ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

BUILDING CONSTRUCTION (CENG 3112)

LECTURE NOTE

APRIL, 2020

COURSE NUMBER: CENG3112

COURSE TITLE: BUILDING CONSTRUCTION

COURSE DESCRIPTION

This course is intended to cover:

- General Introduction;
- .**Building Drawing and Functional Planning of Buildings;**
- **Building structural systems**; reinforces concrete structures, steel framed structures, timber structures and prefabricated building elements
- **Building construction elements**
    - **Foundation:** Definition, types, function, Soil Investigation, construction materials and methods.
    - **Floors**: Types of floors, ground & suspended floors, construction materials and methods, floor finishes.
    - **Walls: types: materials and construction details.**
    - **Wall finishing**: types and construction details, plastering and painting;
    - **Roof**: types and functions, construction System, Roof covering;
    - **Other Building construction elements and systems:** stairs, doors and windows, damp proofing

COURSE OBJECTIVE

- Be acquainted with the overall building construction process and understand design and performance requirements of a building.
- Be able to read and prepare working drawings for building construction (Floor plans, elevations, sections and detail drawings).
- Be able to tell the merits and demerits and select different types of material for the structural system of a building.
- Be able to understand the design parameters required for planning of a building and prepare bubble diagram for functional arrangement of a building.

- Be able to understand the purpose, functional requirement, types, suitability and construction details of different elements and system of a building (foundation, floor, wall, stairs, Doors & windows, roof, finishing and etc.)

COMPETENCES TO BE ACQUIRED/ COURSE LEVEL COMPETENCES

- An ability to demonstrate knowledge and understanding of the overall building construction process.
- An ability to read and prepare different types of working drawings (Floor plans, Elevations, Sections, Detail drawings and etc.)
- A capacity to consider different design parameters for planning of a building and prepare bubble diagrams.
- An ability to select the right type of materials for structural system of a building.
- An ability to demonstrate the knowledge and understanding of the purpose, functional requirement, types, suitability and construction details of different elements and system of a building (foundation, floor, wall, stairs, Doors & windows, roof, finishing and etc.)

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CHAPTER-1

INTRODUCTION

1.1 General

A **Building** can be generally considered as a structure consisting of floors, walls and roofs erected to provide covered space for different uses such as residence, business, entertainment, workshop, etc. And **Construction** is a process of constructing something by man for one purpose or another. It may be a road, bridge, a dam, a dwelling place, an airport, a commercial building, etc. Buildings come in a wide amount of **shapes** and **functions**, and have been adapted throughout history for a wide number of factors such as; available building materials, weather conditions, land prices, ground conditions, specific uses and aesthetic reasons.

Buildings serve several needs of society – primarily as shelter from weather and as general living space, to provide privacy, to store belongings and to comfortably live and work. The initial causes which forced man to look for shelter were:

- Fear of wild animals
- Seeking protection against the cold and the heat
- Seeking shelter against the rain and wind
- The desire for a place where everything belonging to the family could be gathered

The main considerations in architectural design of buildings for all purpose are:

- Climate and its effect
- People and their requirements
- Materials for construction and method of construction
- Regulations and building codes

Requirements which must be satisfied for the construction of a modern house are:

- A plot of land
- Permission from local authorities
- Materials for building
- Skilled labourers for the erection
- Finance
- Professionals, such as architects and engineers

1.2 Definition of Terms

Building: is an assemblage that is firmly attached to the ground and that provides total or nearly total shelter for machines, processing equipment, performance of human activities, storage of human possessions, or any combination of these.

Building design: is the process of providing all information necessary for construction of a building that will meet the owner's requirements and also satisfy public health, welfare, and safety requirements.

Building construction: is the process of assembling materials to form a building based on the building design.

1.3 Building Classifications

Buildings can be generally classified in different groups depending upon their occupancy of use or type of construction.

Classification Based On Occupancy

- Residential buildings
- Educational buildings
- Assembly buildings
- Business buildings
- Mercantile buildings
- Industrial buildings
- Institutional buildings
- Storage buildings
- Hazardous buildings

Classification Based On Types Of Construction

- Type1: Fire-resisting construction
- Type 2: Non-combustible construction
- Type 3: Heavy timber construction
- Type 4: Ordinary construction
- Type 5: Wood frame construction

1.3.1. Classification based on occupancies

- **Residential buildings:** include houses occupied by persons where living accommodations are provided, such as private residences, apartments, dormitories, hotels, etc.

- **Educational buildings:** include any building used for educational instructions such as schools and universities.
- **Assembly buildings:** include any building where group of people gather for amusement, recreation, social, political, religious and similar purposes, like theatres, halls, places of worship, etc.
- **Business buildings:** any building which is used for the transaction of business, for professional services and for keeping accounts & records for similar purpose, such as garages, barbershops, city halls, courthouses, libraries, etc.
- **Mercantile buildings:** any building which is used as shops, stores, market, and for display and sale of merchandise like Shopping malls.
- **Industrial buildings:** Any building or structure, in which products or materials of all kinds are fabricated, assembled, finished or processed such as assembly plants
- **Institutional buildings:** any building which is used for purposes such as medical or other treatment or care or for penal or correctional detention such as hospitals, prisons, etc
- **Storage buildings:** any building which is used for storage or sheltering of goods, merchandise, agricultural products, raw materials such as ware houses, barns, etc
- **Hazardous buildings:** any building used for storage, handling, manufacturing or processing of highly inflammable, combustible or explosive materials such as explosive storage.

1.3.2. Classification based on type of construction

Buildings are classified on the basis of resistance to fire of the elements of the buildings.

- **Type-1 Fire-resisting construction:** Type of construction in which the elements of the building, which include the floors, walls, columns and the roof itself, are non-combustible. The building is sufficiently fire resistant that it withstands the effect of fire and prevents its spread to other rooms.
- **Type-2 Non-combustible construction:** Construction in which the walls, partitions, structural elements etc. are non-combustible with less fire resistance than Type 1.

- **Type-3 Heavy timber construction:** Exterior walls are out of masonry or other non combustible material. Interior structural members, floors and roofs are constructed out of timber either in solid or laminated forms.
- **Type-4 Ordinary construction:** Exterior walls are out of masonry or other non combustible material. Interior structural members could be partially or wholly out of wood of relatively smaller sections unlike Type 3.
- **Type-5 Wood frame construction:** Type of construction in which practically the whole of the building is out of wood or other combustible materials.

1.4. Components of a building

A building has two basic parts:

a. **Sub-structure:** is the lower portion of the building, usually located below the ground level, which transmits the loads of the super-structure to the supporting soil. It includes foundations, basement, and retaining wall.
b. **Super-structure:** is that part of the structure which is above the ground level, and which serves the purpose of its intended use. It may include walls, floors, structural members, roof structures, building finishes, doors, windows and other openings, and vertical transportation like stair and elevators.

1.5. Design and performance requirements

A building structure should satisfy the following basic design and performance requirements

A. The structure should have adequate ***margin of safety*** (factor of safety) in addition to that necessary to support its normal loading.

B. It must have ***sufficient stiffness*** so that its distortion does not offend the eye or reduce the efficiency of the structure for its normal purpose.

C. The building should be planned to provide sufficient ***comfort and convenience*** to the occupants of the building.

To accommodate the basic functional requirements, a building should satisfy the following requirements in its design and construction works:

i. **Strength and stability:** Any structural component of a building should be strong enough to carry or support all possible types of loads to which it is likely to be subjected. The Loads in a building are commonly classified as: dead loads, super imposed or live loads and wind loads.

Dead loads: are static loads due to the weight of the respective structural members, i.e. The wall partitions, roofs, slabs and all other permanent fixtures in the building.

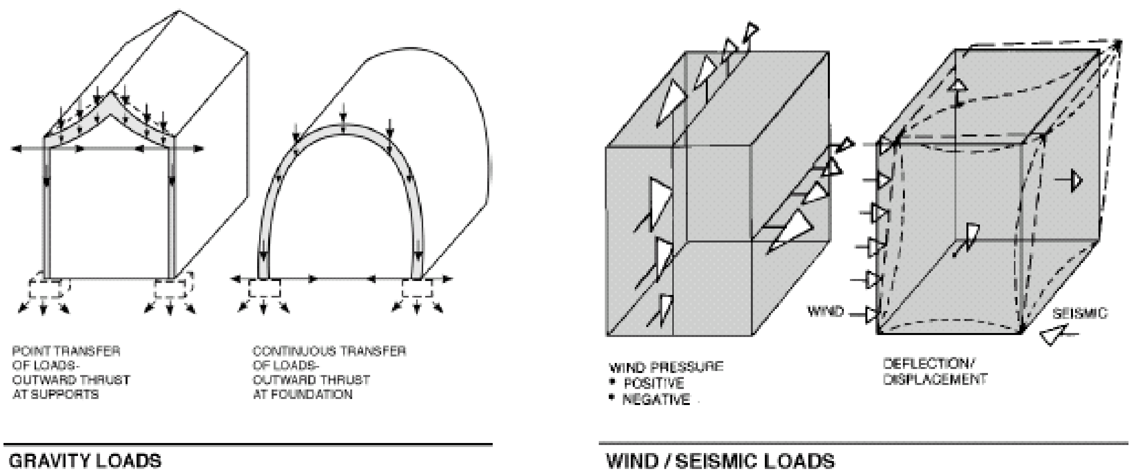


Fig. 1.1 Loads in buildings

Live loads: also called as super-imposed loads, consist of moving or variable loads, due to people or occupants, their furniture, temporary stores, machinery, etc.

Wind loads: are loads, which can cause uplift on a building and reduce the pressure on the foundation on the windward side and increase pressure on the leeward side. The effect of wind pressure increases with the height of the building.

ii. **Dimensional stability:** Refers to the resistance to dimensional changes in building materials and structures caused due to:

- elastic and plastic deformations as a result of applied loads
- expansion and contraction due to changes in temperature and moisture content.

iii. **Comfort and convenience:** Should be satisfied by proper planning of the buildings and its units. The designer can achieve this by optimum utilization of space, lighting considerations and by providing good orientation

iv. **Resistance to moisture penetration:** The presence of moisture in any building structure deteriorates the materials strength, reduces durability and could cause partial or total failure of the structure.

v. **Fire protection:** A building structure should not ignite easily and should be designed to reduce the spread of fire. Plus a building should provide means of fire escape

vi. **Heat insulation:** The building should be designed in such a way to maintain fairly constant temperature of the internal environment independently of the varying climatic conditions externally.

vii. **Day light and ventilation:** Day lighting is essential to promote the activities carried in the building and to create pleasant inside environment. Ventilation is essential to prevent undue concentration of odours, fumes, dust, etc and maintain suitable condition for the user of the building.

viii. **Sound insulation:** The insulation of noise is a very important requirement for buildings such as hospitals, educational institutions, offices and residential building located in noisy areas.

ix. **Durability:** The durability of a building is defined as the time over which a building remains serviceable and depends mainly on, type of building materials, environmental exposure, quality of workmanship and degree of maintenance, etc

x. **Security:** Due considerations should be given in designing and constructing external walls and openings to protect a building against burglary or theft

xi. **Economy:** The designer must exercise economy at every stage of planning, design, construction, maintenance and operation.

1.6 Project life cycle of a building

The project life cycle of a building is summarized as follows;

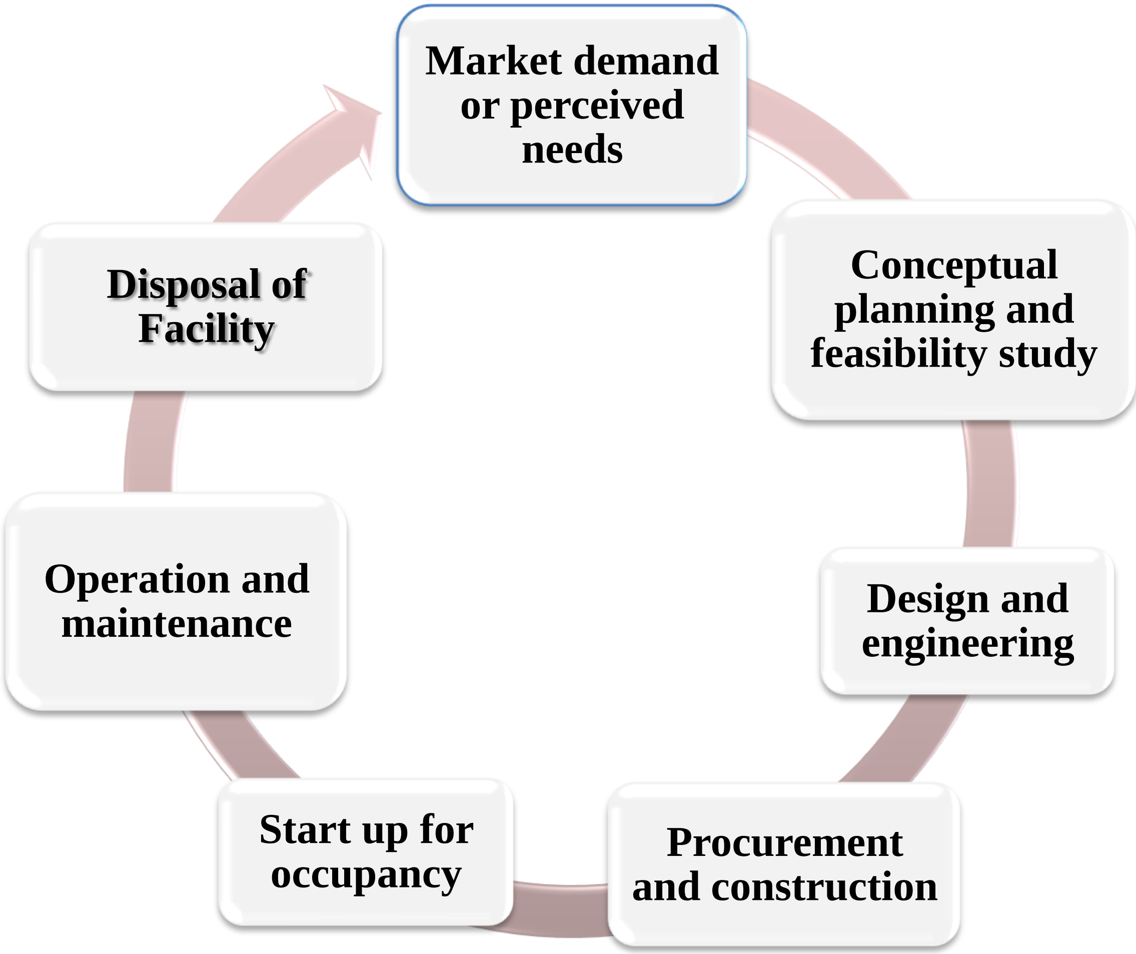


Fig. 1.2 Project life cycle of a building

1.7. Main Parties in Building Construction Project

The practice of **planning**, **designing**, **constructing**, and **operating** buildings is most usually a collective effort of different groups of professionals and trades. Depending on the **size**, **complexity**, and **purpose** of a particular building project, the project team may include:

I. **Client:** The client is the most important party who is active from inception to completion and event to post-occupancy maintenance. Clients may be classified as ***Public sector clients*** and ***private sector clients***.

- **Public sector clients -** Central Government Offices (Ministries), Local Authorities (Regional or Town) and Public Corporations.
- **Private sector clients -** These are private individuals & private companies.

Duty of the Client in a building project includes: availability and cost of land, location & accessibility, price, required infrastructure, legal constraints, current & future development, soil characteristics of land, site preparation (right of way), and permits.

II. **Consultant:** The main role of the consultant is to interpret the client's project requirement into a specific design.

The consultants' team shall:

- Ascertain, interpret and formulate the client's requirement into an understandable project.
- Design the project to much requirements and constraints (imposed by statutory obligations, technical feasibility, environmental factors, site conditions, cost, etc)
- Assess client's cost limit to decide on materials & the like.
- Prepare contract documents.
- Supervise the project and constantly inform the client on the progress
- Approve payments
- Resolve contractual disputes
- Issue provisional and final acceptance certification

III. **Contractor:** These are groups established mainly as commercial companies, that contract to construct development projects. Responsibility of contractors include:

- Carry out a full site investigation prior to submission of tender,
- Submit tender,
- Plan, Program, Control the construction process.
- Notify the consultant about delays, discrepancies,
- Effect all payments to his employees, suppliers, subcontractors,
- Rectify all defects on completion of works, etc
- Provide post occupancy repair & maintenance if required.

IV Public Sector Agencies

A. **Statutory Authorities**: These bodies offer technical advice during design and construction in their respective areas. E.g. EEPCO, AAWSA, Fire Authority - requires meeting their specific requirements. Thus early information to these authorities is required.

B. **Municipalities and Government Authorities**: These bodies offer the basic Land permit and building permit.

In addition, there are also other stakeholders that involve in the construction of building project. Some of them are listed below;

- **Financial institutions or other investors** that provide the funding
- **Local planning and code authorities**
- **Marketing or leasing agents**
- **Facility managers** who are responsible for operating the building.

1.8. Resource for Building Construction

The following resources are vital for construction industry:

A. **Human resource (Labour or Workmen)**: These include professional, skilled, semi skilled and unskilled laborers. Human resources can be understood in two values: **Capacity** and **Capability**.

- **Capacity** - refers to the ***quantity*** of labor for the scope defined.
- **Capability** - refers to ***knowledge***, ***technology know-how*** and ***skill*** as per the demands of the scopes ability.

B. **Financial Resources (Fund):** Usually funds are available from among Governmental institution, Private institutions and Donors in the form of loan or assistance.

C. **Information Resources:** Information can be understood in two terms: **data** whether processed or not; and its **technology**.

D. **Physical Resources**

i. **Materials:** Material covers 55-70% of the total construction cost.

ii. **Equipments**: Though their initial cost is high using equipments are far more better than using labor.

iii. **Other assets**: Physical Infrastructures and Owned Land are assets which can be collaterals for capital base enhancement and credit facilities and are useful to develop the scarce financial resources and getting into business access.

E. **Service and Management**

i. **Service**: Services such as acquisition of land, provisions of water supply, electric power, communication systems, etc., are very much necessary in the construction industry.

ii. **Management**: Management has come to employ a disciplined approach to the use of available resources.

CHAPTER-2

BUILDING DRAWINGS

2.1 Introduction

Construction drawings are prepared so that designers can communicate their requirements to the contractor in a **clear**, **concise** and **unambiguous** manner. They are also used to prepare bill of quantities and as part of contract document.

Building construction drawings shouldn't be unnecessarily congested or complicated. And written descriptions should be as brief as possible. In addition, building drawings should be well dimensioned and should be drawn to scale

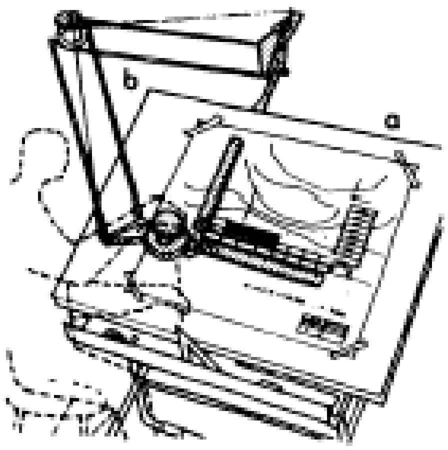
Construction drawings can be prepared by hand assisted by various templates or computer software programs (Ex. AutoCAD).

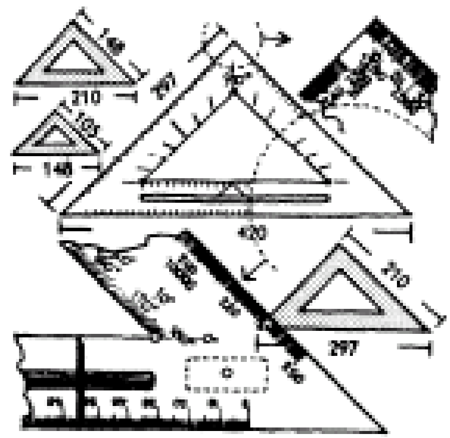
The use of computer programs in building drawing:

- Enables users to produce any type of drawings **quickly**, **precisely**, and **efficiently**
- Enables **editing**, **adding** or **deleting** texts to drawings
- Enables printing to required **sizes** and **color**
- It can easily be communicated via networks and e-mails and integrated with other programs
- Enables to reduce contract time and eases communication between parties in construction.
- Minimizes the need for storage space

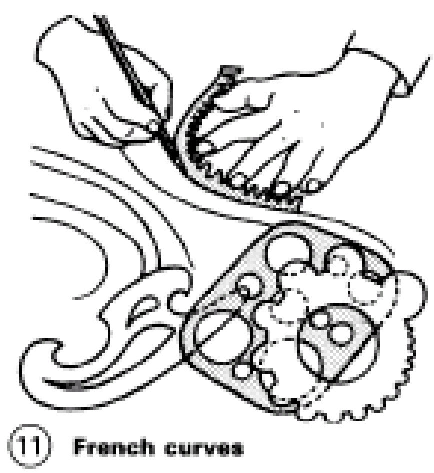
2.1.1Drawing Equipment

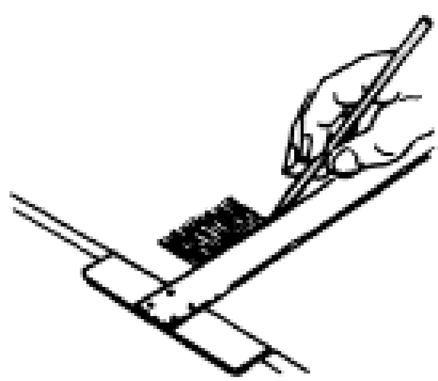
In order to produce construction drawings manually, items like drawing board, drawing paper, drawing pencil, ruler, ink, eraser, various time saving devices such as templates, protractor, T-square, setsquares, etc. are required.





