safe bearing capacity of 80 kN/m^2, with a building load of 50 kN/m. Alternatively, simple field tests on the variety of soils represented in Table 18.1 can be used for guidance. For a wall of a building bearing 50 kN/m to be supported on firm clay the recommended width is given as 600 mm. Nevertheless, in order to avoid eccentric stresses in the foundation, consideration must be given to allowing enough tolerance for the bricklayer to build a perfectly straight wall exactly on the centreline of the concrete mass of the foundation formed within a trench which has been relatively crudely excavated by machine (or hand).

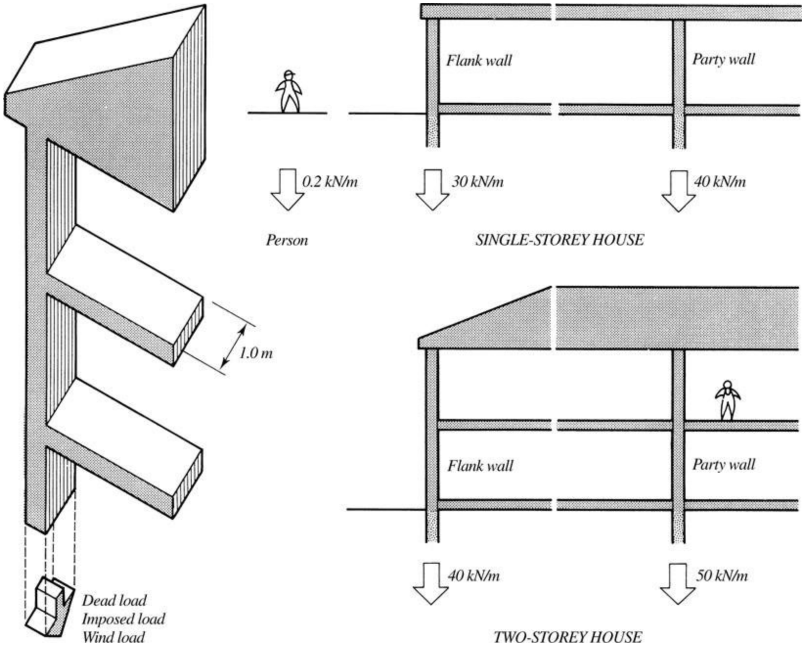


Figure 18.15 Typical loads on a two-storey house.

The vertical strip foundation or trench fill is generally used in firm soils where costs can be reduced because they are self-supporting and do not require the trench support which the more loose soil types need. When safe soil bearing pressures and wall dimensions permit, the width of these foundations can be as little as 300 mm or the width of the smallest mechanical digging tool used for the excavation of the trench in which they are formed. (This is possible because the high vertical 'thickness' or sides of the deep strip foundation are provided with lateral restraint by the surrounding soil, which offsets the likelihood of the foundation overturning.) However, to avoid the possibility of the development of the eccentric stresses mentioned earlier, a tolerance dimension of 75 mm minimum should be allowed either side from the face of the wall above to the edge of the foundation. With the horizontal strip foundation form, allowances must be made for a bricklayer working within the trench (Fig. 18.17). A minimum of 150 mm either side of the proposed wall, together with the structural consideration, may well determine the final width of foundation.

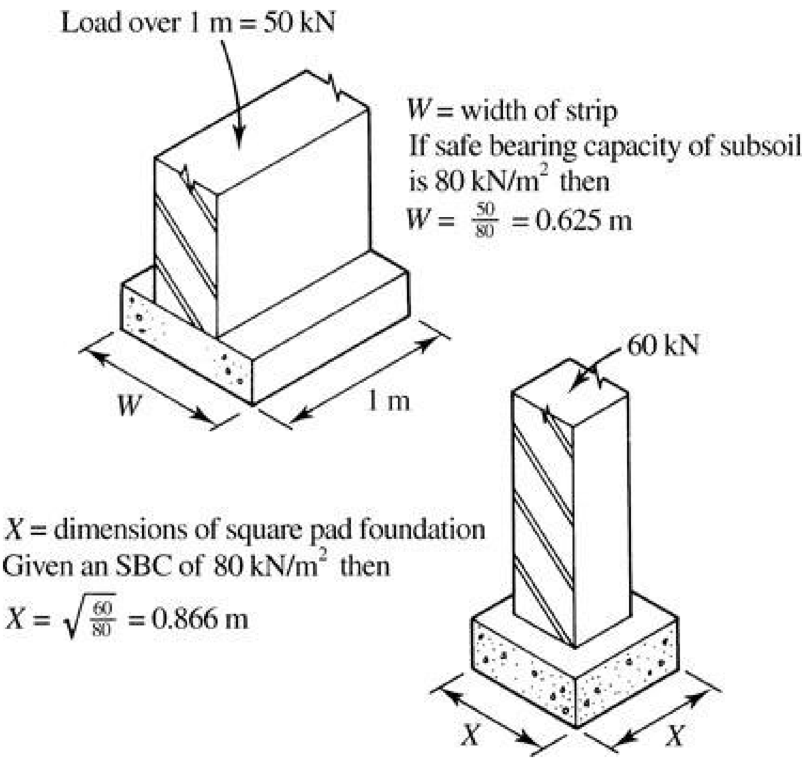


Figure 18.16 Calculations for foundation design.

Table 18.1 Guidance on strip foundation width relative to subsoil quality

Type of subsoil		Condition of subsoil	Field test applicable	Minimum width (mm) for total load of load-bearing walling of not more than (kN/m)					
				20	30	40	50	60	70
I	Rock	Not inferior to sandstone, limestone or firm chalk	Requires at least a pneumatic or other mechanically operated pick for excavation	In each case equal to the width of wall					
II	Gravel Sand	Compact Compact	Requires pick for excavation. Wooden peg 50 mm square in cross-section hard to drive beyond 150 mm	250	300	400	500	600	650
III	Clay Sandy clay	Stiff Stiff	Can be indented slightly by thumb	250	300	400	500	600	650
IV	Clay Sandy clay	Firm Firm	Thumb makes impression easily	300	350	450	600	750	850
V	Sand Silty sand Clayey sand	Loose Loose Loose	Can be excavated with a spade. Wooden peg 50 mm square in cross-section can be easily driven	400	600	Foundations do not satisfy the regulations if the total load exceeds 30 kN/m			
VI	Silt Clay Sandy clay Silty clay	Soft Soft Soft Soft	Finger pushed in up to 10 mm	450	650	In relation to type VI, foundations do not satisfy the regulations if the total load exceeds 30 kN/m			
VII	Silt Clay Sandy clay Silty clay	Very soft Very soft Very soft Very soft	Finger easily pushed in up to 25 mm	Strip foundation inappropriate, seek specialist advice					

Generally, the chosen width of a vertical strip foundation may relate very closely to the width of the horizontal strip foundation, subject to similar loading conditions. However, the advantage of the deep vertical strip foundation over the horizontal strip foundation is that as it finishes just below ground level it reduces bricklaying time and does not limit the working space of the bricklayer (Fig. 18.18). When reinforced with steel rods, the vertical concrete strip can function as a longitudinal beam. Nevertheless, its use should be approached with caution as it is difficult to inspect the bottom of a narrow trench to ensure consistency of soil before the concrete is placed, and also excessive soil movements can cause the narrow but high foundations to overturn unless adequate precautions are taken.

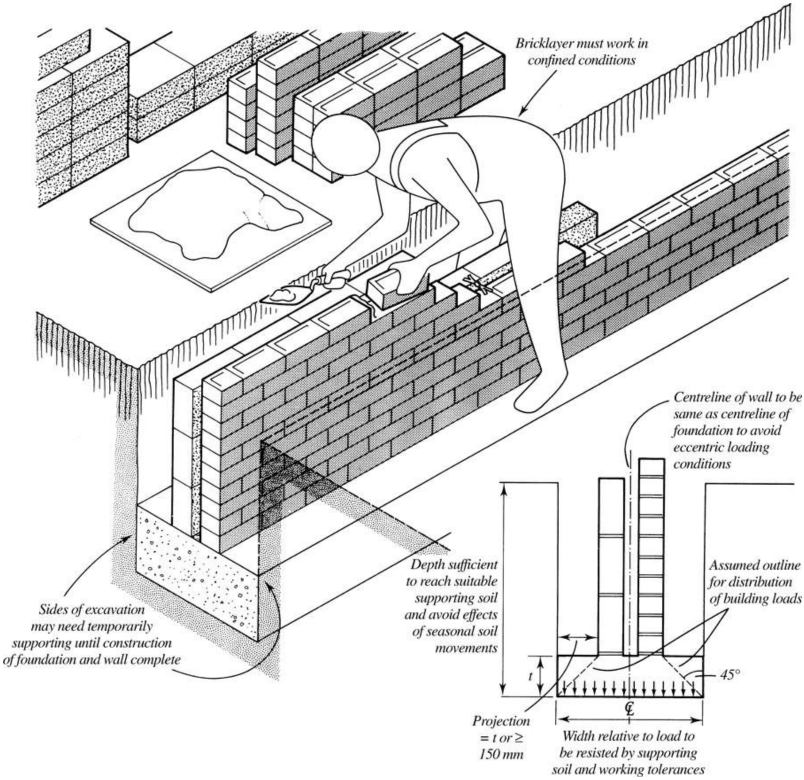


Figure 18.17 Horizontal strip foundation.

The thickness of the horizontal strip should never be less than 150 mm or the amount of projection from the face of the wall supported, whichever is the greater. This rule takes into account the general working tolerances applicable to the formation of an adequate amount of structural concrete for practical purposes. Unreinforced or mass concrete strip foundations can fail under the compressive loads from the building above as a result of excessive bending or from excessive shear stresses developing within the cross-section of the foundation. This latter form of failure generally occurs

along the plane of maximum tensile shear which lies at an angle of about 45° to the horizontal. (In theory the concrete lying outside this plane does little in distributing loads to the supporting soil, but is nevertheless necessary for practical purposes in forming the foundation.) Therefore, if horizontal strip foundations are required to carry heavy loads or if the soil is weak, the corresponding increase in thickness of foundation (to maintain the 45° angle of spread; see Fig. 18.17)
could result in a large amount of concrete being used, which in turn increases the dead load on the soil. In such cases the foundations can be reduced in thickness and weight by using steel reinforcing bars to take up the tensile and bending stresses. These bars must be protected from corrosion by a covering of concrete as explained in section 18.4.4.

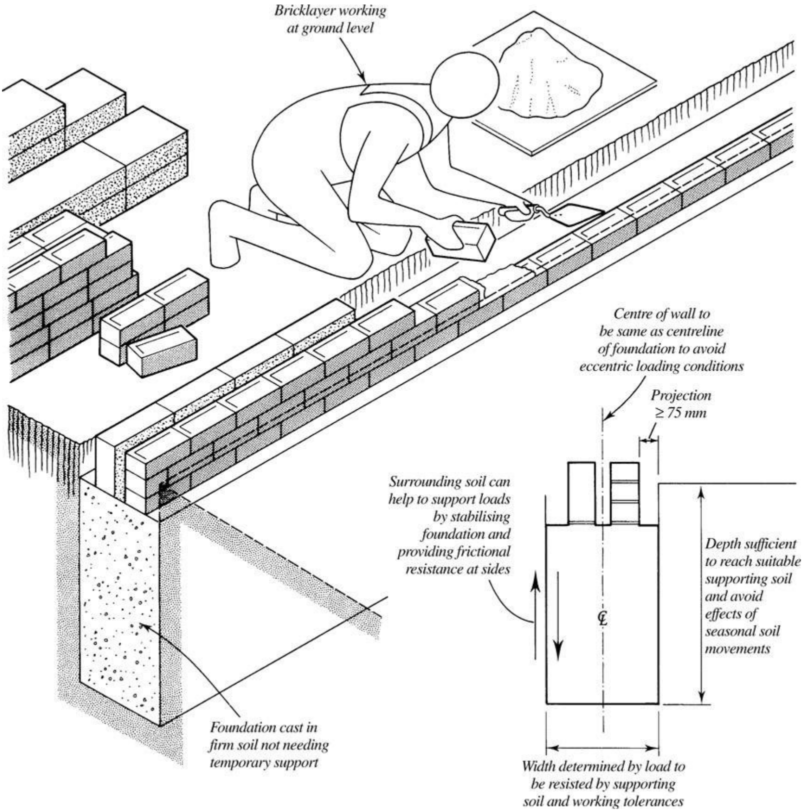


Figure 18.18 Vertical strip foundation.

The bottoms of foundation trenches should be protected from the weather to avoid temporary shrinkage or swelling by leaving the last 100 mm or so unexcavated until immediately before pouring concrete. Alternatively, a blinding layer of concrete, about 50 mm thick, can be placed at the base of the completed excavation. The accurate thickness of concrete can be established prior to pouring by inserting timber stakes at suitable intervals in the base of the excavation. The stakes project from the excavation by the required amount and the concrete is levelled accordingly. Immediately before the pouring of concrete takes place, i.e. after excavation has finished, the bottom of the trench must be inspected and approved by a local authority building control officer, during his or her first formal site inspection.

18.4.4 Materials

The materials employed to make foundations must be strong and durable, particularly as it is not possible or practical to carry out maintenance on them once they have been installed in the ground. For this reason, and with few exceptions, they are formed from good quality dense concrete, consisting of cement, fine aggregate or well-graded coarse sand, and a coarse aggregate of natural gravel or crushed stone, all graded according to the designer's specification for the strength required.

Ordinary Portland cement is generally used in the concrete mixes, but where the ground conditions surrounding the foundation are likely to contain reactive chemicals, special forms of cement should be employed as an alternative. For example, sulphate solutions which occur naturally in groundwaters associated with clay soils, or the acidic solutions with peaty soils, attack and erode ordinary Portland cement. To avoid deterioration of the foundation, sulphate-resisting cement could be used. High-alumina cement, or supersulphated cement, are alternatives, but neither can be recommended since it is extremely difficult to achieve the essential quality of concrete under practical conditions. To avoid using any of these special cements (which are much more expensive than ordinary Portland cement) the foundation can be protected with an impermeable barrier wrapping such as rubber/bitumen-coated polythene sheet.

In certain cases the concrete may be reinforced with steel bars. Depending on loading conditions, these may be ordinary mild steel or high tensile steel bars, and when used they should be provided with a protective concrete cover of not less than 75 mm. In order to protect both steel and concrete from the soil during construction, a blinding layer or excavation coverage of concrete can be provided. This could be 50–100 mm thick, depending on site conditions, and if adopted, the protective concrete cover to reinforcing bars may be reduced to 40 mm.

18.4.5 Concrete strength and specification

Concrete is a composite of cement, fine aggregate (sand), course aggregate (stones) and water. It may also contain steel reinforcing rods to provide resistance to tensile forces. The quality of individual components can be varied considerably to suit a range of applications. BS EN 206-1: Concrete. Specification, performance, production and conformity provides details of acceptable cements, aggregates, mix applications and additives. Types of mix are defined as:

- Designed
- Prescribed
- Standard
- Designated

They have a numerical classification, i.e. 7.5, 10, 15, 20, 25, 30, 35, 40, 50, 55 and 60. Each represents the compressive strength of concrete in N/mm^2, 28 days after mixing and placing. Designed and Prescribed mixes can cover the full range, while Standard mixes are limited from 7.5 to 25 N/mm^2 and Designated mixes from 7.5 to 50 N/mm^2. The mix grade can be prefixed C, F or IT:

- C = characteristic compressive strength
- F = flexural strength
- IT = indirect tensile strength

A P suffix indicates a Prescribed mix, e.g. C30P is a Prescribed mix of 30 N/mm^2 characteristic compressive strength at 28 days.

- Designed mix Concrete specified by its required performance. Variations are permitted for material content and water/cement ratios. Sample testing to ensure strength is essential.
- Prescribed mix Concrete specified by constituent materials as mix proportions, i.e. a recipe of, say, 1:2:4 [20 mm] – 0.5 (1 part cement, 2 parts fine aggregate, 4 parts course aggregate [20 mm maximum size] and a water/cement ratio of 0.5). Only used where there is established evidence of its reliability.
- Standard mix Suitable for general use in limited strength applications such as housing construction, where scale of operations does not justify full mix design procedures.
- Designated mix Suitable for specific situations where the purchaser must provide the producer with full details of use and applications. The British Standard provides categories of mix to suit foundations, floors,

paving, reinforced and prestressed concrete and general applications.

Note that concrete is more accurately batched by weight than by volume, as the larger components, in particular coarse aggregates, contain a higher proportion of voids or gaps between the stones than that between fine aggregates or cement.

18.4.6 Construction

The sequence of the formation for the vertical strip foundation is indicated in Figure 18.19. As strip foundations are used in conjunction with continuous walls of small bonded units (bricks, blocks or stones), their top surfaces are laid to a true level surface. In this way the erection process of the walling unit will be made quicker and the wall will be more stable as the necessity of providing mortar packing of varying depth beneath each first course
of wall unit is avoided. When a building is to be erected on a sloping site and the required bearing strata follow the ground slope, excavation costs and the amount of walling below ground can be reduced by forming the foundation in a series of steps, as shown in Figure 18.20.

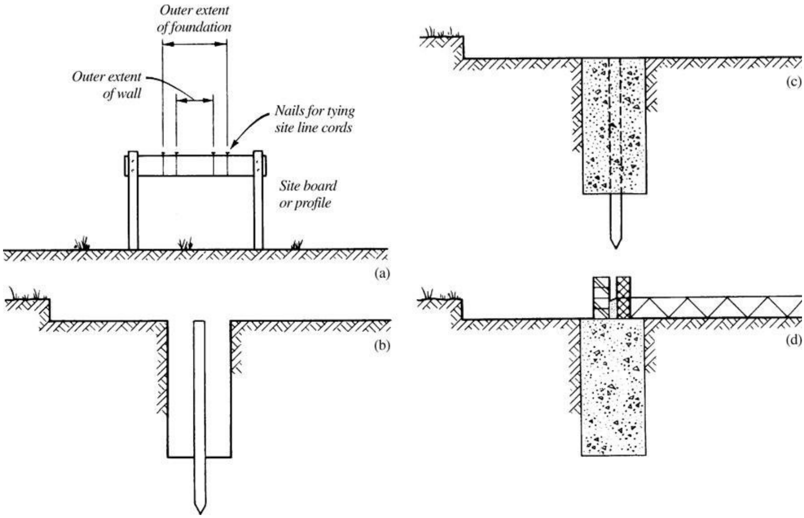


Figure 18.19 Foundation construction: (a) site board or profiles placed to establish position of future foundation (see Fig. 18.11); (b) the foundation is excavated and stakes are inserted to give a consistent level for the top surface; (c) the vertical or deep strip foundation is completed; (d) wall construction is begun just below natural ground level then hardcore is laid and consolidated.

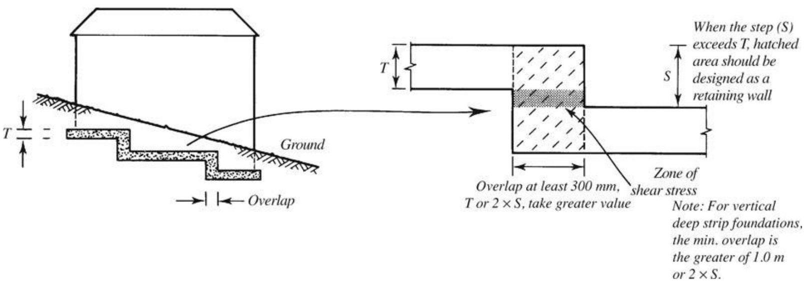


Figure 18.20 Stepped foundations.

Services entering a building below ground (water, electricity, gas, telephone, etc.) and those leaving a building (drainage, refuse systems, etc.) usually pass through the wall below ground in the case of horizontal strip foundation, or through the foundation itself when vertical strip foundations are employed (Fig. 18.21). This presents little problem in the former case as apertures can be left in predetermined positions by using precast reinforced concrete lintels or brick arches over openings, or by laying
wall units in dry sand instead of mortar, so that they can be easily removed prior to the service being installed. If the service pipe can be positioned as the below-ground wall is being built, these processes can be simplified still further. However, when vertical or deep strip foundations are used, the positions for holes must be carefully predetermined and open-ended timber boxes or plastic pipe sleeves placed in position during the concrete-laying procedures. Whichever form of strip foundation is used, it is essential that the holes left are of adequate size to allow about 50 mm clearance all round the proposed services pipe, in order to avoid the possibility of its subsequent deflection or fracture should any settlement of the foundation occur. It is always best to avoid passing services beneath foundations unless precautions are taken to ensure localised settlement of the wall above does not occur at these points through the removal of foundation support (bearing soil).

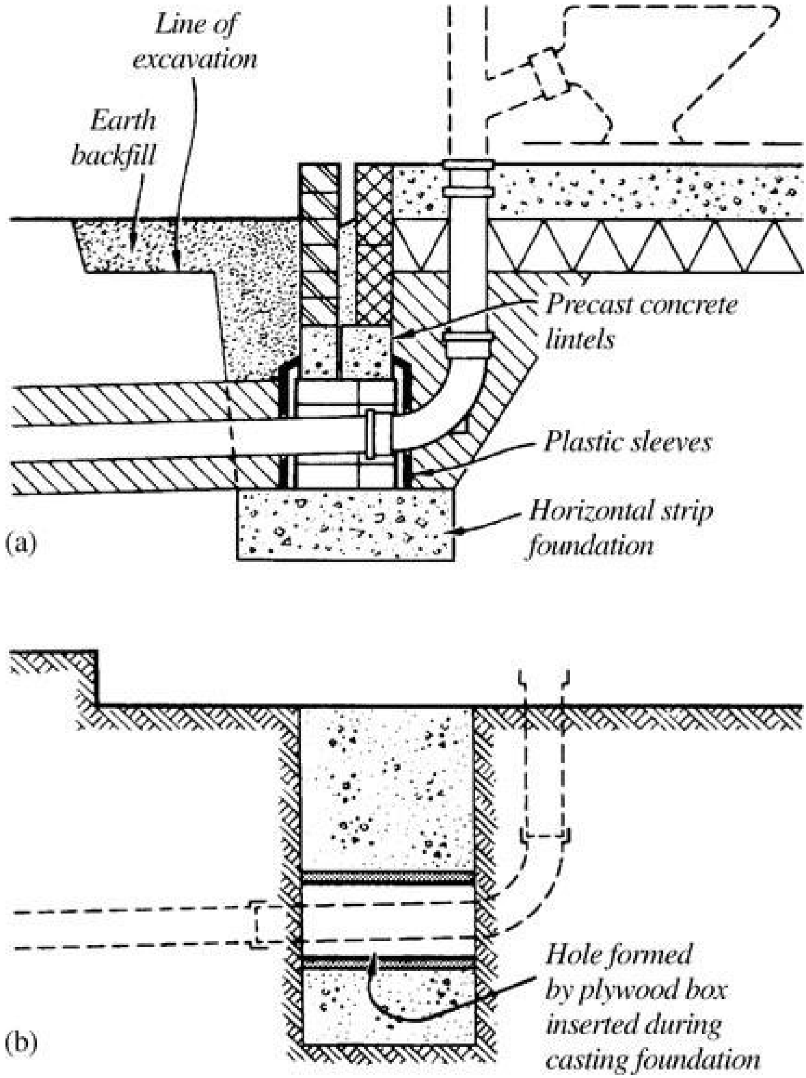


Figure 18.21 Formation of holes for services pipes: (a) horizontal or shallow strip foundation – formed by lintel construction; (b) vertical or deep strip foundation – formed by shuttering.

After the concrete has been poured and has hardened, the construction of the wall above can commence and is subsequently taken to the height of the damp-proof course (see section 18.6). At this stage the local authority building control officer will make his or her second formal visit to the site and inspect the suitability and quality of the work and materials.

Once approval has been given, the rest of the horizontal or shallow strip foundation trenches can be backfilled; ordinary excavated soil is generally suitable for this purpose on the outside face of the foundation; a denser material capable of greater consolidation is used for the backfill on the inside face of the foundation. This is because the backfill on the inside face of the foundation trench may be required to provide support for the ground floor construction.

Alternative forms of foundation to the horizontal or vertical strip may be necessary for a two-storey house when subsoil conditions are difficult. A raft foundation will be required when the soil is so weak that it is necessary to distribute the building loads within a wide volume of soil (Fig. 18.22); a short-bore pile foundation will be required when seasonal variations in moisture or vegetation are likely to affect the stability of the bearing soil lying relatively near the surface (Fig. 18.23). Both these forms of foundation, together with the pad foundation applicable to framed buildings, are described in detail in Mitchell's Structure and Fabric Part 1, Chapter 4. Section 17.7.3 of this book gives details of internal wall foundations.

18.5 Ground floor construction CI/SfB (16) + (43)

18.5.1 Function

Among other performance requirements, the ground floor construction must provide a level surface capable of supporting people, furniture, equipment, wheeled traffic, partitions, finishes, etc.; it must also provide environmental control against the passage of water (liquid and vapour) and heat. Various factors may affect the method of construction as follows:

- Existing ground levels
- Desired finished floor level(s)
- Required floor loading
- Bearing capacity of supporting soil
- Form of building foundation
- Availability and cost of suitable fill material

A ground floor construction which is continuously supported by the ground or through a fill material in contact with the supporting ground is called a solid floor; a construction supported by a foundation system at selected points is called a suspended floor (Fig. 18.24).

It is usual to commence some part of the floor construction as soon as the foundations and walls up to damp-proof course level have been completed. This is because it is normally desirable to provide a firm and dry working surface for subsequent building operations, or for the

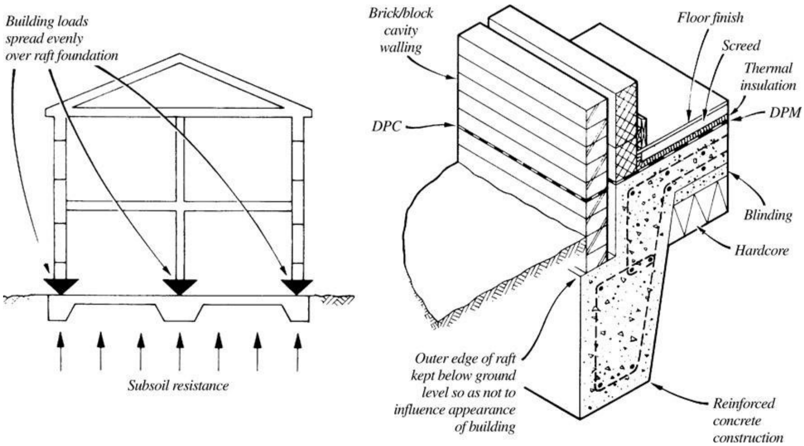


Figure 18.22 Typical details for raft foundation.

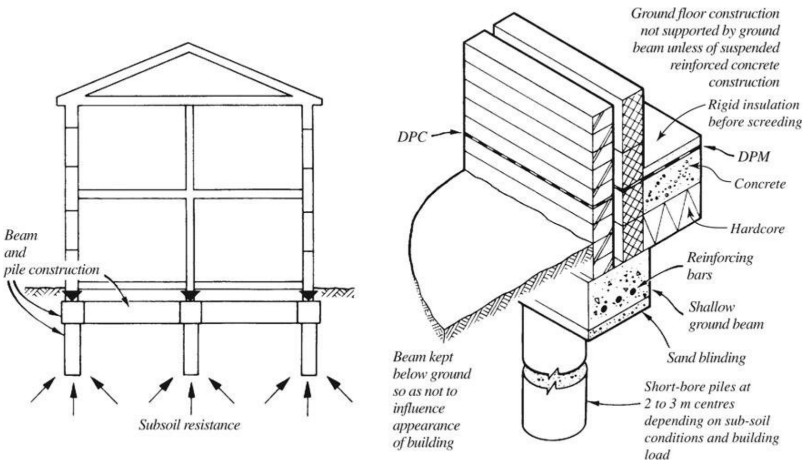


Figure 18.23 Typical short-bore pile foundation.

storage of components and equipment requiring protection from moisture rising from the ground, e.g. windows, doors and frames. This provision is particularly important when the area of the building site is small and leaves little space for storage. However, it is also necessary that any prematurely completed work is suitably protected against damage during subsequent building work and that no materials are used in the construction which will be adversely affected by their temporary exposure to the environment, e.g. timber joists, boards, screeds and finishes.

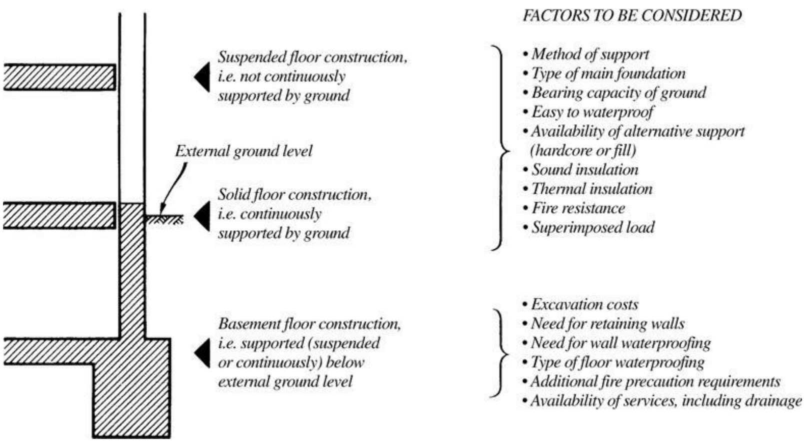


Figure 18.24 Forms of lowest floor construction.

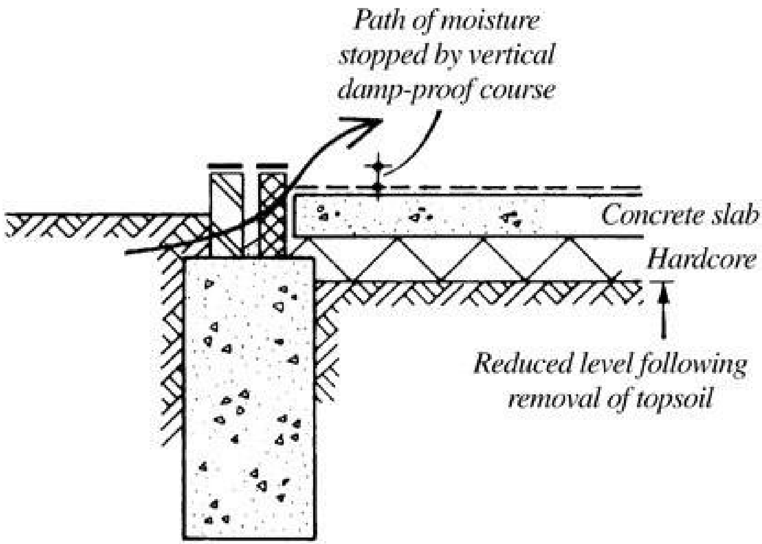
Before the work to the ground floor commences, trenches must be dug and the internal below-ground service pipes for drainage, gas, water, telephone, television and electricity must be installed. These services may need special protection when they occur below the building (e.g. drainage pipes surrounded by concrete) and the trenches should be backfilled as solidly as is practicable. It is important to supply the contractor with accurate information regarding the position of these services in order to avoid subsequent repositioning work.

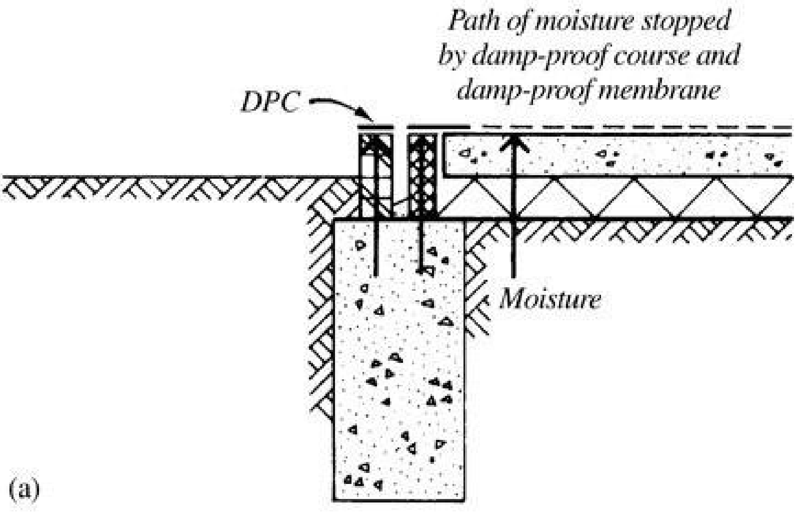
18.5.2 Solid ground floor construction

The concrete ground floor slab must be laid to the correct level, and on a firm base to avoid the possibility of future movements which could cause cracking and produce an uneven top surface or moisture penetration from the sub-soil below. The topsoil will have been removed from the formation area of the floor slab. The resulting reduced level should therefore be made good with a material or fill which is capable of full compaction so as to be strong enough to take the weight of the floor slab and the loads it carries, as well as restricting or reducing the upward capillary movement of water from the soil. A material which most conveniently conforms to these requirements and is easy to use is gravel, but less expensive materials include brick, tile or concrete rubble (hardcore), or other waste products such as blast furnace slag, pulverised fuel ash and colliery shale. However, care must be taken when using these latter products to ensure that their unit size allows thorough compaction, and that they do not contain sulphates, which would attack the cement of the concrete slab under the foundation materials. When completed, the top surface of the fill material or hardcore should be dry and even, and at a level which best ensures the top surface of the concrete floor construction butts against the perimeter walling without the necessity for vertical damp-proofing techniques. This will avoid moisture penetration resulting from the lateral movement of water from outside (Fig. 18.25(a)).