Drawing board Set squares





French curves T-square

Fig. 2.1 Drawing Equipments

2.1.2 Standard size of drawing papers

Generally it is advisable to use international standard-size papers in drawings to facilitate filling of drawings.

Table 2.1 Standard size of drawing papers

Format	A Series	B Series	C Series
0	841 x 1189	1000 x 1414	917 x 1297
1	594 x 841	707 x 1000	648 x 917
2	420 x 594		
3	297 x 420		
4	210 x 297		
5	148 x 210		
6	105 x 148		
7	74 x 105		
8	52 x 74		

2.2 Drawings for building construction

Drawings for building construction shall include:

I. Site plan
II. Sketch drawings
III. Working drawings
IV. Detailed drawings
V. Construction drawings and
VI. Installation drawings

I. Site Plan

A site is a parcel of land which is made up of one, two or more plots. A site plan is a drawing showing various properties in terms of their owners, locations, elevations, states of development and features such as roads, utility supply lines, etc.

Components of a site plan

- **Survey beacons:** these are concrete pillars located at principal corners of the site and at every change in the direction of boundaries. They define the boundary and area of the site.
- **Elevations:** these are the different heights on the surface of the site in relation to a standard reference point known as the bench mark (BM). Locations which have equal elevations are joined together using contour lines. These lines help to define the topography of the land within a site.
- **Site orientation:** these refer to a system of defining the site in terms of its direction to the north, south, east and west. Orientation is important in planning the building area to make into consideration such factors as the direction of rain, wind and sun within the site.
- **Physical features:** these are permanent objects or features existing within the site or adjoining sites which are used for referencing or identification of the site. **Ex.** Existing buildings, trees, roads, fences, etc.
- **Access road:** these shows the means of reaching the site.
- **Utilities:** A site plan shows utility supply lines such as for water, electricity and gas.

The scales used in a site plan drawing depend on size of the site. For small sites: Scales of 1:100, 1:200, and For large sites: Scales of 1:500, 1:1000, 1:2500

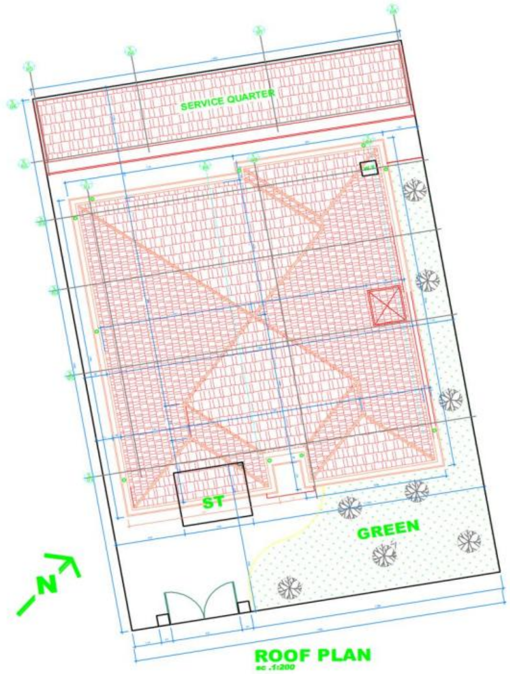


Fig 2.2 Example of Site plan drawing

II. Sketch drawings

Sketch drawings are preliminary drawings prepared for showing the general arrangements of buildings. They are often drawn free hand in pencils. They comprise plans of the most important storey, one or more elevations and a cross-section of the building.

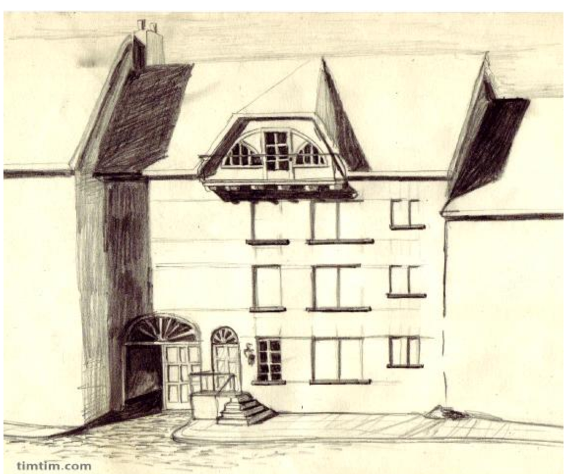


Fig. 2.3 Example of Sketch drawing

III. Detailed drawings

They are prepared to the extent necessary and depending on the complexity of the building. They can be prepared to a scale of 1:1, 1:5, 1:10, or 1:20. They usually show specific details, such as in stair cases, gutter to down pipe connections, wall to foundation connection, metal and wood joineries, etc.

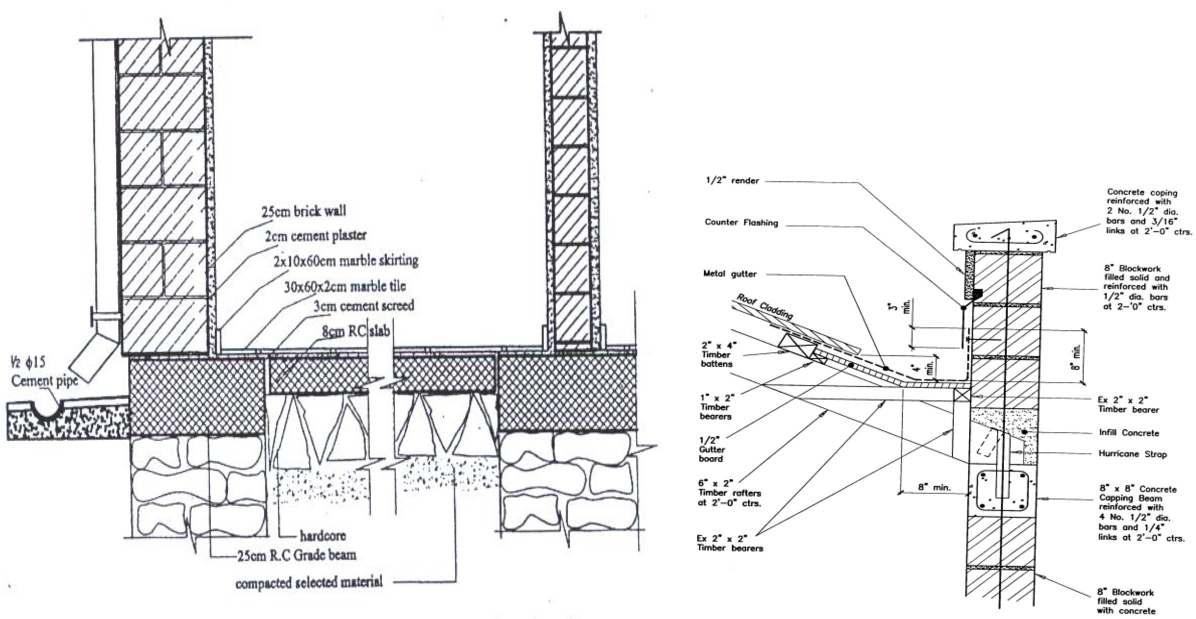


Fig. 2.4 Example of Detail drawing

IV. Construction drawings

They are prepared mainly for the foundation work, for construction in steel, concrete, roofing and wood works. They provide important information for the resident engineer and foremen in the execution of their day-to-day activities.

V. Installation drawings

Installation drawings comprise of drawings for water and drainage pipes, electrical installation as well as mechanical installation. For residential building a scale of 1:50 is normally preferred.

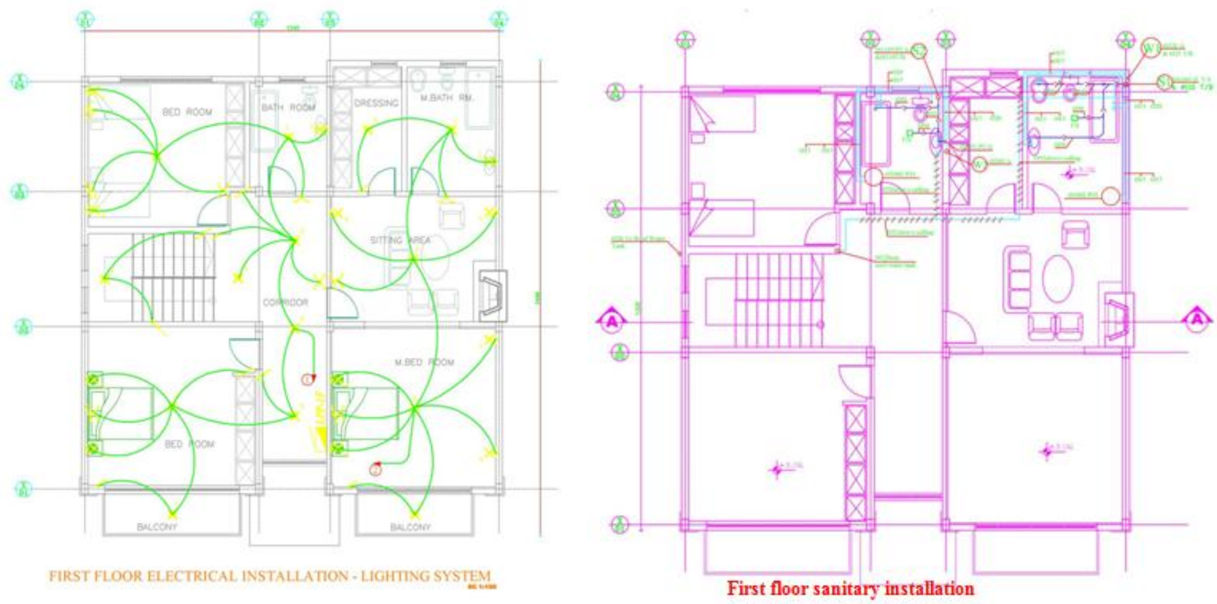


Fig. 2.5 Example of Installation drawing

2.3 Working drawings

They are prepared in greater detail with all dimensions given to avoid the need for taking measurements from scale. They comprise of all plans and elevations as well as an adequate number of cross-sections. The materials to be used for the various parts of the building should be indicated in different symbols. They are the most important components of building drawings since they provide detail information on the internal as well as the external view of a building. They are usually prepared using a scale of 1:50.

a. **Floor plan drawings:** The floor plan is a drawing of the outline and partitions of a building that would be seen when the building was cut horizontally about 1.2m above the floor level. It provides more specific information about the design of the building than any other plan. It is used as the base for the projection of other drawings. The major steps in floor plan drawings preparation are:

- Laying center line of walls,
- Marking window and door openings,
- Marking wall thickness,
- Locating furniture positions,
- Indicating material type,

- Adding measurements and other details.

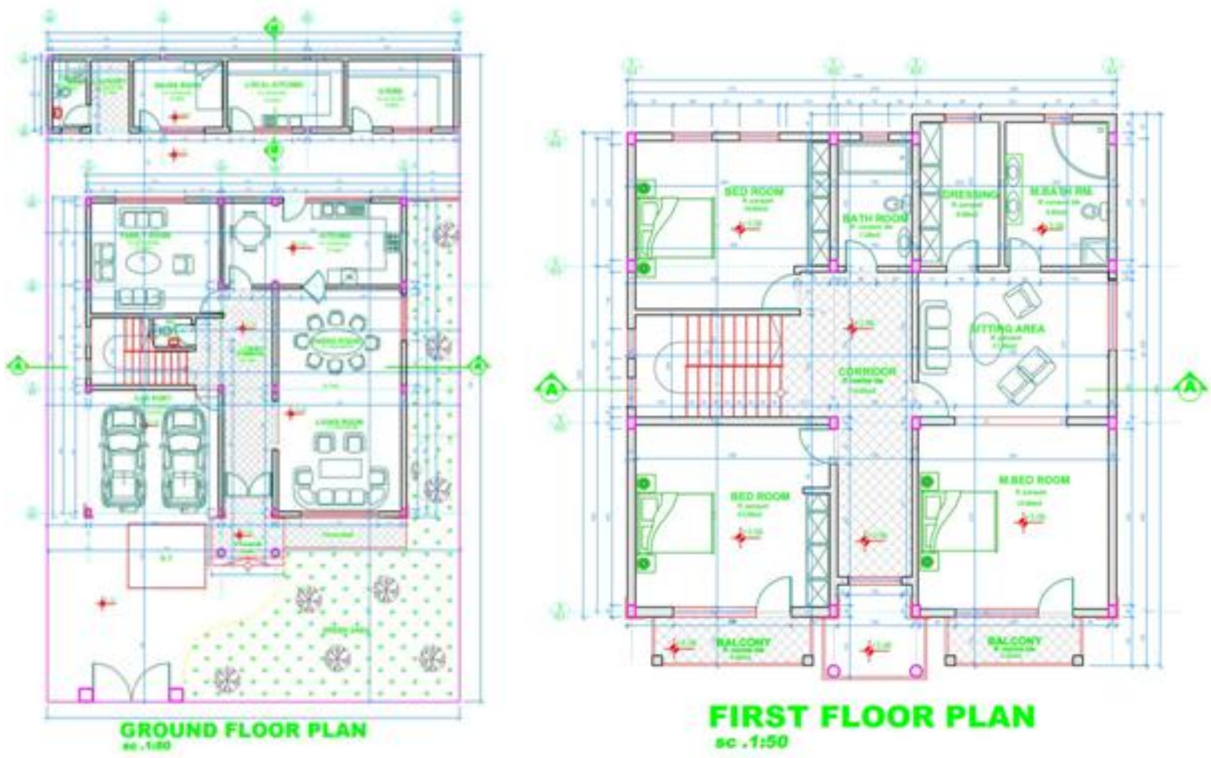


Fig. 2.6 Example of Floor plan drawing

b. **Elevation drawings:** Elevation drawings are orthographic drawings of the exterior of a building. They are prepared to show the design materials, dimensions, and final appearance of the exterior of a building. Elevation drawings are projected from the floor plan of an architectural drawing. The major steps in projecting elevations are:

- Projecting vertical lines
- Projecting horizontal lines
- Locating roof lines
- Adding elevation symbols
- Providing elevation dimensions
- Description of material used and finishing type

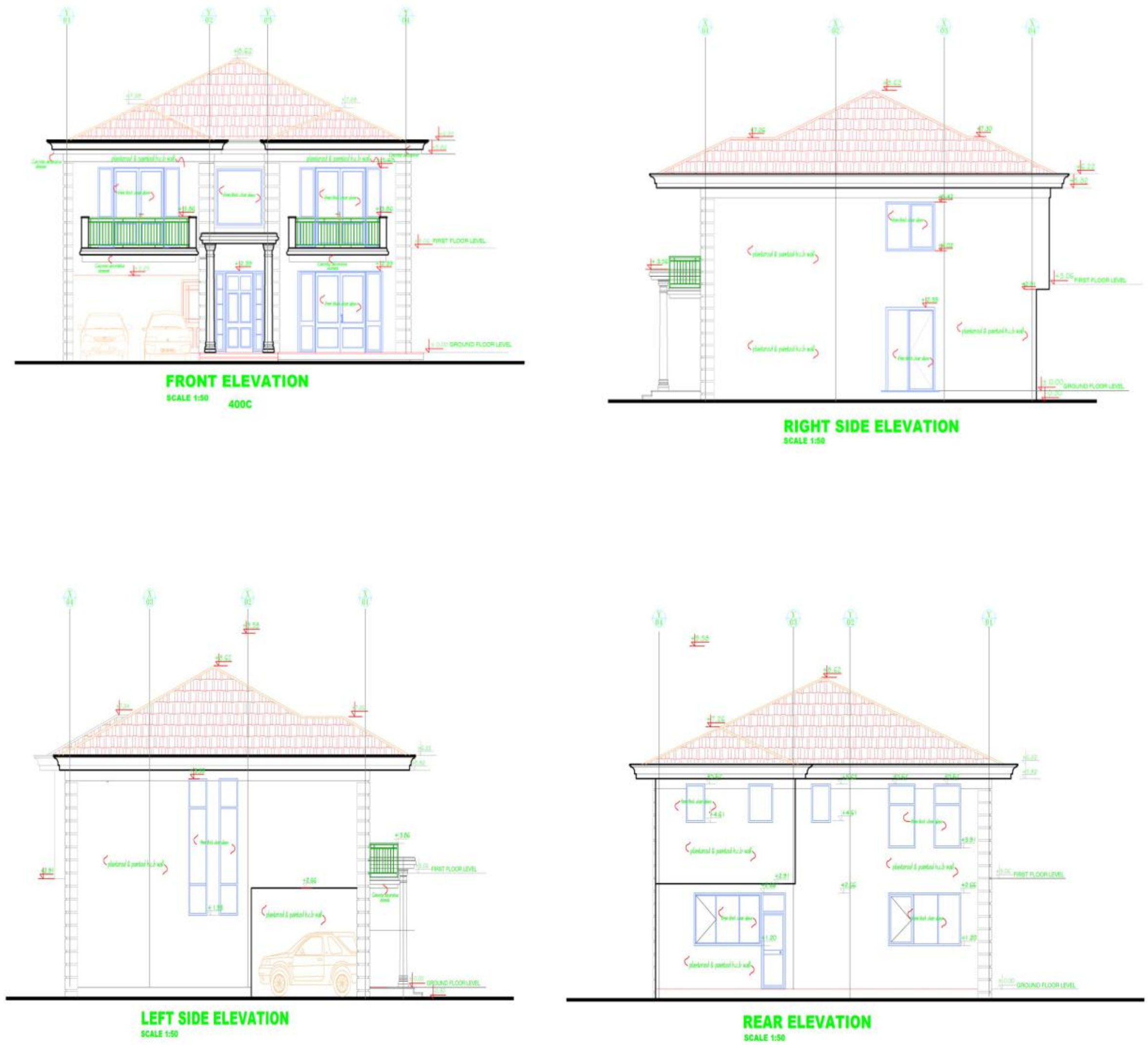


Fig. 2.7 Example of Elevation drawing

c. **Sectional drawings:** Sectional drawings reveal the internal construction of an object. Architectural section drawings are prepared for the entire structure (full sections) or for a specific part(s) of a building (detail sections). The cutting plane is an imaginary plane, which passes through the building and divides it into sections. These sections can be Longitudinal section, Transverse section or Offset section. Removed sections are frequently drawn for areas such as footings, window sill, cornice, gutter line and ridge sections.

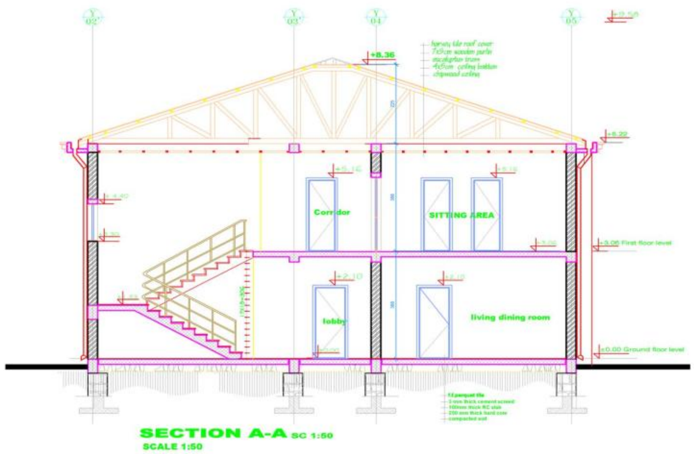


Fig. 2.8 Example of Sectional drawing

2.4 Hatchings, Symbols and Notations

2.4.1 Hatchings

The main objective is to differentiate between the materials being used thus enabling rapid recognition and location. They must be used consistently throughout the whole set of drawings. In large areas it is not always necessary to hatch the whole area.

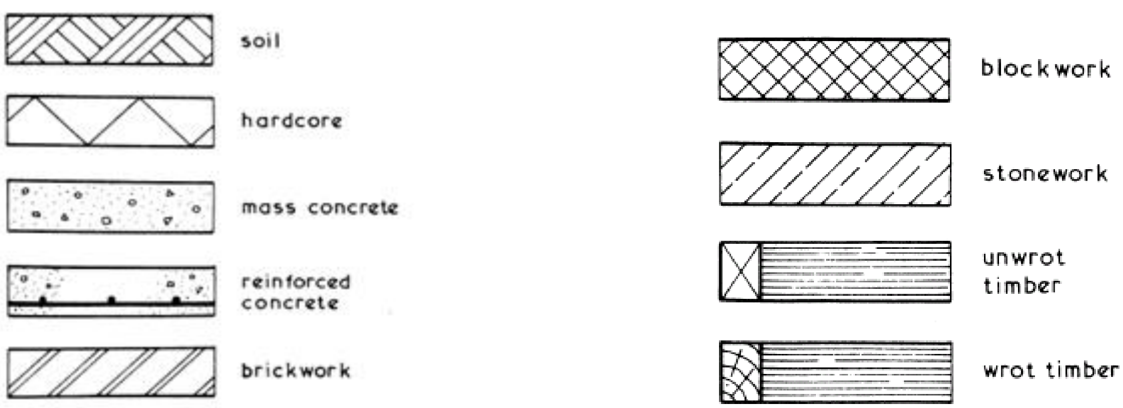


Fig. 2.9 Hatchings in Building construction drawings

2.4.1 Symbols and Notations

These are graphical representations and should wherever possible be drawn to scale. They must be consistent for the whole set of drawings and clearly drawn.

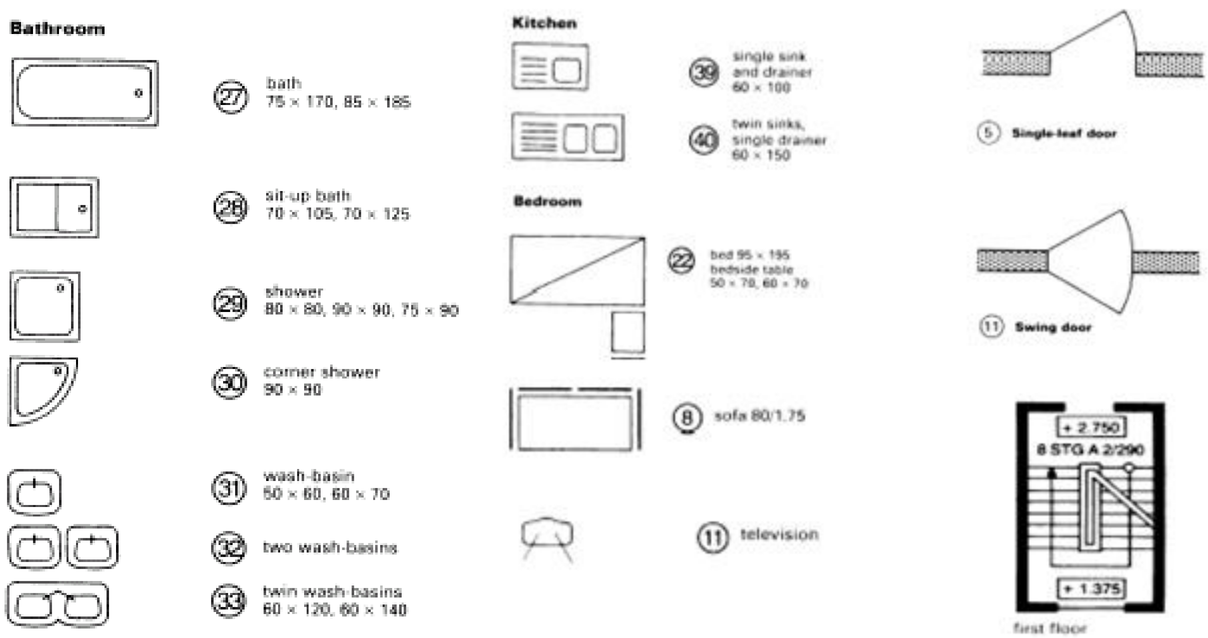


Fig. 2.9 Symbols in Building construction drawings

CHAPTER-3

BUILDING STRUCTURAL SYSTEMS

3.1 Introduction

Structural systems of a building support all loads and resist all constraining forces that may be reasonably expected to be imposed on them during their expected service life. And these systems serve without causing any hazard to users, dangerous deformations, excessive side sway (drift) or annoying vibrations. Loads and environmental forces acting on structural systems are; gravity loads, wind/seismic loads, expansion/contraction of material, heat, cold, moisture and precipitation.

Structural systems could be either of concrete, steel, timber, prefabricated element or a combination. The selection of appropriate structural system or combination of systems depends on; Soil conditions, the program and concept (function of a building), applicable codes, type of building, material delivery and construction timing, local construction capabilities and preferences, ease of construction and schedule, cost of the selected system, cost impact on other systems, appearance and aesthetic potential.

3.2 Reinforced concrete structures

Concrete is a product obtained artificially by hardening of the mixture of binding material (cement), fine aggregate (sand), coarse aggregate (gravel), and water in predetermined proportions. The property of concrete depends on the characteristic of the ingredients and the proportion of the mix. In mix proportioning **workability**, **strength**, **durability** and **economy** should be taken into consideration.

Concrete works are classified as:

- **Class I** - works under the direction of qualified supervisor
- **Class II** – works with lower level of quality

Concrete works can further be classified in different manner, some are mentioned below

Classification of concrete based on density

Classification	**Density (Kg/m^3)**
Normal-weight concrete	2400
Light weight concrete	1800
Heavy weight concrete	3200

Classification based on strength

Classification	**Maximum strength**	**Type**
Ordinary concrete	< 20	Low-strength
Standard concrete	20-40	Medium-strength
High-strength concrete	40-80	High-strength

Advantages and disadvantages of concrete structures

Advantages

- High compressive strength
- High stiffness (rigidity)
- Ability to be cast
- Low thermal and electrical conductivity
- Economical
- Durable
- Fire resistant
- Energy-efficient
- Onsite fabrication
- Aesthetic properties

Disadvantages

- Low tensile strength
- Limited ductility
- Little resistance to cracking
- Volume instability
- Low strength to weight ratio
- Forms and shoring

Reinforced concrete (**RCC**) is a concrete in which steel reinforcement bars have been incorporated to eliminate the major weakness of concrete (**tensile strength**). The number, diameter, spacing, shape and type of bars to be used have to be designed.

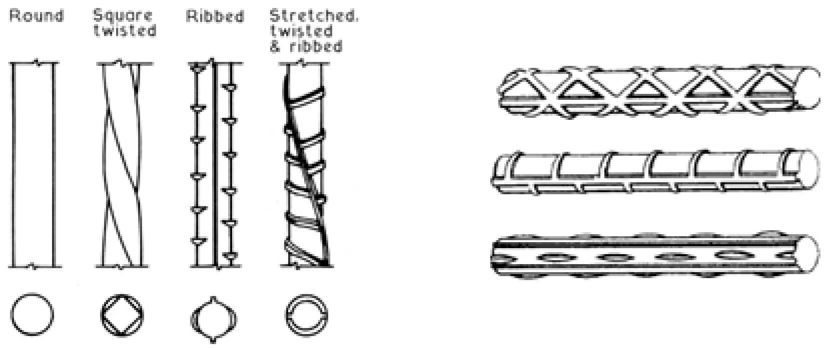


Fig. 3.1 Reinforcement Steel

A reinforced concrete structure is made up of many types of reinforced structural members, including; **footings**, **columns**, **beams**, **slabs**, **walls**, and so forth.

Footings

Footings support the entire structure and distribute the load to the ground. The size and shape of a footing depend upon the design of the structure.

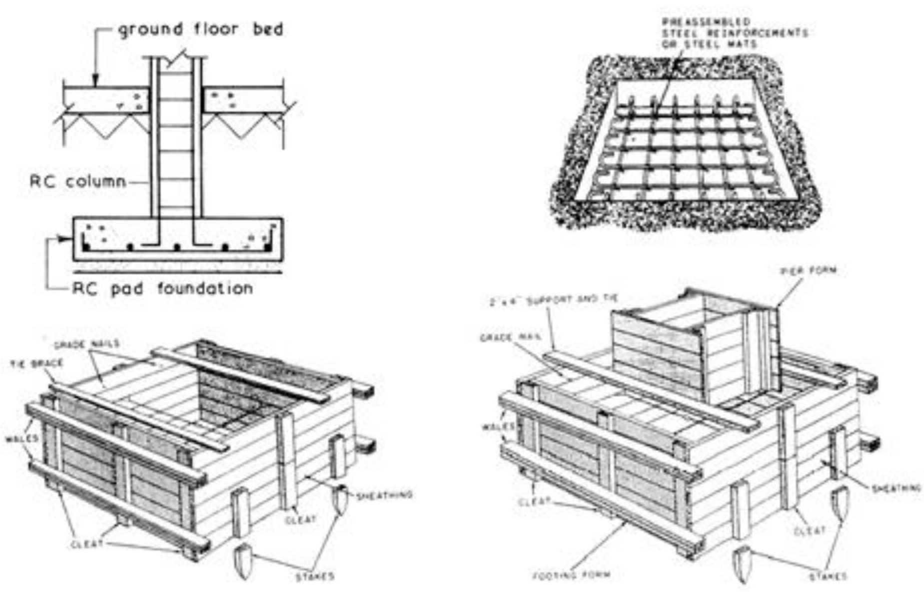


Fig. 3.2 Typical footing drawing

COLUMNS

These are the vertical load bearing members of the structural frame which transmits the beam loads down to the foundations.

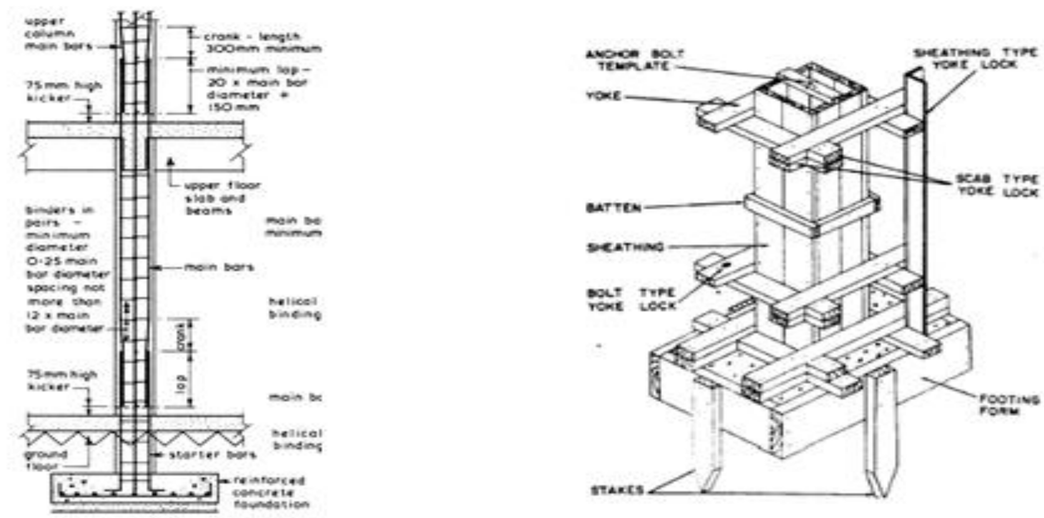


Fig. 3.3 Typical column drawing

BEAMS

These are horizontal load bearing members which are classified as either **Main beams** which transmit floor and secondary beam loads to the columns or **Secondary beams** which transmit floor loads to the main beams.

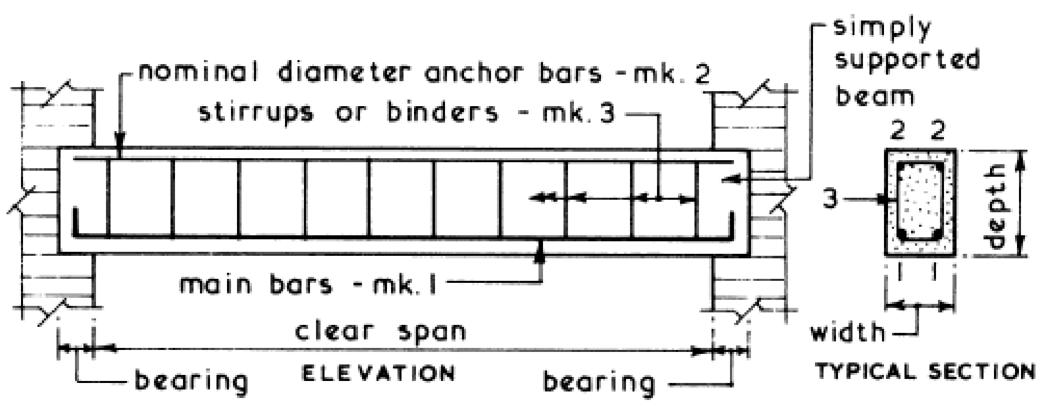


Fig. 3.4 Typical beam drawing

SLABS

Carry the live and dead loads of a building and transfer them to the beams or walls.

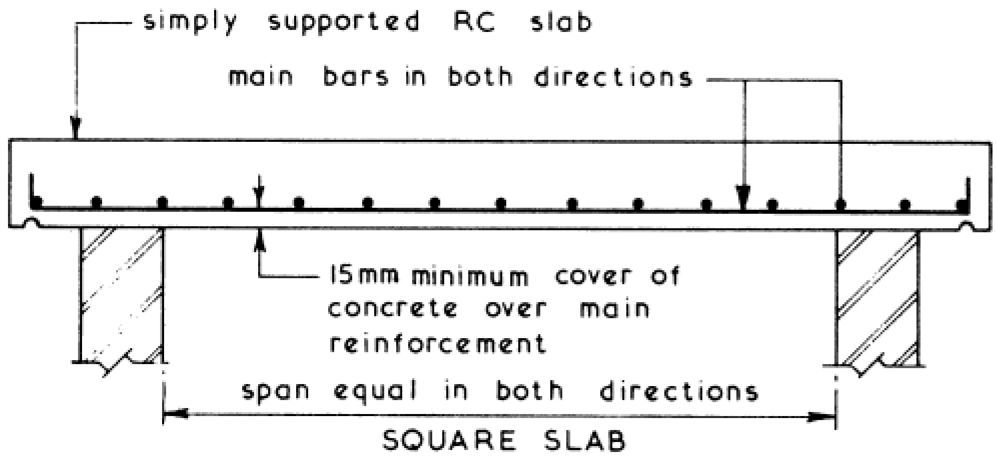
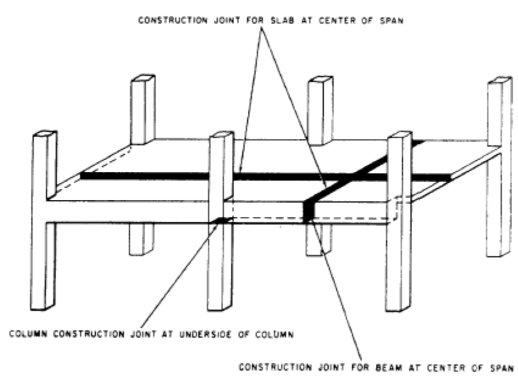
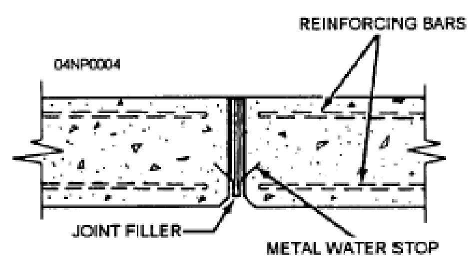


Fig. 3.5 Typical Slab drawing

JOINTS IN CONCRETE STRUCTURES

- **Contraction joints**: the purpose of contraction joints is to control cracking caused by temperature changes.
- **Expansion joints**: Wherever expansion might cause a concrete slab to buckle because of temperature change, expansion joints are required.





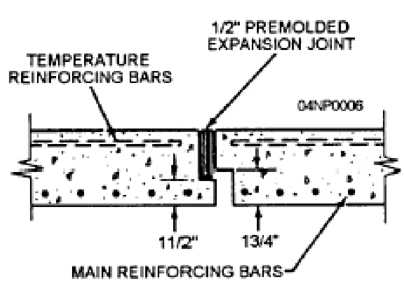


Fig. 3.5 Typical Slab drawing

3.3 Steel Framed Structures

Steel has the maximum number of properties which are not found in any other materials. Some of them are listed below;

- High tensile and compressive strength
- Ability to deform plastically with out damage
- Can be easily welded, forged and riveted
- Large displacement before collapse

Steel is the only material which is equally strong both in tension and compression. Steel is suitable for all construction purposes in the present day practice. Steel bars are widely used as reinforcement in reinforced concrete structures. In addition, Steel frames are used in the construction of steel bridges, Skeleton works in building construction, long span construction, erection of towers, etc. The construction of a framework of structural steel involves two principal operations: **fabrication** and **erection**.

Steel Sections

- **Cold rolled sections:** Cold-formed shapes are relatively thin sections made by bending sheet or strip steel in roll-forming machines, press brakes, or bending brakes. Door and window frames, partitions, wall studs, floor joists, sheathing, and moldings are made by cold forming.

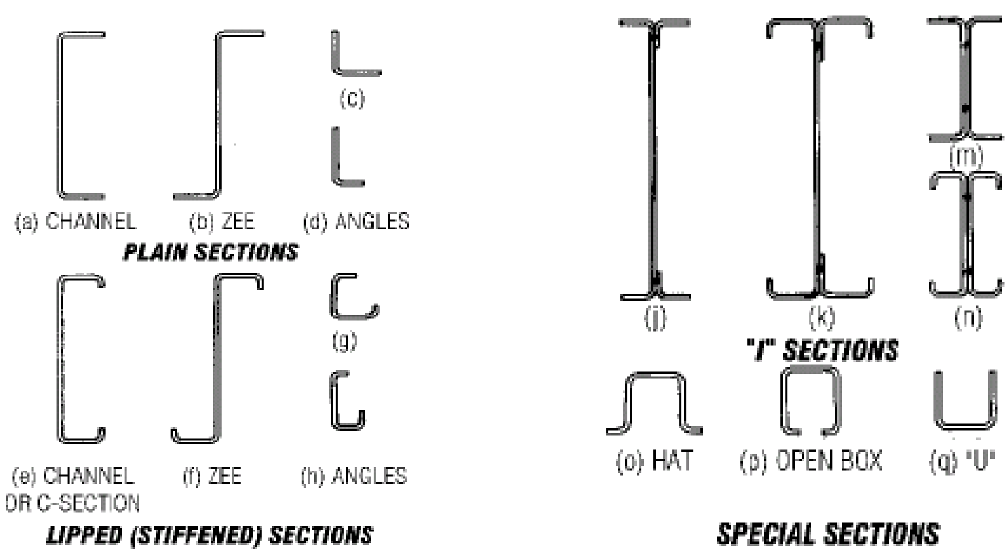


Fig. 3.6 Cold rolled steel sections

- **Hot rolled sections:** these are structural steel available in wide range of size, shape and weight.

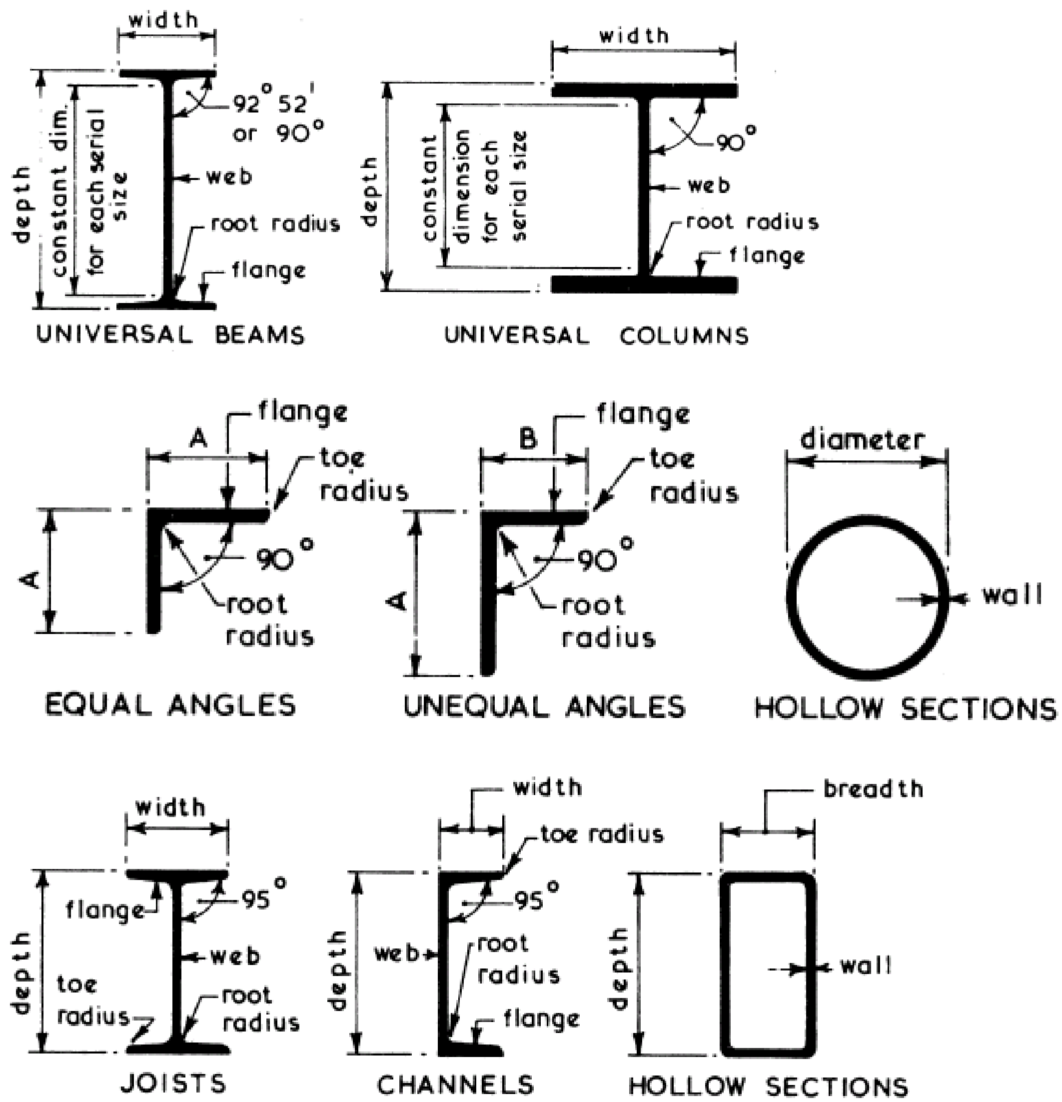


Fig. 3.7 Hot rolled steel sections

Structural Steel Connectors

There are four basic connectors used in making structural steel connections. They are **bolts**, **welds**, **pins**, and **rivets**.