The fill or hardcore must be fully compacted by mechanical hammers or rollers (depending on the area involved). In practice it is usually difficult to ensure enough consolidation when fill or hardcore depths greater than about 600 mm are required, even if compacted in the usual 150–200 mm layers. Therefore, in order to avoid the possibility of settlement occurring in the floor, a suspended floor construction will be more appropriate when the desired finished floor level requires more than 600 mm fill or hardcore (see section 18.5.3).

The concrete for the slab is mixed and poured so as to obtain a minimum thickness of 100 mm, although it is preferable to use a thicker slab of 150 mm when any doubt
exists either about the full compaction of the fill or hard-core, or about the subsoil when it is less than very stable. The thicker slab will also assist in spreading the point loads from load-bearing partitions when separate foundations for this purpose are not necessary; the greater mass of concrete will offer greater resistance to rising moisture. If the subsoil conditions are relatively weak, the 150 mm slab should be reinforced with a mild steel mesh. This should be placed in the slab after an initial layer of concrete has been poured and then be covered by the subsequent and final pour. As concrete shrinks on drying, the reinforcement will also help in avoiding shrinkage hair-cracking. But if large areas of uninterrupted concrete slab are required, movement joints should be incorporated by casting the slab in approximately 3 m bays or using a modular dimension appropriate to the plan area.


Path of moisture
stopped by vertical
damp-proof course
Concrete slab
Hardcore
Reduced level following
removal of topsoil


Path of moisture stopped
by damp-proof course and
damp-proof membrane
DPC
Moisture

(a)

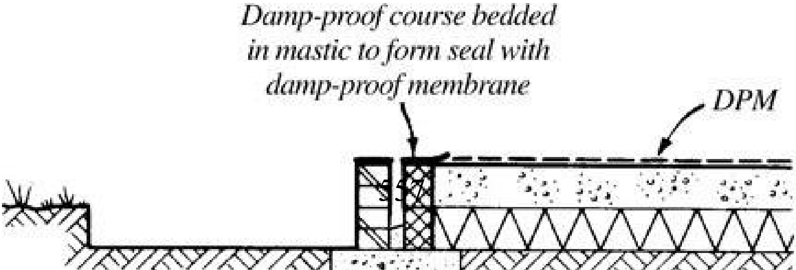

Damp-proof course bedded
in mastic to form seal with
damp-proof membrane
DPM

Figure 18.25 Waterproofing solid ground floor slab: (a) principles; (b) method.

The surface of the concrete slab can be finished in various ways, depending upon the position of the damp-proof membrane. This membrane consists of a sheet of polythene (1 200 gauge), or an in situ coating of hot-poured bitumen, or a minimum of three coats of cold-applied bitumen/rubber solution. The function of a damp-proof membrane (DPM) is to resist moisture in liquid and vapour form coming into contact with the internal surfaces of the floor construction and thereby causing damage. The concrete slab itself may not be able to resist this moisture – particularly when the water-table is close to the ground surface – because of the fine hair-cracks which develop during drying and, unless it contains special admixtures, concrete is not moisture vapour proof.

If either a sheet or an in situ coating damp-proof membrane is to be subsequently applied to the top of the concrete slab, as indicated in Figure 18.25(b), the top surface of the concrete must be trowelled smooth so that it is not punctured. The DPM must also be protected as soon as possible after it is laid by a sand and cement mixture (in the proportion 3:1) known as a screed. This screed should be a minimum thickness of 50 mm, preferably 65 mm over rigid insulation, to avoid cracking and also trowelled smooth to a perfectly level surface in order to be satisfactory for the final floor finish, e.g. quarries, clay or ceramic tile, carpet. The DPM, screed and subsequent floor finish cannot be placed until most of the other building works have been completed because they are all susceptible to damage which will be costly to rectify (see section 18.11).

Figure 18.26 indicates the alternative position for the DPM – below the concrete slab. In this case it is the fill or hardcore which must have the smooth surface to avoid sharp edges damaging the membrane; this is achieved by blinding, consisting of a 30–50 mm thick layer of sand. After the DPM has been positioned, rigid insulation is placed with edges returned and the concrete slab (reinforced if required) is poured very carefully to avoid damaging the insulation and DPM. The top surface of the slab should then be 'finished' with a rough surface by using a long plank of wood placed on edge and tamping across the wet surface. When dry, the resulting slightly irregularly raised surface texture will provide an excellent key for the screed. Because more positive bond is provided to the slab than when laid on the smooth DPM (Fig. 18.25(b)), the finishing screed can be of reduced thickness, say 30 mm. If the screed is laid while the concrete slab is still green, and
therefore providing an even better key, the screed thickness can be reduced to 12 mm. Indeed, as an alternative to providing a screed, the green concrete slab can be finished to a very smooth surface by a light mechanical buffing process using a special machine known as a power float.

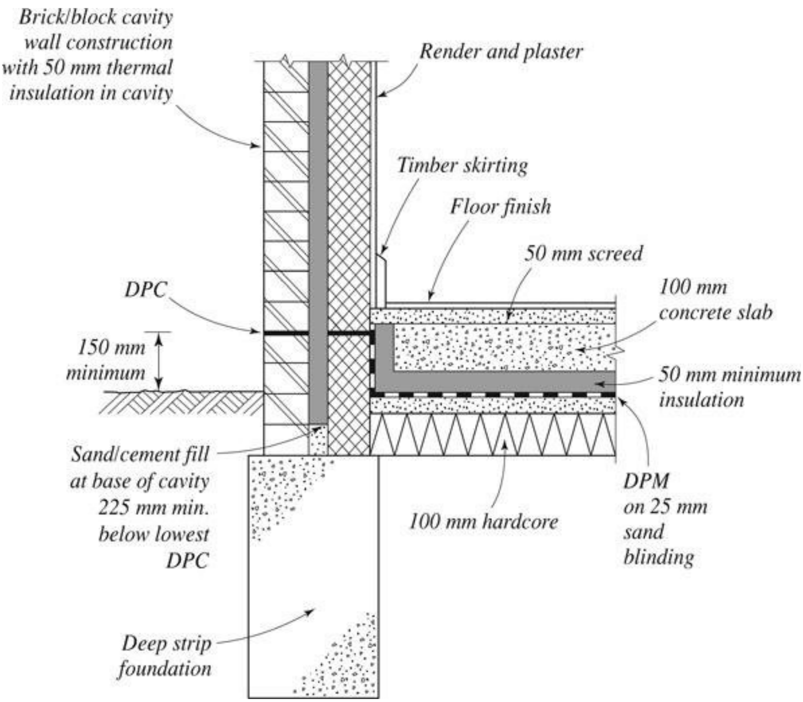


Figure 18.26 Damp-proof membrane below ground floor slab.

The designer must consult with the contractor concerning which of the above two positions for the DPM is most suitable. Both have advantages as well as disadvantages. Below-the-slab DPM leads to savings in both labour and materials, and, if correctly executed, the slab remains dry throughout the life of the building and helps to minimise heat losses as well as providing a thermal reservoir (heat storage). But it does mean great care must be taken during construction to ensure the DPM is not damaged. Unless a screed or some other finish (e.g. timber) is subsequently applied to the surface of the slab, it cannot be cast until quite late in the building operations, otherwise the exposed surface will certainly be damaged. If a power-float finish to the slab is required, it must be temporarily protected until most building operations are complete.

The amount of heat which may be lost through a solid ground floor construction depends on several factors. The greatest concern for heat conservation derives from the extent of external wall bounding the floor because this juxtaposition will provide a direct path for heat loss to the external air. This problem may be overcome by using perimeter insulation material between the junction of the solid floor construction and the inside face of the external wall. This insulation should be waterproof and extend downwards either from the DPC/ DPM position for 300– 1 000 mm, depending upon climatic conditions, or for the thickness of the slab before running horizontally beneath it.

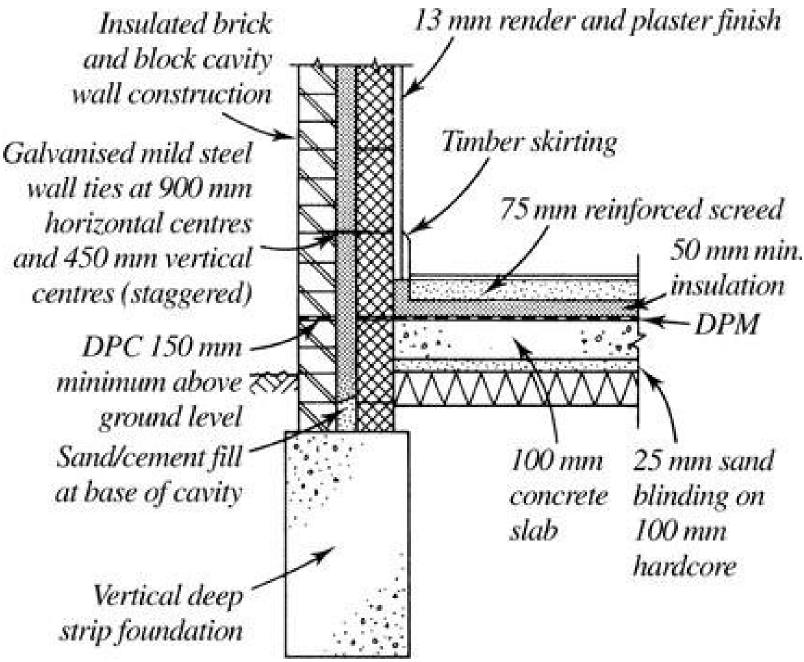


Figure 18.27 Thermal insulation to ground floor slab.

Alternatively, insulating material can be placed directly on the DPM before the floor screed is applied, as indicated in Figure 18.27. This method of heat conservation is particularly useful when underfloor heating cables or pipes are to be inserted in the screed. However, care must be taken to ensure that the resulting floating screed (unattached) is of sufficient thickness to avoid cracking, and that the insulation has an impervious surface layer to avoid saturation of the insulation and loss of the grout (cement/water) from the screed causing a ‘cold bridge’ link with the concrete slab below. The waterproof membrane will also act as a vapour control layer, and eliminate the possibility of interstitial condensation within the insulating material. A minimum screed thickness of 75 mm is required and this should be reinforced with a light mesh reinforcement (chicken wire).

18.5.3 Suspended ground floor construction

This form of ground floor construction should be adopted when the desired finished floor level is above the supporting ground to the extent that the difference cannot conveniently be made up with fill or hardcore (see Fig. 18.24). The structural floor can be formed by timber joists (Fig. 18.28) or with reinforced concrete (cast in situ or by using precast concrete planks, see Fig. 18.32).

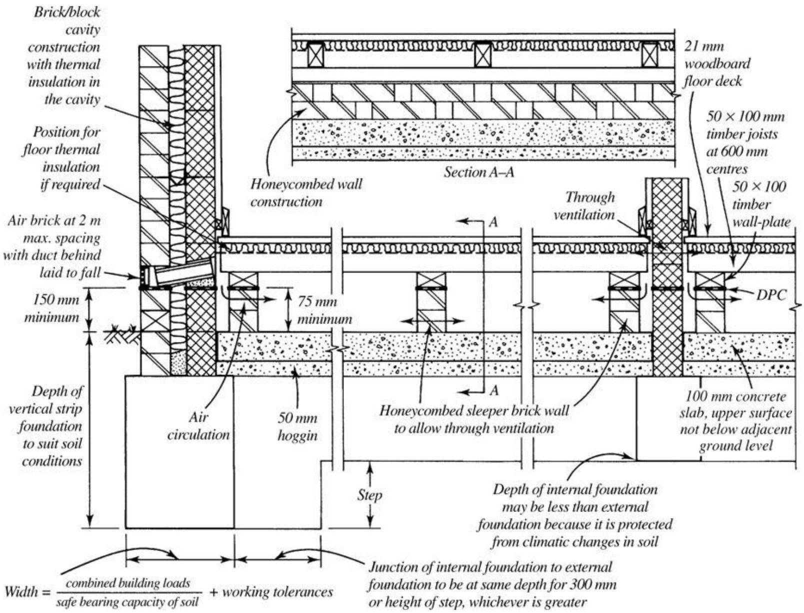
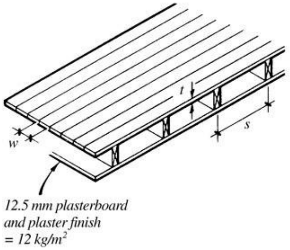
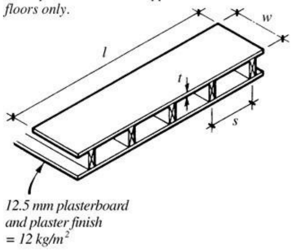


Figure 18.28 Suspended timber ground floor construction.

When timber joists are used, care must be taken to ensure they are not adversely affected by the potentially moist condition existing in the void beneath the floor. Precautions include the provision of a DPC immediately beneath the timber wall-plate which provides bearing for the timber joists through to the sleeper walls below; adequate cross-ventilation of the void by air from external perforated bricks circulating around the timber joists and through gaps in the sleeper walls, which are of ‘honeycomb’ construction; and the use of structural timbers with not more than 18 per cent moisture content at the time of fixing. All timber should be impregnated with a preservative solution to counteract the possibility of fungal attack (dry rot) and act as a precautionary measure against the failure of the construction techniques to keep the moisture content of the timber below 18 per cent during its life in the building. Preservative-impregnated timber also proves unpalatable to the grubs of wood-eating insects (woodworm, house longhorn beetle, etc.).



Boards	Finished thickness, t	Nominal width, w (mm)	Span, s	Approximate weight (kg/m^2)
Softwood t & g	16 19 21 28	100 and 150	505 600 635 790	7 9 10 13
	47	150	2560	23
	60 72	150 150	3230 3830	28 32



Sheets	Thickness, t	Size, ($w \times l$)	Span, s	Approximate weight (kg/m^2)
Plywood t & g (flooring grade)	12 15 18 25	600 and 1200 × 2440 and 2750	400 600 700 1200	8 9 11 15
Chipboard t & g (flooring grade)	18 19	600 and 1200 × 2400	400 450–500	12 13
	22	and 2750	600	15

Figure 18.29 Types of floor decking: dead weight or self-weight of flooring and ceiling can be used in conjunction with Table 18.2 to obtain suitable timber joist sizes.

For further comments regarding timber joists, and their sizes and spacing, see section 18.8.2 and Table 18.2.

The floor decking can be tongue-and-groove hardwood or softwood boarding, chipboard sheets or plywood sheets (Fig. 18.29). The narrow face width of boarding gives greater flexibility when providing a floor in an irregular or non-modular width of room, and also permits easier access to the void below, should it be required during the life of the building, e.g. for alterations or extensions of electric wiring contained within the void. However, sheet floor deckings are generally quicker to install, particularly when the spacing of the timber joists and sizes of rooms have been closely coordinated with dimensions of available plywood or chipboard sheets. Also, provided the sheets are allowed to acclimatise to the atmospheric conditions of the room prior to installation and provided they are correctly fixed, subsequent movements of the sheets are likely to have less effect on applied finishes than would the corresponding movements associated with softwood boarding. Boards as well as sheets should be impregnated with a preservative solution in a similar manner as the structural timbers, although the sheets require special hard-wearing pre-treated flooring grades. When it is thought desirable to leave the top surfaces of the boards or sheets exposed, consideration must be given to the selection of suitable wood grain patterns and the effects of subsequent seals, stains or varnishes.

The in situ concrete slab used with the form of suspended floor construction, indicated in Figure 18.28, can be cast as soon as the walls have been completed up to DPC level in a similar manner to that described for solid floor construction. In this way the slab serves as a relatively dry, clean and level surface for storage and work by other trades, i.e. preparation of purpose-made door and window frames. The remainder of the floor construction can be executed as more of the building is completed.

If it is considered desirable for the floor decking to be installed before 'heavy' trade work is complete, a temporary layer of hardboard sheets must be installed to prevent damage to the surface of the boards or sheets. In any event, it is convenient if the services required to run beneath the floor decking can be installed before all the boards or sheets are finally fixed to the supporting joists. Alternatively, predetermined areas of decking are left open to allow services to be fed through the void below. When the services are installed early, they can be left projecting just above the decking, pending subsequent connections and completion of the above-decking services.

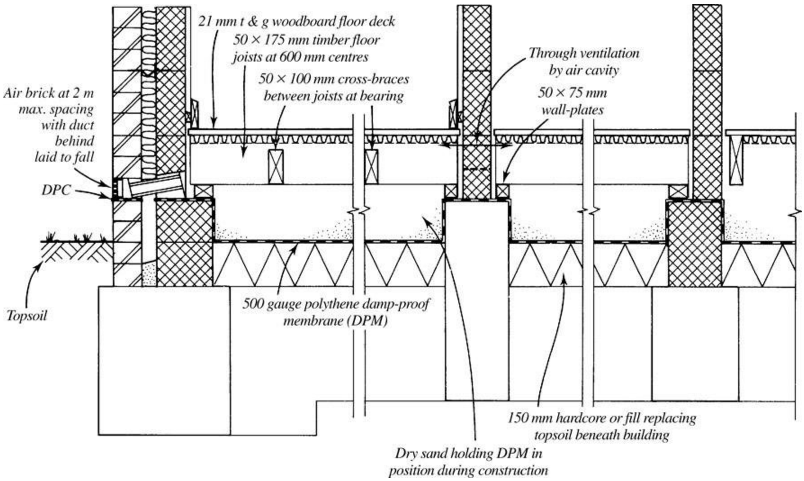


Figure 18.30 Alternative ground floor suspended timber construction.

Figure 18.30 illustrates a form of suspended ground floor construction where a concrete slab is not used. A slab cannot be considered as a water barrier since small cracks will develop through its thickness as a result of drying shrinkage. These gaps may be relatively large (2–3 mm) between two or more areas of slab cast next to each other on different days (daywork joints) and at the junction between a slab and the external wall. Furthermore, concrete is not moisture vapour proof. By using a sheet membrane (polythene) lapped and folded at edges and sealed with the wall DPC, a more positive barrier against free moisture and moisture vapour can be provided. This form of construction can best be executed without the use of intervening sleeper walls, which means that the structural floor joists must be larger to span the resulting longer distances. Ventilation of the floor void must be provided, as described earlier, and timbers should also be impregnated with a preservative treatment against fungal and insect attack.

This method of construction means that the dry working surface previously described is not available to the builder and he or she must take special measures to ensure the membrane barrier is not damaged during the installation of floor joists and decking. It causes some inconvenience to the builder and his or her opinion should therefore be sought before it is specified by the designer, even if considered essential to avoid excessive amounts of moisture occurring in the floor space beneath the decking. If the site is subject to waterlogging, it is probably best not to risk water standing freely on either concrete slab or membrane barrier. Figure 18.31 indicates a method of construction which does not employ either, but allows water to drain away during dry periods.

Generally speaking, a timber suspended floor provides better resistance to loss of heat to the surrounding ground by virtue of the better insulation properties of timber when compared with solid concrete. Additional thermal insulation can be provided, however, and this is usually draped over the timber joists prior to fixing the floor decking. Under these circumstances it is probably best not to provide a vapour barrier on the room side of the insulation (warmer) because it would only serve as a trap for water which may be spilled on the upper surface of the floor decking and seep through joints to the spaces below. Seeping moisture from this source will soon dry out (as will any interstitial condensation) if the void is adequately ventilated.

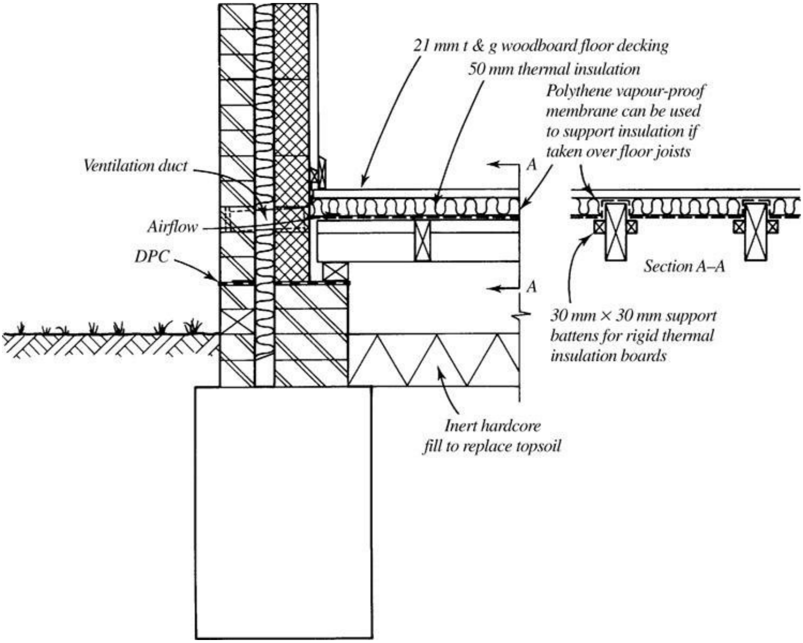


Figure 18.31 Second alternative ground floor suspended timber construction.

Suspended timber ground floors are very common in houses constructed up to and during the 1930s. Thereafter, shortage of suitable quality materials led to the less expensive alternative of concreted solid floors. Today, quality materials are available but the cost of timber and skilled time of carpenters limit suspended timber flooring. A possible application is a client's specific requirement to match a house extension floor to that existing. Other than that, suspended timber flooring is only likely to be experienced during maintenance and repair. Where houses are extended with a solid concrete floor next to a suspended floor, air ducts linking the existing air bricks to air bricks built into the new external wall are essential. 100 mm-diameter drainage pipes positioned in sufficient thickness of concrete slab are generally adequate. These are necessary to maintain continuity of air movement under the existing floor.

Suspended ground floor constructions using reinforced in situ or precast reinforced concrete units allow for 25–40 per cent greater floor loadings than timber joists, and are capable of spans up to 6 m (Fig. 18.32). This may be particularly attractive when poor soil conditions require deep or complicated foundations and which should be formed as widely spaced as possible for reasons of economy. Also, concrete floor construction is not subject to dry rot or insect attack. It does, however, require formwork (permanent or temporary) for in situ construction, and possibly lifting equipment (gantries or cranes) for precast concrete constructions. Precast constructions also require careful dimensional coordination to get the most from a minimum range of standard length and width components, otherwise site cutting will be necessary. As with solid floor construction, a suspended concrete floor construction can be provided with a timber floor finish (boards or sheets on preserved timber battens fixed to the concrete base), but does not provide the desirable springiness of a structural timber construction unless special sprung fixing devices are installed with the timber battens.

18.6 External wall construction CI/SfB (21) + (31) + (41)

18.6.1 Function

The main function of an external wall involves providing the environmental control between the external and internal climates of a building. Also, depending upon the precise nature of the overall structural system, an external wall is usually required to support the combined dead, imposed and wind loads of the roof and floor construction, as well as its own combined loads, and transfer them safely to a foundation. However, apart from the technical requirements, considerations of appearance must be a critical part of the design since to a very large extent an external wall determines the architectural character and quality of a building.

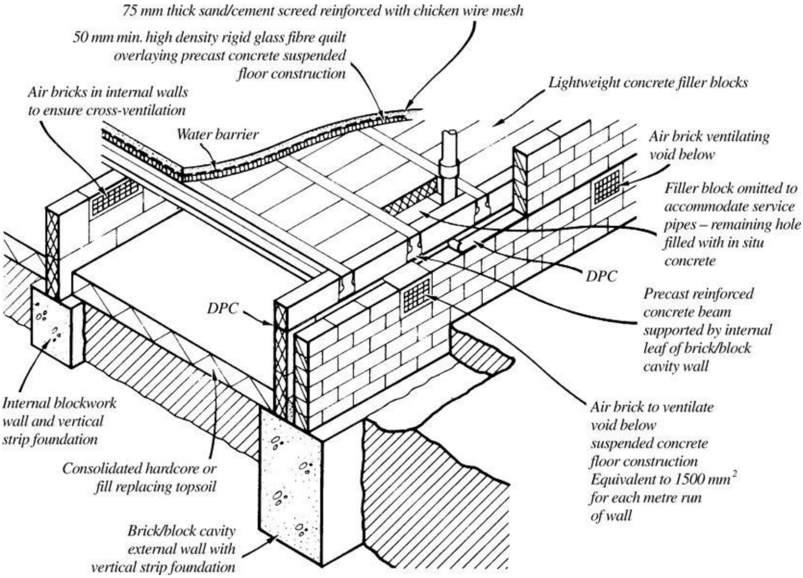


Figure 18.32 Suspended ground floor construction using precast concrete flooring units.

18.6.2 Materials

Both technical and aesthetic criteria are influenced by the type and size of materials employed, standard of work and the effects of weathering and general durability resulting from design and construction methods. Therefore, external walls can take many forms since they can be made from a very wide range of materials used either singly or in combination with others:

- Small bricks or concrete blocks laid in mortar
- Dry-jointed units of timber, metal or concrete
- Homogeneous matrix of reinforced concrete

- Composite systems of timber, metal or concrete pre-formed units
- Rigid single sheets of glass, metal or plastics
- Flexible single sheets of rubber or plastics

When considering the construction of a dwelling in the United Kingdom, the first choice of material for an external wall is bricks and/or concrete blocks laid in mortar (Fig. 18.33). This choice derives partly from traditional attitudes, but is also due to the availability of materials and skilled work as well as the inherent performance requirements known to be satisfactorily fulfilled by this form of construction. Bricks and blocks are unlikely to cause the spread of fire from either outside or inside because they are non-combustible and highly resistant to collapse as a result of being subjected to fire. When used correctly, bricks and blocks are also highly resistant to weather penetration and can provide satisfactory standards of sound control and thermal insulation. However, the selection of the most suitable form would vary according to the location of the external wall relative to the disposition and siting of the dwelling; this involves a thorough analysis of the performance requirements outlined in Part A.

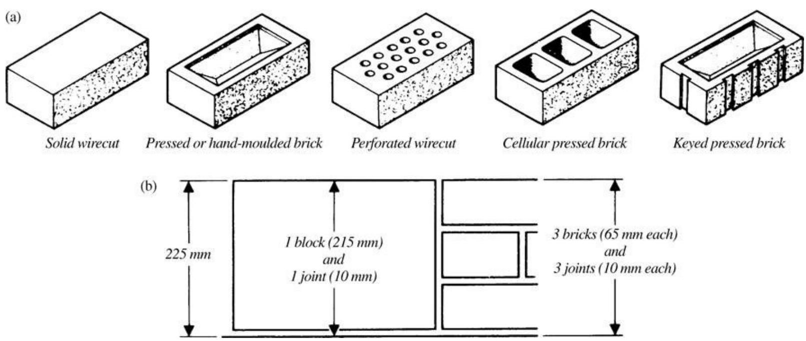


Figure 18.33 Bricks and brickwork: (a) types of brick; (b) relative course heights of brickwork and blockwork.

The majority of bricks used in the United Kingdom are manufactured from clay which, having been moulded to suitable dimensions when in a plastic condition, is burnt to a hardened and vitrified state. There are three technical varieties according to use: common bricks for general and ultimately unseen work; facing bricks specially made or selected to give an attractive appearance; and engineering bricks made to provide high levels of compressive strength and low levels of moisture absorption. The physical characteristics of the bricks are derived through the type of clay used and the manufacturing processes involved. Engineering bricks are of special quality and rely on a special form of clay for their production, whereas common and facing bricks may be of ordinary quality (used in normal exposure condition) or of internal quality (used in protected position only) according to the combined strength and absorption characteristics of the clay used. Bricks can also be manufactured from shale (calcium silicate) or concrete.

Building blocks are larger than bricks and are manufactured from clay, plaster or concrete (see Fig. 18.47). However, concrete is the most suitable material for incorporation in an external wall construction since its use avoids the special measures which have to be taken with the other materials to ensure adequate weathering and thermal insulating properties. Concrete blocks are manufactured in several crushing strengths to BS 6073: 2.8, 3.5, 5, 7, 10, 15, 20 and 35 N/mm^2. The lower figures represent highly insulative blocks produced from lightweight aggregates but having load limitations. Blocks in the upper strength categories are produced from dense concrete for substructural and other high-load-bearing situations. They are also manufactured in solid, perforated or hollow horizontal section.

Walls constructed from bricks and blocks rely for their strength on being laid in horizontal courses so that their vertical joints are staggered or bonded across the face of the wall (see Fig. 5.5). In this way the compression loads which may initially affect bricks or blocks can be successfully distributed through a greater volume of the wall. The bricks and concrete blocks are held together by an adhesive mixture known as mortar, thereby completing the structural and environmental enclosure. This mortar also serves the function of taking up any dimensional variations in the bricks or blocks, so that they can be laid in more or less horizontal and vertical alignment. Most mortars today usually consist of a water-activated binding medium of cement, and a fine aggregate filler such as sand, in the proportion of one part binder to three parts aggregate. The amount of water used to activate the binder in order for it to adhere to the fine particles of the filler and the face of the brick or concrete block must be kept to a minimum to avoid a sloppy, unworkable mix subject to excessive drying shrinkage. The use of an additive will aid workability and avoid an otherwise very dry, stiff mix which could be difficult to apply. Traditionally this was lime, but liquid plasticisers are more common today.

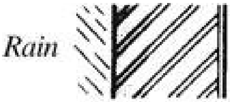
Mortar mixes on site should not be used when the air temperature is below 4 °C, otherwise the water content may freeze and adversely affect the strength of the mortar. When such conditions arise, the contractor will have to stop bricklaying, or provide protective shelters around the building

or over that part to be immediately constructed, and probably also provide artificial space heating sources
to ensure continuity of work for the bricklayers. These precautions must be applied to all on-site 'wet' trade activities, including concrete laying and the application of plaster.

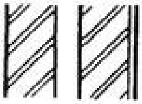
18.6.3 Brick/block cavity walls

Bricks and concrete blocks can be used as a walling material in a number of ways, as indicated in Figure 18.34. Traditionally, solid brick walls were considered sufficiently weather resistant in many areas of the United Kingdom, but under severe exposure conditions quite thick, solid brick walls may well permit water to penetrate to the inner face and would certainly not meet today's requirements for thermal insulation unless special precautions were taken. The most common form today derives from principles originated over 50 years ago, and uses the two materials together to create a brick/block cavity wall construction. This consists of an outer or external leaf of 102.5 mm thick brickwork (although this may be thicker to suit loading conditions), a separating air cavity 50– 100 mm wide, and an inner or internal leaf of 100 mm thick concrete block (although this may be increased to suit loading conditions or thermal insulating requirements) to which a finish may or may not be applied. The cavity may be up to 300 mm wide, with each leaf tied by solid stainless steel vertical twist pattern ties. Double triangle stainless steel wire pattern ties may be used in cavities up to 100 mm. For spacing, see section 18.6.4.

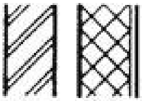
This method of construction accepts that water may permeate through the relatively thin outer leaf of brick-work, but is then prevented by the air cavity from reaching the inner leaf of concrete blockwork which remains dry and therefore provides good thermal insulating properties, particularly when lightweight or aerated blocks are employed. These properties can be further increased by inserting a rigid thermal insulating material on the cavity face of the blockwork, but this must be done with great care to ensure that, whenever possible, a minimum cavity of 50 mm is maintained to provide the water barrier. Alternatively, subject to local building control approval, the cavity can be filled completely with either an insulating board (batt) or insulating foam. Complete cavity-filling techniques are easier for the bricklayer to implement, but can create problems of water penetration under conditions of severe exposure, owing to the possibility of mortar which has squeezed out of the joints in the bricks or blocks forming a link across the cavity. Figure 18.35 indicates the former construction method, which maintains a cavity barrier.



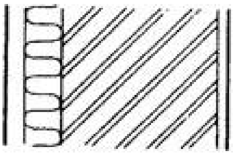
215 solid brick wall
13 plaster
U value = 2.1 W/m^2 K



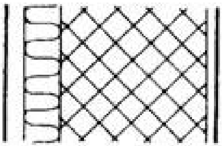
102.5 brick outer leaf
50 cavity
102.5 brick inner leaf
13 plaster
U value = 1.7 W/m^2 K



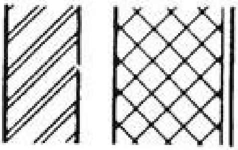
102.5 brick outer leaf
50 cavity
100 lw block inner leaf
13 plaster
U value = 1.0 W/m^2 K



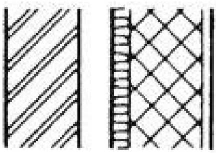
25 external skin
50 insulation
215 solid brick
13 plaster
U value = 0.55 W/m^2 K



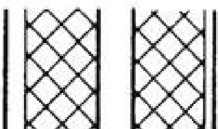
25 external skin
50 insulation
200 solid lw block
13 plaster
U value = 0.4 W/m^2 K



102.5 brick outer leaf
50 cavity
150 lw block inner leaf
13 plaster
U value = 0.6 W/m^2 K



102.5 brick outer leaf
50 cavity
25 insulation
100 lw block inner leaf
13 plaster
U value = 0.6 W/m^2 K



25 external skin
100 lw block outer leaf
50 cavity
100 lw block inner leaf

Figure 18.34 Use of bricks and blocks to form external walls and a comparison of their approximate thermal insulation values. For U value calculation, see Chapter 8.