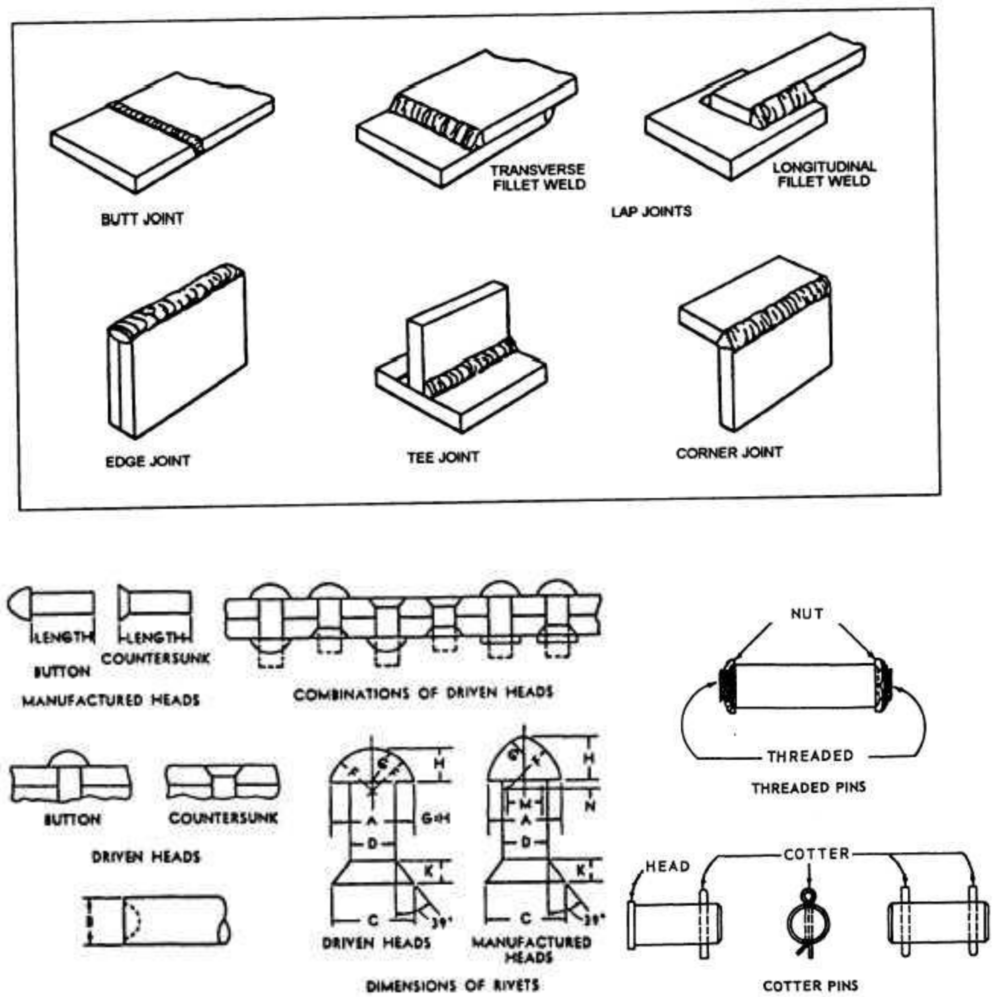


Fig. 3.8 Structural Steel connectors

Advantages and disadvantages of steel structures

Advantages

- High strength to weight ratio
- Non-combustible
- Recyclable
- Consistent material quality
- Safety: offers greater protection

Disadvantages

- Energy intensive material
- Susceptible to rust and corrosion
- Requires fire proofing
- Highly conductive
- Emission of gases during production

- Flexibility
- Inorganic: will not warp, split, creep, crack
- Dimensional stability
- Straight walls, corners
- Speedy construction

- Extra cost for protective coating

3.4 Timber structures

Wood has always been a very good construction material since olden times. And it is still used extensively for construction purpose, railways, furniture, formwork, miscellaneous articles, and transportation. Wood that is suitable for structural work is called timber. It can be used as;: beams, joists and rafters, Studs and posts, girders, trusses, decking, piles, and structural laminated members. The qualities of timber depend upon; type of tree, maturity of tree, time of felling, method of seasoning, and type and process of preservation.

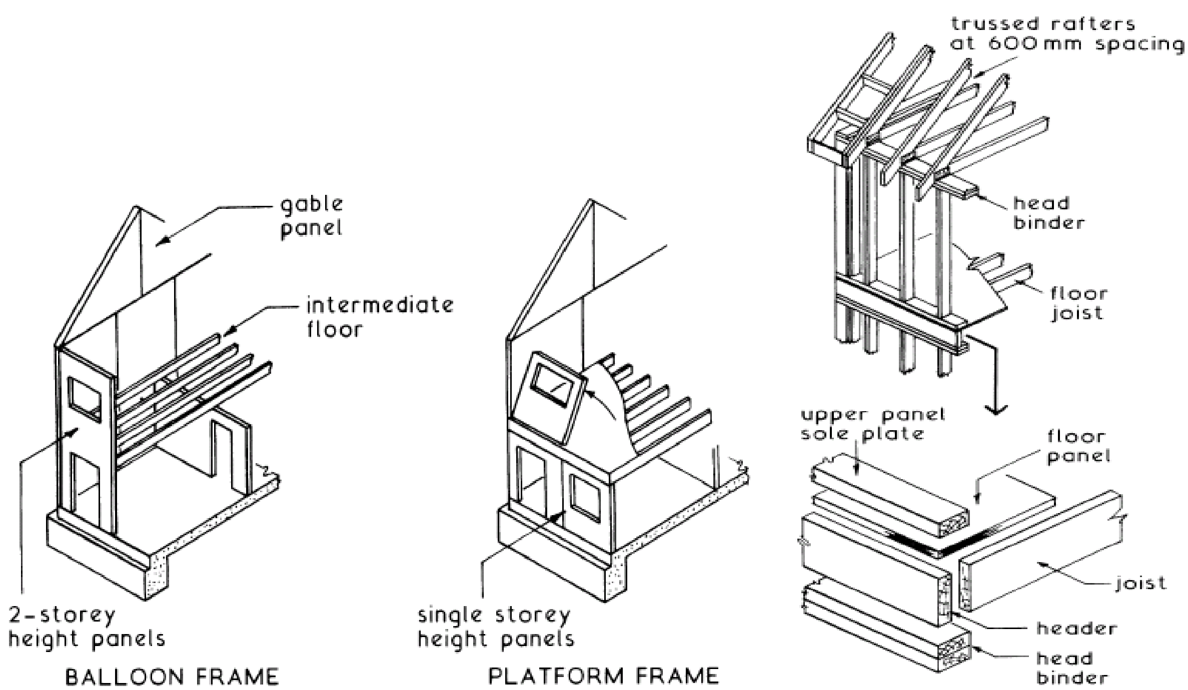


Fig. 3.9 Timber frame construction

Timber can also be used as a composite structure with steel or other materials.

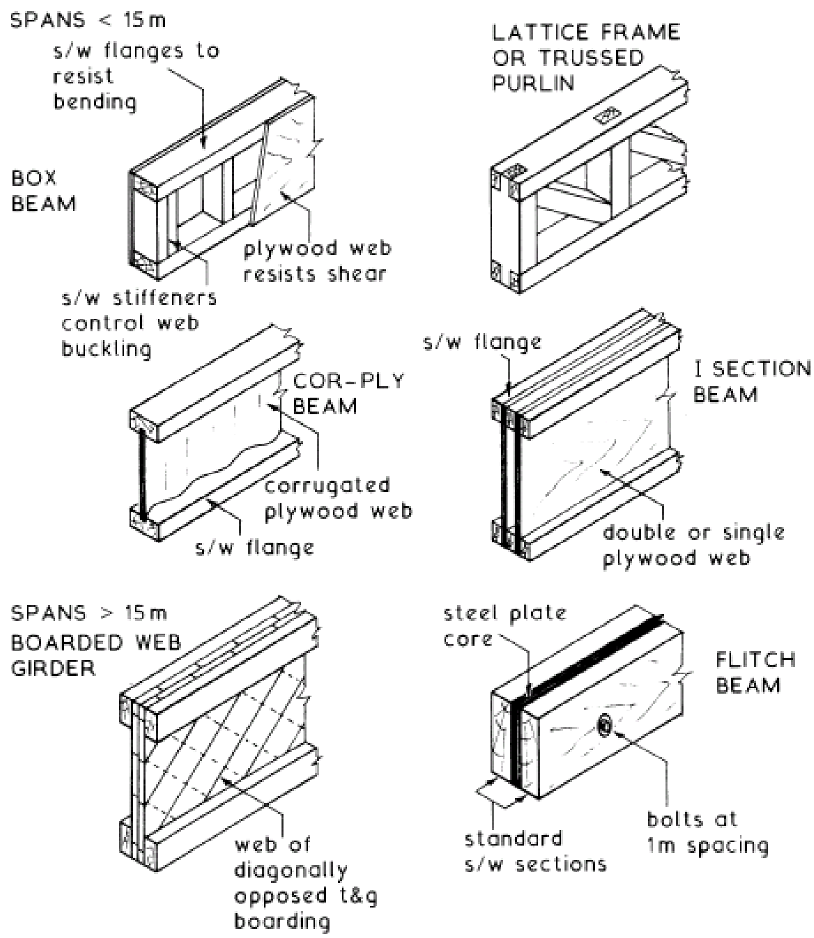


Fig. 3.9 Composite timber beams

Advantages and disadvantages of timber structures

Advantages	Disadvantages
• Quick erection time	• Additional design and engineering time
• Reduced site labour	• Susceptible to decay
• Reduced construction waste	• Very likely to warp and crack
• Easily converted to any shape	• Not fire resistant
• Economical and cheap	• Requires regular maintenance
• High strength to weight ratio	• Lack of experience of following trades
• Light weight structural members	

- Easy alteration and repairs
- Energy efficient in its production
- Non conductor of heat and sound

3.5 Prefabricated building systems

Prefabrication may be in general terms defined as a continuity of production implying; a steady flow of demands, standardization, integration of different stages of production, high degree of organization of work, and mechanization to replace manual labour. The prefabrication practice has advantages with respect to **cost**, **time**, **quality**, **safety** and **environment**.

Types of prefabrication approach:

- Fully Pre-fabricated Construction Method
- Partially pre-fabricated Construction Method
- Prefabrication of elements of the construction.

Fig. 3.10 Precast structural elements

Connections in precast concrete structures

Precast concrete structural members are transported from their production site and assembled in the construction site. The assembling process is done by using connectors which are installed in each precast concrete member.

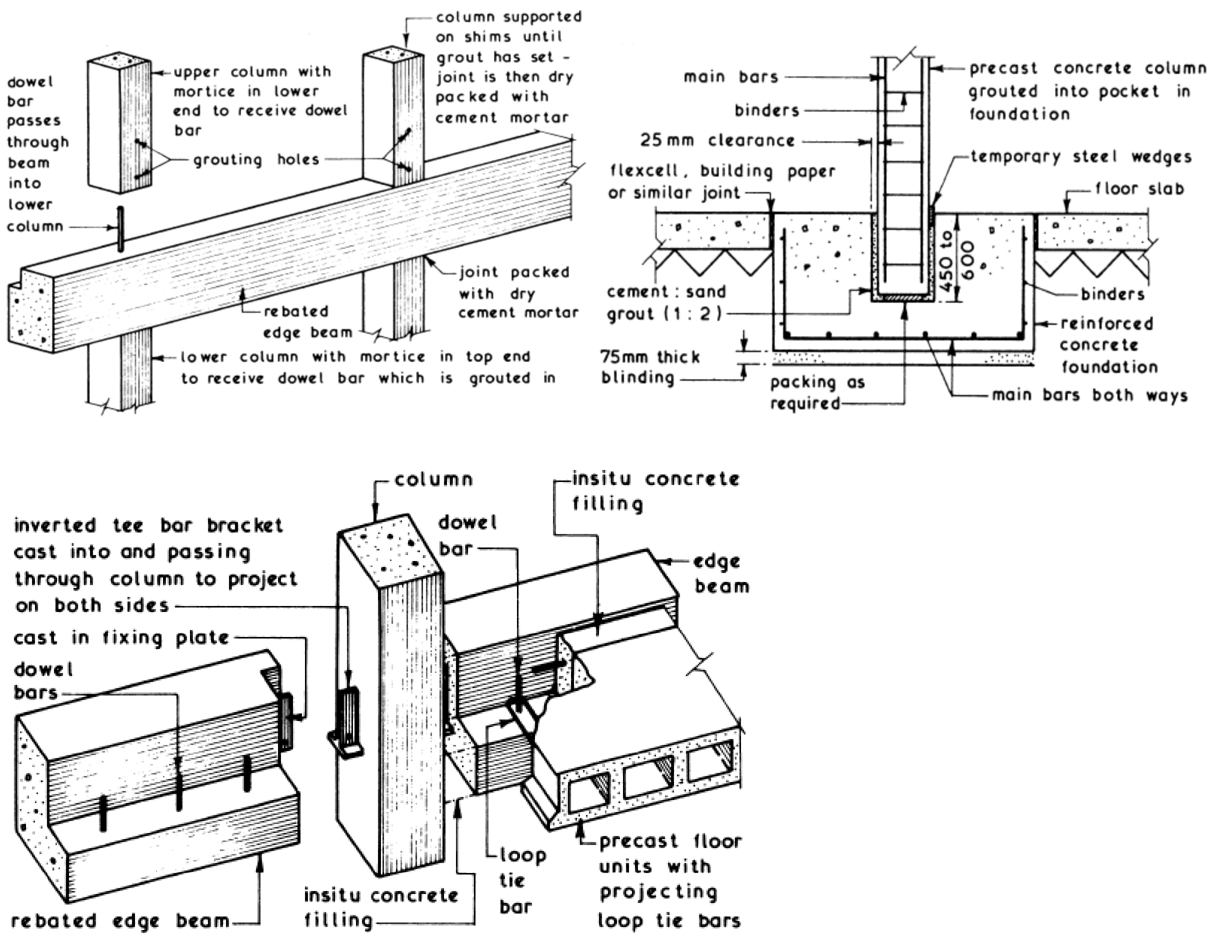


Fig. 3.11 Connections in precast concrete structures

Advantages and disadvantages of precast concrete

Advantages

- More time efficient
- Ensures high quality
- Better cost savings
- safety
- Lower maintenance cost

Disadvantages

- Very heavy members
- Problems at connections
- Requirements for lifting device
- Limited building design flexibility
- Accommodation for last minute change

- Erection at every weather condition
- Less formwork
- Early return of the investment
- Less wet work at the site
- Better fire protection

- Additional reinforcements for handling
- Transportation cost

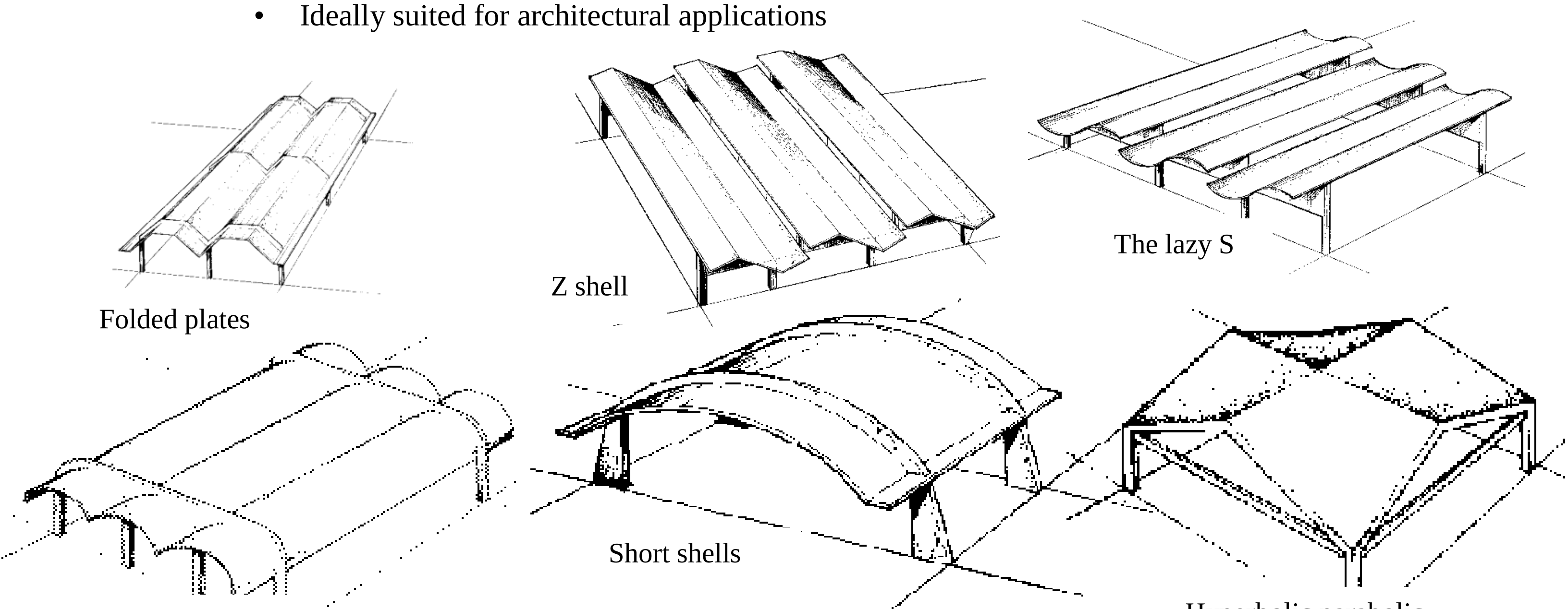
3.6 Shell and dome structures

3.6.1Shells

A shell is structural curved skin covering where the forces in the shell or membrane are compressive and in the restraining edge beams are tensile. The main properties of shell roofs are: the entire roof is a structural element, basic strength is inherent in its geometrical shape and form, and comparatively less material is required than other forms of roof structure.

Some of the advantages of Shell roof structures are:

- The curved shapes are naturally strong structures
- Allow wide areas to be spanned
- No use of internal supports
- Gives an open and unobstructed space
- Ideally suited for architectural applications



.12 Different types of shell structures

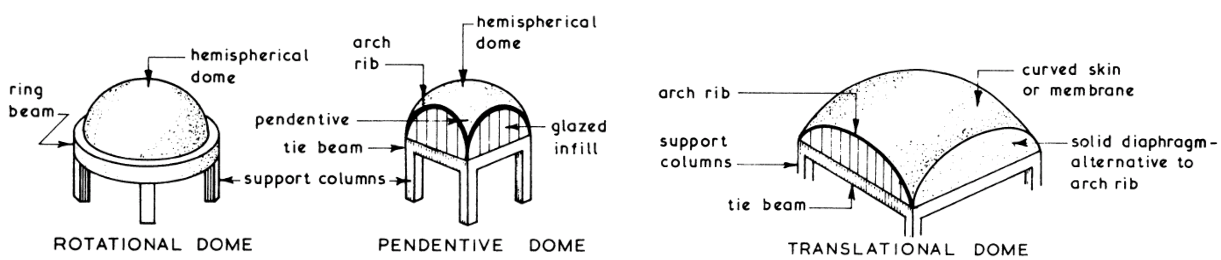
3.6.2 Domes

Domes are double curvature shells which can be rotationally formed by any curved geometrical plane figure rotating about a central vertical axis. These are shells curved in two directions. They are one of the oldest types of construction.

Some of the advantages of shell:

- They are completely span-free
- Have high ratio of span to thickness
- Aesthetically very pleasing
- Virtually any size and number of openings are possible
- Excellent for athletic facilities, schools, auditoriums, churches, convention halls, museums etc.

Types of dome structures



3.13 Different types of dome structures

3.7 Review Questions

1. What do you understand by structural system of a building?
2. Discuss the different loads and environmental forces acting on structural systems?
3. Discuss the conditions for selection of structural systems.
4. Briefly discuss the advantage and disadvantages of concrete, steel, timber and precast concrete structures.
5. Concrete structures are the most widely used structural systems in our country. Why?
6. What are the advantages and disadvantages of shell and dome structures?
7. List the different buildings in Addis which were constructed using precast concrete structural system.
8. List the different buildings in Addis which comprises of shell and dome structures.

CHAPTER-4

PLANNING OF BUILDINGS

4.1 General

Building construction and design involves a number of steps in office as well as on building site. Design is considered to be a process of blending, selecting, performance and creation. In civil engineering construction work there are four basic types of design: Architectural design, Structural design, Electrical design, and Sanitary design.

- Architectural design can simply described as humanization of space. The study of architecture encompasses: sensitivity to design, skill in drawing techniques and knowledge of materials.

- Structural design centers about the conception design and construction of the structural systems.

- Electrical design focuses on the provision of adequate electrical power supply and assembly of associated electrical equipments.

- Sanitary design involves mainly on the supply of pure water, disposal and treatment of sewage.

4.2 Site Selection

Site selection has an important bearing on planning and design of buildings. Where we choose to build and how we build on a site have an impact on the local and global environments, ongoing costs and our physical and psychological well-being. Unsatisfactory conditions in the neighborhood will cause unhappy living condition. Natural defects of the site will involve considerable expenditure on construction and maintenance of a building.

The following are the few factors which must be taken into account while selecting a site.

- Topography
- Nature of sub-soil
- Position of ground water table
- Facilities

- Neighborhood
- Certain things those should not be near the site
- Vegetation
- Shape of the site
- Availability of labor and materials

4.3 Principle of Planning

The basic objective of planning of buildings is to arrange all the units of a building on all floors and at level according to their functional requirements. Shape of a building plan is governed by several factors such as human factor, climatic conditions, site location, accommodation requirements, local bylaws, surrounding environment, etc.

Some of the important factors to be considered in planning are: Aspect, Prospect, Privacy, Grouping, Roominess, Flexibility, Circulation, Economy and Practical Considerations.

- **Aspect:** is the arrangement of doors and windows in the external walls of a building which allows the occupants to enjoy the natural gifts such as sunshine, breeze, etc... A room which receives light and air from a particular side is said to have aspect of that direction. From this angle, the following aspects for different rooms are preferred:
    - For kitchen E aspect.
    - For dining room S-aspect
    - For drawing and living room S-aspect or S-E- aspect
    - For bed rooms S-W -aspect or W-aspect.
    - For verandahs S-W-aspect or W-aspect
    - For reading rooms, stores, class rooms, studios, stairs, etc N-aspect
- **Prospect:** is the impression that the house is likely to make on person who looks at it from outside.
- **Privacy:** is an important principle in the planning of buildings. Privacy requires consideration in two ways
    - Privacy of one room from another.
    - Privacy of all parts of a building from the neighboring buildings and public streets.

- **Grouping**: means the positioning of various parts of the building in a typical fashion so that all the rooms are placed in proper correlation of their function and in proximity with each other
- **Roominess**: refers to the effect produced by deriving the maximum benefit from the minimum dimensions of a room.
- **Flexibility**: means planning room or rooms in such away which, though originally designed for a specific purpose, may be used to serve other overlapping purposes when desired.
- **Elegance (aesthetic merit)**: is the effect produced by the elevation and general layout of the plan.
- **Circulation**: means the movement space provided on the same floor either between the rooms or within the rooms called 'horizontal circulation' and between the different floors through stairs or lifts called 'vertical circulation'.
- **Economy**: The economy may not be a principle of planning but a factor that certainly affects planning. The economy may restrict the liberties of the architect and may also require certain alterations and omissions in the original plan.

4.4 Architectural Design

Architectural design is influenced by various factors such as; the human factor, the environmental aspect, the technical background, the aesthetics merit and the conveyance of message play a major role.

- **Human factor**: the size, shape and scope of the objects are derived physical characteristics of the modeler.
- **Environmental aspect**: some of the conditions and objects which are directly connected to the environmental aspects are climatic, geological, topographic condition, organisms and social condition.
- **Technological background**: the materials used and sources of energy affects the method of construction and the structural system.
- **Aesthetics merit**: creating a building which is pleasant to see.

CHAPTER-5

BUILDING ELEMENTS

5.1 FOUNDATIONS AND SOIL EXPLORATION

5.1.1 FOUNDATIONS

5.1.1.1 Introduction

Every building consists of two basic parts, which are the **super-structure** and **sub-structure** (foundation). Foundation is that part of the structure which is in direct contact with the ground to which the loads are transmitted. The function of a foundation is to distribute the load of super-structure over a larger area, in such a way that settlements are within permissible limit and the soil does not fail.

A foundation should be sufficiently strong to prevent **excessive settlement** as well as **unequal settlement**. Unequal settlement or differential settlement may be caused by:

- Weak sub-soils, such as made up ground,
- Shrinkable and expansive soil (such as clay),
- Frost action,
- Movement of ground water, and uplift pressure
- Excessive vibrations, due to traffic, machinery etc.,
- Slow consolidation of saturated clays, and
- Slipping of strata on sloping sites.

5.1.1.2 Functions of foundation

Foundations serve the following purposes:

1. **Reduction of load intensity**: Foundation distribute the loads of superstructure, to a larger area so that the intensity of the load at its base does not exceed the safe bearing capacity of the sub-soil.
2. **Even distribution of load**: foundations distribute the non-uniform load of the superstructure evenly to the sub soil.
3. **Provision of level surface**: foundations provide levelled and hard surface over which the superstructure can be built.

4. **Lateral stability**: it anchors the superstructure to the ground, thus imparting lateral stability to the superstructure.
5. **Safety against undermining**: it provides safety against scouring due to burrowing animal and flood water.
6. **Protection against soil movements**: minimises the distress on the superstructure due to expansion or contraction of sub-soil because of moisture movement in some problematic soil.

5.1.1.3 Essential Requirements of a Foundation

Foundations should be constructed to satisfy the following requirements:

1. The foundations shall be constructed to sustain all loads and transmit them to the sub soil without causing settlement which would impair the stability of the building or adjoining structure.
2. Foundation base should be rigid so that differential settlements are minimised, specially for the case when super-imposed loads are not evenly distributed.
3. Foundation should be taken sufficiently deep to guard the building against damage or distress caused by swelling or shrinkage of sub-soil.
4. Foundations should be ideally located so that its performance may not be affected due to any unexpected future influence.

5.1.1.4 Types of Foundations

Foundations may be broadly classified under two heads:

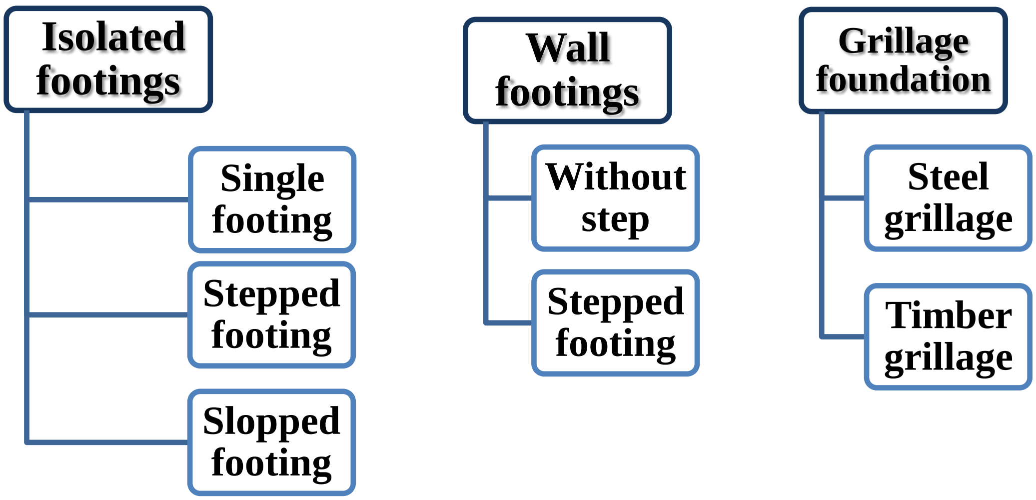
A. Shallow Foundations
B. Deep Foundations

A. Shallow foundations

Shallow foundations are those founded near to the finished ground surface. Generally where the founding depth (D_f) is less than the width of the footing and less than 3m. Shallow foundations are used when surface soils are sufficiently strong and stiff to support the imposed loads. They are generally unsuitable in weak or highly compressible soils, such as poorly-compacted fill, peat, alluvial deposits, etc

A.1 Spread Footings

Spread footings are those which spread the super-imposed load of wall or column over large area. Spread footings support either a column or wall. They are most widely used foundation types since they do not require special equipment and skill for construction and are usually economical. Spread footings may be of the following types:



i. **Isolated Footings -** These footings are sometimes known as column footings and are used to support the individual columns, piers or other concentrated load. Most column footings are slab footings with two-way reinforcements and constant depth.

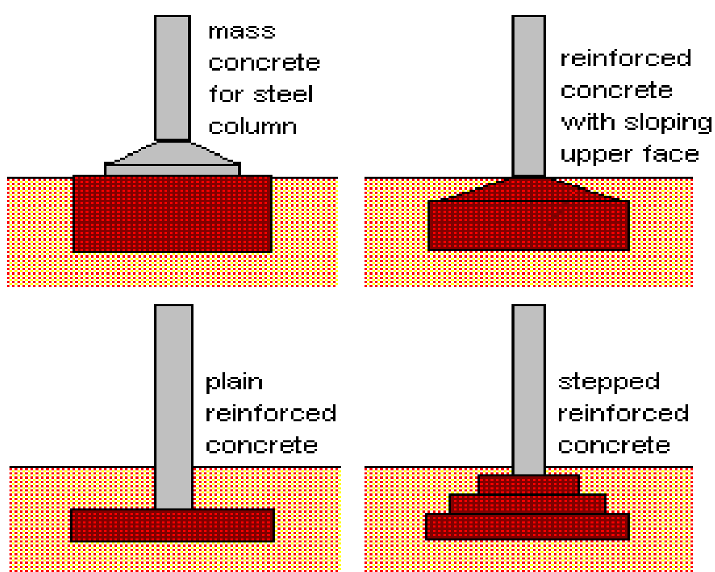


Fig. 5.1.1.1 Isolated Footings

ii. **Wall footings (strip footings) -** Strip foundations are used to support a line of loads, either due to a load-bearing wall, or if a line of columns need supporting. A wall footing may have a base course of concrete; may be entirely built up of one material , e.g. bricks or stones.

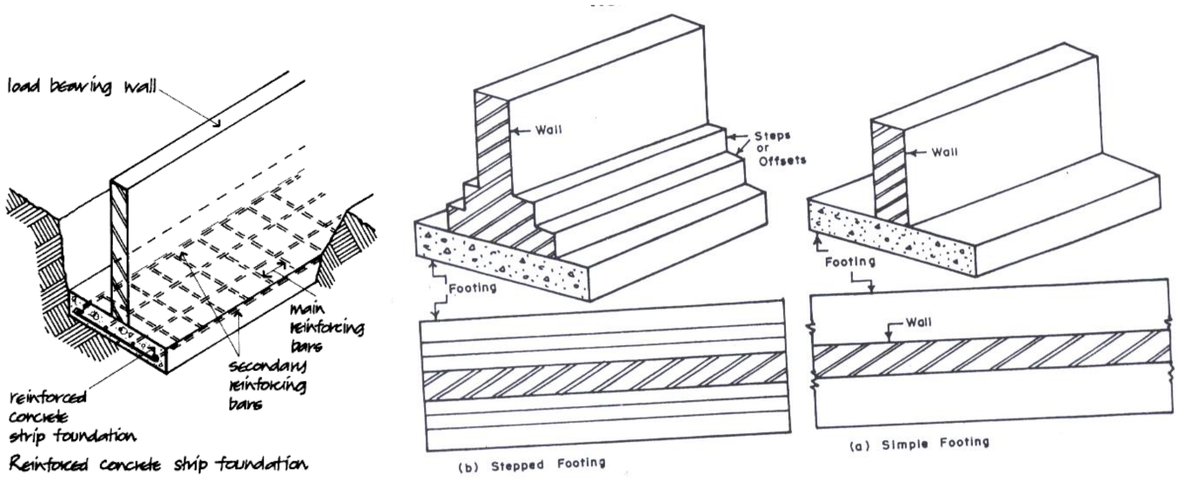


Fig. 5.1.1.2 Strip Footings

iii. **Grillage foundations -** They consist of steel beams arranged in layers at right angles to one another and embedded in concrete. They are generally provided for heavily loaded steel column and used in locations where bearing capacity of soil is poor.

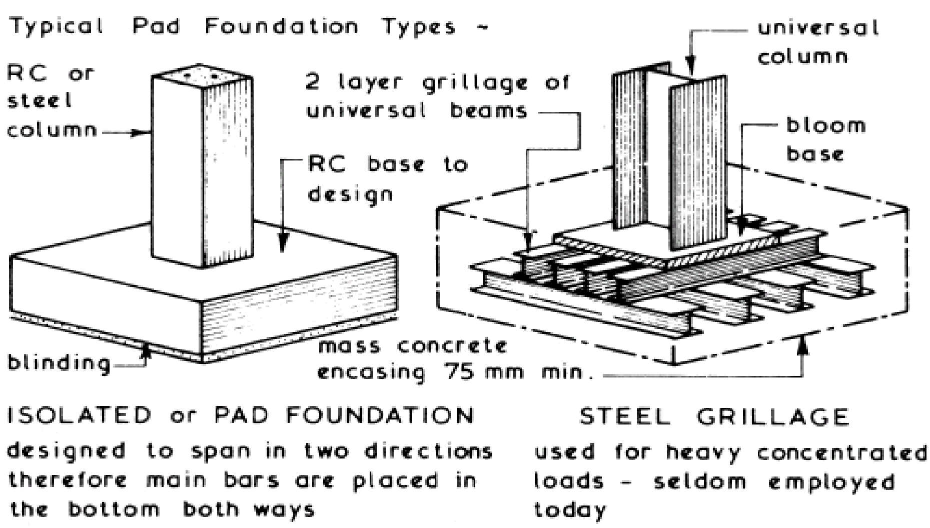


Fig. 5.1.1.3 Grillage Foundation

A.2 Combined Footings

A spread footing which supports two or more columns is termed as combined footing. Footings of this type are most frequently used to support walls and columns, which are close to the property line. Combined footings are essential whenever the projections of columns are not possible on one side due to limited available space and when the spacing of two consecutive columns are close for isolated footing. Combined footings for columns will be **rectangular** in shape if they carry equal load or **trapezoidal** shape for unequal loads.

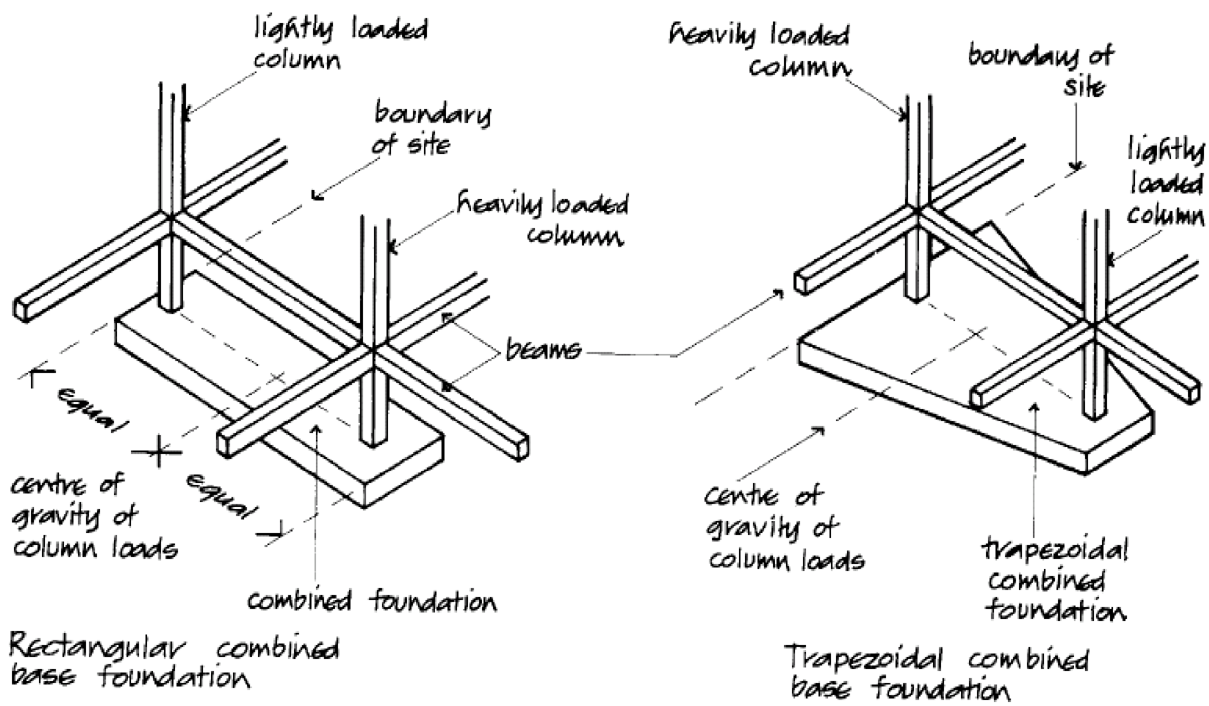


Fig. 5.1.1.4 Combined Footings

A.3 Strap Footings (Cantilever Footing)

If the independent footings of two columns are connected by a beam, it is called a **strap footing**. They serve the same function as combined footings by permitting a column load to be placed near the edge of the footing. It is used where a large spacing between two columns create a situation where a continuous footing is uneconomical due to the usage of large quantity of concrete. A rigid beam connects the two pads to transmit the unbalanced shear and moment from the statically unbalanced footing to the second footing.

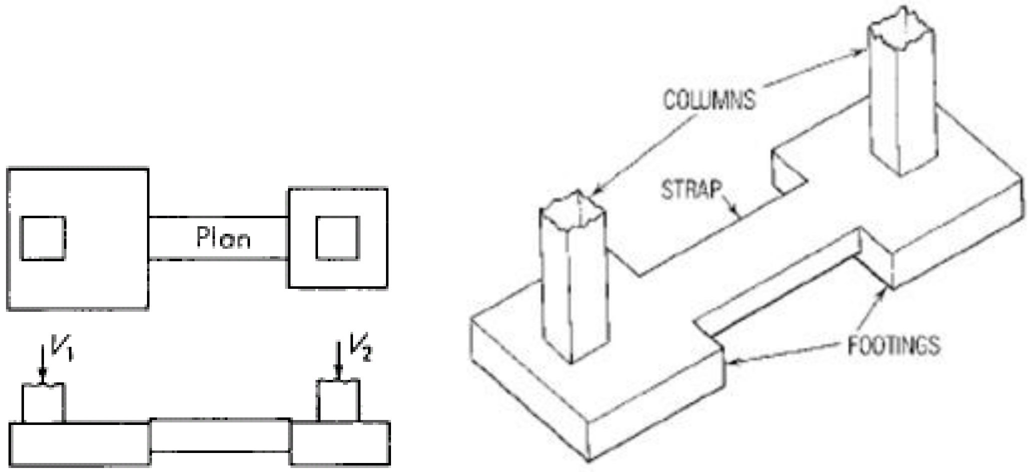


Fig. 5.1.1.5 Strap Footings

A.4 Mat (Raft) foundation

A raft or mat is a combined footing that covers the entire area beneath the structure and supports all the walls and columns. It is used where:

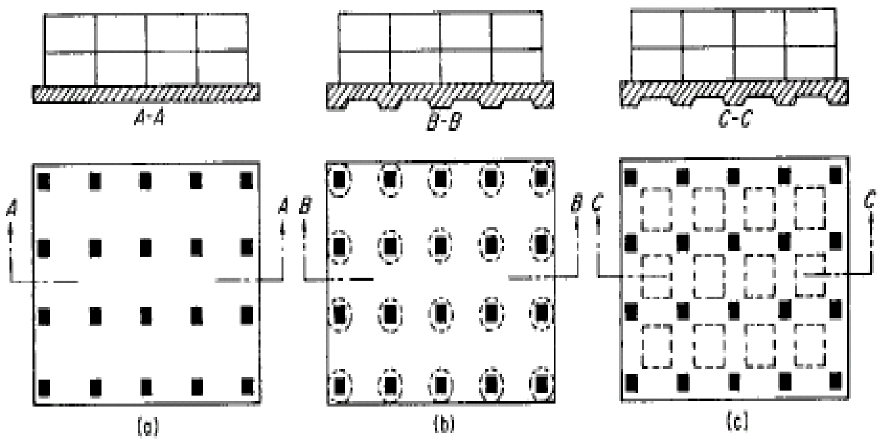
- The allowable soil pressure is low,
- The building loads are heavy,
- The use of spread footings would cover more than half the area,
- The soil mass contains compressible lenses,
- The soil is sufficiently erratic so that differential settlement would be difficult to control.

Raft foundation is also used to reduce settlement above highly compressible soils, by making the weight of the structure and raft approximately equal to the weight of the soil excavated (**Floating Buildings**).

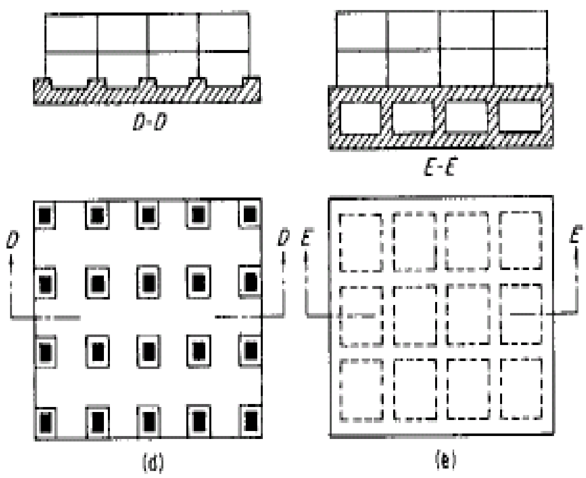
Raft foundation is not suitable for steeply sloping sites where excavation would be excessive, and to framed buildings with heavy concentrated loads where raft thickness and reinforcement would be excessive.

Rafts may be divided into three types, based on their design and construction

i. **Solid slab system**: is a solid reinforced concrete slab generally uniform thickness.
ii. **Beam slab system**: consists of up-stand or down-stand beams that take the loads of the walls or columns and spread them.
iii. **Cellular system**: consists of top and bottom slab separated by and reinforced with vertical cross ribs in both directions.



Solid Slab **Slab thickened at column** **Slab & beam**



Slab & beam **Cellular raft**

Fig. 5.1.1.5 Mat (Raft) Foundation

B. Deep foundations

Deep foundations are those founding too deeply below the finished ground surface for their base bearing capacity to be affected by surface conditions. This is usually at depths greater than 3 m below finished ground level. Deep foundations can be used to transfer the loading to deeper, more competent strata at depth if unsuitable soils are present near the surface.

B.1 Pile foundation

This is an element of a construction placed in the ground either vertically or slightly inclined to increase the load carrying capacity of the soil. Pile foundations may be adopted:

i. Instead of raft foundation where no firm bearing strata exists at any reasonable depth and the loading is uneven.
ii. When a firm bearing strata does not exist but at a depth such as to make strip or spread footing uneconomical
iii. When pumping of sub-soil water would be too costly or timbering to excavations too difficult.