The relatively thin cross-section walling materials must be selected to withstand the effects of movements, mostly caused by dramatic temperature changes arising from winter to summer (seasonal) and, to a lesser extent, from night to day (diurnal). It is not uncommon for the annual temperature range of an external wall surface to be in the order of 90 °C, although this will occur quite slowly over the four seasons, thereby giving time for corresponding movements to happen gradually. The continually alternating wetting and drying created by weather processes can also cause problems of movements as well as frost and sulphate attack of the outer brick leaf. Open-pored bricks have a high rate of water absorption and may allow water to pass through their body. Although dense bricks have a low absorption rate and transfer little water through their body, large quantities of water running down the 'glass-like' wall face may be drawn in through capillary paths formed by fine hair-cracks between the mortar used for the joints and the brick (see Fig. 6.9). However, the design of the cavity wall is such that, once water has reached the inner face of the outer leaf, it can run down to a point of collection before being redirected to the outside through strategically placed weepholes (see Fig. 6.5). These can be provided by vertical joints (perpends) left open without mortar filling. The cavity must be kept clear of obstructions and damp-proof courses must be inserted to stop and redirect water at points where the cavity is unavoidably bridged, e.g. around door and window openings, air bricks, etc.

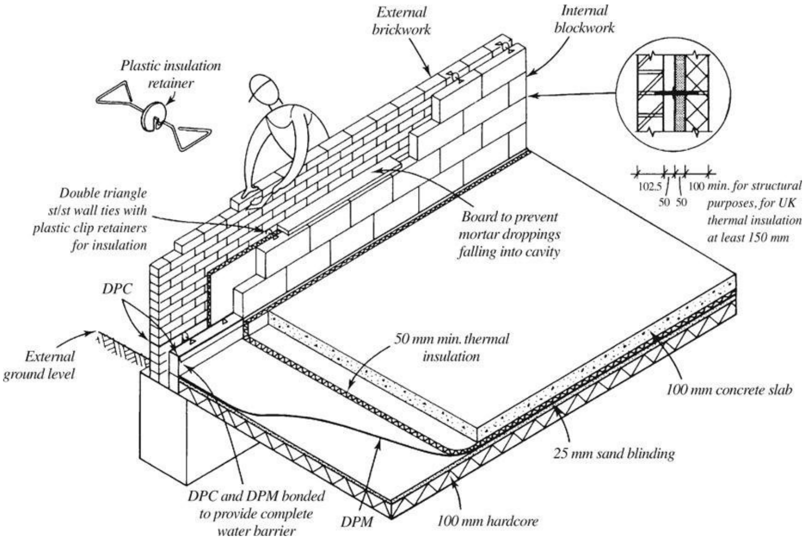


Figure 18.35 Construction of brick/block cavity wall.

Water which may come up from the ground or down from the exposed top of a wall is also barred from those parts of the wall where it will cause damage or loss of environmental control by a damp-proof course appropriately linked to damp-proof membranes as described for floor and roof construction.

18.6.4 Construction

The brickwork and blockwork are normally laid in stretcher bond, although half bats or ‘snap headers’ may be used to achieve the appearance of Flemish or other bonds. The brick and block leaves must be held together by wall ties placed at intervals which will ensure that the two leaves develop a mutual stiffness and act in unison in resisting the combined building loads. This is achieved with the ties spaced at 900

mm maximum horizontally, 450 mm vertically and staggered. A maximum of 300 mm (normally 225 mm to suit block dimensions) vertical spacing is required at door and window openings (see Fig. 18.40). The design of wall ties also ensures that water entering the outer leaf is stopped before reaching the inner leaf by a drip, which occurs centrally over the cavity. The ties should be embedded within the horizontal mortar joints to a minimum penetration of 50 mm in order to provide
adequate restraint to each leaf of the wall. They must be completely surrounded by the mortar of the joint, and ideally laid to a slight fall from the inner leaf down to the outer leaf of wall construction. A range of overall lengths is available to suit different cavity widths, and the ties are produced in non-corrosive metals and plastics to varying shapes. It is essential that ties are kept clear of mortar droppings, which could accumulate during construction, as they may negate the drip mechanism of the ties and thereby provide a bridge for water to reach the inner leaf. Any mortar droppings must therefore be removed daily as the work proceeds; temporary openings called 'coring holes' or 'clean outs' are provided at 1 m centres to allow their clearance from the bottom of the cavity.

Where the type of cavity wall is that indicated by Figure 18.35, the construction method is briefly as follows:

- The DPC material is bedded on a layer of mortar on each leaf of the brick/block cavity foundation wall. It is important that the DPC is the same width as the walling below and the lengths are adequately lapped at the ends, at least 100 mm or the leaf thickness if greater, in order to prevent rising moisture travelling past to the walling above.

- A layer of mortar is placed on the DPC to provide a level bedding for the cavity wall construction. The load from each leaf is then evenly distributed to the foundation wall, the DPC is protected from damage which may be caused by the rough brick or block underface (bed face), and the bond between DPC, mortar and walling material ensures minimal horizontal water penetration by capillary attraction.
- The first row of wall ties is also positioned at 600 mm centres within the layer of mortar placed on the DPC. Polythene retaining discs on the ties should be spaced at a distance from the blockwork inner leaf to suit the thickness of thermal insulation material.
- The blockwork inner leaf is built up to one course above the next row of wall ties which should not have retaining discs fitted at this stage.
- Excess mortar oozing from joints between newly placed blocks should be removed from surfaces, and all mortar droppings must be cleaned from cavity and wall ties.
- Rigid insulating boards or batts of glass fibre, fire-resistant extruded or expanded polystyrene are placed between polythene discs on the lower wall ties and against the blockwork inner leaf. Care should be taken to ensure edges of the insulating boards are butted closely together before the polythene retaining discs of the upper row of wall ties are fitted to hold the insulation firmly against the inner leaf. If full cavity width insulation is specified, the retaining discs are omitted.

- The brickwork outer leaf is built up to the top level of the insulation batt, ensuring that mortar does not drop into the remaining cavity. In practice this is difficult to achieve unless a special cavity batten is used, which is suspended on cords and collects the droppings as they fall. The batten is subsequently drawn up at each stage of wall construction to be cleaned.
- The blockwork inner leaf is built up and followed by the brickwork outer leaf and, as work progresses, the wall ties and insulating batts are positioned, ensuring at all times that the cavity, the wall ties and joints between batts are kept clean of mortar.

The usual procedure is to build the corners or the extremities of the wall to a height of about 8 or 12 brick courses (600–900 mm), care being taken to ensure all edges are vertically plumb. The base of the corner is then extended along the wall and raked back as the work is carried up. The intermediate portion of the wall is built between the two corners, the bricks and blocks being kept level and straight by building their upper edges to a string line stretched between the corners of the building. Notwithstanding this building sequence, the whole of the walling should be carried up simultaneously; no part should be built higher than 900 mm to avoid the risk of unequal settlement on the foundations before the mortar has sufficiently set. The outside face of the mortar joints can be finished in a number of ways, as illustrated in Figure 18.36.

At the end of a day's work, or during rain, exposed areas of insulation, including edges, must be protected with polythene sheets. Without using special techniques, building work should not be carried out using wet mixes when the temperature is at 4 °C or may soon approach it. Whenever necessary, newly completed work should be adequately protected overnight or during non-working days to avoid the detrimental effects of freezing.

Figure 18.37 illustrates an alternative construction method for an external wall using a timber frame technique incorporating thermal insulation, clad on both sides to provide a complete environmental enclosure. This construction technique is described fully in Mitchell's Structure and Fabric Part 1, Chapter 5.

18.6.5 Doors and windows

Doors and windows can provide the weak link in those performance requirements for an external wall concerned with weather exclusion, sound control, thermal comfort, fire protection and security (see Part A). In addition, their location, size, shape, proportion and material profiles profoundly influence the overall and detail appearance as well as the aesthetic aim of a building. The designer must carefully select the sizes of doors and windows relative to their location to ensure all these factors have equal value.

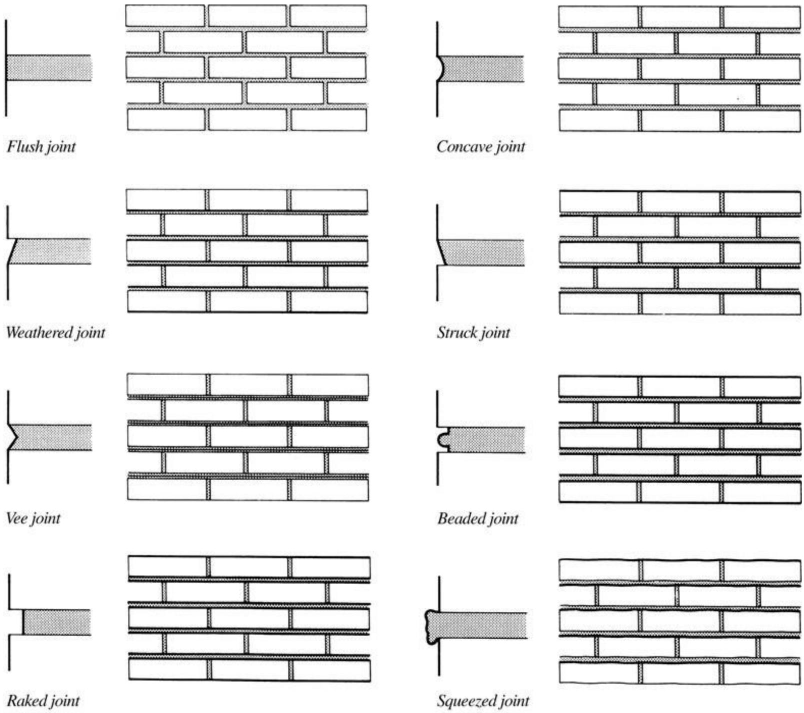


Figure 18.36 Types of mortar joint. A concave joint is better than a flush joint when bricks are uneven; struck, beaded or raked joints should not be used in exposed conditions because water will lie on the exposed edge of the bricks. The squeezed joint will also allow water to penetrate brickwork. Ordinary mortar joints can be raked back and repointed in coloured mortar to any of these profiles; coloured joints may have a dramatic effect on the overall appearance of the brickwork.

The frames for doors and windows can be 'built-in' openings left in the brick/block cavity wall construction, or can be positioned earlier so that the wall is constructed around them. Earlier positioning has many advantages when it comes to forming a weatherproof joint between wall construction and frame. However, the contractor must ensure that the frames are available on site at an early stage of the contract, and that they are adequately protected from physical damage as well as the weather during storage and after their positioning. It is important that the designer has ensured the horizontal lengths and vertical heights of wall construction conform with the overall dimensions and the distances between individual door and window frames (Fig. 18.38). Materials used for door and window frames include timber (softwood and hardwood), metals and plastics. Timber window and door frames should be treated in the factory with a preservative solution and, ideally, a primer so that all hidden surfaces are protected after building in. Both preservative and primer must be chemically compatible with subsequent paint systems. Alternatively, timber frames can be delivered to site having been treated with a decorative preservative stain which only requires recoating after installation.

Before any wall construction is built around the frames, they should be checked with a level to ensure perfect verticality, then they can be securely propped (Fig. 18.39). As the wall is constructed around the frames, they can be permanently fixed by building in right-angled galvanised mild steel lugs screwed to their side edges as the work proceeds (Figs 18.40 and 18.41). Traditionally, the cavity of the wall construction is closed by cutting the block-work and making a 90° return to the inside face of the brick outer leaf and bedding a vertical DPC between the two wall materials to form an effective water barrier. Returning the blockwork in this manner can create a cold bridge through the masonry. In order to prevent this particular area of masonry having an increased heat loss, and to retain the structural integrity of the cavity wall, it is now usual to build in a proprietary uPVC cavity closer. The hollow core of the closer is filled with a non-combustible rock mineral wool to satisfy continuity of cavity insulation and a 30-minute fire resistance if required. To ensure that the sides or jambs of the cavity wall construction are sufficiently robust to withstand the forces exerted by the door or window frames (wind pressures, slamming, etc.), the cavity wall ties around the opening are positioned at increased vertical centres of 300 mm or every three horizontal brick courses.

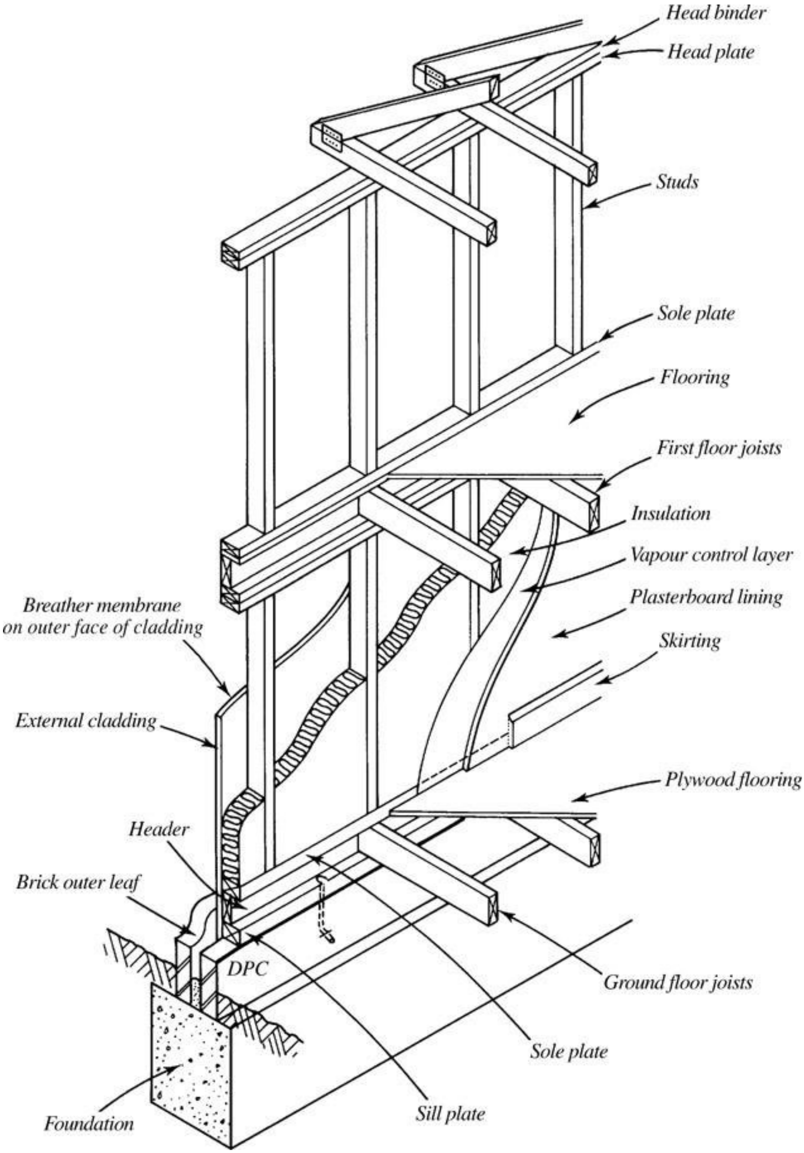


Figure 18.37 Typical timber wall construction using platform frame.

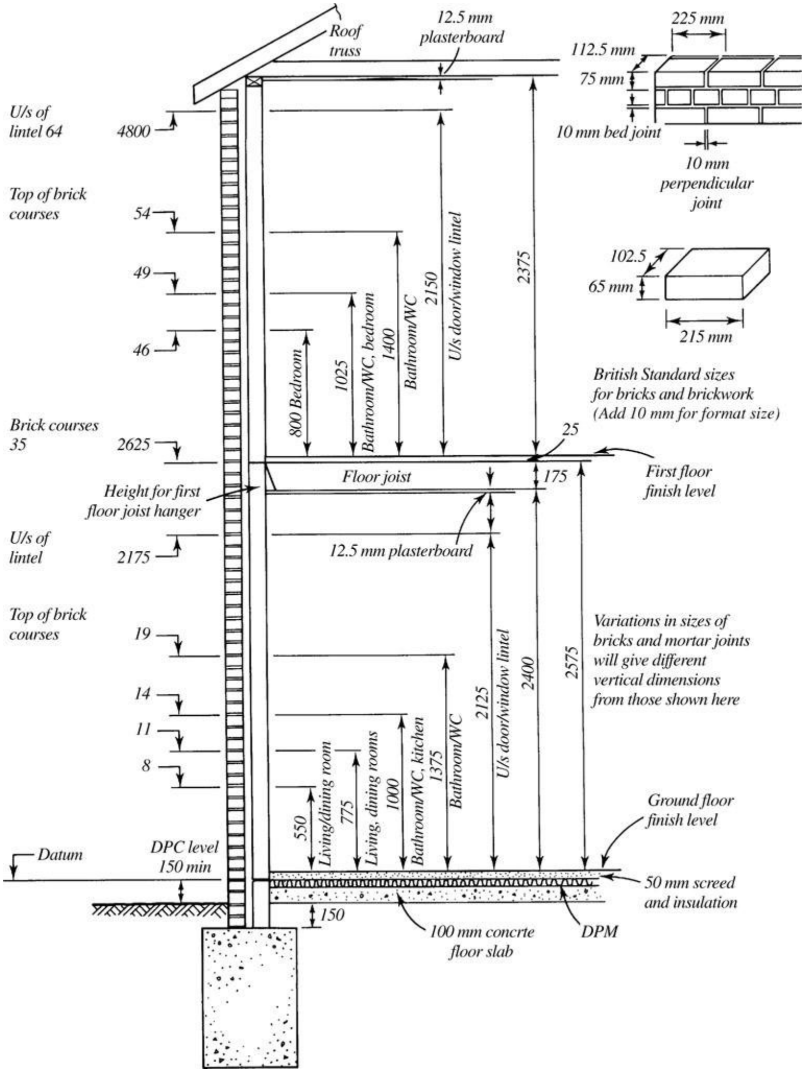


Figure 18.38 Coordination of vertical brick courses and positioning of openings as well as horizontal structure; all of them can eliminate wastage of materials and speed construction sequences (see also Figs 4.8 and 18.33).

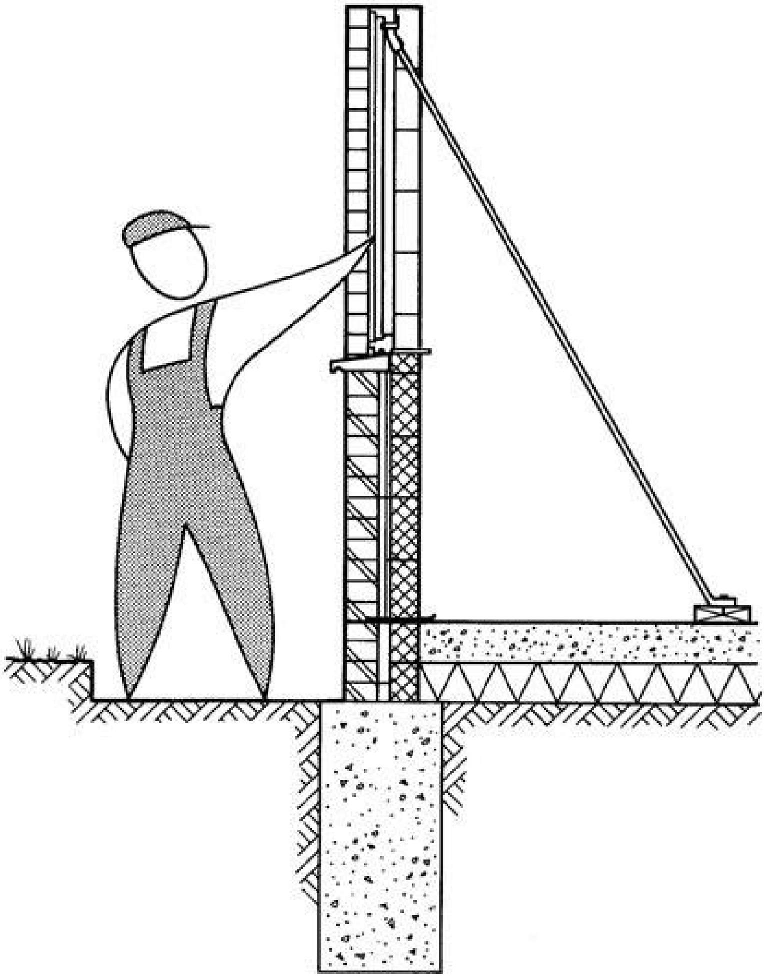
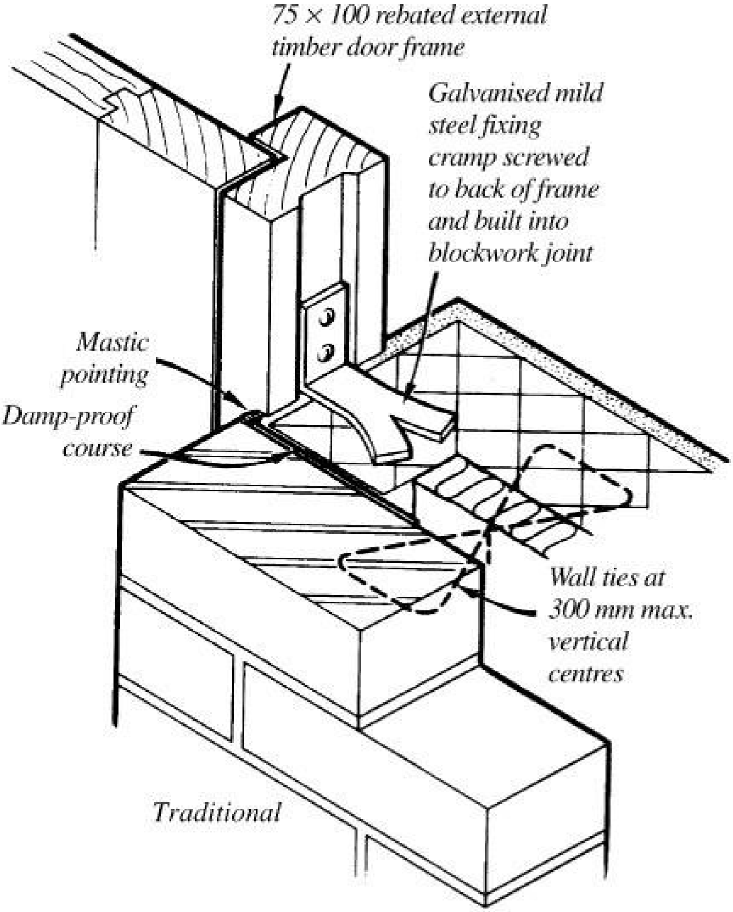


Figure 18.39 Timber window frame temporarily propped until lintel construction has been completed.

Once the cavity wall construction has reached the top of the door or window frame, a lintel construction must be formed to carry the walling above the opening. Together with the number and proportion of openings, the method of forming a lintel has a critical influence on the appearance of the building. Furthermore, if not formed correctly, the lintel construction will also give rise to damp penetration problems as well as condensation due to occurrence of cold bridges. Lintels can be formed with reinforced concrete; with preformed steel section; or with a combination of these two which may or may not include a structural contribution of the walling material itself. When considering the thermal insulation value of a door or a window opening, its effect on the total value provided by the whole external wall enclosure must be with regard to the thermal insulation provisions of the Building Regulations; see also section 8.3.

Reinforced concrete lintels can be formed in situ when the openings to be spanned are sufficiently large to make the bulk of the lintel too heavy to lift into position. Otherwise, they are generally preformed or precast by setting up a precast unit mould into which the steel reinforcement is placed at the bottom on spacers to ensure adequate concrete cover. Concrete can then be poured into the mould. When many lintels of similar shape and size are required, a batch precast unit mould can be employed. This and the other methods of forming reinforced concrete lintels are indicated in Figure 18.42.


75 × 100 rebated external timber door frame
Galvanised mild steel fixing cramp screwed to back of frame and built into blockwork joint
Mastic pointing
Damp-proof course
Wall ties at 300 mm max. vertical centres
Traditional

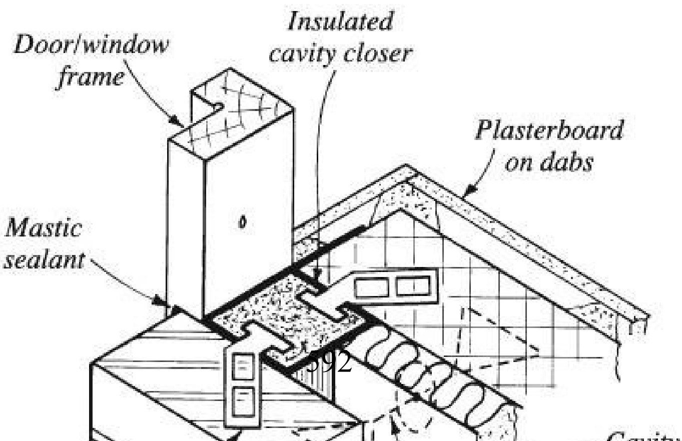
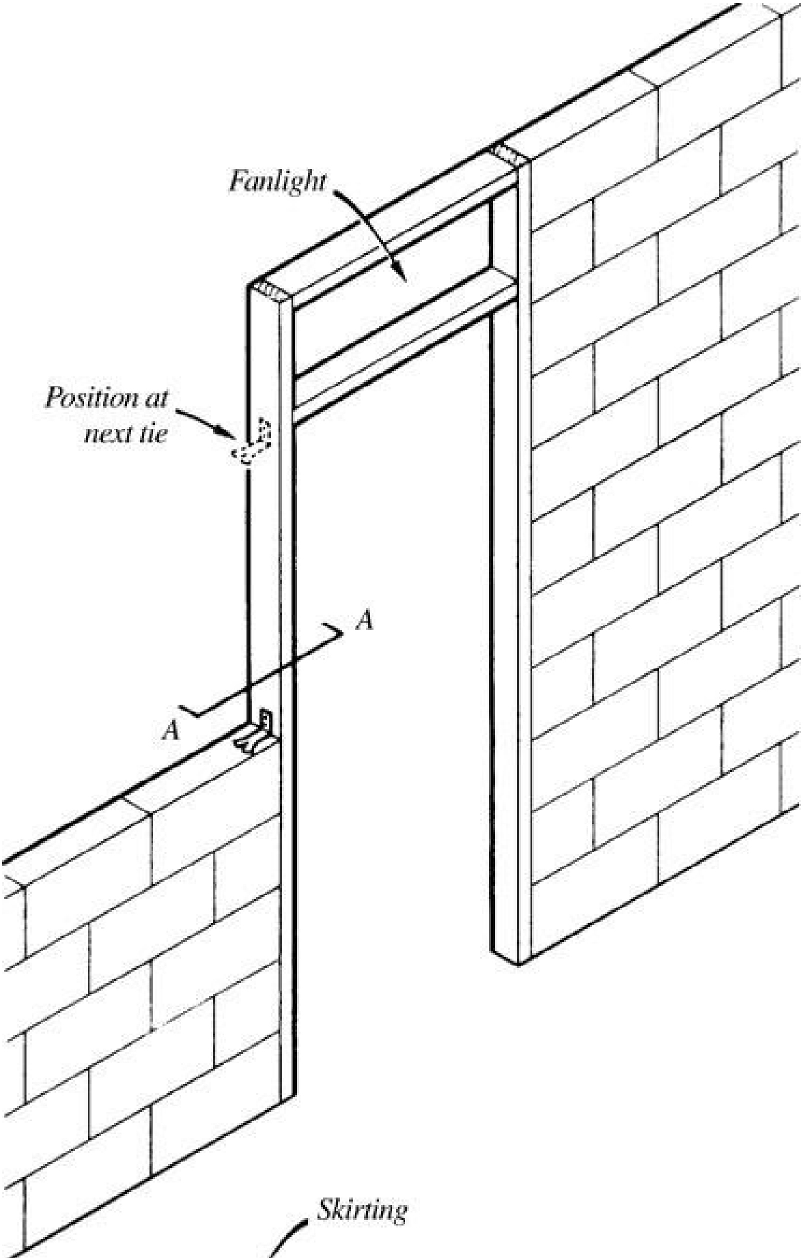

Door/window frame
Insulated cavity closer
Plasterboard on dabs
Mastic sealant

Figure 18.40 Alternative fixing methods for external door (or window) frame to brick/block cavity wall.

The various forms of lintel construction are shown in Figure 18.43. Where thermal insulation standards have

to satisfy current UK Building Regulations, the concrete examples (a) to (e) are no longer applicable as excessive heat loss and cold bridging will occur through these units. They are retained here, as many of these examples can be found in existing construction. Notice also that each variation considerably affects the building appearance.


Fanlight
Position at
next tie
A
A

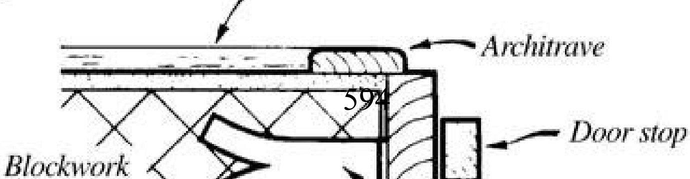
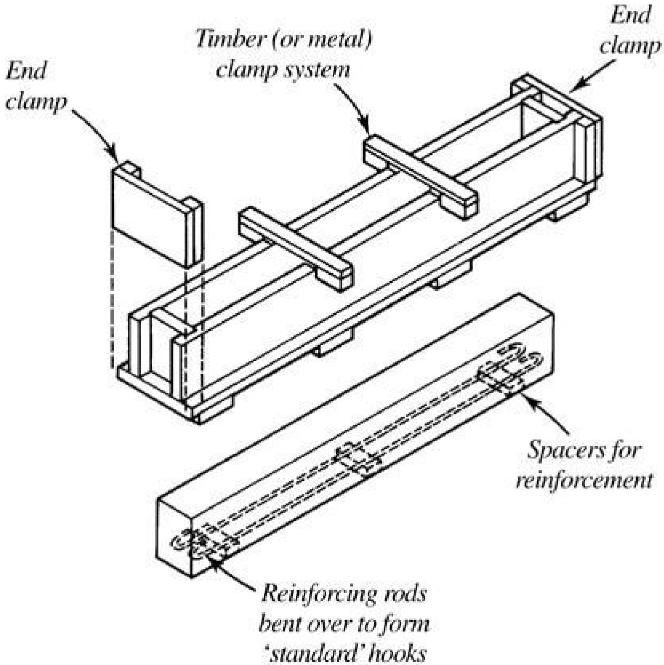
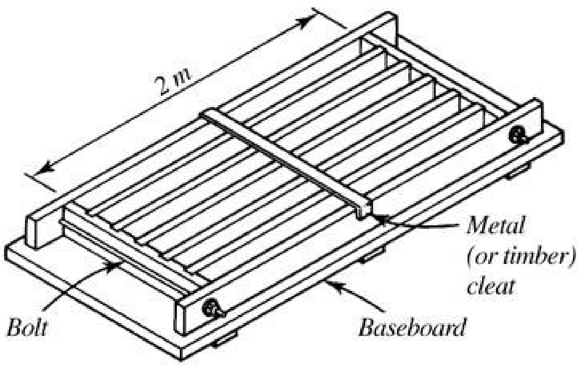

Skirting
Architrave
Door stop
Blockwork

Figure 18.41 Fixing method of door lining to internal brickwork wall.

- (a) Rectangular section precast or in situ reinforced concrete lintel The full depth of the concrete lintel shows on the face of the building. Because of its



PRECAST UNIT



BATCH PRECAST UNITS

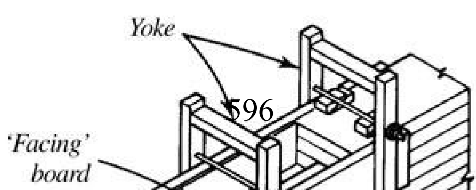


Figure 18.42 Methods used for casting reinforced concrete lintels.

fully rectangular section, a separate cavity tray must be provided in order that water percolating in the cavity wall is diverted through the weepholes to the outside. The effects of heat losses (cold bridge and

condensation) should be lessened by providing insulation material on the internal faces of the lintel, although this goes only a small way towards matching the total thermal insulation value of the wall supported, and ‘pattern staining’ is likely to occur (see section 8.3). The provision of a pelmet board for curtain hanging helps to hide the resulting dark staining. Depth of lintel depends upon the span.