Classification of Pile Foundation

Piles commonly used in buildings are classified into the following types:

1. Classification based on basic design function

- 1a. End Bearing piles
- 1b. Friction piles
- 1c. Combined end bearing & friction
- 1d. Compaction piles

2. Classification based on method of construction

- 2a. Replacement piles
- 2b. Displacement piles

3. Classification based on the materials used

- 3a. Timber piles
- 3b. Precast concrete piles
- 3c. Cast insitu concrete piles
- 3d. Steel piles
- 3e. Composite piles

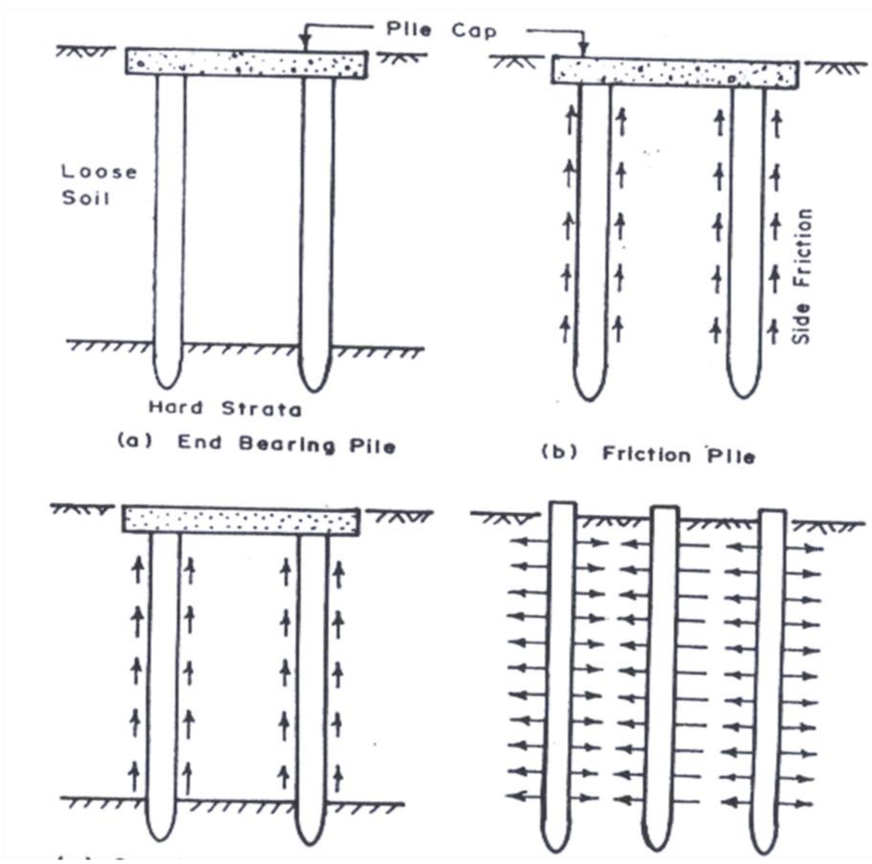
1. Classification based on basic design function

1a. End bearing piles - transfer load through water or soft soil to a suitable bearing stratum. Such piles are used to carry heavy loads safely to hard strata. Multi-storied buildings are invariably founded on end bearing piles, so that the settlements are minimised.

1b. Friction piles - are used to transfer loads to a depth of a friction-load-carrying material by means of skin friction along the length of the pile. Such piles are generally used in granular soil where the depth of hard stratum is very great.

1c. Combined end bearing and friction piles - transfer the superimposed load both through side friction as well as end bearing.

1d. Compaction piles - are used to compact loose granular soils, thus increasing bearing capacity.



(c) Combined end bearing and friction (d) Compaction pile

Fig. 5.1.1.6 Pile Foundations -Classified based on basic design function

2. Classification based on method of construction

2a. Replacement piles - These are often called **bored piles** since the removal of the soil to form the hole for the pile is always carried out by a boring technique.

2b. Displacement piles - These are often called **driven piles** since they are usually driven into the ground displacing the earth around the pile shaft.

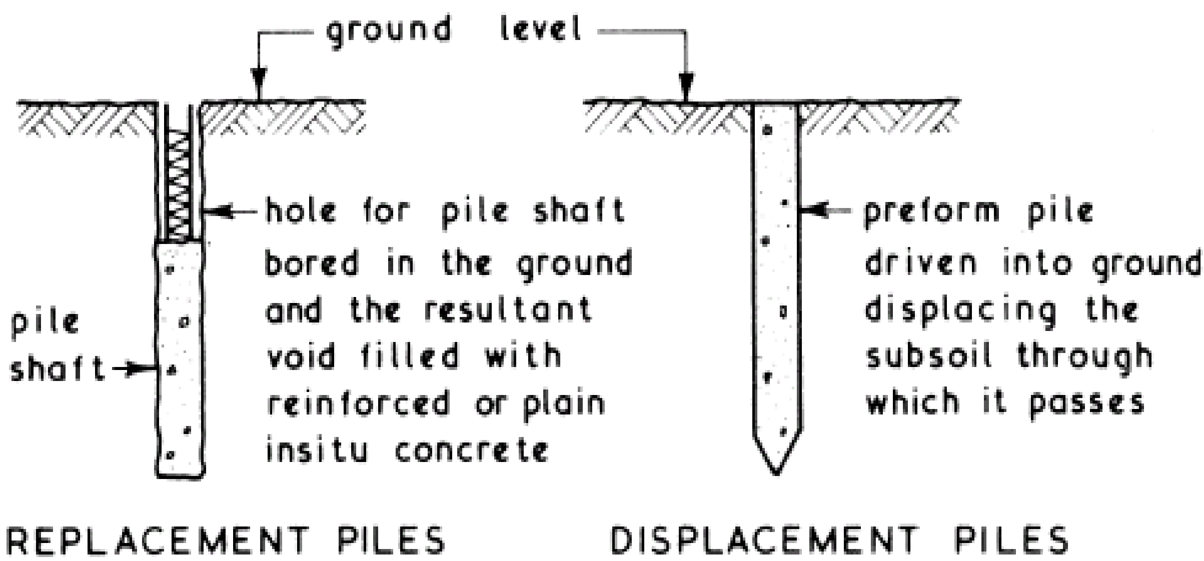


Fig. 5.1.1.7 Pile Foundations -Classified based on method of construction

3. Classification based on the materials used

3a. Timber piles - piles made of timber have the following advantages and disadvantages:

Advantages

- Less expensive
- Can be made longer by joining individual piles
- Cutting of piles is very easy
- Can be driven quickly with lighter machine

Disadvantages

- Deteriorate by different actions
- Have lesser loading capacity
- Possibility of damage due to over driving
- Joining work is time taking and expensive

3b. Precast concrete piles - piles made of precast concrete have the following advantages and disadvantages:

Advantages

- Best concrete quality
- Reinforcement bars remain in position
- Concrete withstand loads after complete curing
- Convenient when driven through wet soil
- More suitable where part of length remain exposed

Disadvantages

- Heavy and difficult to transport
- Shocks of driving make them weaker
- Trimming is difficult

3c. Cast in situ concrete pile - is a concrete pile built in permanent location within a hole made for this purpose. Advantages and disadvantages of cast in situ concrete pile are listed below:

Advantages

- Avoid vibration caused by driving
- Underlying soil can be explored during the process
- Less wastage of material
- No time spent on curing
- Lighter equipment is required than driven piles

Disadvantages

- Quality of concrete may be compromised due to height
- Possible displacement of reinforcement
- Difficult to use under water

Under-Reamed Piles

Under reamed piles are bored and cast in situ concrete piles having **bulb shaped** arrangement near base. The principle of this type of foundation is to anchor the structure at a depth where ground movements due to changes in moisture content or consolidation of the poor strata are negligible.

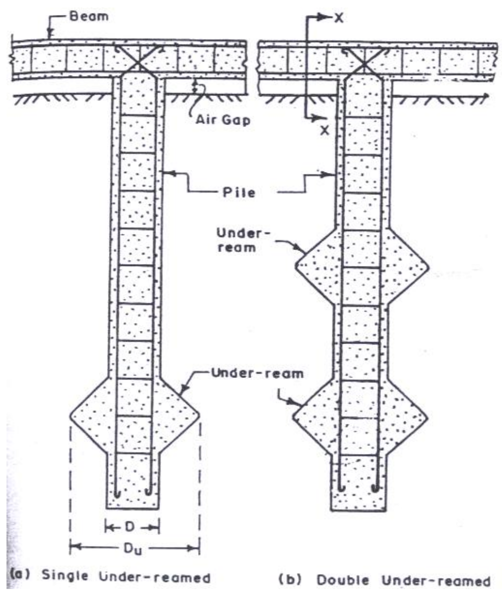


Fig. 5.1.1.8 Under-Reamed Piles

3d. Steel piles - may be made of I-section or hollow pipe section. Some of the attributes of steel piles are;

- Because of small sectional area, steel piles are easy to drive.
- They are mostly used as bearing piles.
- It is usual to fill the tube with mass concrete to form a composite pile.

B.2 Pier foundation

Consists of cylindrical column of large diameter to support and transfer large super imposed loads to the firm strata below. The difference between pile foundation and pier foundation lies in the method of construction. The major differences are:

- Pier foundation mainly transfer load through bearing
- Pier foundation is shallower in depth than pile foundation.
- Pier foundation is preferred where the top strata consists of decomposed rock overlaying a strata of hard rock.
- Pier foundations are preferred in case of stiff clays, which offer large resistance to the driving of a bearing pile.
- In case of piers, the excavation can be carried to the desired depth easily.

Pier foundations may be classified as either masonry concrete pier or drilled Pier/Caissons. When a good bearing stratum exists up to 5m below ground level, brick, masonry or concrete foundation piers in excavated pits may be used. A drilled pier/caisson is largely a compressed member subjected to an axial load at the top and reaction at the bottom. Drilled caissons are generally drilled with the mechanical means.

Drilled Pier/caissons may be of three types:

- Concrete caisson with enlarged bottom
- Caisson of steel pipe with concrete filled in the pipe
- Caisson with concrete and steel core in steel pipe

There are various methods of driving the piers:

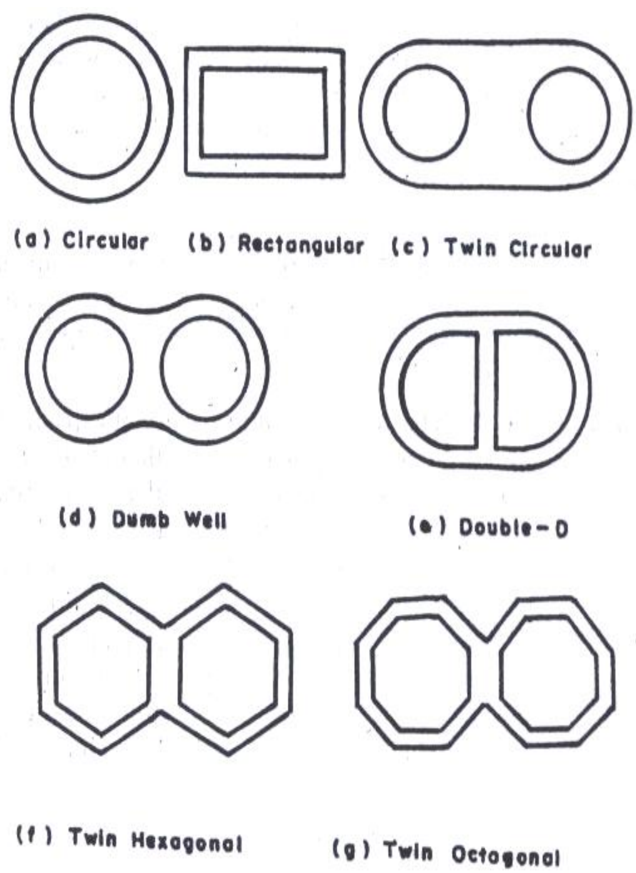
- Open caisson method
- Compressed air (Caisson method)
- Ordinary excavation method
- Use of sheeting and sheet pile

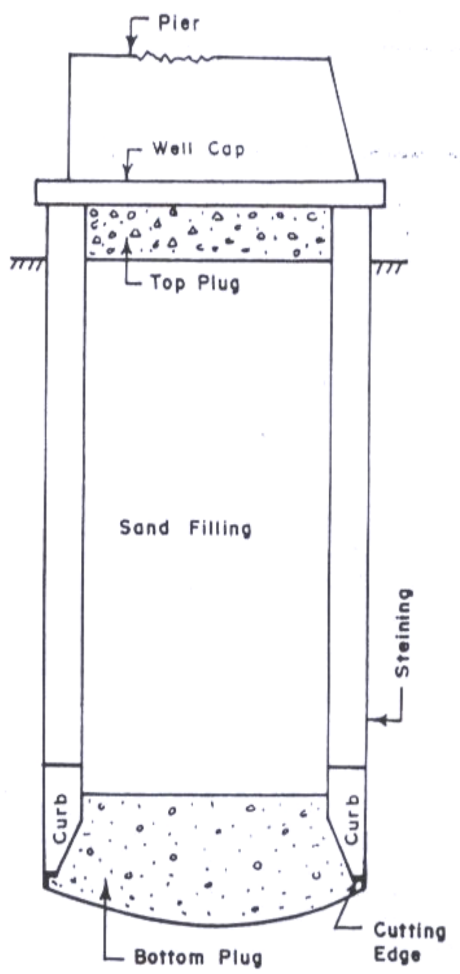
B.3 Well foundation (Caissons)

They are box like structure- circular or rectangular- which are sunk from the surface of either land or water to the desired depth. They are much large in diameter than the pier foundation or drilled caissons. Well foundations are used for major foundation works, such as for:

- Bridge piers and abutments in rivers, lakes etc.
- Break waters and other structures for shore protection
- Large water front structures such as pump houses.

Well foundations or caissons are hollow from inside, which may be filled with sand and are plugged at the bottom. The load is transferred through the perimeter wall. Well foundations are not used for building





Shapes of wells   Well foundation

Fig. 5.1.1.9 Well Foundation (Caissons)

5.1.1.5 Excavation for Foundation

Excavation with various scales is done in the construction of foundations. There are steps that should be followed before marking points of excavation. Some of them are; clearing the site of all plants, debris, levelling the site to remove large inequalities and preparing a setting out plan. Steps in marking points of excavation is summarised as follow:

a) Establish reference points
b) Fix wooden pegs and batter boards (profile board) around the site to be excavated.
c) Mark the center line of the walls, columns
d) Mark the plinth lines: lines making the inside and outside of walls
e) Mark the inside and outside line of excavation,
f) By stretching strings, check right angles,
g) If all dimensions are correct and all corners are right angle, mark the cutting on the ground

Since the soil being excavated has different properties and the depths of excavation vary, there are different ways used to support the excavated soil from collapsing and affecting the neighboring sites. Giving certain slope instead of sharp cuts in trench excavation and supporting the soil with timber (timbering) or piles of different type are among the methods used.

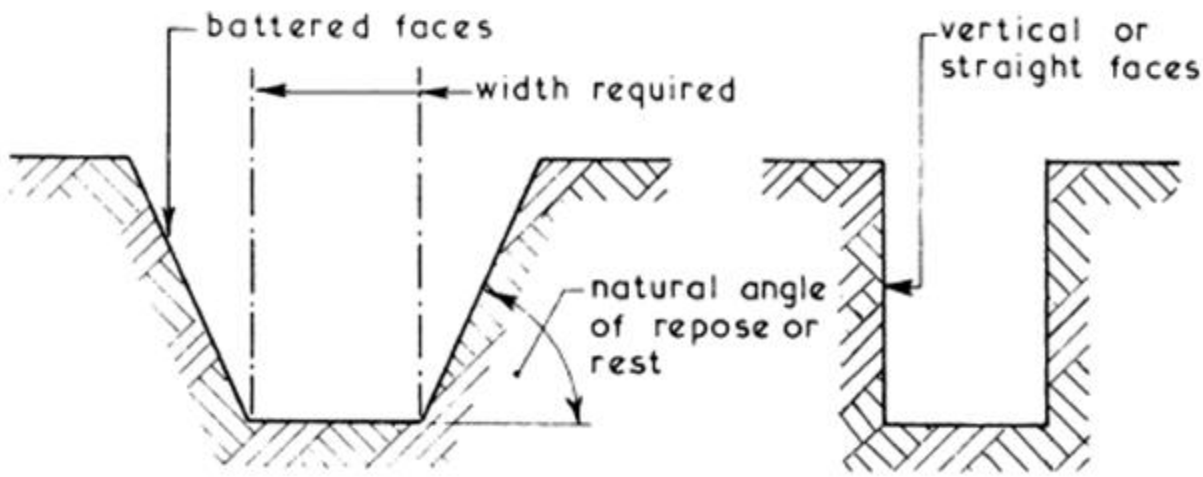
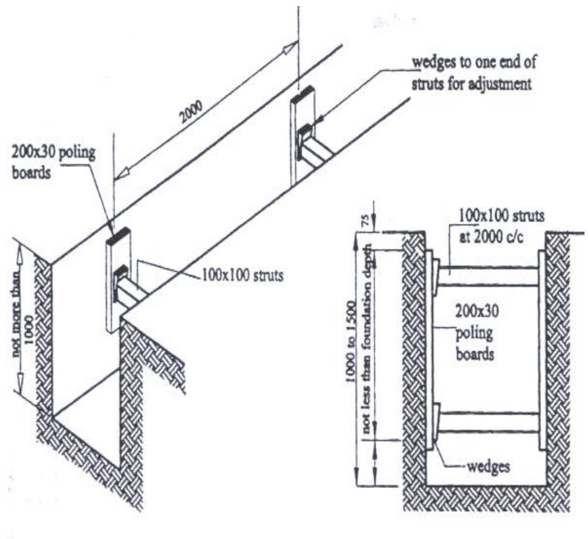
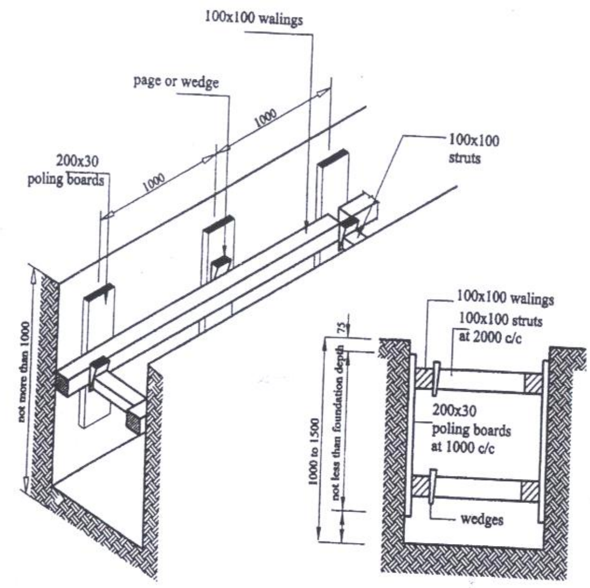


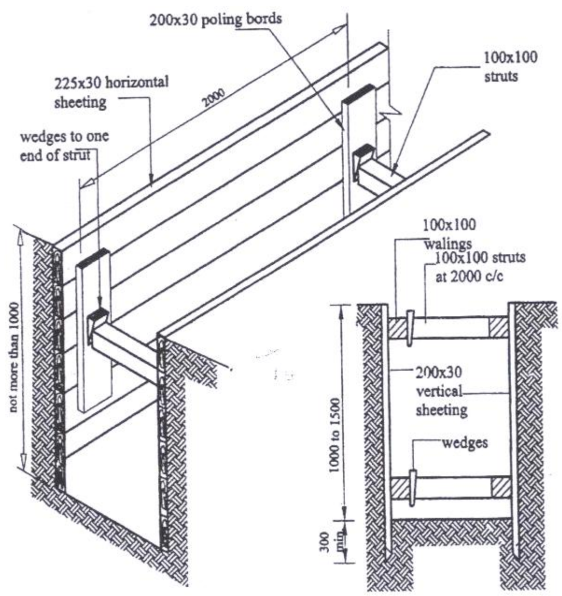
Fig. 5.1.1.10 Trench excavation



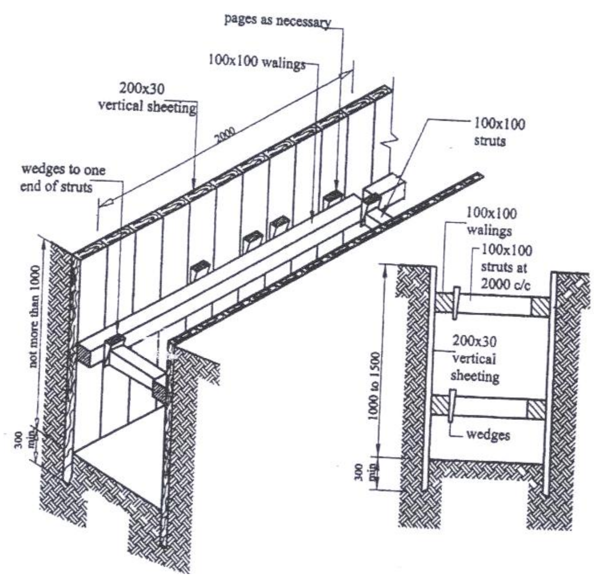
(a) Typical timbering in hard soil



(b) Typical timbering in firm soil



(c) Typical timbering in dry loose soil



(d) Typical timbering in loose wet soil

Fig. 5.1.1.11 Typical timbering of different type of soil

5.1.1.6 Excavation in Ground with Sub-soil Water

Excavations of foundation trenches in ground having **high water table**, or in **water-logged** area pose great problems. Excavations can be carried out by dewatering the subsoil water. Construction sites are dewatered for the following purposes:

- To provide suitable working surface at the bottom

- To stabilize the banks of excavation, avoiding the hazards of sliding
- Prevent disturbance of soil at the bottom (which may reduce the bearing capacity)
- Reduce lateral load on sheeting and bracing.

Foundation dewatering can be done by the following methods:

- Ditches and sumps
- Well point system
- Shallow well system
- Deep well system
- Vacuum method

5.1.1.7 Foundation Failure

A. **Causes of foundation failure**

Foundations may fail due to the following reasons:

- Unequal settlement of subsoil
- Unequal settlement of masonry
- Sub-soil moisture movement
- Lateral pressure on the walls
- Lateral movement of sub soil
- Weathering of sub-soil due to trees
- Atmospheric action

B. Sites with potential hazards

- Clay of high shrinkage or swelling potential
- Sloping ground
- Deep fill
- Mining areas
- Peat or other soft soils
- Old building foundations and basements
- Ground waters

5.1.1.8 Review Questions

1. Discuss various functions served by foundations.
2. What are the requirements of a good foundation?
3. What are the causes of failure of foundation? What remedial measures would you adopt?
4. What do you understand by a ‘shallow foundation’? Draw sketches to show various types of shallow foundation.
5. Differentiate between ‘strip footing’ and ‘pad footing’.
6. Explain with the help of sketches, the following (i) trapezoidal combined footing (ii) strap footing (iii) mat foundation.
7. Explain the situations in which the pile foundation is preferred.
8. Classify various types of piles based on (i) function, (ii) method of construction and (iii) materials and composition.
9. Differentiate between pile foundation and pier foundation. How does pier foundation differ from caisson foundation?
10. Describe with sketches the method of setting out foundation trenches.
11. What do you understand by ‘timbering’? Explain with the help of sketches various methods adopted for different types of soil.
12. Explain ditch sump, well point and deep well system of foundation dewatering with the help of sketch.
13. What are the main causes of foundation failure? Enumerate those sites considered to be potentially hazardous for foundation construction.

5.1.2 SOIL INVESTIGATION

5.1.2.1 Introduction

Since foundations have to transfer the load to the sub-soil, **surface conditions** at any given site must be **adequately explored**. Sub soil investigation is essential to gather information required both for the **design** and **construction** of foundation. Some of the reasons for sub-surface investigation are to study site suitability, for efficient & economic design, to anticipate immediate/future problems, and for confidence in design assumption.

Sub-soil investigation is done for the following purposes:

A. **For New Structures**

1. The selection of type and depth of foundations
2. The determination of bearing capacity
3. The prediction of settlement
4. The determination of ground water level
5. The evaluation of earth pressure against walls, basements, etc.
6. The provision against constructional difficulties.
7. The stability of soil and degree of compaction

B. **For Existing Structures**

1. The investigation of safety of structure
2. The prediction of settlement
3. The determination of remedial measure if the structure is unsafe

5.1.2.2 Site Reconnaissance

Site Reconnaissance is an inspection of the site and study of topographical features is often helpful. In site reconnaissance a study of the following features is useful: local topography, excavations, cuttings, quarries, evidence of land slide, fills and water level in wells.

If there has been an earlier use of the site, information should be gathered, in particular about: the underground working if any, location of fills, and excavation.

5.1.2.3 Site Exploration

The purpose of site exploration is to provide **reliable**, **specific** and **detailed** information about the soil and ground water conditions for safe and economic design of foundations. Site exploration should yield precise information about the following:

i. The order of occurrence and extent of soil and rock strata,
ii. The nature and engineering properties of the soil and rock, and
iii. The location of ground water and its variation

5.1.2.3.1 Depth of Exploration

Depth (Significant Depth) shall be up to the level where the pressure increase will cause settlement or shear failure of foundations. Significant depth depends on the type of structure, its weight, size, shape and disposition of loaded areas, and the soil profile and its properties. The significant depth may be assumed to be equal to 1.5 to 2.0 times the width of the loaded area.

Guide rules for the depth of exploration are stated below:

- Isolated spread footing or raft: 1.5 times the width
- Adjacent footings with clear spacing less than twice the width: 1.5 times the length
- Pile foundation: 10 to 30 meters, or more, or at least 1.5 times the width of the structure.
- Base of the retaining wall: 1.5 times the base width or 1.5 times the exposed height of face of wall, whichever is greater.
- Floating basements: depth of construction

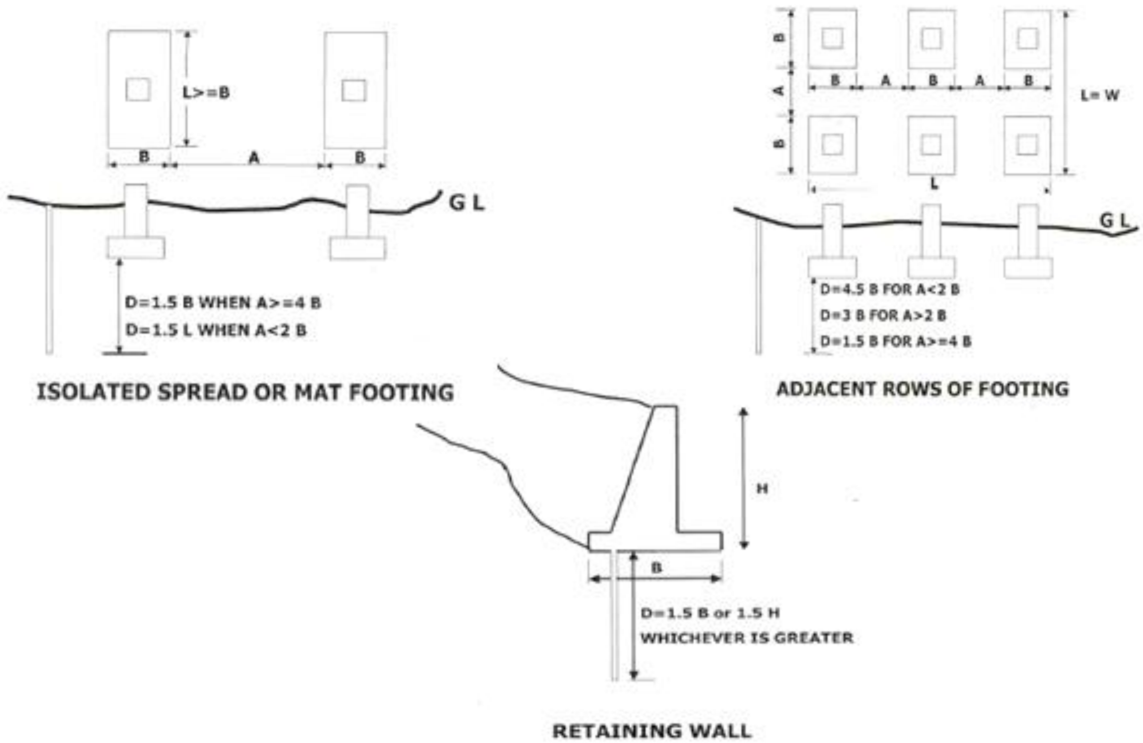


Fig. 5.1.2.1 Depth of Soil Exploration

5.1.2.3.2 Spacing of Exploration

The number of borings should be sufficient so that a reliable model of the subsurface conditions can be established. The boring layout depend on the geology of the site, type of structure to be built, purpose of boring, nature of construction and the sub soil profile.

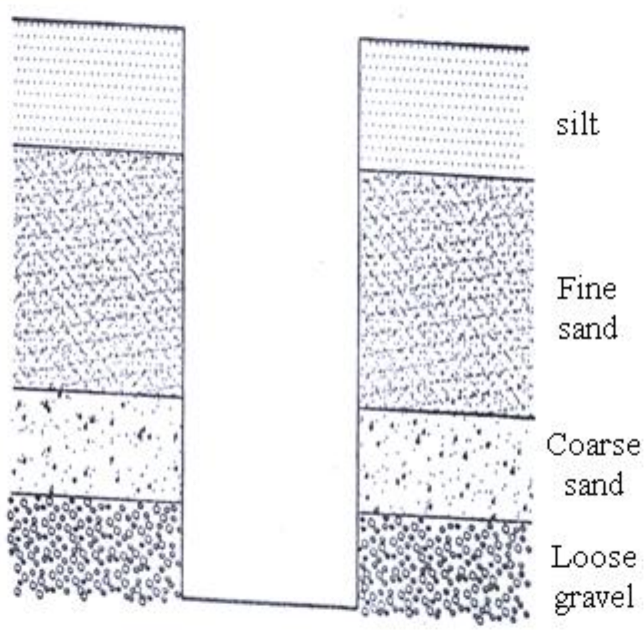
5.1.2.3.3 Methods of site Exploration

The choice of particular exploration method depends on **nature of ground**, **topography** and **cost**. The various methods of site exploration may be grouped as follow:

1. Open excavations
2. Borings
3. Sub-surface soundings
4. Geophysical methods

1. Open Excavation (Open Trial Pits)

Trial pits are the cheapest method of exploration. The biggest advantage of this method is that soil strata can be inspected in their natural condition and samples (disturbed and undisturbed) can be taken. They are suitable for shallow depths, up to 3m. The cost of open excavation increases rapidly with depth.



Typical section of a test pit

Fig. 5.1.2.2 Open Excavation (Open Trial Pit)

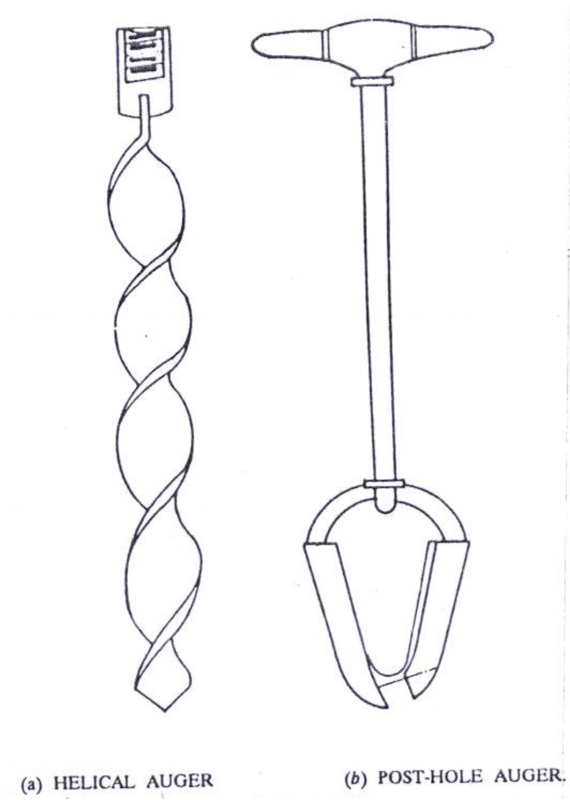
2. Boring Methods

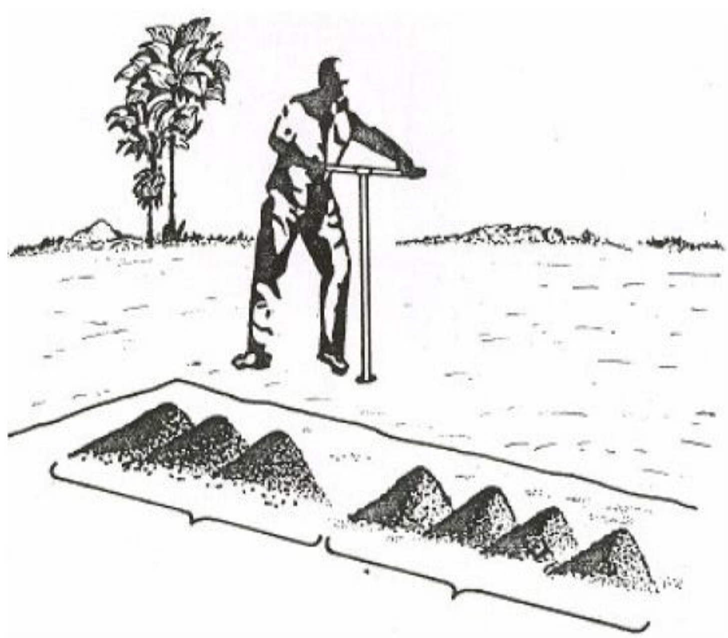
Soil borings are probably the most common methods of subsurface exploration. The following are the various boring methods commonly used:

i. Auger boring
ii. Auger and shell boring
iii. wash boring
iv. Percussion boring and
v. Rotary boring

i. Auger Boring

Augers are used in **cohesive** and other **soft soils** above water table. They may either be operated **manually** or **mechanically**. Hand Augers are used up to depth of **6m**. Mechanically operated augers are used for greater depth and they can also be used in gravely soil.





Hand Auger Sampling

Fig. 5.1.2.3 Auger Boring

ii. Auger and shell Boring

Cylindrical augers and shells with cutting edge at lower end can be used for deep boring. Hand operated rigs are used for depths up to 25m and mechanised rigs up to 50m. Augers are suitable for soft to stiff clay, shells for very stiff and hard clays. Small boulders, thin soft strata, or rock or cemented gravel can be broken by chisel bits attached to drill rods.

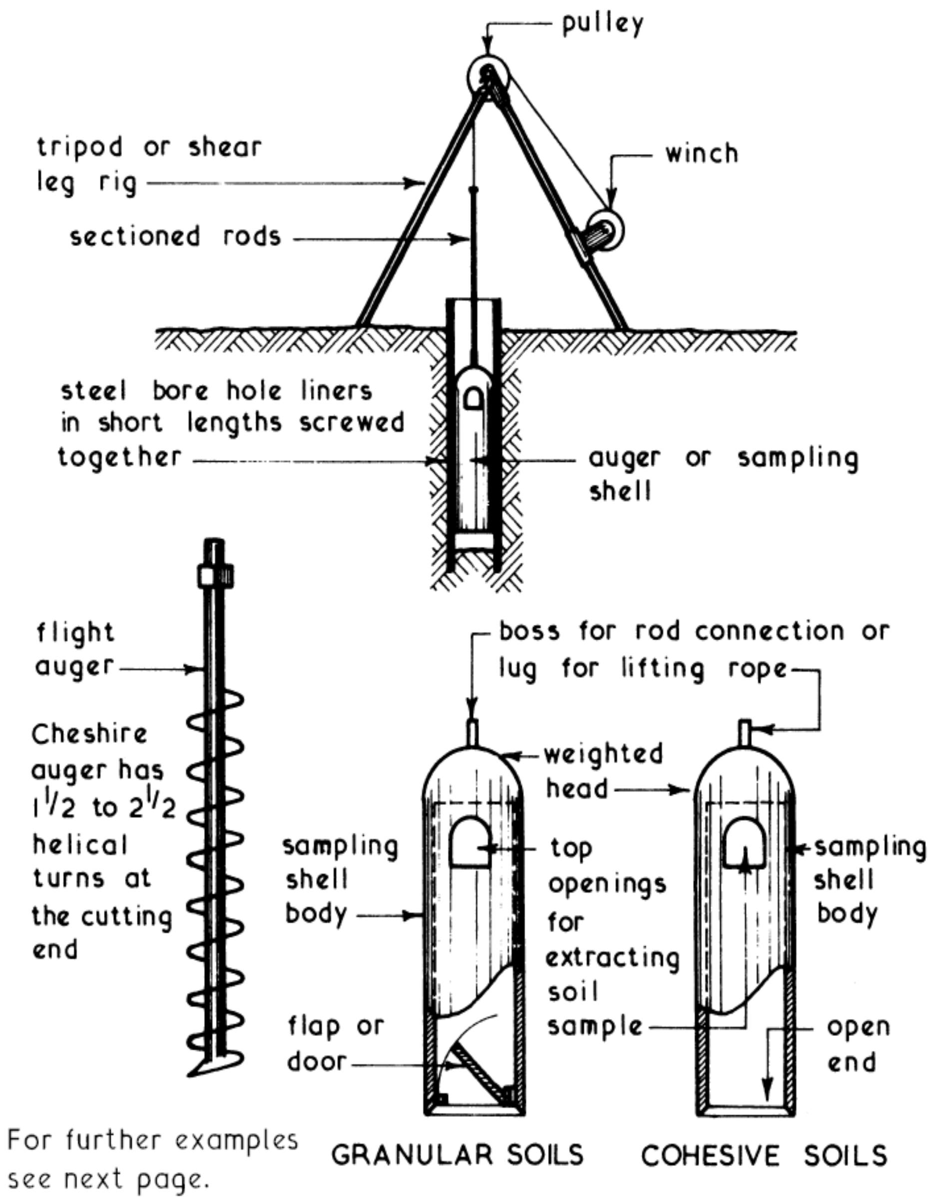


Fig. 5.1.2.4 Auger and Shell Boring

iii. Wash Boring

Wash boring is a fast and simple method for advancing holes in all types of soils. Boulders and rocks can't be penetrated by this method.

Steps:

- Driving a casing with hollow drilled rod with sharp chisel or chopping bit
- Forcing water under pressure
- Resulting in Chopping and jetting action
- Forcing the cutting up ward and reviewing the color of wash
- Typical wash boring arrangement

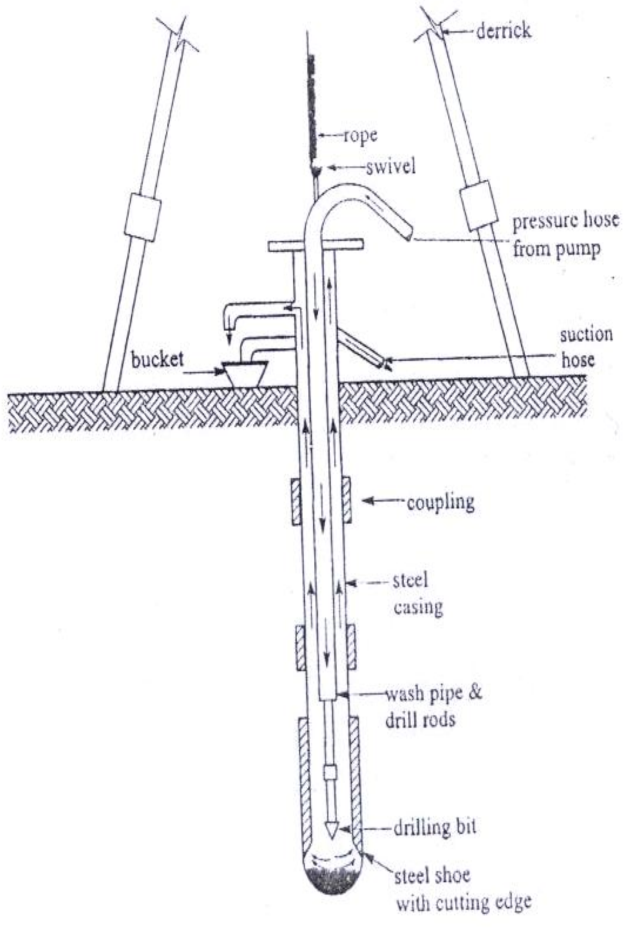


Fig. 5.1.2.5 Typical Wash Boring arrangement

iv. Percussion Boring

In this boring method soil and rock formations are broken by repeated blows of heavy chisel or bit suspended by a cable or drill rod. Water is added to the hole during boring, if not already present. It is suitable for advancing a hole in all types of soils, boulders and rock.

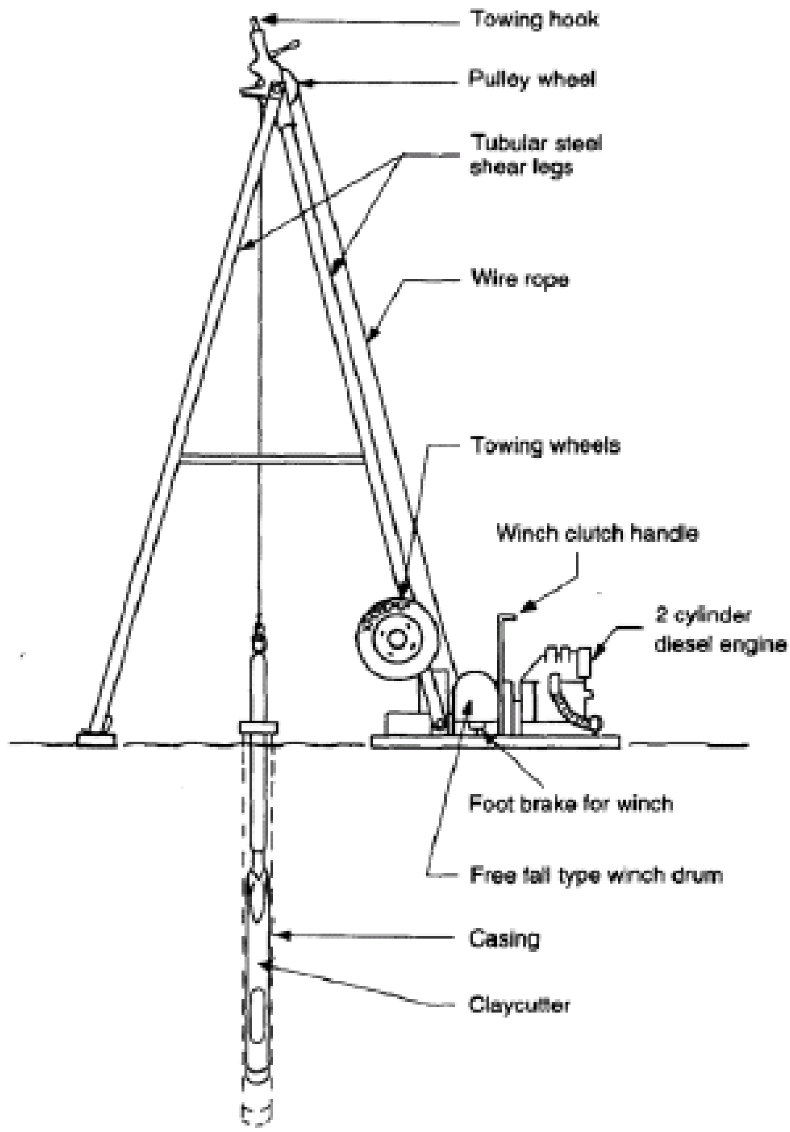


Fig. 5.1.2.6 Light Percussion Drilling Rig

v. Rotary Boring

Rotary drilling is a very fast method of advancing hole in both rocks and soils. A drill bit, fixed to the lower end of the drill rods is always kept in firm contact with the bottom of the hole. A water solution of bentonite, with or without admixtures is continuously forced down. The mud coming up wards bring the cuttings to the surface. The method is also known as mud rotary drilling.