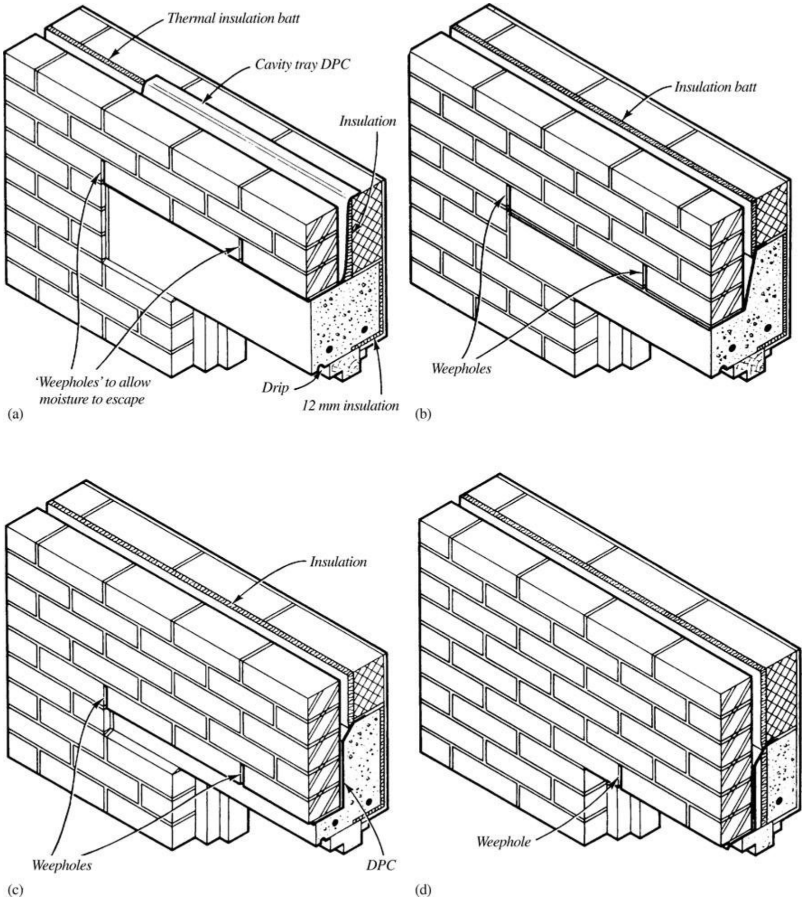


Figure 18.43 Traditional lintel construction: (a) rectangular section: precast or in situ reinforced concrete lintel; (b) & (c) boot section: precast or in situ reinforced concrete lintel; (d) composite metal and precast reinforced concrete lintel.

- (b) 'Boot' section precast or in situ reinforced concrete lintel Similar to (a) except that the lintel is shaped to reduce the amount of exposed concrete on the face of the wall. The sloping shape in the cavity provides

support for the cavity tray, which would otherwise be liable to damage during construction, especially when the cavity is being raked clean of mortar droppings.

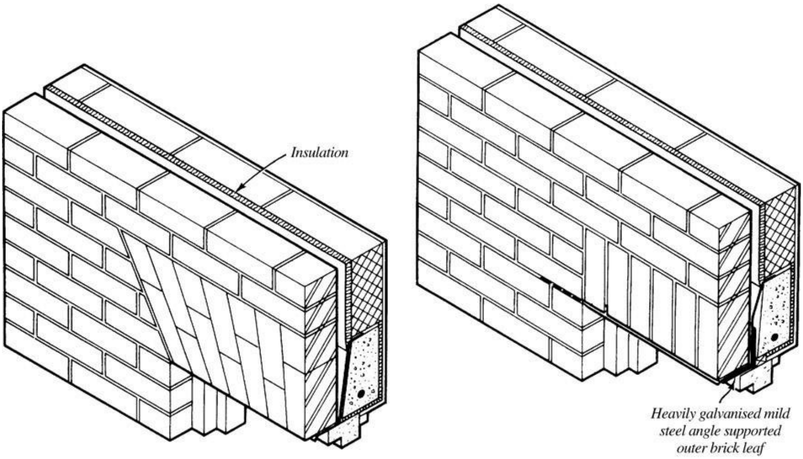


Figure 18.43 Traditional lintel construction (continued): (e) composite metal and precast reinforced concrete lintel with exposed brickwork arch construction. Note: none of these examples ((a) to (e)) will satisfy current UK thermal insulation requirements for use with housing. They are retained here as examples of existing construction.

- (c) ‘Boot’ section precast or in situ reinforced concrete lintel Similar to (b) except that the face depth of the externally exposed concrete is further reduced. To add to the visual effect of this lintel, the front edge or toe of the lintel can be slightly recessed back from the brick face to create a shadow.

- (d) Composite metal and precast reinforced concrete lintel This uses a precast concrete lintel to support the blockwork inner leaf and a preformed metal section to support the brickwork outer leaf (see Fig. 6.8). The metal lintel also acts as a cavity tray, which should be heavily galvanised or painted with bituminous paint, in order to prevent corrosion. This composite lintel system maintains the cavity wall construction right down to the head of the door/window frame, and with the internally insulated concrete lintel goes some way towards maintaining a degree of thermal insulation at this point in the wall construction. Except for the narrow edge of the metal lintel, the supporting mechanism over openings is not visible and gives a different aesthetic from the exposed concrete lintels previously described.
- (e) Composite metal and precast reinforced concrete lintel with exposed brick arch construction Both diagrams show a brick lintel construction but the right-hand version would not actually provide structural support to the outer leaf unless reinforced internally. Both brick arch forms are in fact supported by the preformed non-ferrous or galvanised metal section.
- (f) Preformed metal lintel The full advantage of pre-formed lightweight metal sections is taken in this example and there is no heavy precast concrete employed. The lintels can be supplied with the cavity filled with insulating foam, which gives thermal insulation properties corresponding to those of the supported wall. Again, the lintel is virtually unseen after construction is complete.

- (g) Preformed metal lintel with block infill Both these maintain the inner blockwork leaf as part of the lintel construction and, although giving a slightly reduced insulation value compared to the wall construction, they provide a consistency of internal surfaces for fixings and finishes.

These forms of lintel construction would be suitable for doors and windows; alternative forms of sill construction for each of the two components are indicated in

Figure 18.44. The threshold variation shown at (e) is to satisfy the Building Regulations, Part M: Access to and use of buildings. The principal entrance to all dwellings must not have a vertical projection in excess of 15 mm. This, along with a minimum clear opening width of 775 mm, is to ease wheelchair manoeuvrability.

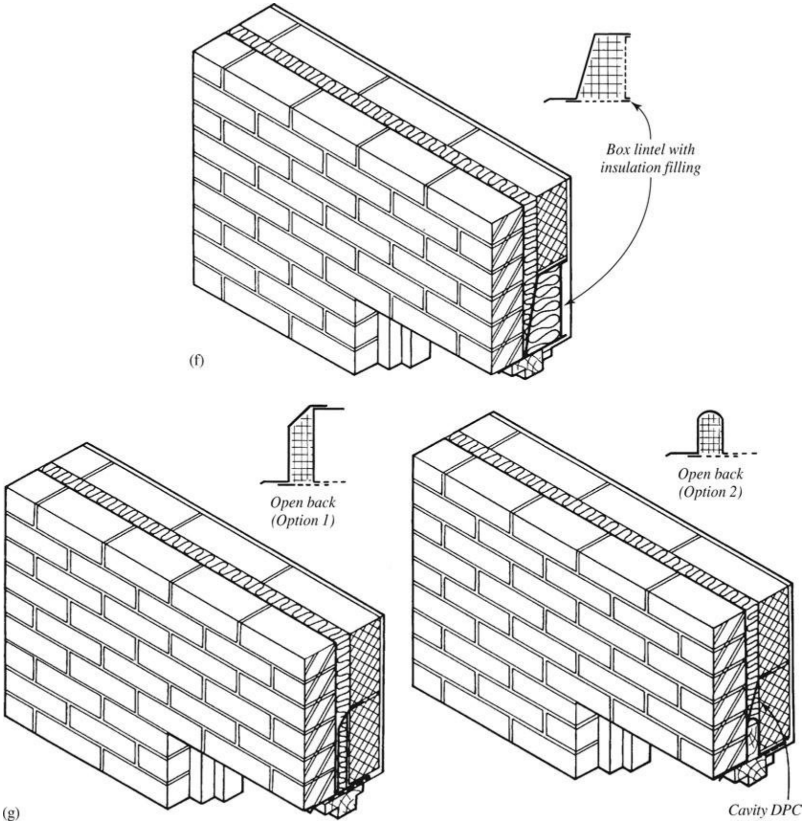


Figure 18.43 Lintel construction (continued): (f) preformed metal lintel; (g) preformed metal lintel and blockwork infill.

18.6.6 Scaffolding

As the work progresses beyond a height where it is reasonable for the bricklayer to lift materials from ground level, it will be necessary to erect scaffolding to support raised working platforms. The scaffolding generally consists of tubular steel or aluminium alloy connected by special fittings or couplings;

the platform consists of scaffold boards of softwood. Figure 18.45 and some subsequent construction sequence figures indicate a bricklayer's or putlog scaffolding, which consists of a single row of uprights set away from the wall for a sufficient distance to accommodate a working platform. The uprights (standards) are connected or coupled together with horizontal members (ledgers) which are tied back to the wall under construction by

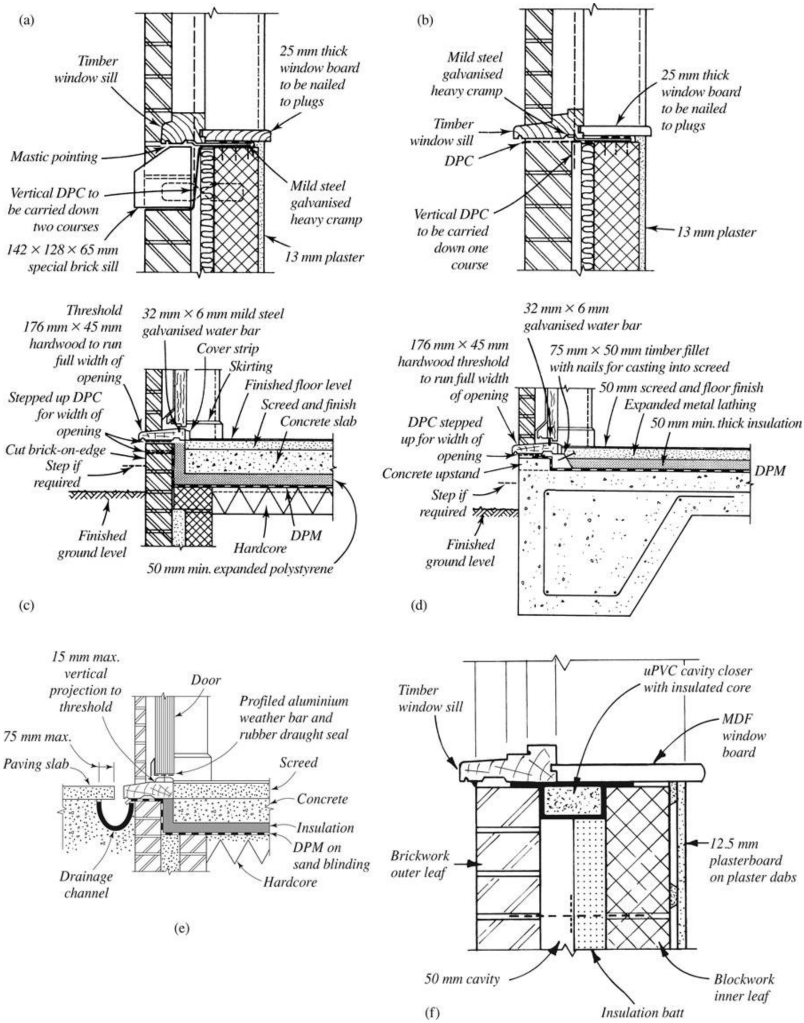


Figure 18.44 Sill construction: (a) combined brick and timber window sill; (b) timber window sill; (c) & (d) timber door threshold, with variation (e) for disabled access; (f) window sill with cavity closer.

means of putlogs. Scaffolding platforms are provided at the required height by coupling putlogs to the ledgers, and their flattened ends are supported on the outer leaf of the cavity wall construction. After the scaffolding is no longer required, it will be dismantled and putlog holes filled or made good.

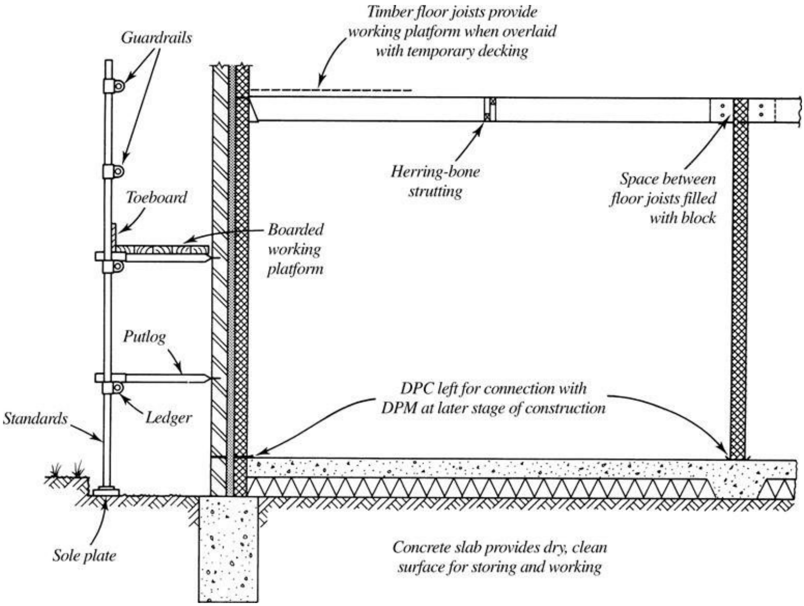


Figure 18.45 Construction sequence: first lift.

18.7 Internal wall construction CI/SfB (22) + (32) + (42)

18.7.1 Function

Internal walls, or partitions, provide the physical space separation within a building which is necessary to isolate certain activities in order to provide privacy and security. They may be required to provide fire protection between the spaces they enclose as well as between the spaces and general circulation routes. A sufficient amount of thermal insulation and sound control may be necessary to permit some check on overall performances. Internal walls must be robust enough to take various fixings for furniture and equipment, and be sufficiently durable to withstand the wear and tear associated with the activities of the building in which they are located. They should be of pleasing appearance, colour and texture which together should be compatible with the overall aesthetic character of the building of which they form a part.

Internal walls can be non-load-bearing or load-bearing. Load-bearing internal walls will assist in distributing the combined loads (dead, live and wind) of the building down to the foundation system then to the supporting soil. Also, they may sometimes be required to act as buttresses and provide lateral restraint to the external walls. By acting as sides of cellular forms (in conjunction with external wall and rigidly fixed floor/ceiling joists), the whole constructional system acts in structural unison in resisting the combined building loads (see section 5.3 and Fig. 5.4).

When planning the layout of internal walls, consideration must be given to the various components applied to the walls, floors and ceilings of the spaces they define. It is particularly important that, as with external walls, door openings are located so as to avoid excessive cutting and wastage of the bricks and blocks (see section 4.7).

18.7.2 Materials

Like external walls, internal walls may also be built from bricks or blocks, but rarely both together. Internal walls are seldom cavity walls unless they are used to separate two dwellings (i.e. party walls) or are designed as specific sound control barriers, e.g. walls to music rooms.

The internal walls of a house separate rooms in which the activities are relatively quiet. Also, at most, they are required to support only domestic loads from floors or roofs. Therefore, a single 102.5 mm thick brick (half brick) or 75–100 mm thick block is generally adequate and satisfies slenderness ratio requirements (see section 5.7). These thicknesses and materials are adequate in giving support for internal doors and frames, as well as fixings for cupboards, sanitary appliances, kitchen units, etc. They will also provide an adequate domestic standard of sound control, thermal insulation and fire resistance. For sound insulation specifically between bathrooms, bedrooms and other rooms, masonry walls will require a minimum mass of 120 kg/m^2, excluding finishing treatment.

As an alternative to bricks or blocks, internal partitions can be constructed from preserved timber using 50 mm ´ 100 mm vertical studs at 400 mm centres (to suit 1200 mm wide plasterboard cladding) braced at the midpoint by staggered timber noggins of the same cross-section (Fig. 18.46). The timber sections are planed prior to erection to ensure that the wall is of constant thickness with parallel faces to facilitate easy fixing of the plasterboard.

Another alternative is galvanised cold rolled steel channel profiles to BS 7364: Specification for galvanised steel studs and channels for stud and sheet partitions and linings using screw fixed gypsum wallboards, which can be used to provide a lightweight construction. Studs and channels are available in a variety of sizes and lengths, the smallest profile commencing with 50 ´ 32 mm channels for head and sole plates secured to the ceiling and floor. These are compatible with 48 ´ 32 mm stud sections which can be cut to length to slot into head and sole plates. Flat-headed self-tapping screws are used as fixings. Channels 50 mm deep with a timber core are used around door openings. Plasterboard of 12.5 mm minimum thickness is secured to the framing with self-drilling/self-tapping countersunk-head screws through the board and into the framing. As with all dry lining, taper edge boarding is preferred, with joints plaster filled, paper taped and plaster skimmed.

Stud partitions are generally non-load-bearing and are easy to construct, lightweight, adaptable and can be clad as well as infilled with various materials to give different finishes and properties. Stud partitions are of ‘dry’ construction and should not be commenced until the building has been made waterproof. Where sound insulation is critical, i.e. separating bedrooms and bathrooms from other rooms, the linings to each side of the studwork should be of at least two layers of minimum mass 9 kg/m^2 each. Two 12.5 mm plasterboard sheets each side will be adequate.

18.7.3 Construction

Brick and block internal walls can be erected directly from the ground floor solid concrete slab; from a sleeper wall forming part of a suspended ground floor construction; or, provided loads are not excessive, from some point between the main supports of a suspended floor (Fig. 18.47).

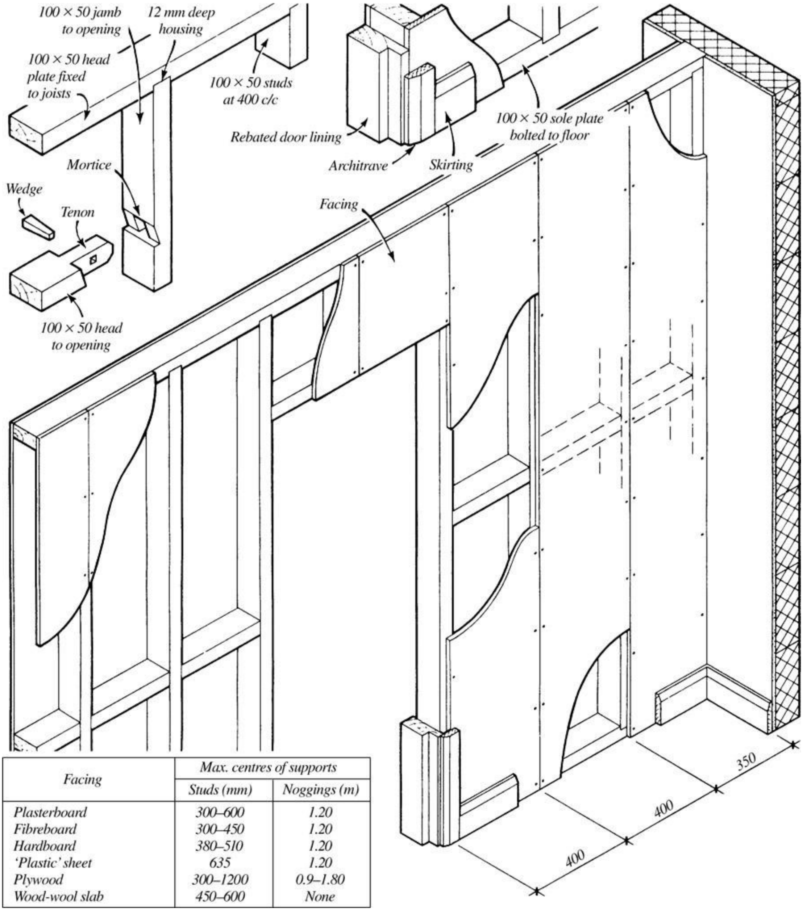
When subsoil conditions are less than stable or the loads on the partition are high, it will be necessary to provide separate foundations for internal walls (see Figs 18.30 and 18.32). The wall should incorporate a DPC, and when a separate foundation is not used, the DPC can be laid directly on the concrete slab and the first course of bricks or blocks bonded to it by a bed of mortar. This DPC should have been lapped with the DPC of the external cavity wall inner leaf, and must also extend a short distance either side of the internal wall so that eventually it can be stuck to the DPM laid on the concrete slab, at a later stage of construction. At junctions with the external wall, the partition will be block bonded into the inner leaf – it will be built into this leaf vertically every other block course, or be attached to the inner leaf with a proprietory system of structural profiles and ties.

First-floor internal walls can also be constructed using bricks or blocks. Continuing upwards from the ground floor internal wall presents no particular problems, although when floor joists penetrate the partition care must be taken to ensure the brick or blockwork between is continued solidly to the underside of the wall above. If there is no wall below, a first-floor non-load-bearing wall can be carried on double floor joists which have been bolted together at about 600 mm centres to ensure they act in unison. However, as the partition load may cause supporting joists to deflect slightly and therefore damage later finishes, it is probably best to insert a steel beam at this point (Fig. 18.48).

A non-load-bearing internal wall running across the timber joists can be carried by providing a timber sole plate at its base. Load-bearing partitions not continued from the floor below should always incorporate a rolled steel joist (RSJ) or a universal beam (UB) support in the intermediate timber floor construction.

18.7.4 Door openings

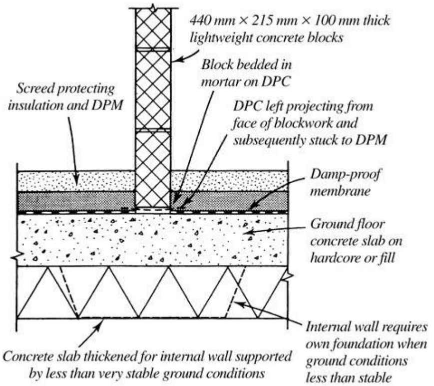
Doors may be incorporated in the internal wall by building in standard door linings using galvanised metal ties similar to those used for the external door and window frames (see Fig. 18.41). The space over the door is often filled with a window or fanlight rather than solid brick or block-work. The use of a fanlight avoids the need for a lintel in this position and also for cutting the bricks or blocks to bond between the walls either side of the opening. Although



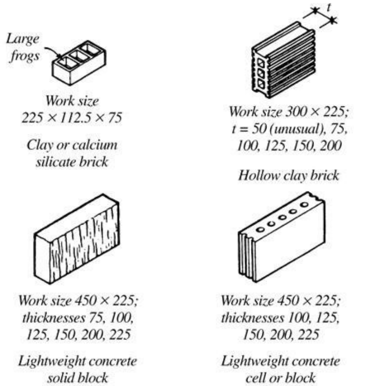
Facing	Max. centres of supports	
	Studs (mm)	Noggings (m)
Plasterboard	300–600	1.20
Fibreboard	300–450	1.20
Hardboard	380–510	1.20
'Plastic' sheet	635	1.20
Plywood	300–1200	0.9–1.80
Wood-wool slab	450–600	None

Figure 18.46 Stud partition details.

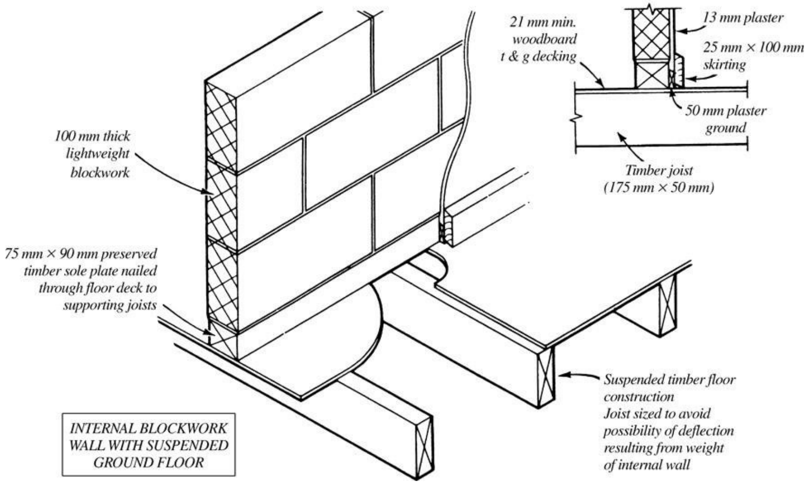
the use of fanlights may be economical, care must be taken to ensure that the interrupted lengths of internal walls are adequately stabilised at door openings. When an internal wall is load-bearing, stability is enhanced by embedding intermediate floor or ceiling joists onto the top of the wall, as shown in Figure 18.49. If the partition is non-load-bearing and does not support floor or ceiling joists, it is necessary to connect the top of the wall firmly to the underside of joists with timber wedges. Often the top of the brick or block partition is capped by a 50 mm deep



INTERNAL BLOCKWORK WALL WITH GROUND FLOOR CONCRETE SLAB



ALTERNATIVE SOLID INTERNAL WALL MATERIALS



INTERNAL BLOCKWORK WALL WITH SUSPENDED GROUND FLOOR

Figure 18.47 Methods of support for internal walls.

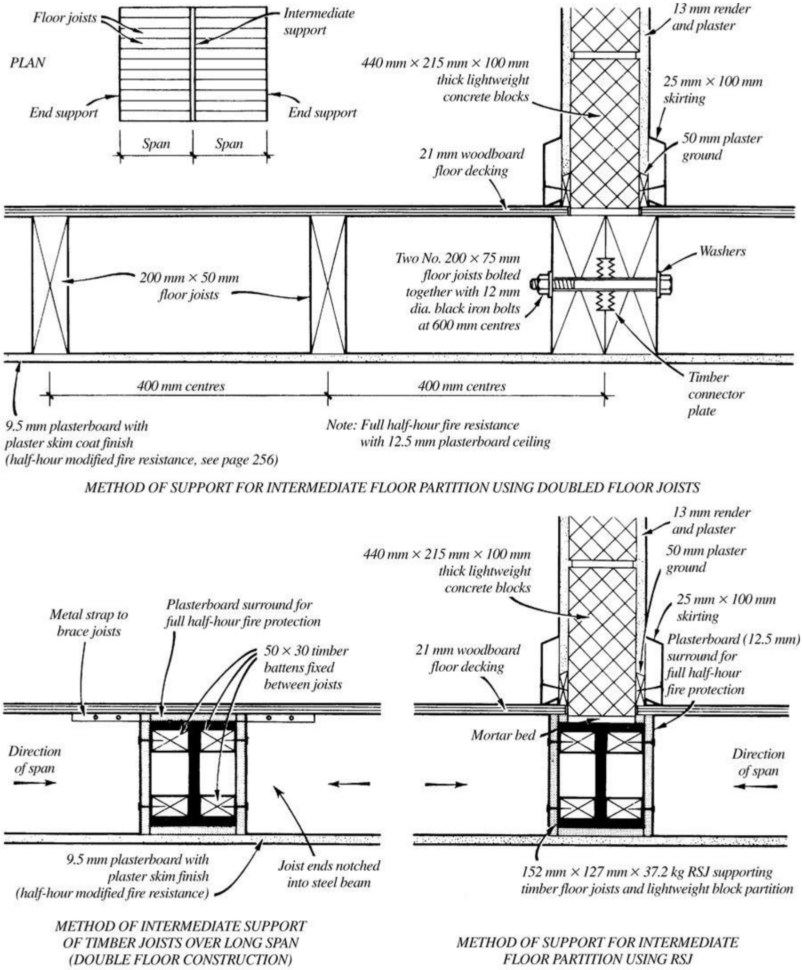


Figure 18.48 Methods of support for first floor partitions.

timber wall-plate, which facilitates this process by providing a level top surface. When a load-bearing partition is not required to continue up to the next floor, this timber plate also provides a level fixing for the supported joists.

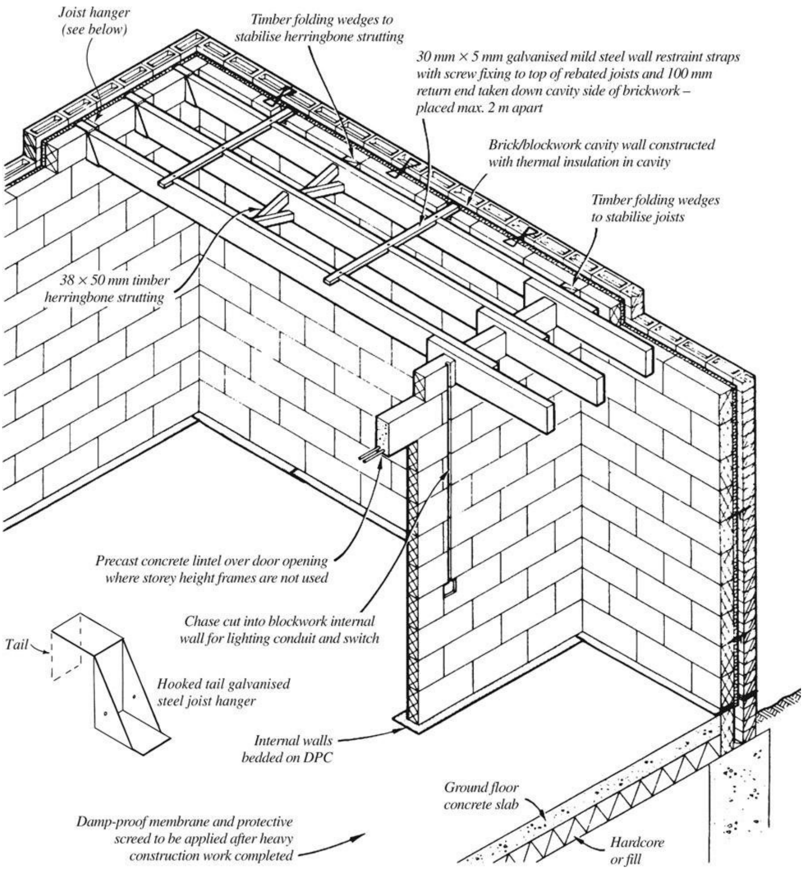


Figure 18.49 Lateral bracing of walls by intermediate floor construction.

Brief comments regarding the fixing of door linings are given in section 18.11.2.

18.8 Intermediate floor construction CI/SfB (23) + (33) + (43)

18.8.1 Function

The construction of the external cavity wall and the internal walls of the house continues until the correct height is reached for the first floor timber joists to be put in position. The function of the intermediate floor, of which these joists form a part, is to provide a level surface with sufficient strength to support the dead loads of flooring and ceiling plus imposed loads of people and furniture. In addition, it must provide a degree of sound control and fire protection between the two levels. Often an intermediate floor must also assist in providing lateral restraint to heights of external and internal walls. This form of wall stability is shown in Figure 18.49 and may be achieved by the following means:

- At least 90 mm end bearing of joists
- Approved joist hangers
- Lateral restraint straps at no more than 2 m centre spacing

18.8.2 Materials

The materials used for the structure of domestic intermediate floors are reinforced concrete, or pressed metal joists, or timber joists. Although reinforced concrete construction (in situ or precast units) has many advantages associated with sound control and fire resistance, the materials are heavy and can involve complicated methods of assembly. Pressed steel joists do not have these advantages but are very lightweight; however, timber joist construction remains the most adaptable.

Table 18.2 Span/depth for intermediate timber floor joists

Size of joist in millimetres graded GS or MGS	Maximum span of joist (m) for given dead load (kg/m²) supported by joist (excluding the mass of the joist)								
	Not more than 25			More than 25 but not more than 50			More than 50 but not more than 125		
	Spacing of joists (mm)			Spacing of joists (mm)			Spacing of joists (mm)		
	400	450	600	400	450	600	400	450	600
38 × 75	1.05	0.95	0.72	0.99	0.90	0.69	0.87	0.79	0.62
38 × 100	1.77	1.60	1.23	1.63	1.48	1.16	1.36	1.24	1.00
38 × 125	2.53	2.35	1.84	2.33	2.12	1.69	1.88	1.73	1.40
38 × 150	3.02	2.85	2.48	2.83	2.67	2.26	2.41	2.23	1.83
38 × 175	3.51	3.32	2.89	3.29	3.11	2.71	2.82	2.66	2.27
38 × 200	4.00	3.78	3.30	3.75	3.55	3.09	3.21	3.03	2.64
38 × 225	4.49	4.24	3.70	4.21	3.98	3.47	3.61	3.41	2.96
44 × 75	1.20	1.08	0.83	1.13	1.02	0.79	0.98	0.89	0.70
44 × 100	2.01	1.82	1.41	1.83	1.67	1.31	1.51	1.39	1.12
44 × 125	2.71	2.56	2.09	2.54	2.38	1.90	2.08	1.92	1.56
44 × 150	3.24	3.06	2.67	3.04	2.87	2.50	2.60	2.45	2.03
44 × 175	3.77	3.56	3.10	3.53	3.34	2.91	3.02	2.86	2.48
44 × 200	4.29	4.06	3.54	4.02	3.80	3.31	3.45	3.26	2.83
44 × 225	4.81	4.55	3.97	4.51	4.27	3.72	3.87	3.66	3.18
50 × 75	1.35	1.22	0.93	1.26	1.14	0.89	1.08	0.99	0.78
50 × 100	2.22	2.03	1.58	2.03	1.85	1.46	1.66	1.53	1.23
50 × 125	2.84	2.72	2.33	2.70	2.55	2.10	2.27	2.09	1.71
50 × 150	3.40	3.26	2.84	3.23	3.05	2.66	2.76	2.61	2.21
50 × 175	3.95	3.78	3.30	3.75	3.55	3.09	3.22	3.04	2.64
50 × 200	4.51	4.31	3.76	4.27	4.04	3.52	3.67	3.46	3.01
50 × 225	5.06	4.83	4.22	4.79	4.53	3.95	4.11	3.89	3.39
63 × 150	3.66	3.52	3.17	3.50	3.38	2.97	3.09	2.92	2.54
63 × 175	4.25	4.10	3.68	4.07	3.93	3.45	3.59	3.40	2.96
63 × 200	4.84	4.67	4.20	4.64	4.48	3.93	4.09	3.87	3.37
63 × 225	5.43	5.24	4.70	5.21	5.02	4.41	4.59	4.34	3.78
75 × 200	5.10	4.93	4.51	4.90	4.72	4.27	4.43	4.20	3.67
75 × 225	5.72	5.52	5.06	5.49	5.30	4.79	4.97	4.71	4.11

In working out the layout of timber joists, consideration must be given to their spacing, the clear spans and openings to be formed or 'trimmed' for the staircase, etc. Table 18.2 indicates typical spacings and spans. Variations in spans can be achieved for a given cross-sectional size of
timber according to the actual stresses it can withstand. This capacity depends upon characteristics of the timber (structure, grain, knots, etc.) and is stress-graded to BS 4978:

Specification for visual strength grading of soft-wood, to provide known limits of loading which make the most economical use of timber.

The sizing of joists can be arrived at by calculation or by reference sources from the Building Regulations or supplied by timber-interested organisations such as TRADA Technology Ltd, the Nordic Timber Council UK, etc. An approximate, although uneconomical, guide can be given by the formula D = (S/24) + 50, where D = depth of joist in mm and S = span in mm. This formula assumes that joists have a breadth of 50 mm and are used at 400 mm centre spacing.

- Example: span of 4 m or 4 000 mm: 4000 ¸ 24 + 50 = 217 mm
- Nearest commercial oversize is 225 mm
- Joist size is 225 mm ´ 50 mm at 400 mm spacing

Timber joists should be treated with a preservative against fungal and insect attack prior to final placing in the building. Joist lengths can be treated before delivery to site, but touching up on site will always be necessary as a result of cutting. Particular care needs to be taken with the ends of joists because they are most susceptible and are placed in vulnerable positions, such as adjoining the external wall construction.

The decking for timber intermediate floors can be tongue-and-groove hardwood or softwood boarding, or chipboard or plywood sheets. These are indicated in Figure 18.29. Tongue-and-groove profiles are preferred to butt-jointed boards because they reduce the effects of curling caused by thermal and moisture movement. In addition, the reduction of the amount of clear gaps is essential in obtaining a satisfactory resistance to the travel of flames and smoke during a fire. A timber tongue-and-groove board decking to floor joists acts in conjunction with a 9.5 mm plasterboard finish to form the ceiling to give the ‘modified’ half-hour fire resistance. This means that for at least half an hour the floor must not collapse or allow the passage of flame or smoke, but the integrity and insulation requirement is reduced to 15 minutes (see section 9.2); 12.5 mm or 15 mm plasterboard is a preferable ceiling lining, to provide a full half-hour fire resistance (see Fig. 18.48). Brief comments regarding the fixing of floor decking are given in section 18.11.2.

18.8.3 Construction

For the cavity wall construction already described, the level of the top of 175 mm ´ 50 mm joists should coincide with the level of 35 courses of brickwork (each brick 65 mm + 10 mm for bed joint) from the top of the DPC, as shown in Figure 18.38. This will provide a joist top level of 2 625 mm and an underside joist level of 2 450 mm: an allowance of 50 mm for screed will permit a 2 400 mm clear storey height (excluding plasterboard ceiling), which is ideal for the storey-height door frames, as mentioned earlier (see Fig. 18.38). The ends of the joists are traditionally built into the inner blockwork leaf of the cavity wall because this prevents the end of the joists twisting as well as providing lateral restraint to the external wall by preloading (see section 5.3). However, the current tendency to use an increased amount of sapwood for structural timber, also to avoid the risk of cold bridge or condensation, which might occur if the inner leaf is interrupted and the need to mastic/silicone seal against possible air leakage at the junction of timber and blockwork means that it is probably wiser to use a metal hanger to support the joists. These are made of galvanised mild steel and can be supplied with a ‘hooked’ tail, which provides the necessary lateral restraint to the blockwork leaf of the cavity wall. The joists will be prevented from twisting by the shape of the hanger (see Fig. 18.49). In order to avoid cutting the blocks of the inner leaf so that the tail of the joist hangers aligns perfectly with the top of the joists, it will be necessary to provide one course of 140 mm high blocks (150 mm including joint) instead of the normal 215 mm high blocks (225 mm including joint). At the other end to the external wall, timber joists can be lapped over partitions where the bedded wall-plate mentioned earlier assists in spreading the loads taken by the joists, and provides fixing for them by cross or ‘skew’ nailing. Another method for accurate levelling of joists over partitions is to use a bearer bar cogged to the joists.

Having fixed the structure of the floor, a temporary decking of plywood can be laid over the joists in order to provide a working platform for subsequent building processes. The final finished decking should not be fixed until the building is weatherproof and all necessary work in the void of the floor has been completed. Similarly, a ceiling of plasterboard should not be fixed until electric cables, etc., have been installed and there is little risk of subsequent damage occurring. The plasterboard for the ceiling is usually fixed at the same time as any other plasterboard, e.g. for stud partitions, ductwork, etc. (see section 18.11).

Standard timber joists become uneconomically large as span requirements extend beyond about 4 m (see Table 18.2).

Intermediate support is required from a load-bearing wall, double-timber joist or a steel joist as shown in Figure 18.48. The latter two options create a double floor construction, suitable where clear ground floor space is required. Another way of overcoming span limitations is use of structural floor joists, also known as composite or lattice joists. These are factory-produced to standard lengths, or can be custom-made to specific requirements. Subject to
loading, clear spans up to about 8 m are possible with normal joist spacing at 400 to 600 mm while retaining the maximum permitted structural deflection of 0.003 ´ span. Figure 18.50 shows two variations, each using a pair of parallel timber flanges: the open web or lattice frame type with flanges spaced apart by galvanised steel web plates in a ‘V’ formation and the solid web with flanges separated by plywood or oriented strand board (OSB).

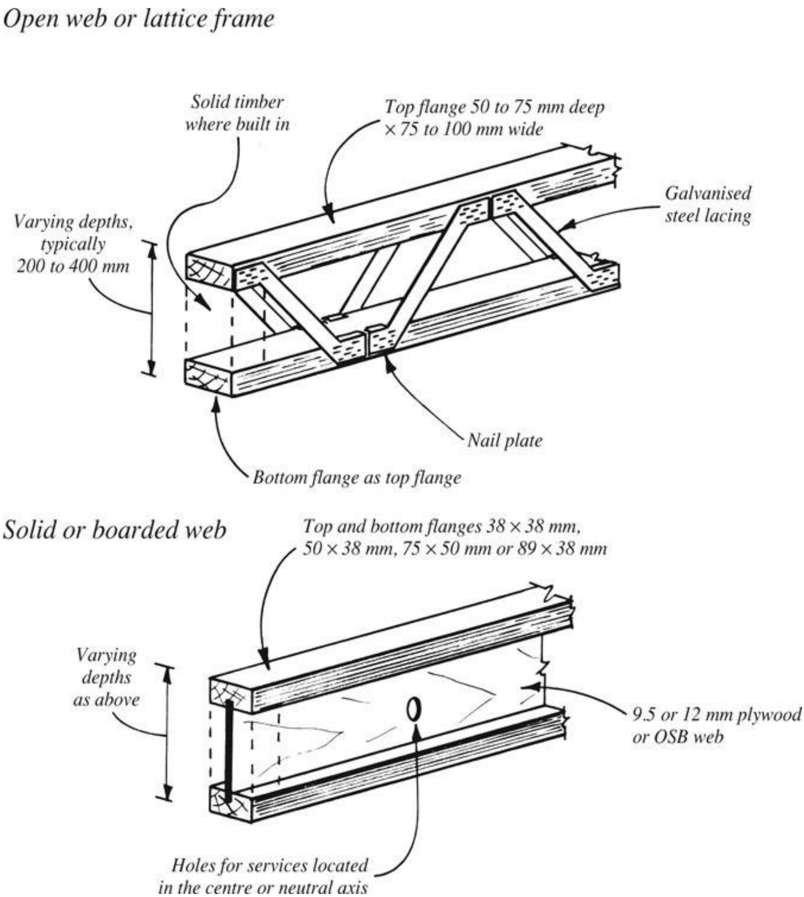


Figure 18.50 Composite floor joists.

Further advantages of composite floor joists:

- High strength-to-weight ratio.
- Suitable for other applications, e.g. roof members.
- Manufactured to factory quality-controlled conditions.

- Ample space for pipes and cables to pass through (open web type).
- Wide section flanges provide large bearing area for decking and ceiling boards.
- Minimal shrinkage and deflection.

18.8.4 Lateral bracing of joists

When the timber joists span more than 2.4 m, it is necessary to provide lateral bracing or strutting in order to restrict the movements due to twisting, and vibrations which would damage ceiling finishes (see Fig. 18.49). The strutting can consist of 38 mm ´ 50 mm softwood battens or galvanised steel sections fixed diagonally between joists in a herring-bone pattern. They should occur at midspan or at centres not less than 50 times the width of one joist. Alternatively, blocks of timber can be fixed between the joists at alternative centres for each space; they are easier to fix but provide less restraint. It is important that the restraint provided to the joists by strutting is continued through to the flanking walls. This is done by ensuring that the first joist next to the wall is positioned so as to allow a 40 mm gap into which timber folding wedges are driven on the line of the strutting.

18.8.5 Lateral bracing of walls

Hooked-tail joist hangers provide restraint to walls once in position and the joists have been securely nailed in position. Lateral bracing may also be required for walls which run parallel with the direction of span of the timber joists, particularly when the flanking wall is an external cavity wall.

Bracing in this direction can be provided by galvanised mild steel straps fixed at not more than 2 m centres, each strap being screwed to at least three joists and having a 90° return end built into the cavity wall construction (see Fig. 18.49).

18.8.6 Notches and holes in joists

Structural timbers used today can be stress-graded to give maximum economical depth/span ratios. It is therefore important that certain rules are observed should it be necessary to notch or drill holes in timber joists so that services (electrical cables, central heating pipes, etc.) can be accommodated within the floor space. For example, it is recommended that notches should occur within the middle half of the span of any joist, should be in the upper cross-section, and should never be more than one-eighth the depth of the joist. Holes should be situated within the middle two-thirds of the joist span and their diameter should not exceed one-sixth of the depth of the joist. In practice it may be very difficult to prevent workers on site from placing notches or holes anywhere in the joists; they tend to choose the most suitable position for their particular services. To overcome this problem, a prudent designer will oversize the joist sizes when services are required to be concealed in an intermediate floor space.

18.8.7 Openings in floor

Openings must be left in the intermediate floor so that staircases can be fitted and, perhaps, to allow service pipes which have been grouped together or central heating air ducts to pass from one floor to another. This means that the timber joists, which would normally span from one wall to another, would be stopped short and trimmed to allow for an opening. It is good practice for the designer to provide floor trimming layout drawings so that the carpenters can set out the joists for maximum usage. The joists forming the perimeter of the required opening will have to be at least 25 mm wider than the other joists, as indicated in Figure 18.51. The joists interrupted by the formation of the opening are trimmed and secured to a trimmer joist which in turn is carried by trimming joists. Methods adopted for fixing trimmed joists to a trimmer, and for fixing trimmers to trimming joists, will vary according to the expertise of the contractor's workers. Timber joints (tusk tenon and housed joints) are often found in older construction, but the convenience of fixing plates or joist hangers is the preferred option for modern practice.

Typical details of a timber staircase to be incorporated in an opening are shown in Figure 18.52. These can be made on site, but it is more usual for prefabricated staircases to be fitted into a prepared opening.

18.9 Roof construction CI/SfB (27) + (47)

18.9.1 Function

A roof is more vulnerable to the effects of wind, rain, snow, solar radiation and atmospheric pollution than any other part of a building. While avoiding the harmful results of these phenomena, it must also prevent excessive heat loss from the building in winter and be able to keep the interior cool during hot seasons. And in serving these functions, the roof construction is required to defy gravity by spanning horizontally between load-bearing elements (unless the roof and walls are combined in a tensile structure as described in section 5.6) while accommodating all stresses encountered, including movements due to changes in temperature and moisture content.

The roof of a building must also provide adequate defence for the occupants against the effects of fire and must limit its potential to spread. This is done by ensuring that the external cladding is able to withstand the penetration of fire from adjacent sources and for a defined period according to the proximity of the roof to a boundary. The roof cladding must also be able to limit the spread of flame over its surface.

Although hybrid variations occur, it is most convenient to consider roofs as being either flat if the external face is at not more than 10° to the horizontal, or pitched if the external face is at more than 10° to the horizontal. A short span roof is considered to be up to 7.5 m, medium span 7.5 m to 25 m, and long span over 25 m.

Apart from the purely technical factors, the choice between flat or pitched roof forms involves consideration of aesthetic appeal. When a flat roof is chosen, the buildings have a ‘cut-off’, or ‘block’ shape, but the appearance of the roof surface is relatively unimportant unless it is overlooked from higher levels or used as a terrace. Conversely, the selection of a pitched roof will provide a dominant visual feature, the importance of which will depend on the viewing distance. Then the shape, colour and texture of the roof surface are very important factors.

18.9.2 Pitched roof construction

Of the many considerations involved in the selection of an appropriate form, the construction of a pitched roof is mainly dictated by the shape of the building and the

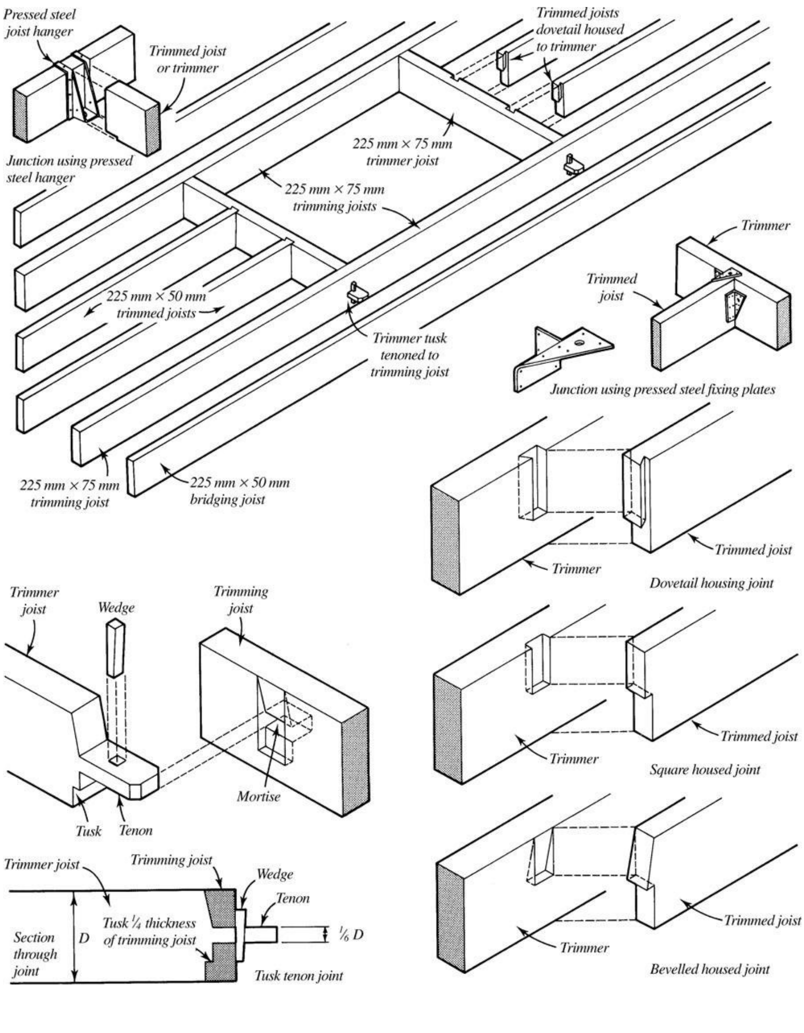


Figure 18.51 Trimming to timber floors.

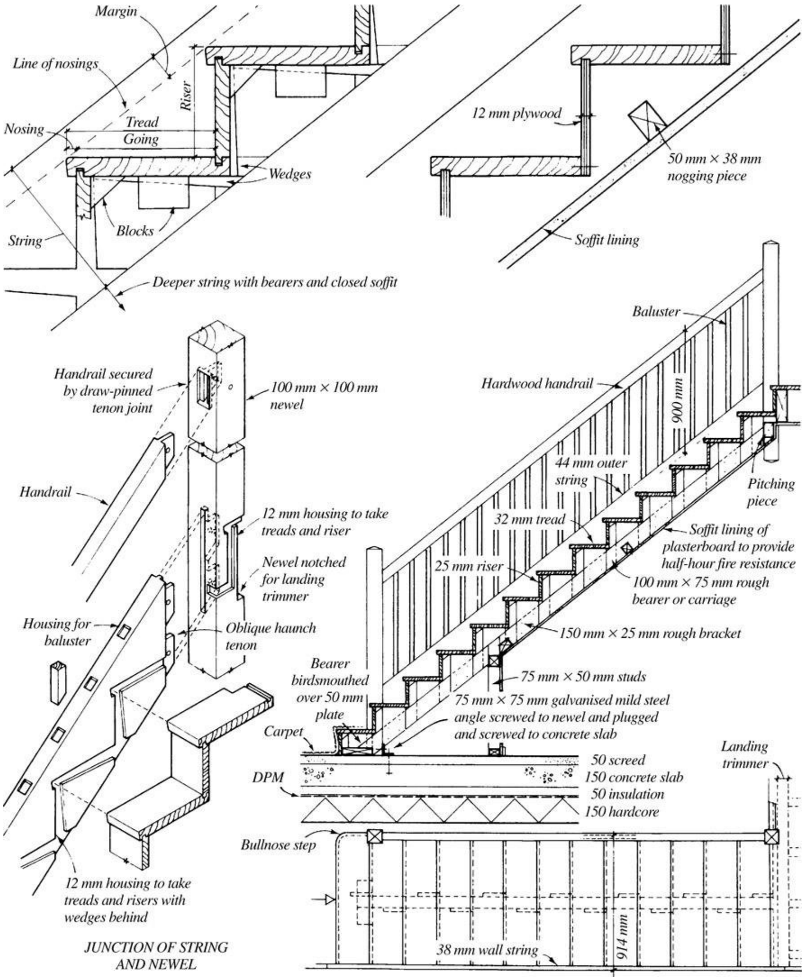


Figure 18.52 Typical timber staircase details.

span between supporting elements. The arrangement of the structural members forming the roof may follow similar principles, but their size, disposition and jointing methods will vary considerably. Figure 18.53 indicates a typical conventional domestic pitched roof construction. However, for simple spans without internal support walls, a method employing timber trussed rafters could be more economical (Fig. 18.54).

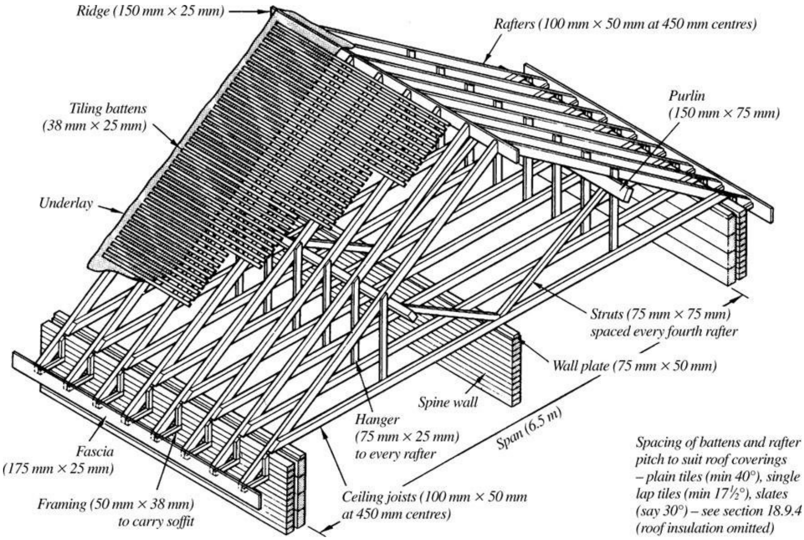


Figure 18.53 Traditional method of roof construction.

The modern trussed rafter roof indicates the development in empirical knowledge of triangulated roof forms. It involves the incorporation of more recent scientific techniques resulting from the analysis of actual stresses induced in timber sections as well as at the critical points where two or more members are joined to act in unison. Instead of forming joints on site, using oversized sections for structural safety and convenience, the trussed rafter employs stress-graded timbers (section 18.8.2) joined when appropriate and with precision under factory-controlled conditions by galvanised mild steel truss plates. The resulting prefabricated, economical and lightweight truss rafters are delivered to the site at an appropriate time in the building programme. They are then hoisted into position, placed on the supporting wall and relatively rapidly fixed. However, it is particularly important that the light trusses are adequately protected from the elements during the period from when they leave the factory until they are finally covered by the external roof cladding. Should these trusses be allowed to become exposed to the weather for any length of time, the relatively thin sections of timber will become saturated, causing them to twist and loosen the truss plates. Twisting is still likely to occur after the roof construction is completed, particularly if the central heating of the building causes rapid drying.

18.9.3 Pitched roof bracing

Trussed rafters are spaced at close centres, usually 600 mm, to provide direct support for roof cladding and ceiling, which in turn helps in giving the necessary lateral bracing to the individual trussed rafter. Each rafter is securely nailed to the wall-plate already placed on a mortar bed and located directly above the inner leaf of blockwork, as indicated in Figure 18.57. The trussed rafters are lightweight and a wind tends to lift the whole roof construction, so it is important that this wall-plate is anchored to the supporting wall by galvanised mild steel straps at about 1.5 m
centres (2 m maximum). When a flank wall of the house continues up above the lowest part of the rafter to form a gable wall, it is important that lateral bracing is provided for this otherwise free-standing wall by similar steel straps, as indicated in Figure 18.55. Finally, the whole roof system

should be provided with wind braces running diagonally from a bottom corner to a top corner. This brace will prevent the roof timber from collapsing sideways as a result of laterally applied wind forces. Other timber braces are generally required to provide stability when trussed rafters are used, in order to prevent twisting and deflection from vertical alignment.

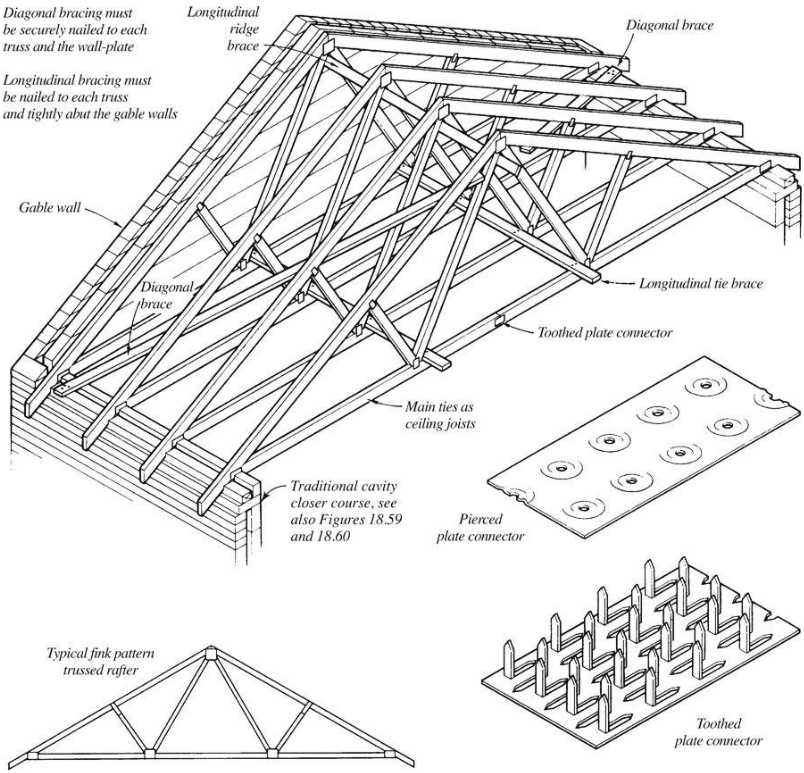


Figure 18.54 Trussed rafter roof construction.

18.9.4 Pitched roof – batten spacing and sizing

Margin – the amount of tile or slate exposed.
Gauge – the spacing of timber battens for tile or slate fixing.

Plain tile batten gauge = [tile length (mm) – lap (mm)] ÷ 2 = [265 – 65] ÷ 2 = 100 mm

Single lap tile batten gauge = tile length (mm) − lap (mm)

Example: concrete interlocking tile 381 mm long ´ 229 mm wide, laid to a 75 mm head lap: gauge = 381 − 75 = 306 mm

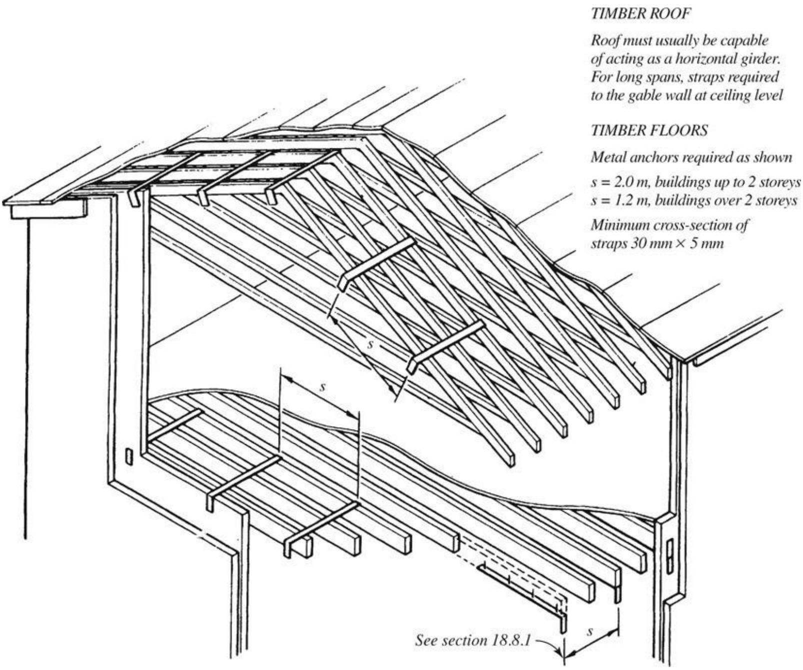


Figure 18.55 Means of providing lateral restraint to external brick/block cavity walls.

Slate batten gauge:

Head nailed = slate length (mm) − [lap (mm) + 25 mm] ÷ 2

Centre nailed = [slate length (mm) − lap (mm)] ÷ 2

Example: 610 ´ 305 mm standard Duchess slate laid to a 125 mm lap (note that slates are manufactured in a variety of sizes with established traditional names; see producers' catalogues for a full listing)

Head nailed batten gauge = 610 − [125 + 25] ÷ 2
= 230 mm

Centre nailed batten gauge = [610 − 125] ÷ 2
= 242 mm

Note: Head nailing is generally limited to smaller slates as wind lift and vibration may snap larger slates.

Timber batten sizes vary with type of tile or slate application and spacing of rafters:

Plain tiles: 38 mm × 25 mm (rafters up to 450 mm c/c)
50 mm × 25 mm (rafters up to 600 mm c/c)

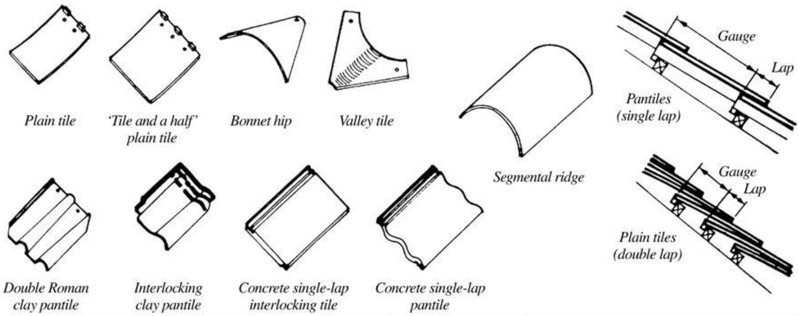
Single lap tiles: 38 mm × 25 mm (rafters up to 450 mm c/c)
50 mm × 25 mm (rafters up to 600 mm c/c)

Slates: 50 mm × 25 mm (rafters up to 600 mm c/c)

Batten nails: about 3 mm diameter ´ 65 mm long to penetrate the rafter at least 40 mm.

18.9.5 Pitched roof cladding

On a pitched roof, gravitational forces move rainwater down the slope and, aggravated by wind currents, try to move it inwards (see Fig. 6.6). Because the roof has a relatively rapid degree of run-off, the external covering usually consists of relatively small lapped units such as tiles or slates, which are dry jointed and supported independently at intervals by timber battens. As the slope of the roof decreases, the resistance to the inward flow of water becomes less. Therefore, the amount of water penetration
likely depends on the angle of slope and the amount of horizontal overlap provided by the slates or tiles. The movement of water around the tiles or slates depends on the angle of creep: the bigger the overlap (which corresponds to the size of cladding unit), the less the pitch can be (Fig. 18.56). Slates and tiles are complemented as a water barrier by an independent underlay or waterproof membrane of sarking felt laid under the battens, as shown in Fig. 6.6. This membrane prevents wind and rain, driven through gaps in the cladding, from penetrating the roof void. It also prevents rain penetration where tiles are broken. However, these traditional bituminous felts do not have the water vapour permeability required to reduce moisture levels and condensation which can occur in highly insulated roofs. In conjunction with ventilated roofs (see Figs 18.58 and 18.60) a bonded polypropylene-based breather membrane underlay is preferred, as this is capable of permitting air circulation through the roof without perforation.



Description	Size (mm)	Head lap (mm)	Minimum pitch angle (degrees)	
			Exposed	Sheltered
Plain tile	165 wide × 265 long	65	40	35
Double Roman pantile	406 wide × 419 long	76	35	30
Single pantile	430 wide × 380 long	76	30	$17\frac{1}{2}$

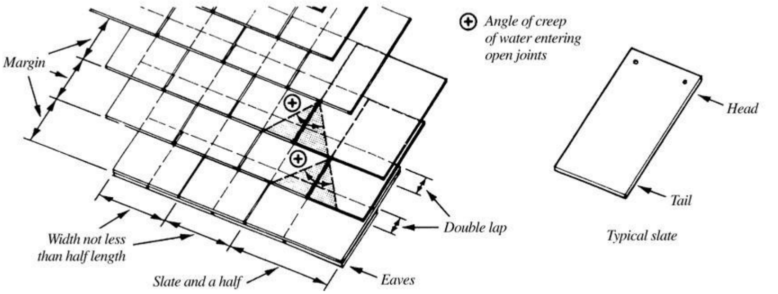


Figure 18.56 The angle of creep depends on the pitch of the roof. The steeper the pitch, the smaller the angle; this can be used to determine the minimum acceptable size for a tile or slate.

Working from the scaffolding platform at roof level, the sarking felt or underlay is unrolled and laid across the rafters starting at the lowest point (eaves). The underlay is placed over a tilting fillet and lapped over the fascia board to form a small projection or drip. It is important that the underlay is allowed to sag slightly between rafters in order to form the space which permits the water permeating around the slates or tiles to be caught and transferred by gravity to the eaves drip and rainwater gutter. Where a breather membrane underlay is used with counter batten support to tile battens, the underlay should be installed taut across the rafters (see Fig. 18.59). The underlay is nailed into position before the next horizontal length is placed so as to permit an overlap to be formed of at least 150 mm. All sides of the roof are continued upwards until the underlay is taken over the top of the roof or ridge, except where gaps are left for continuity of roof-void ventilation through purpose-made ridge tiles (see Fig. 18.60). Vertically sloping edges of the roof or hips are overlayed to ensure a complete enclosure. Slate or tile battens are then fixed at horizontal centres to suit the type and size of cladding unit.

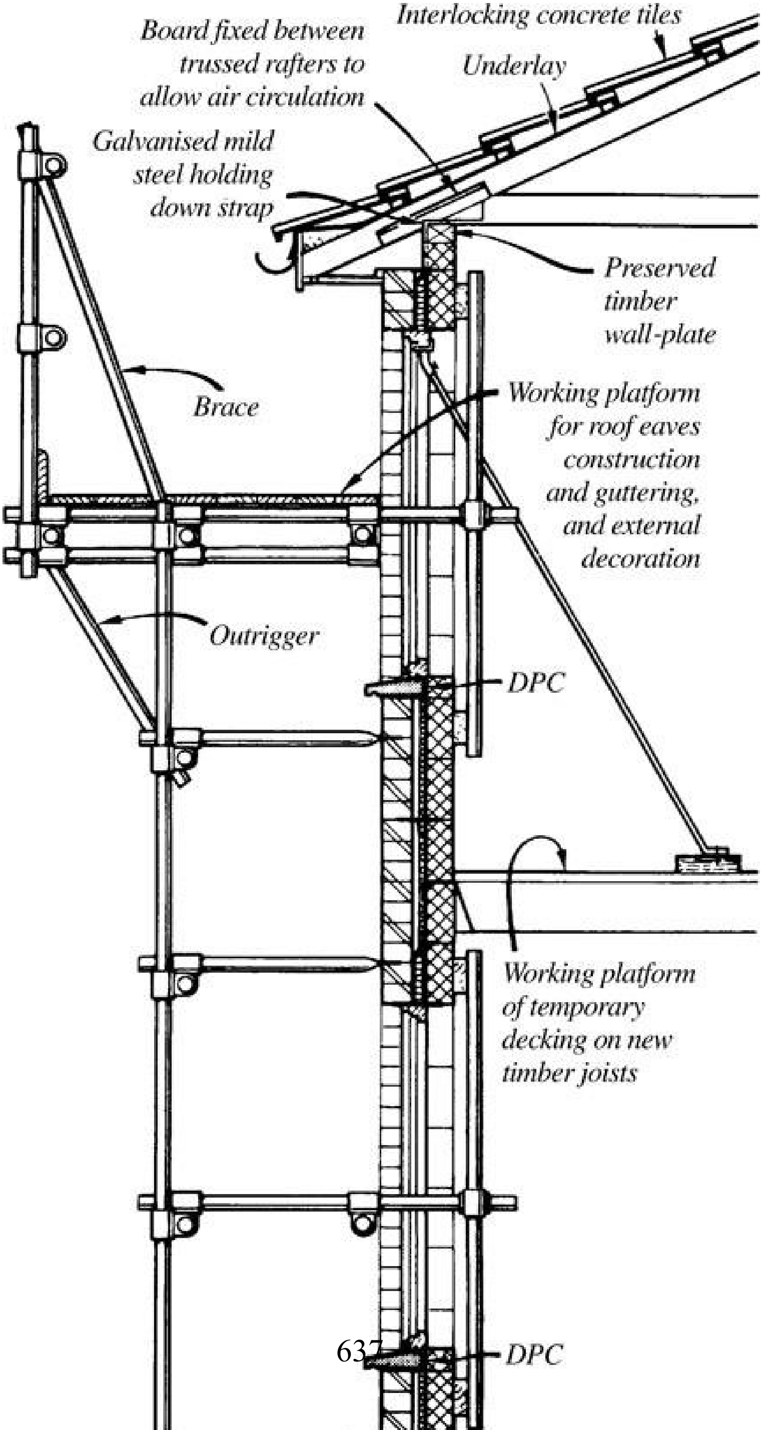
When cladding to the pitched roof is to be in slates, each horizontal row is laid starting again from the eaves. Each slate is butt-jointed at the side and overlapped at the head so as to form two thicknesses of slate over each nail hole as protection, making in all three thicknesses of material at the overlaps. The side butt joint should be left slightly open so that water will drain quickly. Special lengths of slate are required at eaves and sloping edges or verges. Each slate is fixed twice by yellow metal, aluminium alloy, copper or zinc nails. The slate should be holed so that breaking away of the edges of the hole (spalling) will form a countersinking for the nail-heads. This is best done by machine on site so that the holes can be correctly positioned by the fixers.

Clay plain tiles are fixed in a similar fashion except that each tile is retained on the battens by nibs, and, unless the roof is very exposed, they need only be nail-fixed every fourth or fifth course.

On completion of the external waterproofing system to the roof (Fig. 18.57), the rainwater gutters and drainpipes should be installed to prevent the water collected by the roof surface from cascading down the face of the walls below and causing later problems. Work can also commence to the interior of the building, hitherto left until a dry interior 'climate' could be ensured.

18.9.6 Thermal insulation and ventilation

Pitched roofs using slate or tile external cladding can be either warm roofs or cold roofs according to the positioning of the insulation (Fig. 18.58). An effective vapour control layer must always be incorporated on the warm side of the insulation.



Interlocking concrete tiles
Board fixed between trussed rafters to allow air circulation
Underlay
Galvanised mild steel holding down strap
Preserved timber wall-plate
Brace
Working platform for roof eaves construction and guttering, and external decoration
Outrigger
DPC
Working platform of temporary decking on new timber joists
DPC

Figure 18.57 Construction sequence: final lift.

Warm roof construction allows the roof space to catch the rising warm air from the rooms below, or even to be heated when it forms a room itself. Also, the roof timbers are protected from external solar heat gains which could cause excessive thermal movement and crack ceiling finishes, etc. Rigid thermal insulating material is placed over the rafter prior to fixing the underlay. As it may be difficult to form the sag in the underlay necessary to allow permeating water from the roof cladding to run to the eaves, an alternative constructional system is required. This involves the incorporation of vertically fixed counter battens over the underlay and insulation on the lines of the rafters so that the space is created between the underside of the horizontal slate or tile battens (Fig. 18.59).

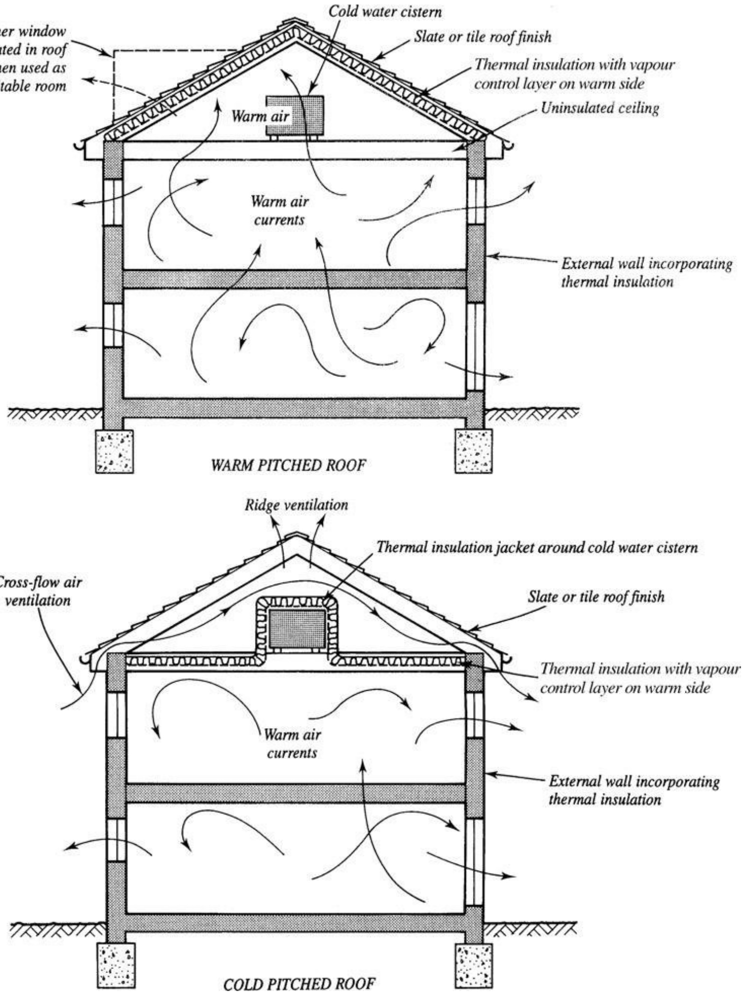


Figure 18.58 Warm and cold pitched roofs. Objective maximum U value for roofs with insulation between joists or between rafters is 0.15 $W/m^2 K$.

A similar system of counter battening is also necessary when boarding has to be fixed to the top face of the rafter to provide additional resistance to wind penetration. This boarding also gives the roof greater internal stability as well as greater defence against illegal entry. (There is easy access for a burglar into a dwelling through the roof; tiles can be lifted and the underlay cut away.)

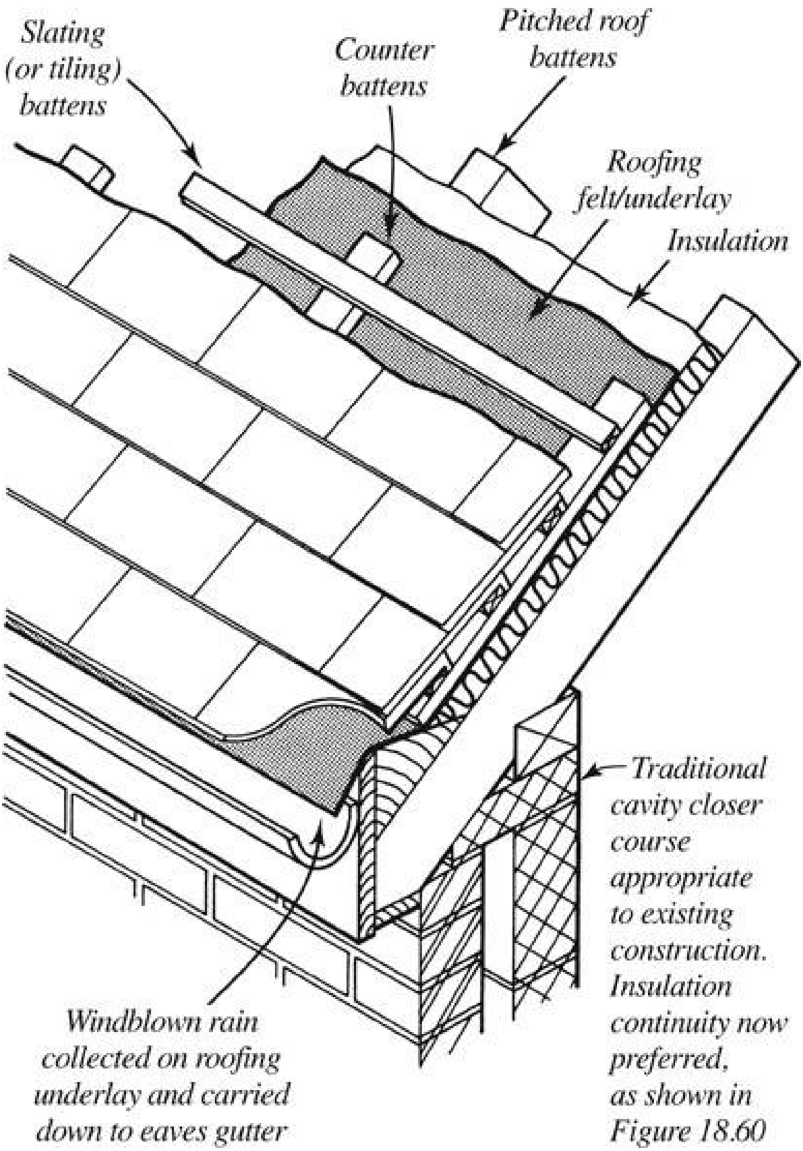


Figure 18.59 Counter battens provide a gap between roofing felt and slating battens (see also Fig. 6.6).

The advantage of cold pitched roof construction lies in energy conservation; the roof space is unheated, and most of the heat in the rooms below is used solely for those spaces. However, thermal movements caused by solar gain within the roof space are likely to provide problems of movement and special cover strips or scrim tape reinforcement will be required at junctions between the ceiling and the walls below. Having completed the outer cladding of the roof and made it waterproof, the builder is more able to accommodate insulating material over and/or between the ceiling joist later in the building programme, just prior to the finishes. However, care must be taken to ensure that a thermal insulation jacket is located over and around water cisterns so that the lost heat from the rooms below is at least used to prevent them freezing. Water pipes must be separately lagged if they are located within the cold roof space.

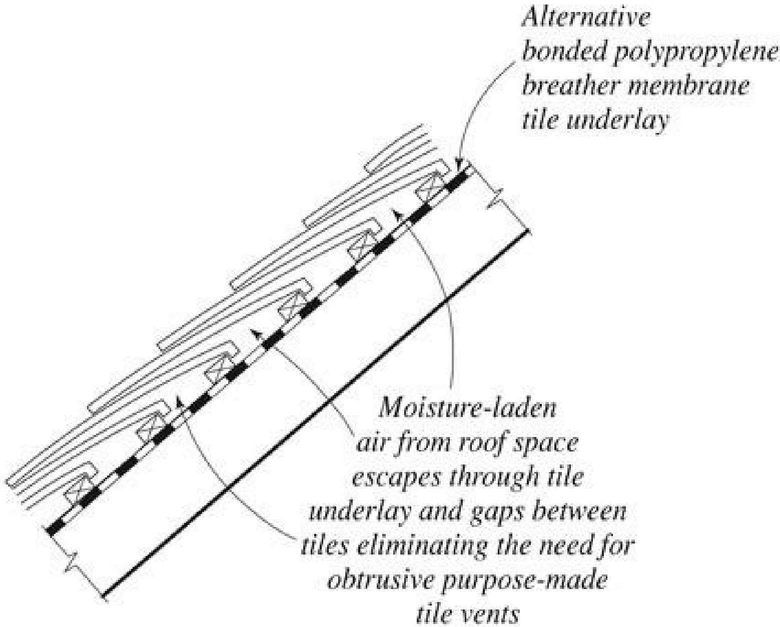
As no vapour control layer system can be guaranteed to be entirely effective, it is very important that the space above the thermal insulation is adequately ventilated to remove the last vestige of moist air which could cause condensation. This is particularly important when 'cold roof' construction is employed and the Building Regulations (Approved Document C) require the provision of cross-ventilation by voids equivalent to a 10 mm gap at the eaves. However, insulation can prevent this gap from being effective unless a board or patent profiled plastic spacer is inserted between rafters, as shown in Figure 18.60. Eaves ventilation gaps will also require a mesh screen to prevent insect penetration. Moreover, the effectiveness of ventilation can be more easily achieved by establishing the method most suitable relative to the airflow required, determined by wind speed, the availability of a free flow of air and the plan shape of the roof space. Further details on the means for preventing condensation in roofs can be found in BS 5250: Code of practice for control of condensation in buildings, BS EN ISO 13788: Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation. Calculation methods, and BRE Report BR 262: Thermal insulation: avoiding risks. See also Figures 18.60 and 18.61.

The use of tiles or slates provides a roof cladding which gives good protection against the effects of an external fire; they will not allow flames to penetrate into the roof space or allow flames to travel along their surface.

18.9.7 Flat roof construction

The structure of a flat roof is similar to intermediate floor construction, except that it must be waterproofed externally, thermally insulated, and, as lighter loads are usually required to be carried, the timber joist sections can be reduced in size. Because gravity cannot carry the rainwater away, a water barrier must be provided, consisting of continuous impervious membrane such as jointed metal sheets, asphalt, multi-layer roofing felt or single-layer plastics. These have to be laid on a firm decking to falls to ensure that water drains away to the water collection points. On a timber-joist flat roof the falls are generally provided by firring pieces. Figure 18.61 illustrates typical details; particular care is required by the designer when detailing, and by the builder when constructing, the junctions between a ‘flat’ roof and any upstand, such as walls or projecting service pipes. When inadequately formed, these points usually provide sources of water penetration and,

therefore, failure of the roof system. It should also be borne in mind that flat roof construction generally forms the major source of building failures in the United
Kingdom; faults are attributed to poor design, inadequate materials and low standards of work.


Alternative
bonded polypropylene
breather membrane
tile underlay
Moisture-laden
air from roof space
escapes through tile
underlay and gaps between
tiles eliminating the need for
obtrusive purpose-made
tile vents

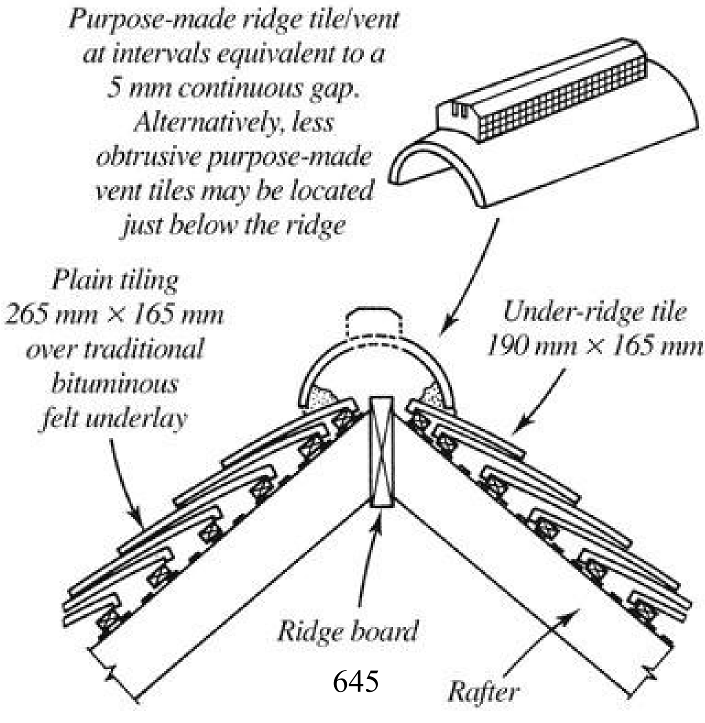

Purpose-made ridge tile/vent
at intervals equivalent to a
5 mm continuous gap.
Alternatively, less
obtrusive purpose-made
vent tiles may be located
just below the ridge
Plain tiling
265 mm × 165 mm
over traditional
bituminous
felt underlay
Under-ridge tile
190 mm × 165 mm
Ridge board
Rafter

Figure 18.60 Ventilation of roof space.

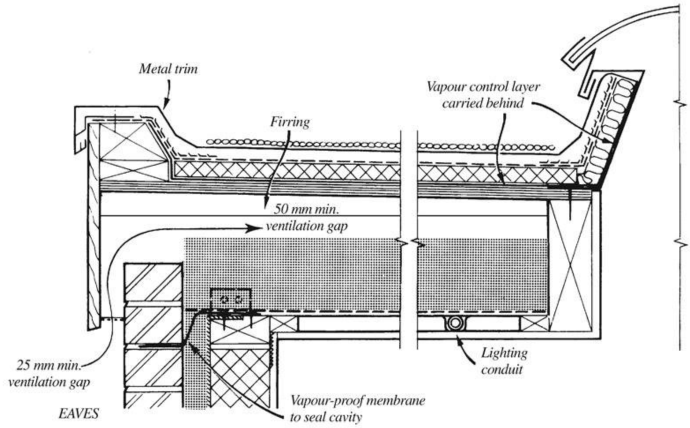
Flat roof construction can also provide a 'warm' roof or a 'cold' roof, and various systems are shown in Figure 18.62. The jointed metal sheets and asphalt provide adequate protection against the effects of an external fire, but multilayer roofing felts and single-layer plastic systems must be finished with a coating of stone chippings to provide the equivalent protection. Stone chippings also give protection against solar radiation and mechanical damage, and may therefore be incorporated on asphalt membranes.

18.10 Services CI/SfB (5−) + (6−)

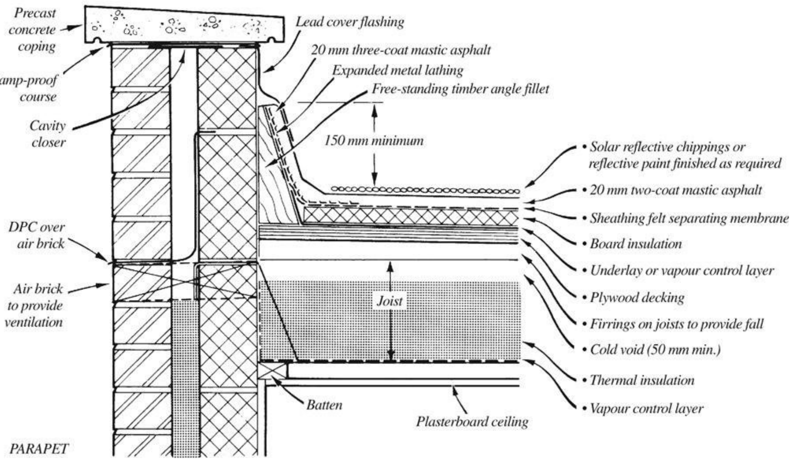
18.10.1 Below-ground drainage

Below-ground drains for a house are installed in trenches formed at appropriate falls by excavation techniques similar to those used for foundation trenches (Fig. 18.63). If the builder needs to hire an excavator or a specialist subcontractor for this purpose, it will be more economical to form all trenches, both foundation and drainage, during the same period of building work. Lengths of pipes can be installed and connected together up to convenient points where the above-ground drainage commences, such as gullies and WC outlets. The trenches can then be back-filled so as not to cause inconvenience to subsequent site and building work. Alternatively, the builder may prefer to carry out the majority of excavations for drainage (other than that affecting service pipes through foundation walls and ground floor slabs) once the bulk of the work on the building itself has been completed. In this way the installation of the drains, and subsequent backfilling processes, becomes part of the general work relating to external landscaping. Similarly, the connection to the public sewer can be delayed until most of the site drainage work is complete; or connection can be made at a very early stage in the building programme by forming the link drain between the sewer and a manhole on site. This means of drain access must be within 22 m of the sewer, where a saddle connection is permitted, as shown in Figure 11.4. The manhole (inspection chamber if less than 1 m deep) will also accommodate any difference in levels which may exist between the two drains. Local authority permission must be sought when connections to a public sewer are required, and the work should be carefully planned to cause minimum inconvenience to the public. Normally the local authority forms the connection using its own appointed contractor.

Drainage 'tails', left for future connections with aboveground drainage, must be temporarily sealed against the leakage of smells and gases from the main sewer, and/or
the possibility of their becoming blocked by debris. Backfilling drainage trenches must be done with great care; the exact method employed for casing the pipes will depend to a large extent on local conditions.



Metal trim
Vapour control layer carried behind
Firring
50 mm min. ventilation gap
25 mm min. ventilation gap
Lighting conduit
Vapour-proof membrane to seal cavity
EAVES



Precast concrete coping
Lead cover flashing
20 mm three-coat mastic asphalt
Expanded metal lathing
Free-standing timber angle fillet
Damp-proof course
Cavity closer
150 mm minimum
• Solar reflective chippings or reflective paint finished as required
• 20 mm two-coat mastic asphalt
• Sheathing felt separating membrane
• Board insulation
• Underlay or vapour control layer
• Plywood decking
• Firrings on joists to provide fall
• Cold void (50 mm min.)
• Thermal insulation
• Vapour control layer
DPC over air brick
Air brick to provide ventilation
Joist
Batten
Plasterboard ceiling
PARAPET

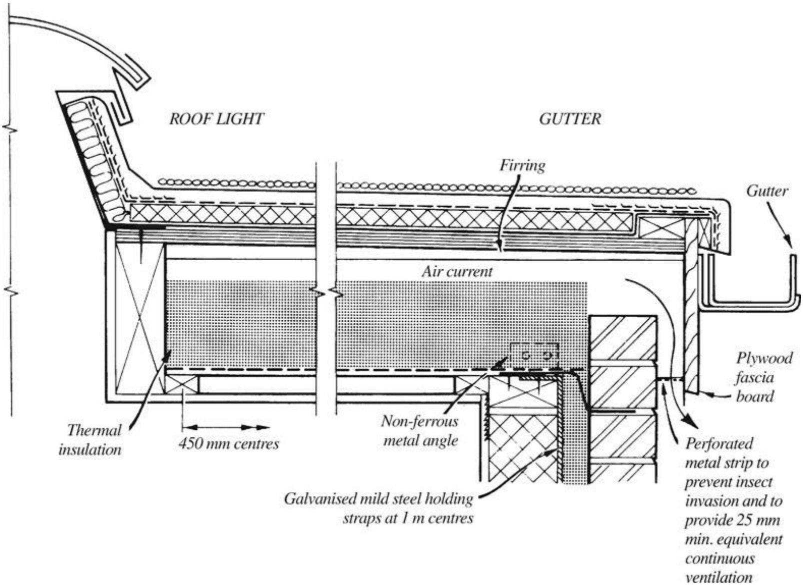


Figure 18.61 Typical flat roof construction. Details are for a cold roof construction where the thermal insulation and vapour control layer are held against the underside of structural timber joists by battens placed at right angles. In order to minimise the perforations in the vapour control layer, electrical lighting conduits are not installed in the structural zone of the roof. Note: A metal-foil-backed plasterboard nailed direct to the underside of timber joists is a simpler alternative to battening.

It will be necessary for the local authority to inspect and approve all drainage work and the subsequently installed plumbing work. Although the drains and associated pipework are looked at during installation for general approval, the final tests on drainage by the inspector generally take place after the trenches have been backfilled. Consequently, it is desirable for the builder to give the drains a preliminary water test before backfilling commences, in order to avoid the trouble and expense of opening up again at a later date if leaks become evident as a result of the local authority test.

18.10.2 Above-ground drainage and plumbing

The drainage above ground can be installed as soon as practicable; usually this means after the basic structural work has been completed (walls, floors and roof). Care needs to be taken to ensure that all necessary holes have been formed in the correct position before the drainage is installed. Once the interior of the building has been made ‘dry’ by completion of the external enclosure, plumbing work can also commence.

Sanitary fittings connecting to the internal drainage system are not usually installed until after the basic finishes of the building have been completed. This is because it is often easier for operatives, such as plasterers, to carry out their work on walls and ceilings unhampered by pipes and fittings, saving on the ‘cleaning down’ processes after they have finished. Plumbing and heating pipes are generally left until after plastering for similar reasons. However, when the fittings and pipes are to be surrounded with duct enclosures or other built-in features, or where finishes of a less ‘messy’ nature than wet plastering processes are used, it is often more convenient to install them as soon as the internal drainage is complete. These matters should have been considered during the design stage of the project, and normally form a subject of discussion between designer and builder during the progress of the work on site.

18.10.3 Water

The water supply pipe is taken from the water company’s stop valve on the distribution main to another valve and a meter at the site boundary. From here the underground

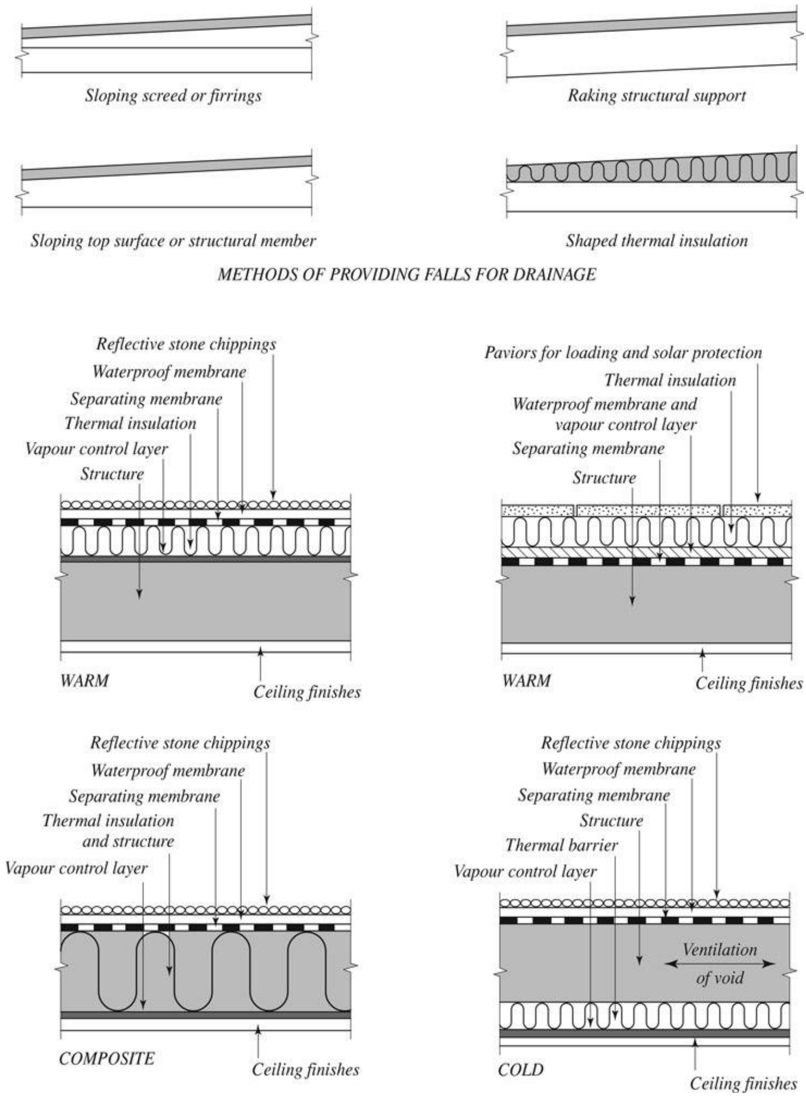


Figure 18.62 Warm and cold flat roof construction.

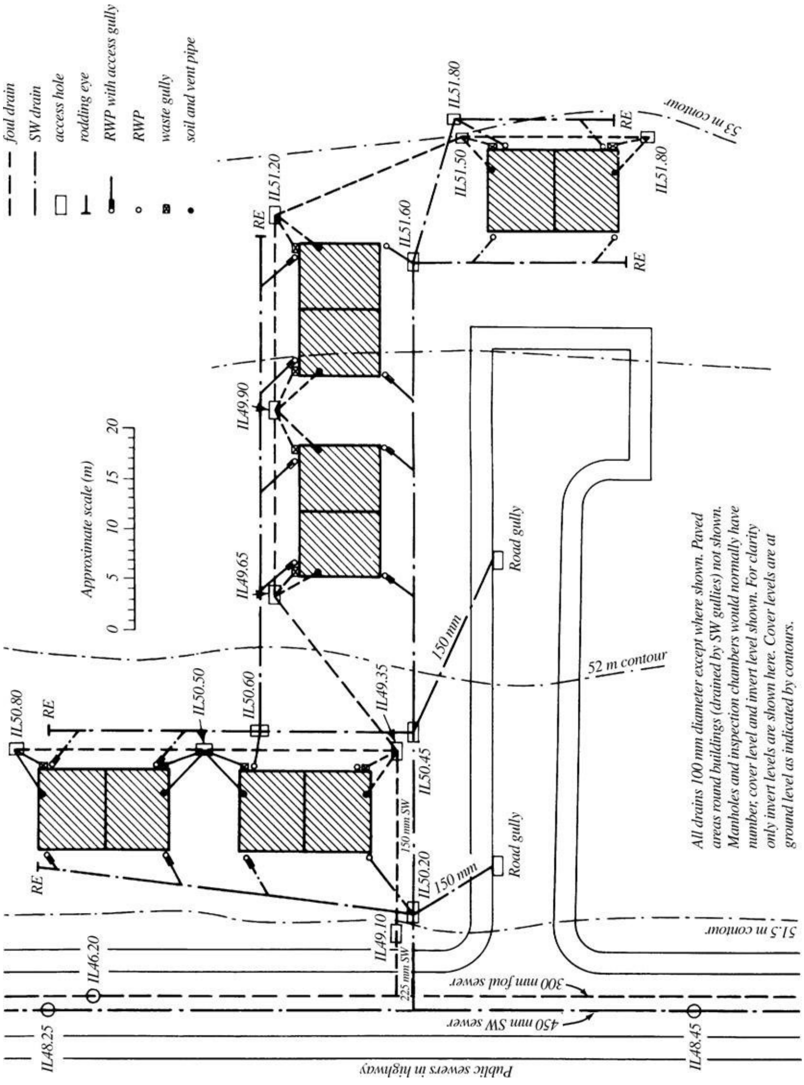


Figure 18.63 Below-ground drainage: read this layout in conjunction with Figure 11.4.

service continues into the building, terminating with a combined stop and drain valve at a convenient point (usually under the kitchen sink) – see Figures 11.1 and 18.64. From this point the rising main serves drinking-water facilities and a cold water storage cistern installed at high level.

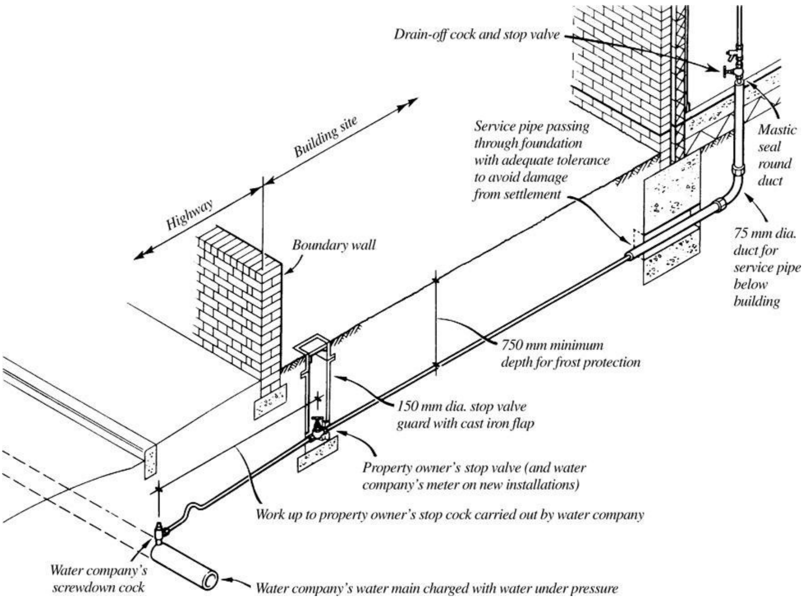


Figure 18.64 Water supply.

18.10.4 Gas and electricity

The gas pipe and electricity service cable are brought independently from their mains position outside the site to a point of termination by a meter (Fig. 18.65). (The entry of the gas connecting pipe should not be through the same duct as the electrical cabling duct.) This work is carried out by the gas and electricity companies' approved contractors to a programme agreed with the builder.

Unless separately ducted, the work of installing internal gas pipes and electricity cables from the meter positions should be carried out before basic finishes to the building are commenced. This work may also be carried out by the relevant authorities, but is more usually carried out by specialist subcontractors, a satisfactory price for the work having been given through competitive tendering procedures. Once the gas and electrical services have been installed to the layout requirements stipulated by the drawings and specification of the designer, the work must be tested and certificated by competent installers (Gas Safe Register and Building Regulations Part P Approved, respectively) for compliance with safety regulations.

18.10.5 Telecommunication systems

Like the other services described, the telephone, computer and cable television terminals may have localised common supply points from which connections are made to a building (Fig. 18.66). Alternatively, they can be supplied from remotely located exchanges. These installations are carried out externally and internally by the provider's engineers, although the site electrician's work can include internal distribution to telephone sockets.

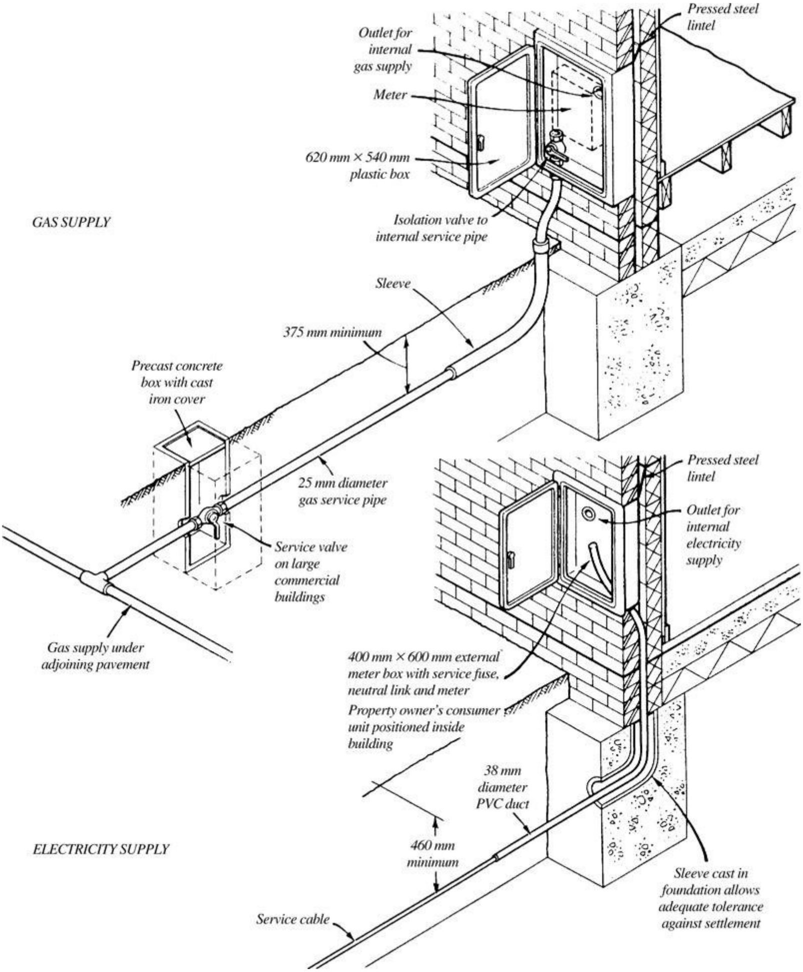


Figure 18.65 Gas and electricity supply.

18.11 Finishes CI/SfB (4–)

As soon as the constructional processes reach the stage where the structural elements of the house (walls, floors and roof)

have more or less been finished, and the weather-proofing completed by window/door glazing and roof claddings, etc., the work on the interior can commence in earnest. Initially, this will involve the erection of dry construction components such as stud partitions, and internal door frames and linings as described earlier. At about the same time, the service trades – gas, water, plumbing, heating and electrical – will be continuing their installations from the previously incorporated terminal points. In close
association with all these activities, the building contractor will wish to make a start on the coverings for the internal surfaces of walls, floors and ceilings, as well as finished joinery, cupboard fitments and ducting work. Therefore, whereas previous trades were working relatively independently of each other and progress relied on consecutive working programmes, the processes now required are much more interdependent and the degree of organisation required increases. Builders and subcontractors must work closely together to ensure that the correct labour skills and adequate material resources are available, so as to avoid the accumulation of unreasonable delays with their consequent frustrations and financial penalties.

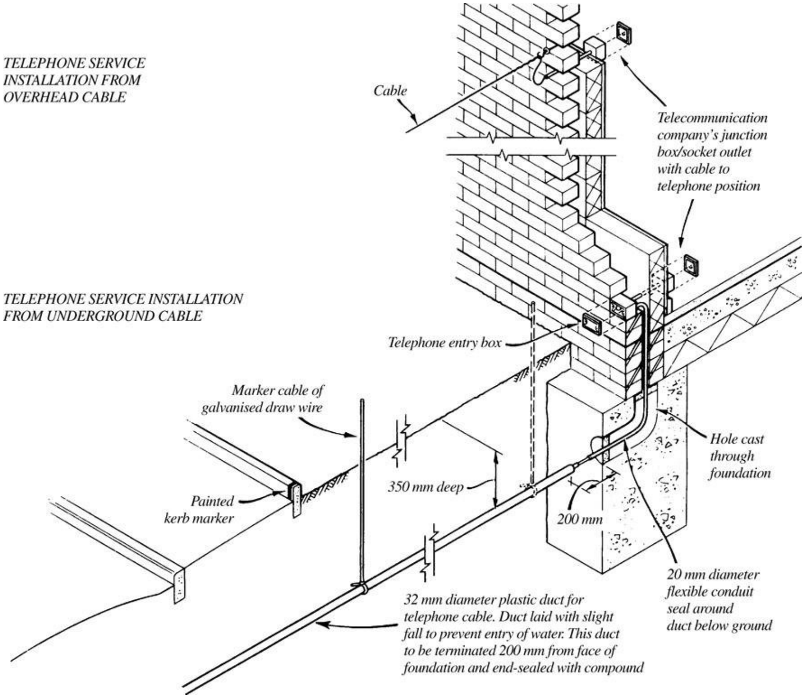


Figure 18.66 Telephone cable supply.

18.11.1 Plasterboard and plastering

Stud partitions and joisted ceilings are usually faced with plasterboard as it is reasonably strong, flexible in use, and contributes towards fire protection. Plasterboard consists of a plaster core encased in and firmly bonded to specially prepared durable lining paper. A grey lining paper indicates that it is meant to receive a coating of wet plaster and ivory that can be decorated direct. Plasterboard used without wet plaster (except in joints) is called dry lining.

Plasterboards are available in a number of standard sizes to conform with the centres of structural studs or joists, and are supplied in various thicknesses, i.e. 6, 9.5, 12.5, 15, 19 and 25 mm. A metallised vapour check backing is an option on 9.5 and 12.5 mm boards. Thermal-check boards with a bonded expanded polystyrene (eps) laminate are also available in various overall thicknesses up to 55 mm. For fire-resisting purposes, a 12.5 mm thickness of plasterboard applied to each side of 75 ´ 38 mm (minimum) timber stud partition framing at 600 mm (maximum) spacing will achieve a half-hour fire resistance. The same fire-resisting standard for a floor is achieved with 38 mm (minimum) width joists at 450 mm (maximum) spacing, a 12.5 mm plasterboard ceiling and 21 mm (minimum) tongued and grooved woodboard decking (see section 18.8.2).

Plasterboards are secured by galvanised or sheradised nails at 150 mm maximum spacing. Inevitably, some cutting will be necessary, particularly around door openings, electric light switches and power points, and when splays (to form bulkheads around a staircase) are incorporated in the design of the stud wall and/or ceiling. It is essential that all cross-joints in the plasterboards are staggered and that they are covered with a plastic mesh scrim or paper tape, which forms a seal and helps to prevent subsequent cracking of future finishes caused by thermal movements. It is also good practice to form the joints at right angles to the support of the sheets, and for each joint to be backed by a timber batten or noggin.

When all the plasterboard is in place, the plastering can commence to the plasterboard as well as the internal blockwork surfaces. A plaster finish fulfils the function of camouflaging irregularities in the backing wall as well as exposed conduits on the surface. It also provides a sufficiently hard surface to resist damage by impact and a surface smooth enough to be suitable for direct decoration. Gypsum plasters are suitable for this, and the choice of mix, type and number of coats will depend upon the characteristics of the background and its surface texture. Generally, the lightweight concrete blocks used for the internal leaf of the external cavity wall and for the internal partitions, and the surface of plasterboard, provide a suitable key for the direct application of plasters without further preparations. Although one-coat plasters are also available for blockwork, it is more usual to use a two-coat process. The undercoat of cement and sand render is applied using a wooden float or rule which is worked between 'dots' or 'runs' of plaster to give a true level surface. This undercoat is about 10 mm thick and is scratched before drying to provide a suitable key for the finishing coat. The thin finishing coat is applied to a depth of about 3 mm and finished with a steel float to provide a glass-like surface.

Junctions between backing walls of different materials (plasterboard adjoining block walls) require special treatment if cracking is to be avoided as a result of subsequent differential movements. A plastic mesh scrim reinforcement can be used at these points, although a much better detail can be adopted by using alloy edge-reinforcing strips, as indicated in Figure 18.67. These can also be used on the corners of walls to prevent damage by impact. Plaster reinforcing details between roof ceiling joists and the wall below are also indicated in Figure 18.67.

When a 'cold roof' construction is used, it will be necessary to install a vapour control layer prior to the fixing of the plasterboard lining for the ceiling, although plasterboards are available with a thin metallised foil bonded to their back face for this purpose. With the high degree of insulation required it is wise to ensure that any damage to the metallised backing is sealed or taped, particularly where pierced for electric light fittings. An independent vapour control layer can be incorporated as part of the insulation, which is laid once the ceiling and electrical work has been completed. It is important that insulation is provided for any water cisterns in the roof space and that any water pipes are suitably lagged to prevent the possibility of freezing.

18.11.2 Joinery

As soon as practicable, the upper surfaces of the horizontal structural elements should be made available by fixing the decking in an order which allows other work to be carried out from them. The staircase, which links these surfaces, should also be constructed in parallel, and door linings as well as window sills, etc., must be fixed so that plasterboard linings and plastering can continue without hindrance.

The intermediate floor decking can be tongue-and-groove (t & g) hardwood or softwood boarding, or chip-board or plywood sheets (see Fig. 18.29). When narrow face width boarding is used, it will be necessary for the boards to be cramped securely together before nailing to the joists in order to close the joints between each, and lessen the effect of shrinkage once the central heating has been switched on. Areas requiring future access for maintenance and alterations to electric wiring, junction boxes, etc., can be accommodated by removing the tongues from the perimeter board affected and using screws to form a removable panel. The use of t & g chipboard, or plywood sheets (say 1.2 m ´ 2.4 m), will speed the laying of floor decking provided their standardised dimensions are coordinated with the centres of the structural joists and the overall sizes of individual rooms.

Access areas can be provided by removable screwdown panels in a similar manner to hardwood or softwood boarding. Flooring grades of chipboard sheets need particular attention if subsequent bowing of the floor deck is to be avoided as a result of moisture absorption. It is recommended that the boards are allowed to acclimatise to the moisture levels of the room in which they are to be used before being fixed, and that movement gaps are left around the perimeter of the floor at junctions with walls.

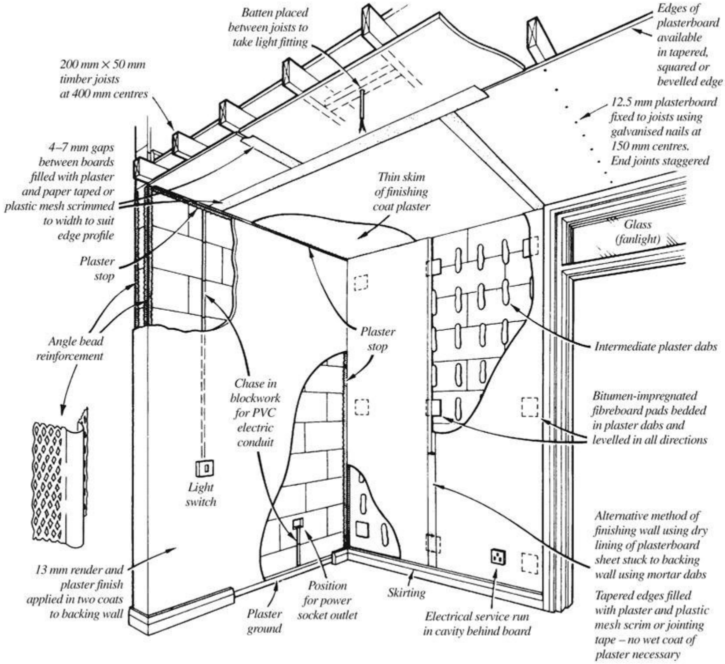


Figure 18.67 Plasterboard and plastering finishes.

Door linings and window boards are normally included in the ‘first fixing’ programme of the joinery. Linings are carefully set up to be plumb, then screwed to the plugs already built into blockwork or to the double stud and head timbers of stud partitioning. They should be of a width which allows for the thickness of plasterboard and/or plaster. Internal window boards are levelled and fixed direct to the blocks using cut nails or screws or, depending on the precise detail, they can be nailed to timber packing pieces already fixed to the top course of the blockwork opening. Sometimes tiled sills are required, so the tiles are bedded in mortar direct to the blockwork. ‘Second fixing’ joinery, which includes items such as doors, architraves, skirtings, shelves, cupboard units and ironmongery (locks, handles, etc.), should not be installed until just prior to final finishing. When considering the design of joinery items, it is important to select appropriate sizes for timber sections to allow for the reduction in size of the original rough or sawn (unwrot) standard sections caused by their being smooth (wrot). The amount of reduction will vary according to species of timber and the original sawn size – the range for softwoods is from 1.5 mm of each face to be planed for up to 22 mm sections, to 6.5 mm of each face for sections over 150 mm. Joinery sections are therefore specified by using the prefix 'ex:' (out of) against the unwrot size of timber to be used, e.g. an ex: 100 mm ´ 25 mm softwood skirting produces a wrot size of 97 mm ´ 22 mm.

After the main construction work has been completed, but before the 'second fixing' of the joinery, the ground floor damp-proof membrane (DPM) and insulation can be installed if they have not already been incorporated under the solid concrete slab. After the DPM has been laid on the top surface of a concrete floor slab, rigid insulation is placed before screeding, as detailed in Figure 18.27. If the final floor finish is to be applied by the builder (ceramic tiles, wood strip, parquet, etc.), the DPM, insulation and screed should not be begun until the very last period of the construction programme.

18.11.3 Decorations

Once the construction work has been completed, those parts of the house which require decoration can be appropriately prepared (Fig. 18.68). The more care that is taken with preparatory work, the better the finished result will be.

Sometimes the externally decorated areas will have been prepared and finished during an earlier stage of the building programme. This involves bringing in the painters and decorators out of sequence relative to the work to be done inside the building. This procedure may still be economical since it allows the scaffolding to be removed much earlier in the contract, and may mean that the external landscaping can proceed earlier and unhampered by construction activities. However, it is important that allowance is made for protecting the newly finished work while any construction work is still being carried out in the interior of the building. Protection is particularly important for window and door openings, especially as they are often supplied to site in some prefinished form (primed or preservative decorative staining to timber window and door frames, or anodised aluminium sections). They will require protection against mechanical damage arising from loading material to upper levels from scaffolding platforms.

Before any of the woodwork is to be painted on site, it should be carefully rubbed down, all nails punched below the surface and any necessary filling done. When choosing a particular manufacturer's priming, undercoat and finishing coat, it is essential to check that they are chemically compatible with any preservative treatment used on the joinery. The outside junction between door and window frames with the brickwork should be sealed with a mastic or silicone bead.

Internally, the walls to be decorated should receive their final preparation. This process includes the removal of temporary fixing nails, the repair of damaged plaster-work, and the smoothing of rough surfaces generally. In a new building there may be a small amount of movement due to initial structural settlement, and to the drying out of structural timbers, blockwork, etc. Drying out may persist for some time, and is likely to cause some cracking in plaster finishes, particularly during the first heating season. Plastered blockwork walls need a 'drying out' period after their completion because of the amount of water used in their construction. Their initial decoration should therefore be regarded as temporary. Certain emulsion paints allow the walls to breathe and residual moisture to escape without causing excessive or speedy breakdown of the surface film. It is normal to choose a neutral colour for the temporary finishing emulsion. Blemishes will be less obvious, and the occupants of the dwelling will be able more easily to appreciate the quality of space and light around them before selecting the colours and textures of more permanent wall finishes which will complement the chosen style of furnishings.

18.12 Landscaping and external works CI/SfB (90)

The external landscaping around the building provides the vital aesthetic and physical link between outside spaces and inside spaces (Fig. 18.69). For this reason the design and construction of landscaped areas requires just as much detailed consideration as applies to the building itself. Apart from purely enhancing the appearance and quality of the building with which it most closely associates, as well as that of the surrounding environment, the landscaping will also serve in providing the following practical functions:

- Convenient methods of circulation for foot and vehicular travel
- Shelter from wind, snow, rain and unwanted sunshine
- Visual and/or aural privacy
- Security from unlawful access to the site and building

The required function and subsequent design of the building should maximise the natural landscaping of the site as far as is possible. Beyond this, consideration must be given to the need for the planting of trees and shrubs, the formation of paths, driveways and roads, the erection of fences and walls, and the construction of shelters for storage or amenity. Most of this work will be executed after the construction of the main building because the areas of site will become progressively free as storage areas, etc., become redundant. Also, newly completed landscaped areas are less likely to be damaged because the majority of building construction will be completed. (An exception might occur on large building contracts when the long period of construction can be used to allow planting to mature in advance of the finally completed buildings.)

It would be economically desirable if most of the earth landscape features can be formed from the topsoil saved as

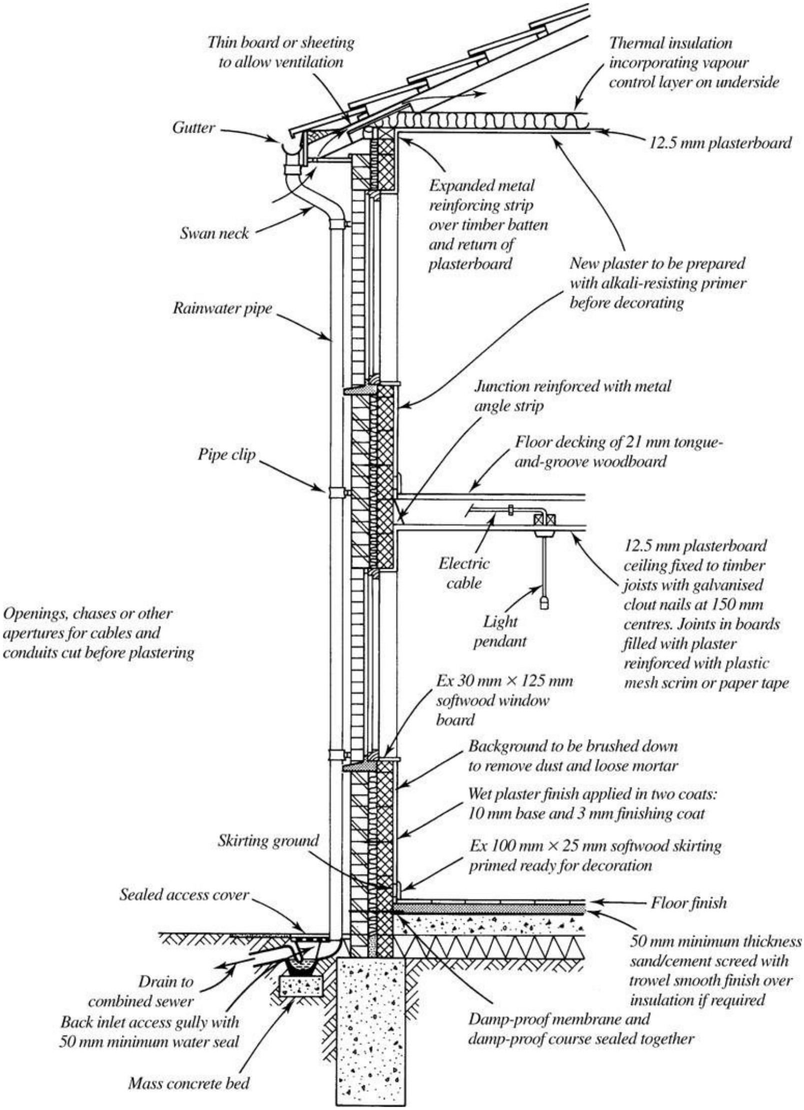


Figure 18.68 Construction sequence: finishes.

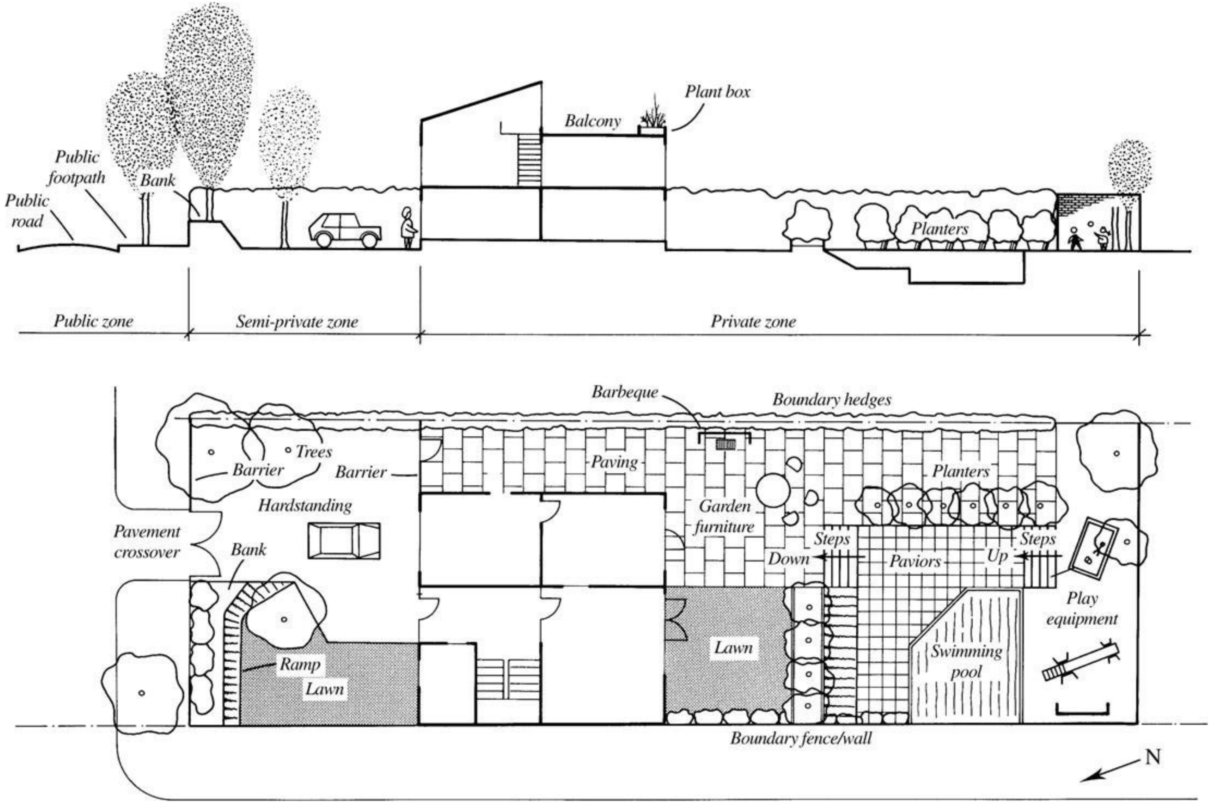

Plant box
Balcony
Public footpath
Bank
Public road
Planters
Public zone
Semi-private zone
Private zone
Barbeque
Boundary hedges
Trees
Barrier
Barrier
Paving
Planters
Hardstanding
Garden furniture
Pavement crossover
Bank
Steps
Steps
Down
Paviors
Up
Play equipment
Ramp
Lawn
Lawn
Swimming pool
Boundary fence/wall
N

Figure 18.69 The role of landscaping (see also Fig. 12.1).

a result of excavation of the building area of the site (see section 18.3.3). If there is an insufficient amount, the contractor will be required to import additional quantities from an outside source. Existing trees and shrubs which have been retained and protected during construction work will also provide considerable saving against planting new ones.

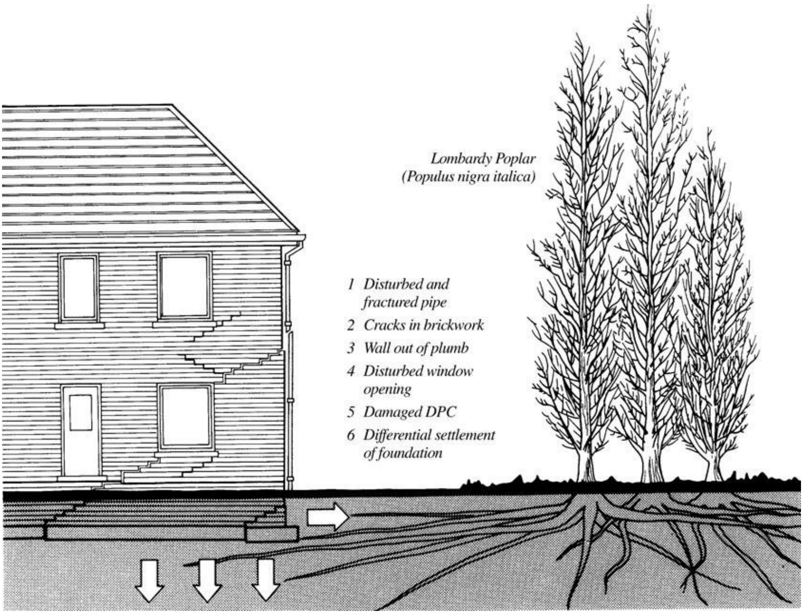
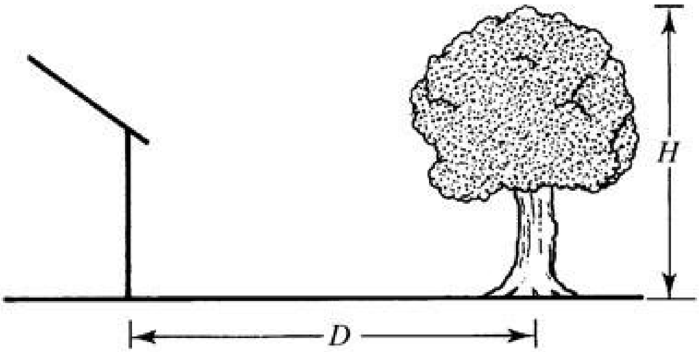


Figure 18.70 Danger of planting trees too close to a building erected on conventional foundations.

It is important that detailed thought is given to the selection of the correct species of new trees or shrubs. These will be small during their infancy and subsequent growth may result in undesirable amounts of overshadowing and the curtailment of desirable vistas. It is particularly necessary to analyse the effects of future root growth relative to the type of soil (including the proximity of water sources and the influences of pruning) and the proximity to the building (Fig. 18.70). Building closer to a tree than its mature height is not recommended, and, where several trees occur, the safe distance is considered to be 1 ½ times the mature height of the trees. Some guidance on precautionary measures for foundation dimensions in the proximity of trees is shown in Figure 18.71.



Tree	Depth of foundation trench (m)						
	D/H = 1/10	D/H = 1/4	D/H = 1/3	D/H = 1/2	D/H = 2/3	D/H = 3/4	D/H = 1
Poplar, elm and willow	Not acceptable	2.8	2.6	2.3	2.1	1.9	1.5
All others	Not acceptable	2.4	2.1	1.5	1.5	1.2	1.0

Figure 18.71 Proximity of trees.

The hard surface landscaping areas created by paths, driveways and roads on the site must be designed to retain their interest through all the changing seasons of the year. Natural stone pavings and gravels can be incorporated in a way which permits mosses and lichen to spread over areas of their surfaces to unify them with the natural landscape. Alternatively, they can be designed and constructed to create a separation rigidly defining dry and durable circulation paths. Hard surfaces may also require a system of rainwater collection to ensure that they are relatively free from the effects of rainwater. Large expanses can be drained by continuous 'monsoon-type' drains which are revealed at the surface only by a continuous gap. Other materials considered suitable for large hard-surfaced areas include tarmacadam, hot rolled asphalt and in situ concrete. Care must be taken to ensure that they do not give a monotonous appearance or crack excessively owing to dimensional movements. Accordingly, these materials can be formed in bays using another material at the joints which helps relieve monotony and create the opportunity for an aesthetically acceptable movement joint. Precast concrete paving slabs, brick pavers, clay tiles or cobbles can also be used with effect.

The provision of screening and boundary fences/walls has an important influence on the overall quality of the site and building. Timber can be used in a variety of ways which result from construction techniques ranging from driving poles for fixing preformed panels, to sophisticated joinery incorporating hardwood sections to give maximum visual appeal. Brick-built walls may also be pleasing, and can form an 'introduction' at the perimeter of the site to the aesthetic of the brick-faced building within. However, in order for this ideal to be maintained for the life of the building, it will be necessary to ensure that the effects of weathering on a fully exposed boundary wall remain similar to the walls of the building which are subjected to less hazardous conditions. The choice of brick and mortar should be primarily influenced by the exposure condition of the boundary wall. Typical details are indicated in Figure 18.72.

18.13 Completion CI/SfB (A8)

Once all work has been completed the contractor will be required to clear away all surplus materials and debris, remove plant/huts, etc., and leave the building and site in a clean and workable condition. The designer will inspect the work, ensure the satisfaction of the local authority inspectors and private insurance companies such as the NHBC, and prepare the necessary maintenance manual before passing the completed project to the client (see section 17.8).

Further specific reading

Note: The Building Regulations Approved Document supporting Regulation 7 – Materials and workmanship – applies throughout.

18.1 Building Team and communications

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 2 The production of buildings
Structure and Fabric Part 2	Chapter 1 Contract planning and site organization Chapter 2 Contractors' mechanical plant

18.2 Site considerations

Mitchell's Building Series

Structure and Fabric Part 1	Section 4.2 Foundations: soil and soil characteristics Section 4.3 Foundations: site exploration
Structure and Fabric Part 2	Section 3.1 Foundations: soil mechanics

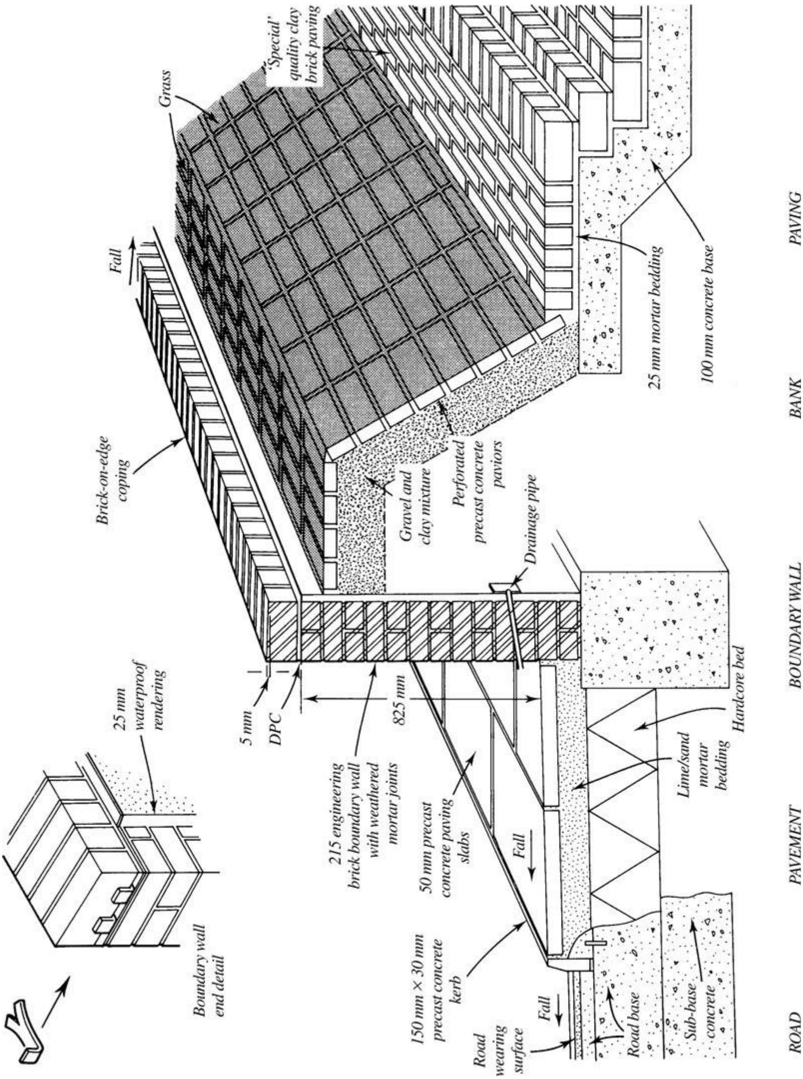


Figure 18.72 Typical landscaping details.

Building Research Establishment

Digest 298 *The low-rise building foundations: the influence of trees in clay soils*
Digest 318 *Site investigation for low-rise building: desk studies*
Digest 322 *Site investigation for low-rise building: procurement*
Digest 348 *Site investigation for low-rise building: the walk-over survey*
Digest 381 *Site investigation for low-rise building: trial pits*
Digest 383 *Site investigation for low-rise building: soil description*
Digest 411 *Site investigation for low-rise building: direct investigations*
Digest 412 *Desiccation in clay soils*
Digest 427 *Low-rise buildings on fill* (Parts 1–3)
Digest 447 *Waste minimisation on a construction site*
Digest 471 *Low-rise buildings on soft ground*
Digest 472 *Optimising ground investigation*
Digest 482 *Contaminated land: ingress of organic vapours into buildings*
Special Digest SD1 *Concrete in aggressive ground*
Good Building Guide GG25 *Buildings and radon*
Good Building Guide GG59 *Building on brownfield sites* (2 parts)

See also BRE *Soils, ground investigation and foundations pack* (AP 264)

Building Regulations

A1 Loading
A2 Ground movement
C1 Site preparation and resistance to contaminants
C2 Resistance to moisture

18.3 Initial site works

Mitchell's Building Series

Structure and Fabric Part 1	Chapter 2 The production of buildings Section 11.1 Support for excavations
Structure and Fabric Part 2	Chapter 2 Contractors' mechanical plant Section 11.2 Timbering for excavations Section 11.2 Timbering for excavations

Building Research Establishment

Digest 298	*The low-rise building foundations: the influence of trees in clay soils*
Digest 318	*Site investigation for low-rise building: desk studies*
Digest 322	*Site investigation for low-rise building: procurement*
Digest 343	*Simple measuring and monitoring of movement in low-rise buildings* Part 1: Cracks
Digest 344	*Simple measuring and monitoring of movement in low-rise buildings* Part 2: Settlement, heave and out-of-plumb
Digest 361	*Why do buildings crack?*
Digest 381	*Site investigation for low-rise building: trial pits*
Digest 383	*Site investigation for low-rise building: soil description*
Digest 411	*Site investigation for low-rise buildings: direct investigations*
Digest 412	*Desiccation in clay soils*
Digest 427	*Low-rise buildings on fill* (3 parts)
Digest 471	*Low-rise building foundations on soft ground*
Digest 472	*Optimising ground investigation*
Digest 482	*Contaminated land: ingress of organic vapours into buildings*

Building Regulations

A1 Loading
A2 Ground movement
C1 Site preparation and resistance to contaminants
C2 Resistance to moisture

18.4 Foundation construction

Mitchell's Building Series

Structure and Fabric Part 1 Chapter 4 Foundations
Structure and Fabric Part 2 Section 3.2 Foundation design
Section 3.3 Foundation types

Building Research Establishment

Digest 240 *Low-rise buildings on shrinkable clay soils* Part 1
Digest 241 *Low-rise buildings on shrinkable clay soils* Part 2
Digest 251 *Assessment of damage in low-rise building*
Digest 298 *The low-rise building foundations: the influence of trees in clay soils*
Digest 343 *Simple measuring and monitoring of movement in low-rise buildings – Cracks*
Digest 344 *Simple measuring and monitoring of movement in low-rise buildings – Settlement, heave and out-of-plumb*
Digest 352 *Underpinning*
Digest 412 *Desiccation in clay soils*
Digest 427 *Low-rise buildings on fill* Parts 1, 2 and 3
Digest 471 *Low-rise buildings on soft ground*
Digest 475 *Tilt of low-rise buildings with particular reference to progressive foundation movement*
Good Building Guide GG39 *Simple foundations for low-rise housing* (3 parts)
Good Building Guide GG53 *Foundations for low-rise building extensions*
Good Repair Guide GR1 *Cracks caused by foundation movement*

Building Regulations

A1 Loading
A2 Ground movement
C1 Site preparation and resistance to contaminants
C2 Resistance to moisture

18.5 Ground floor construction

Mitchell's Building Series

Environment and Services	Chapter 5 Heat
Structure and Fabric Part 1	Section 8.3 Ground floor construction

Building Research Establishment

Digest 145	*Heat losses through ground floors*
Digest 163	*Drying out buildings*
Digest 364	*Design of timber floors to prevent decay*
Digest 380	*Damp-proof courses*
Digest 416	*Specifying structural timbers*
Digest 429	*Timbers: their natural durability and resistance to preservative treatment*
Digest 445	*Advances in timber grading*
Digest 477	*Wood based panels* (7 parts)
Digest 492	*Timber grading and scanning*
Good Building Guide GG45	*Insulating ground floors*
Good Repair Guide GR17	*Repairing and replacing ground floors*
Information Paper IP10	*Safer floors: guidance on specifying flooring for internal and external safety in domestic buildings*
See also BRE	*Floors, flooring and stairs pack* (AP 260)

Building Regulations

A1	Loading
C2	Resistance to moisture
L1	Conservation of fuel and power in dwellings
L2	Conservation of fuel and power in buildings other than dwellings

18.6 External wall construction

Mitchell's Building Series

Environment and Services	Chapter 5 Heat
Structure and Fabric Part 1	Chapter 5 Walls and piers Chapter 9 Fireplaces, flues and chimneys

Structure and Fabric Part 2	Section 4.1 Solid masonry walls Section 4.3 Cavity load-bearing walls

Building Research Establishment

Digest 273 *Perforated clay bricks*
Digest 294 *Fire risk from combustible cavity insulation*
Digest 297 *Surface condensation and mould growth in traditionally built dwellings*
Digest 338 *Insulation against external noise*
Digest 362 *Building mortar*
Digest 369 *Interstitial condensation and fabric degradation*
Digest 377 *Selecting windows by performance*
Digest 379 *Double glazing for heat and sound insulation*
Digest 380 *Damp-proof courses*
Digest 401 *Replacing wall ties*
Digest 404 *PVC-U windows*
Digest 420 *Selecting natural building stones*
Digest 440 *Weathering of white external PVC-U*
Digest 441 *Clay bricks and clay masonry* (Parts 1 and 2)
Digest 460 *Bricks, blocks and masonry made from aggregate concrete* (2 parts)
Digest 496 *Timber frame buildings. A guide to the construction process*
Good Building Guide GG44 *Insulating masonry cavity walls* (2 parts)
Good Building Guide GG66 *Building masonry with lime-based mortars*

See also BRE *Masonry, walls and chimneys pack* (AP 261)

Building Regulations

A1 Loading
B4 External fire spread
C2 Resistance to moisture
D1 Cavity insulation
F1 Means of ventilation
J1 Air supply
L1 Conservation of fuel and power in dwellings
N1 Glazing – Protection against impact
N3 Glazing – Safe opening and closing of windows, skylights and ventilators
N4 Glazing – Safe access for cleaning windows, etc.

18.7 Internal wall construction

Mitchell's Building Series

Environment and Services	Chapter 6 Sound
Structure and Fabric Part 1	Section 5.8 Partitions
Structure and Fabric Part 2	Section 4.6 Cross-wall construction Section 4.8 Compartment, separating and other walls

Building Research Establishment

Digest 293	Improving the sound insulation of separating walls and floors
Digest 320	Fire doors
Digest 337	Sound insulation: basic principles
Good Building Guide GG 65	Plastering and internal rendering (2 parts)

Building Regulations

A1	Loading
B2	Internal fire spread (linings)
B3	Internal fire spread (structure)
E1	Protection against sound from other parts of the building and adjoining buildings
E2	Protection against sound within a dwelling – house, etc.
E3	Reverberation in the common internal parts of buildings containing flats or rooms for residential purposes
L1	Conservation of fuel and power in dwellings
N1	Glazing – Protection against impact
N2	Glazing – Manifestation of glazing

18.8 Intermediate floor construction

Mitchell's Building Series

Environment and Services	Chapter 6 Sound
Structure and Fabric Part 1	Section 8.4 Upper floor construction Chapter 10 Stairs
Structure and Fabric Part 2	Chapter 6 Floor structures Section 8.1 Stairs

Building Research Establishment

Digest 208	*Increasing the fire resistance of existing timber floors*
Digest 293	*Improving the sound insulation of separating walls and floors*
Digest 337	*Sound insulation: basic principles*
Digest 373	*Wood chipboard*
Digest 416	*Specifying structural timber*
Report 128	*Guidelines for the construction of fire-resisting structural elements*
Good Building Guide GG21	*Joist hangers*
Good Building Guide GG28	*Domestic floors* (5 parts)
See also BRE	*Floors, flooring and stairs pack* (AP 260)

Building Regulations

A1	Loading
B2	Internal fire spread (linings)
B3	Internal fire spread (structure)
E1	Protection against sound from other parts of the building and adjoining buildings
E2	Protection against sound within a dwelling – house, etc.
E3	Reverberation in the common internal parts of buildings containing flats or rooms for residential purposes
L1	Conservation of fuel and power in dwellings

18.9 Roof construction

Mitchell's Building Series

Environment and Services Chapter 5 Heat
Structure and Fabric Part 1 Chapter 7 Roof structures

Building Research Establishment

Digest 163	*Drying out buildings*
Digest 180	*Condensation in roofs*
Digest 284	*Wind loads on canopy roofs*
Digest 295	*Stability under wind loads of loose laid external roof insulation boards*
Digest 312	*Flat roof design: the technical options*
Digest 324	*Flat roof design: thermal insulation*
Digest 336	*Swimming pool roofs: minimising the risk of condensation using warm-deck roofing*
Digest 338	*Insulation against external noise*
Digest 416	*Specifying structural timber*
Digest 419	*Flat roof design: bituminous roofing membranes*
Digest 429	*Timbers: their natural durability and resistance to preservative treatment*
Digest 439	*Roof loads due to drifting of snow*
Digest 467	*Slate and tile roofs: avoiding damage from aircraft wake vortices*
Digest 493	*Safety considerations in designing roofs*
Good Building Guide GG8	*Bracing trussed rafter roofs*
Good Building Guide GG16	*Erecting, fixing and strapping trussed rafter roofs*
Good Building Guide GG36	*Building a new felted flat roof*
Good Building Guide GG37	*Insulating roofs at rafter level: sarking insulation*
Good Building Guide GG52	*Site cut pitched timber roofs* (2 parts)
Good Building Guide GG64	*Tiling and slating pitched roofs* (3 parts)
See also BRE	*Roofs and roofing pack* (AP 263)

Building Regulations

A1 Loading
B2 Internal fire spread (linings)
B3 Internal fire spread (structure)
B4 External fire spread
C2 Resistance to moisture
H3 Rainwater drainage
L1 Conservation of fuel and power in dwellings

18.10 Services

Mitchell's Building Series

Environment and Services	Chapter 7 Thermal installations Chapter 8 Electric lighting Chapter 9 Water supply Chapter 10 Sanitary appliances Chapter 11 Pipes Chapter 12 Drainage installations Chapter 13 Sewage disposal Chapter 15 Electricity and telecommunications Chapter 16 Gas
Structure and Fabric Part 1	Chapter 9 Fireplaces, flues and chimneys
Structure and Fabric Part 2	Chapter 7 Chimney shafts, flues and ducts

Building Research Establishment

Digest 248	*Sanitary pipework* Part 1: Design basis
Digest 249	*Sanitary pipework* Part 2: Design of pipework
Digest 254	*Reliability and performance of solar collector systems*
Digest 292	*Access to domestic underground drainage systems*
Digest 308	*Domestic unvented hot-water systems*
Digest 335	*Electric interferences in buildings*
Digest 339	*Condensing boilers*

See also BRE *Water supply, drainage and sanitation pack* (AP 266)

Further references under **Further specific reading**, Chapter 11

Building Regulations

B3	Internal fire spread (structure)
F1	Means of ventilation
G1	Cold water supply
G2	Water efficiency
G3	Hot water supply and systems
G4	Sanitary conveniences and washing facilities
G5	Bathrooms
G6	Kitchens and food preparation areas
H1	Foul water drainage
H2	Cesspools, septic tanks and settlement tanks
H3	Rainwater drainage
J1	Air supply
J2	Discharge of products of combustion
J3	Protection of building
L1	Conservation of fuel and power in dwellings

18.11 Finishes

Building Research Establishment

Digest 163	*Drying out buildings*
Digest 301	*Corrosion of metals by wood*
Digest 407	*Timber for joinery*
Digest 422	*Painting exterior wood*
Digest 429	*Timbers: their natural durability and resistance to preservative treatment*
Digest 448	*Cleaning buildings: legislation and good practice*
Digest 449	*Cleaning exterior masonry* (2 parts)
Digest 466	*EN 927: the new European Standard for exterior wood coatings*
Digest 477	*Wood based panels* (7 parts)
Good Building Guide GG65	*Plastering and internal rendering* (2 parts)
Good Building Guide GG70	*Plasterboard* (3 parts)
See also BRE	*Composites, metals, paints, adhesives and sealant pack* (AP 253)

Building Regulations

B2 Internal fire spread (linings)
G5 Bathrooms
G6 Kitchens and food preparation areas

18.12 Landscaping and external works

Building Research Establishment

Digest 298	The low-rise building foundations: the influence of trees in clay soils
Good Building Guide GG27	Building brickwork or blockwork retaining walls
Good Repair Guide GR2	Damage to buildings caused by trees

Appendix I Working drawings and schedules

This list should not be taken as a definitive checklist of items to be included on working drawings/schedules. It is only a guide as to the types of information which may be required. Drawings and schedules may be supplemented by information given in specifications, bills of quantities, sample boards and three-dimensional representations.

1.00 General information on each drawing/schedule

1.01 Name of project and location
1.02 Project reference and drawing number
1.03 Name of designer/consultant and address of contract, including telephone number
1.04 General description of content of drawing
1.05 Cross-reference to other relevant drawings, schedules or bills of quantities/specification
1.06 Scale(s) employed on drawing(s)
1.07 Date of drawing when completed
1.08 Space for date of issue stamp
1.09 North point when appropriate
1.10 Amendment panel, including date of revision
1.11 General instructions panel
1.12 Subtitles for each individual item shown
1.13 Key to non-standard conventions

2.00 Site plans

2.01 District and address
2.02 Boundaries and site lines
2.03 Adjoining buildings, road and paths (existing and proposed)
2.04 Rights of way to be maintained or temporarily obstructed
2.05 Existing features (trees, mounds, fences, hedges, ditches, etc.)
2.06 Existing datum, levels, and contours
2.07 Existing drainage: sewers, cesspools, septic tanks, soakaways and watercourses, including levels
2.08 Existing gas, water, electricity, telecommunication services, including levels
2.09 Means of access
2.10 Setting out of proposed building and site, including levels
2.11 Proposed routes for rubbish disposal and fire-fighting vehicles
2.12 Proposed landscape feature, including levels
2.13 Alteration to existing features (boundaries, trees, landscape)
2.14 Alterations to existing drainage, gas, water, electricity and telecommunication services, including points of connection to proposed buildings
2.15 Location of proposed drainage, gas, water, electricity and telecommunication services

3.00 Foundation plans

3.01 Grid/modular planning lines
3.02 Datum level for excavation
3.03 Indication of existing foundations, earthworks, etc., to be removed
3.04 Dimensions of new foundations to define shape, including vertical steps
3.05 Levels of top and/or underside of foundations
3.06 Positions of walls relative to foundations
3.07 Positions of services to be installed below ground level
3.08 Location and size of holes left through foundations for service pipes
3.09 Drain and manhole foundations and levels
3.10 Typical details of excavations

4.00 Floor plans

4.01 Grid/modular planning lines
4.02 Datum level
4.03 Finished floor levels and changes of level
4.04 External dimensions
(a) changes of direction, openings, etc.
(b) overall of building
4.05 Internal dimensions
(a) changes of direction, openings, etc.
(b) overall of areas
4.06 Room/space names and areas if required
4.07 Wall dimensions and description of materials, thickness and jointing
4.08 Location of movement joints
4.09 Air bricks and ventilation grilles
4.10 Layout of horizontal and vertical service ducting: dimensions and description of services carried (gas, water, electricity, telephone, TV and cable)
4.11 Fireplaces: dimensions and/or description of openings, hearth, projections, etc.
4.12 Flues: dimensions and/or description of type, position, size, lining, etc.
4.13 Mat wells and other changes in floor surface
4.14 Overhead floor/roof construction: materials, size, spacing and direction of span, etc.
4.15 Overhead rooflights, ventilation cowls, etc.
4.16 Staircases: dimension and/or description of direction (up/down), treads (and number), rise/going, flight width, handrails, landings, balconies, etc.
4.17 Doors and door frames/linings: dimensions and/or description cross-referenced to schedules (including ironmongery)
4.18 Windows and window frames: dimensions and/or description cross-referenced to schedules (including ironmongery)
4.19 Hatches/access panels and frames: dimensions and/or description cross-referenced to schedules (including ironmongery)
4.20 Door (and window) direction of opening, number, and manufacturer's reference if applicable

4.21 Vertical damp-proof courses and membranes

4.22 External and internal wall and floor finishes, including materials, thickness, jointing, position and techniques

4.23 Internal ceiling finishes where to be linked in with wall components

Depending on the size of the project, the following items may be included, either on the main drawings or on separate 'specialist' drawings *cross-referenced* with main drawings.

4.24 Built-in furniture, cupboards, units, etc.: dimensions and/or description cross-referenced to schedule/detail drawings

4.25 Heating units/radiators, etc.: dimensions and/or description cross-referenced to schedule

4.26 Sanitary fittings: dimensions and/or description cross-referenced to schedule

4.27 Specialist equipment, fire hoses, alarms, mechanical plant

4.28 Electrical installation: description and dimensioned position of intake, consumer unit (main switch/fuses), power socket outlets, lighting points and switches, emergency lighting, etc.

4.29 Gas installation: description and dimensioned position of intake, meter and supply points

4.30 Water installation: description and dimensioned position of intake, valve controls, rising main, supply points, and cold water tank, draindown points, etc.

4.31 Heating installation: description and dimensioned position of boiler (equipment, model, size and rating), hot water cylinder, expansion tank, heating units, draindown points, etc.

4.32 Drainage installation: description and dimension of outfall, manholes, drainpipes, soil stacks, wastes, vent pipes, gullies, branch drains from fittings to include details of material, size, gradient and direction of flow when appropriate

4.33 Rainwater drainage installation: description and dimensions of outfall, manholes, drainpipes, rainwater pipes and gullies, surface water gullies and direction of falls, etc.

4.34 External works and landscaping: steps, ramps, paving, grass, planting, trees and built features, such as terraces, playgrounds (including equipment), amenities, etc.

4.35 Details, dimensions and/or description of external fuel storage, oil-tanks and sheds, garages, car ports, etc.

5.00 Roof plans

5.01 Grid/modular planning lines

5.02 Datum level

5.03 Dimensions
(a) changes of direction, openings, etc.
(b) overall of building

5.04 Description of roof structure: decking, firrings, and integral thermal insulation – vapour control layer and ventilation

5.05 Screeds: composition, maximum and minimum thicknesses

5.06 Roof finishes: materials, sizes, thickness, gauge, pitch, etc.

5.07 Direction of falls

5.08 Rooflights and ventilation cowls: description and dimensions cross-referenced to schedule if applicable

5.09 Solar panels, location

5.10 Ventilation pipes, rainwater pipes and gutters: description and dimensions

5.11 Parapet, coping, eaves, ridge and upstands: description and dimensions

5.12 Lift-motor and mechanical plant rooms: description and dimensions

5.13 Location and description of cantilever beams, cradle fixing position, etc., for window cleaning

5.14 Location of areas unsafe for maintenance workers without additional precautions; areas safe for maintenance workers only; areas safe for foot traffic and/or heavier loads

5.15 Access positions: staircases, traps, ladders, etc.

5.16 Landscaping, terraces and balconies: description and dimensions, including arrangements for waterproofing and drainage

6.00 Sections

6.01 Grid/modular section lines

6.02 Datum levels

6.03 Ground levels: existing and new finished ground and floor levels

6.04 Floor levels and identification

6.05 Room/space names when applicable

6.06 External dimensions
(a) changes of direction, openings, etc.
(b) overall of building

6.07 Internal dimensions
(a) door/window openings, staircases, ducts, built-in furniture, guard-rails, etc.
(b) room heights and suspended floors or ceilings

6.08 Foundations: description and dimensions, including composition, size and stepping details

6.09 Foundation walls: materials, thickness, bonding, backfilling, damp-proof course, holes for drainage and ventilation

6.10 Fill and hardcore material, thickness, and layering

6.11 Solid ground floor construction: thickness, composition, additives, reinforcement, damp-proof membrane, insulation, screeds and finishes

6.12 Suspended ground floor construction: type, materials, dimensions, fixings, insulation, damp-proof membrane, ventilation and finishes
6.13 Intermediate floor construction: type, materials, dimensions, fixings, insulation, and finishes, including ceilings
6.14 Roof construction: type, materials, dimensions, fixing, insulation and finishes, including soffits and ceilings
6.15 External wall construction: type, material, dimensions, fixings, ties, insulation and finishes
6.16 Internal wall construction: type, material, dimensions, fixings, ties, insulation and finishes
6.17 Staircases: dimension and/or description of direction (up/down), treads (and number), rise/going, flight width, handrails, landings, balconies, etc.
6.18 Doors and door frames/linings: dimensions and/or description cross-referenced to schedules (including ironmongery)
6.19 Windows and window frames: dimensions and/or description cross-referenced to schedules (including ironmongery)
6.20 Lintel types, sizes and materials cross-referenced to schedule when appropriate
6.21 Location of movement joints
6.22 Air bricks and ventilation grilles
6.23 Layout of horizontal and vertical service ducting: dimensions and description of services carried (gas, water, electricity, telephone, TV and cable)
6.24 Fireplaces: dimensions and/or description of openings, hearth, projections, etc.
6.25 Flues: dimensions and/or description of type, position, size, lining, etc.
6.26 Mat wells and other changes in floor surface

Depending on the size of the project, the following items may be included either on the main drawings or on separate 'specialist' drawings *cross-referenced* with main drawings

6.27 Built-in furniture, cupboards, units, etc.: dimensions and/or description, cross-referenced to schedule/detail drawings
6.28 Heating units/radiators, etc.: dimensions and/or description cross-referenced to schedule
6.29 Sanitary fittings: dimensions and/or description cross-referenced to schedule
6.30 Specialist equipment, fire hoses, alarms, mechanical plant
6.31 Electrical installation: description and dimensioned position of intake, consumer unit (main switch/fuses), power socket outlets, lighting points and switches, emergency lighting, etc.
6.32 Gas installation: description and dimensioned position of intake, meter and supply points
6.33 Water installation: description and dimensioned position of intake, valve controls, rising main, supply points, and cold water storage cistern, draindown points, etc.
6.34 Heating installation: description and dimensioned position of boiler (equipment, model, size and rating), hot water cylinder, expansion tank, heating units, draindown points, etc.
6.35 Drainage installation: description and dimension of outfall, manholes, drainpipes, soil stacks, wastes, vent pipes, gullies, branch drains from fittings to include details of material size, gradient and direction of flow when appropriate.
6.36 Rainwater drainage installation: description and dimensions of outfall, manholes, drainpipes, rainwater pipes and gullies, surface water gullies and direction of falls, etc.
6.37 External works and landscaping: steps, ramps, paving, grass planting, trees and built features, such as terraces, playgrounds (including equipment), amenities, etc.
6.38 Details, dimensions and/or description of external fuel storage, oil-tanks and sheds, garages, car ports, etc.

7.00 Elevations
7.01 Grid/modular section lines
7.02 Datum levels
7.03 Ground levels: existing and new finished ground and floor levels
7.04 Foundation lines
7.05 General description of facing materials including type, material, texture and colour
7.06 Door positions and cross-reference to schedules
7.07 Window positions and cross-reference to schedules
7.08 Direction of opening of door and windows
7.09 Air bricks and ventilation cowls
7.10 Description and position of movement joints
7.11 Soil stacks, gutters, rainwater pipes, and other exposed services, including alarms, lighting, power points, standpipes, etc.
7.12 Description and position of special features: signs, sculptures, decorative displays, etc.
7.13 Description and location of sheds, storage rooms, etc., detached from main building
7.14 Description and location of landscape features: trees, bushes, plants, earth ramps and mounds, etc.

8.00 Detail drawings, axonometrics and isometrics
8.01 Grid/modular planning/section lines
8.02 Location of doors, windows and other openings
8.03 Wall, floor, roof thicknesses
8.04 Location of furniture and other fixings
8.05 Details of construction and finishes

9.00 Schedules
9.01 Reference number (from drawings), location, type and size of items
9.02 Manufacturer's reference if applicable
9.03 Ancillary information concerning colour, ironmongery, methods of fixing, applications and details of immediately surrounding elements or components, etc.
9.04 Cross-reference with other schedules unless fully described; colour to be painted, ironmongery involved, etc.

Appendix II
Examples of planning and Building Regulations application forms

PLANNING APPLICATION

OFFICE USE ONLY
APPLICATION NUMBER

DATE RECEIVED

DATE VALID

Use this form to apply for **Planning permission** for:
Outline Permission
Full Permission
Approval of Reserved Matters
Renewal of Temporary Permission
Change of Use

Please return:
*6 copies of the Form
*6 copies of the Plans
*a Certificate under Article 7
*the correct fee

1. NAME AND ADDRESS OF APPLICANT

Post-code ______
Day Tel. No. ______
Email ______

2. NAME AND ADDRESS OF AGENT (if used)

Post-code ______
Tel. No. ______
Email ______

3. ADDRESS OR LOCATION OF LAND TO WHICH APPLICATION RELATES

State Site Area ______ Hectares
This must be shown edged Red on the site plan

4. OWNERSHIP

Please indicate applicants interest in the property and complete the appropriate Certificate under Article 7.

Freeholder ☐ Other ☐
Leaseholder ☐ Purchaser ☐

Any adjoining land owned or controlled and not part of this application must be edged Blue on the site plan

5. WHAT ARE YOU APPLYING FOR?

Please tick one box and then answer relevant questions.

☐ **Outline Planning Permission**

Which of the following are to be considered? ☐ Siting ☐ Design ☐ External Appearance ☐ Means of Access ☐ Landscaping

☐ **Full Planning Permission/Change of use**

☐ **Approval of Reserved Matters following Outline Permission**

O/P No. ______ Date ______ No. of Condition this application refers to: ______

☐ **Continuance of Use without complying with a condition of previous permission**

P/P No. ______ Date ______ No. of Condition this application relates to: ______

☐ **Permission for Retention of works**

Date of Use of land or when buildings or works were constructed: ______ Length of temporary permission: ______

Is the use temporary or permanent? ______ No. of previous temporary permission if applicable: ______

6. BRIEF DESCRIPTION OF PROPOSED DEVELOPMENT

Please indicate the purpose for which the land or buildings are to be used. ______

What is the present use of the land/buildings? ______

What buildings are to be demolished? ______

______ Gross Floor Area ______ m^2

7. NEW RESIDENTIAL DEVELOPMENTS

Please answer the following if appropriate.

Please state what type of building you are proposing i.e. house, flat: ____________________

Please give the following:

No. of dwellings ________ No. of surveys: ________ No. of Habitable rooms: ________

No. of Garages: ________ No. of Parking Spaces: ________ Total Gross Area of all buildings: ________

How will surface water be disposed of? ____________________

How will foul sewage be dealt with? ____________________

8. ACCESS

Does the proposed development involve any of the following? Please tick the appropriate boxes.

New access to a highway	☐ Pedestrian	☐ Vehicular
Alteration of an existing highway	☐ Pedestrian	☐ Vehicular
The felling of any trees	☐ Yes	☐ No

If you answer Yes to any of the above, they should be clearly indicated on all plans submitted.

9. BUILDING DETAILS

Please give details of all external materials to be used, if you are submitting them at this stage for approval.

____

____

____

List any samples that are being submitted for consideration. ____________________

____

10. LISTED BUILDINGS OR CONSERVATION AREA

Are any Listed buildings to be demolished or altered? ☐ Yes ☐ No

If Yes, then Listed Building Consent will be required and a separate application should be submitted.

Are any non-listed buildings within a Conservation Area to be demolished? ☐ Yes ☐ No

If Yes, then Conservation Area consent will be required to demolish. Again, a separate application should be submitted.

11. NOTES

Part 2 of this Planning Application Form should be completed for all applications involving Industrial, Warehousing, Storage, or Shopping development.

An appropriate Certificate must accompany this application unless you are seeking approval to Reserved Matters.

A separate application for Building Regulation approval is also required.

Separate applications may also be required if the proposals relate to a Listed Building or non-listed building within a Conservation Area.

12. PLEASE SIGN AND DATE THIS FORM BEFORE SUBMITTING

I/We hereby apply for Planning Permission for the development described above and shown on the accompanying plans.

Signed ____________________

On behalf of (if agent) ____________________ **Date** ________

HOUSEHOLDER PLANNING APPLICATION

OFFICE USE ONLY
APPLICATION NUMBER

DATE RECEIVED

DATE VALID

Use this form to apply for **Planning Permission** for:

* an Extension
* a Loft Conversion
* a New or Altered Access
* a High Wall or Fence
* a Garage or Outbuilding
* a Satellite Dish

Please return:

* 5 copies of the Form
* 5 copies of the Plans
* a Certificate under Article 7
* the correct fee

1. NAME AND ADDRESS OF APPLICANT

Post-code

Day Tel. No.

Email

2. NAME AND ADDRESS OF AGENT (if used)

Post-code

Tel. No.

Email

3. ADDRESS OF PROPERTY TO BEALTERED OR EXTENDED

4. OWNERSHIP

Please indicate applicant's interest in the property and complete the appropriate Certificate under Article 7.

Freeholder ☐ Other ☐

Leaseholder ☐

Purchaser ☐

5. BRIEF DESCRIPTION OF WORKS (including any demolition works) e.g. erection of a two-storey rear extension.

6. DESCRIPTION OF MATERIALS

7. ACCESS AND PARKING

Will your proposal affect?	Please tick appropriate boxes	
Vehicular Access	Yes ☐	No ☐
A Public Right of Way	Yes ☐	No ☐
Existing Parking	Yes ☐	No ☐

8. DRAINAGE

a. Please indicate method of Surface Water Disposal

b. Please indicate method of Foul Water Disposal

Please tick one box

Mains Sewer ☐ Septic Tank ☐

Cesspit ☐ Other ☐

9. TREES

Does the proposal involve the felling of any trees?

Please tick one box Yes ☐ No ☐

If Yes, please show details on plans

10. PLEASE SIGN AND DATE THIS FORM BEFORE SUBMITTING

I/We hereby apply for Full Planning Permission for the development described above and shown on the accompanying plans.

Signed ______ **Date** ______

Date

On behalf of (if agent) ______

BUILDING REGULATIONS APPLICATION

OFFICE USE ONLY
APPLICATION NUMBER

DATE RECEIVED

DATE VALID

Use this form to give notice of intention to erect, extend, or alter a building, install fittings or make a material change of use of the building.

Please return:
*3 copies of the Form
*3 copies of the Plans
*the correct fee

1. NAME AND ADDRESS OF APPLICANT
Applicant will be invoiced on commencement of work.

Post-code ______

Day Tel. No. ______ Fax No. ______
Email ______

2. NAME AND ADDRESS OF AGENT (If Used)

Post-code ______

Tel. No. ______ Fax No. ______
Email ______

3. ADDRESS OR LOCATION OF PROPOSED WORK

4. DESCRIPTION OF PROPOSED WORKS

5. IF NEW BUILDING OR EXTENSION PLEASE STATE PROPOSED USE

6. IF EXISTING BUILDING PLEASE STATE PRESENT USE

7. DRAINAGE

Please state means of:
Water Supply ______
Foul Water Disposal ______
Storm Water Disposal ______

8. CONDITIONS

Do you consent to the Plans being passed subject to conditions where appropriate? Yes ☐ No ☐

Do you agree to an extension of time if this is required by the Council? Yes ☐ No ☐

9. COMPLETION CERTIFICATE
Do you wish the Council to issue a Completion Certificate upon satisfactory completion of the work?
Yes ☐ No ☐

10. REGULATORY REFORM ORDER (Fire Safety) 2005
Is the building intended for any other purpose than occupation as a domestic living unit by one family group?
Yes ☐ No ☐

11. FEE
Please state estimated cost of the work (at current market value) £ .... Amount of Fee submitted £ ....
Has Planning Permission been sought? Yes ☐ No ☐ If Yes, please give Application No ______

12. PLEASE SIGN AND DATE THIS FORM BEFORE SUBMITTING
I/We hereby give notice of intention to carry out the work set out above and deposit the attached drawings and documents in accordance with the requirements of Regulations 11. Also enclosed is the appropriate Plan Fee and I understand that a further Fee will be payable when the first inspection of the work on site is made by the Local Authority.

Signed ______ **Date** ______ **On behalf of (if agent)** ______

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