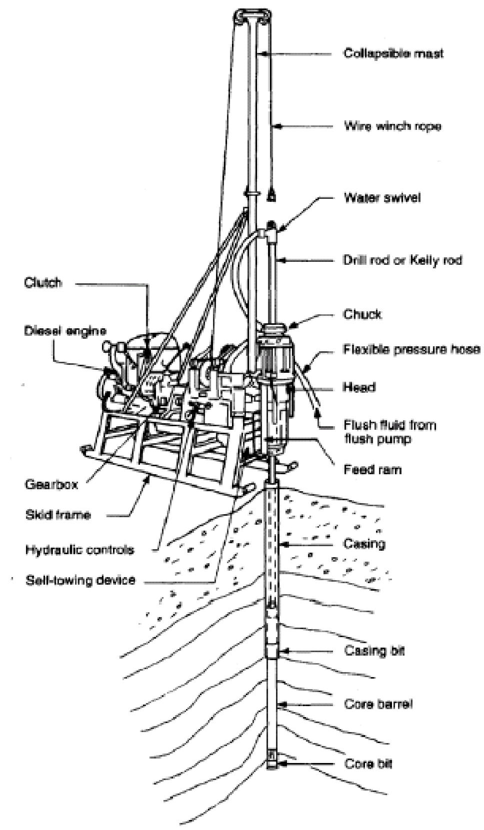


Fig. 5.1.2.7 Light Percussion Drilling Rig

Record of borings

In all exploration work accurate and explicit record of borings shall be kept. Soil/rock samples are collected at various depths, during boring. These samples are tested in the laboratory for identification and classification. The samples are properly preserved and arranged serially according to the depth at which they are found. Boring chart should be prepared for each bore hole. In addition, a site plan should be prepared; showing the disposition of various bore holes on it.

3. Sub-surface soundings

Sounding methods consist of measuring the resistance of the soil with depth by a means of **Penetrometer** under static and dynamic loading. The penetrometer may consist of a sampling spoon, a cone or other shaped tool. The resistance to penetration is empirically correlated with some of the engineering properties of soil, such as density index, consistency, bearing capacity etc. These tests are useful for general exploration of erratic soil profiles, for finding depth to bed rock, to have an approximate induction of the strength and other properties of the soil.

The two commonly used tests are :

- Standard penetration test
- Cone penetration test

Table 5.1.2.1 The Relation between N-values, Ø, and relative density of sand particles

N	4	4-10	10-30	30-50	>50
Ø	25-30°	27-32°	30-35°	35-40°	38-43°
Relative density	Very loose	Loose	Medium	Dense	Very dense

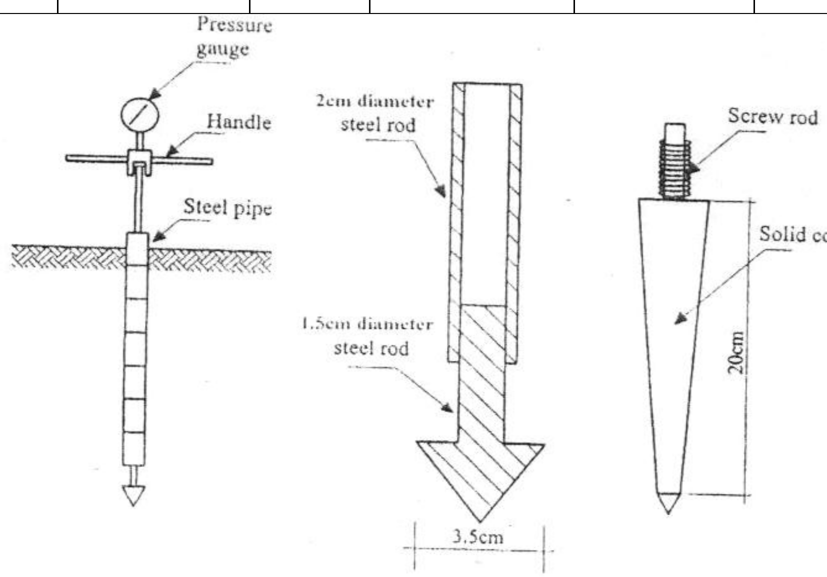


Fig. 5.1.2.8 Typical types of penetrometers

4. Geo-physical methods

Geo-physical methods are used when the depth of exploration is very large and the speed of investigation is of primary importance. These methods were developed in connection with prospecting of useful minerals and oils.

The major methods of geophysical investigations are:

- Gravitational methods
- Magnetic methods
- Seismic refraction method
- Electrical resistivity method

Seismic refraction and **electrical resistivity** methods are the most commonly used for civil engineering purpose

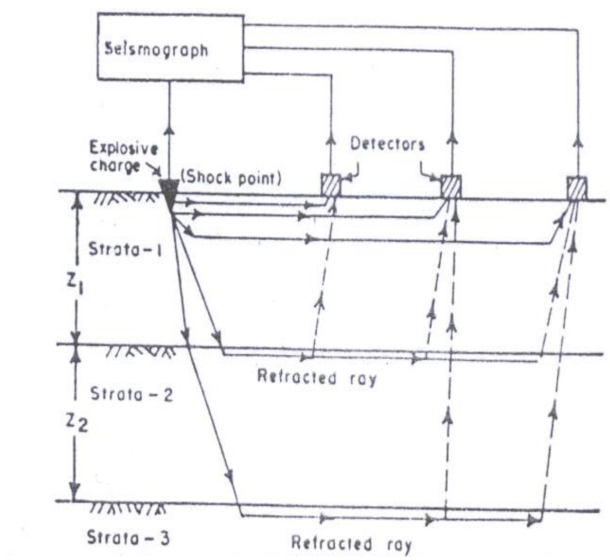


Fig. 5.1.2.9 Seismic Refraction method

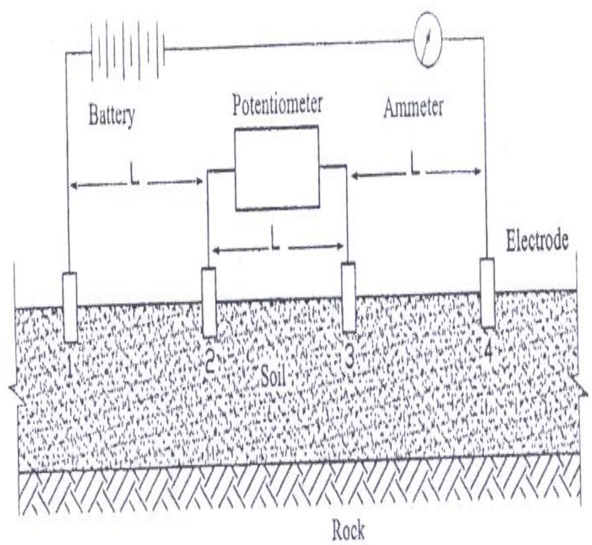


Fig. 5.1.2.10 Electrical Resistivity method

5.1.2.4 Bearing Capacity of Soils

The supporting power of a soil or rock is refer to as its bearing capacity. The ultimate bearing capacity is the minimum gross pressure intensity at the base of the foundation at which the soil fails in shear.

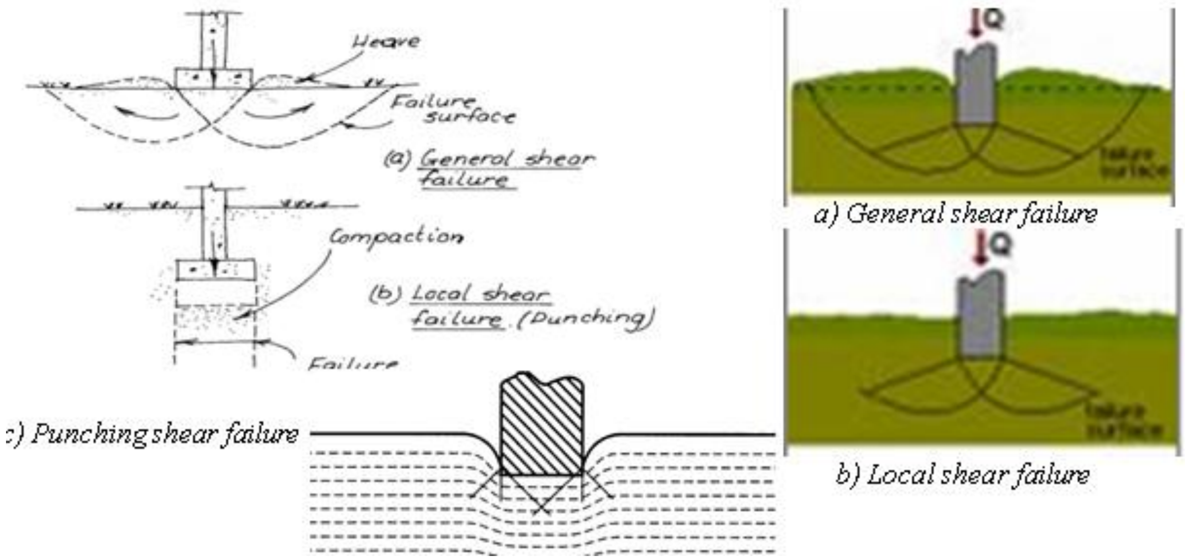


Fig. 5.1.2.11 Soil failure modes

The bearing capacity of soil can be determined by:

a) Analytical methods involving the use of soil parameter

b) Plate load test on soil

c) Penetration test

5.1.2..5 Soil samples

Soil samples can be of two types: disturbed samples and undisturbed samples.

i. **Disturbed sample -**Disturbed sample is that in which the natural structure of soil gets partly or fully modified and destroyed. The soil sample is representative of the natural soil by maintaining the original proportion of the various particles intact.

ii. **Undisturbed sample -** Undisturbed sample is that in which the natural structure and properties remain reserved. The sample disturbance depends upon the design of the samplers and the method of sampling.

5.1.2.6 Review Questions

1. Explain the purposes for which sub-soil investigation is done.
2. In site reconnaissance what are the things we need to examine.
3. How do you decide the depth of exploration? Mention the recommended depth of exploration for various types of foundations.
4. What do you understand by a trial pit? When do you adopt this method?
5. Explain in brief the various methods of boring for sub-soil exploration.
6. What do you understand by a bore hole? How do you maintain the details of various types of strata obtained during boring?
7. Write a short note on sub-surface soundings.
8. What do you understand by geo-physical methods? Enumerate various methods used.
9. What do you understand by ultimate bearing capacity? Enumerate the different methods to determine the bearing capacity of soil.
10. Explain in detail the plate load test for determining safe bearing capacity of soil.
11. Differentiate clearly between disturbed sample and undisturbed sample.

5.2 FLOOR SYSTEMS

5.2.1 Introduction

The primary purpose of a floor is to provide a level surface capable of supporting the occupants of a building, furniture, equipments, and sometimes the internal partition walls. And floors should exclude the passage of water and water vapor to the interior of the building. In addition, floor should provide resistance to unacceptable heat loss through the floor, and provide the correct type of surface to receive the chosen finish.

To perform its function a floor must satisfy the following requirements:

- Adequate strength and stability,
- Adequate fire resistance,
- Sound insulation,
- Damp resistance, and
- Thermal insulation.

In the traditional floor construction, a floor is needed to have a ***clean***, ***smooth***, ***impervious***, ***level*** and ***durable surface***. Generally floors are classified as **ground floor** and **upper floor**. The floors resting directly on the ground surface are known as **ground floors**. While the other floors of each storey, situated above the ground level are known as **upper floors**.

5.2.2 Components of a floor

A floor is composed of two essential components s**ub-floor, base course or floor base** which is a structural component, and f**loor covering or simply, flooring.**

5.2.3 Ground floors

5.2.3.1 Introduction

Ground floors are further subdivided into **solid floors**, **suspended floors** and **basement floors**.

Solid floors - The floors supported directly on the ground are known as solid floors.

Suspended floors - These are floors supported above the ground level. And suspended floors do not rely on the ground for support.

Basement floors - These are floors resting at the lowest/basement level. Resistance to moisture ingress is one of the main criteria in the design of basement floors.

5.2.3.2 Functional Requirement of Ground Floors

For good performance of a ground floor, it should be able to perform the following:

1. Support without failure the loads imposed on it.
2. Prevent dampness inside the building by providing a damp proof membrane in or below the floor.
3. Prevent the growth of matter and other living organisms.
4. Be reasonably durable so as to require minimum maintenance or replacement work.
5. Provide a surface finish with a standard of appearance, comfort, cleanliness, and heat retention.

5.2.3.3 Solid Floors

A solid ground floor consists of three components

i. **Hard core**: The main purpose is to prevent the dampness from the soil penetrating and affecting the floor through capillary action.

ii. **Damp proof membrane**: an impervious layer such as heavy duty polythene sheeting to prevent moisture passing through the floor to the interior of the building.

iii. **Concrete bed**: the component providing the solid level surface to which screeds and finishes can be applied.

5.2.3.4 Suspended Floors

These types of ground floors are supported on other elements of structure, and there is a void beneath them. Suspended ground floor is needed rather than a ground bearing slab on the following occasions:

- Soil with a low bearing capacity,
- Sloping sites,
- Soils containing aggressive chemicals, and
- Sites with high water levels.

Suspended floors are most commonly constructed using **timber** and **concrete beams and blocks.**

5.2.4 Upper floors

5.2.4.1 Introduction

An upper floor is basically a principal structural element, and the general structural design of a building greatly influences the choice of type of floor. Upper floors are supported either on the walls or on columns; they have therefore the major problems of strength and stability. The structural design of upper floors has to be such as to support the loads exerted by the users of the building, self weight of the floor, weight of partitions, etc. An upper floor can be constructed either from timber or concrete (Cast in situ and precast concrete).

Upper floors are regarded to be composed of three parts:

- The structural element,
- Upper surface or floor finish, and
- Lower surface or ceiling.

5.2.4.2 Functional Requirements of Upper Floors

An upper floor should:

1. Sustain its own weight and any other weights imposed on it.
2. Offer fire resistance especially in very tall buildings.
3. Minimise noise transfer from upper floor to the lower floor.
4. Be reasonably durable – minimum maintenance and replacement.
5. Provide an acceptable surface finish which is safe, comfortable, clean and of good appearance.
6. Prevent dampness.

5.2.4.3 Concrete Floors (R.C.C Floors)

Floors of modern buildings are invariably made of reinforced cement concrete (R.C.C) for different advantages such as; moderately cheap, quite durable, easy to construct, fire proof and damp proof, can be used in large spans, etc. R.C.C floors can be cast in situ or prefabricated.

5.2.4.3.1 Cast In situ R.C.C Floors

Cast in situ concrete floors give the maximum freedom in design since they can take up any shape dictated by the plan. Based on the design requirements cast in situ concrete can be:

A. Simple slab flooring
B. Beam and slab flooring
C. Flat slab flooring
D. Waffle grid slab flooring
E. Drop slab floor
F. Ribbed or hollow tiled flooring

A. Simple slab flooring

These slabs are **quite suitable** and **economical** for short spans and in most cases they are wall supported.

- ***One way reinforced slab*** ($l_y/l_x > 2$): the main reinforcement is placed in the direction of the shortest side.
- ***Two way reinforced slab*** ($l_y/l_x < 2$): the main reinforcement is placed in both directions.

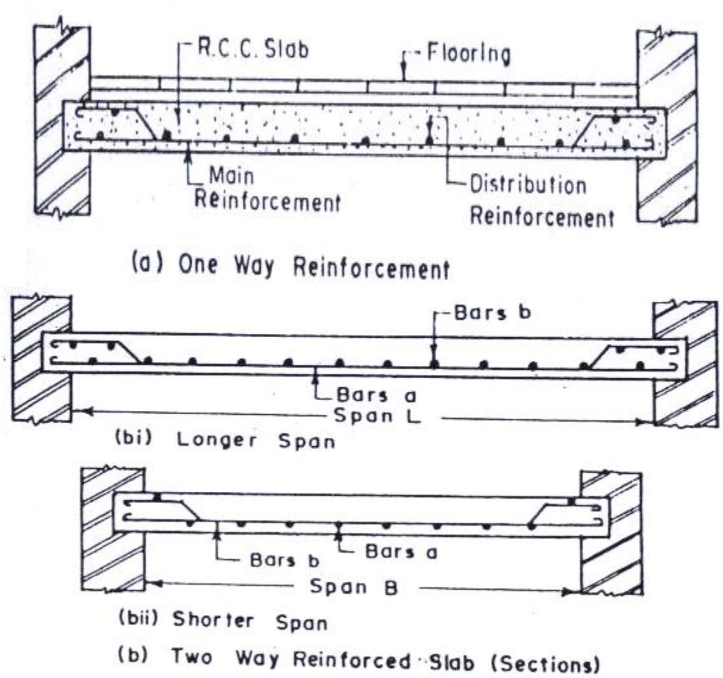


Fig. 5.2.1 Simple slab flooring

B. Beam and slab flooring

When the width of the room becomes more, the span of slab increases, and simple R.C.C slab becomes more uneconomical. In that case, the floor structure consists of RCC beams and slab cast monolithically. The beams known as T-beams, act as intermediate supports to the slab which is continuous over these beams. These types of floors are generally the most economical and most usual form of floor construction.

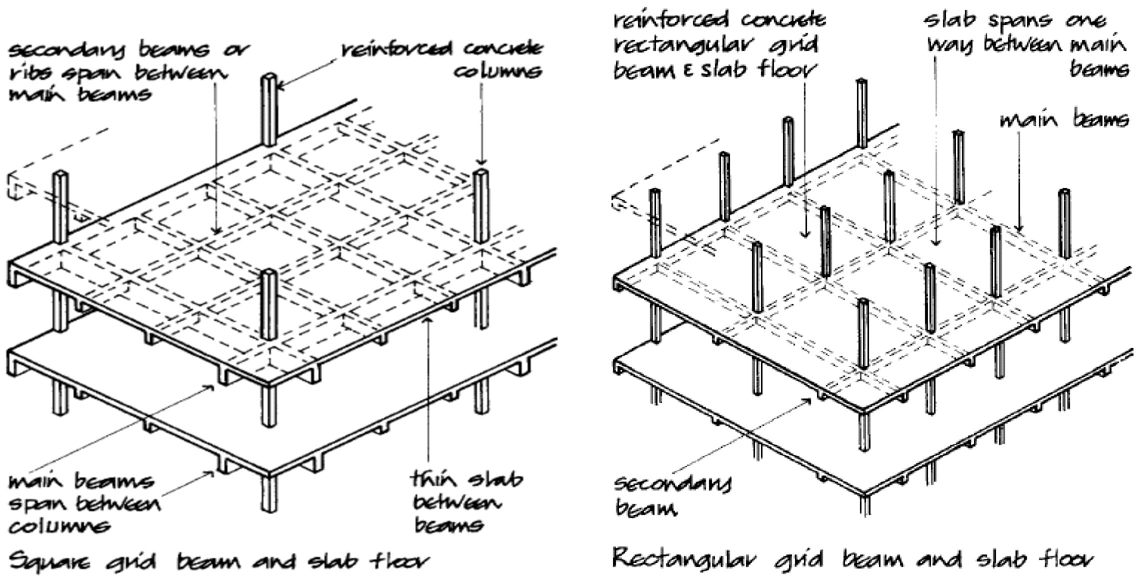


Fig. 5.2.2 Beam slab flooring

C. Flat slab flooring

The slab is of uniform thickness throughout without down stand beams and with the reinforcement more closely spaced. The reinforced slab is monolithically cast with the supporting columns without any provision of beams. The flat slab transfers the load directly to the supporting columns suitably spaced below the slab. It is used in case of ***large span*** and ***heavy loads***.

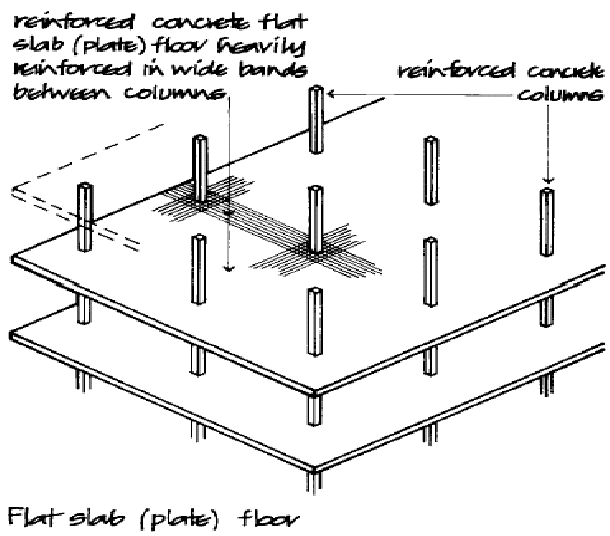


Fig. 5.2.3 Flat slab flooring

D. Waffle slab flooring

The intermediate cross beams are cast on a rectangular square grid that gives the underside of the floor the appearance of a waffle. The advantage of the intermediate beams of the waffle is they support a thin floor slab and reduce the dead weight of the floor. This type of floor is used where a widely spaced square column grid is necessary and floors support comparatively heavy loads.

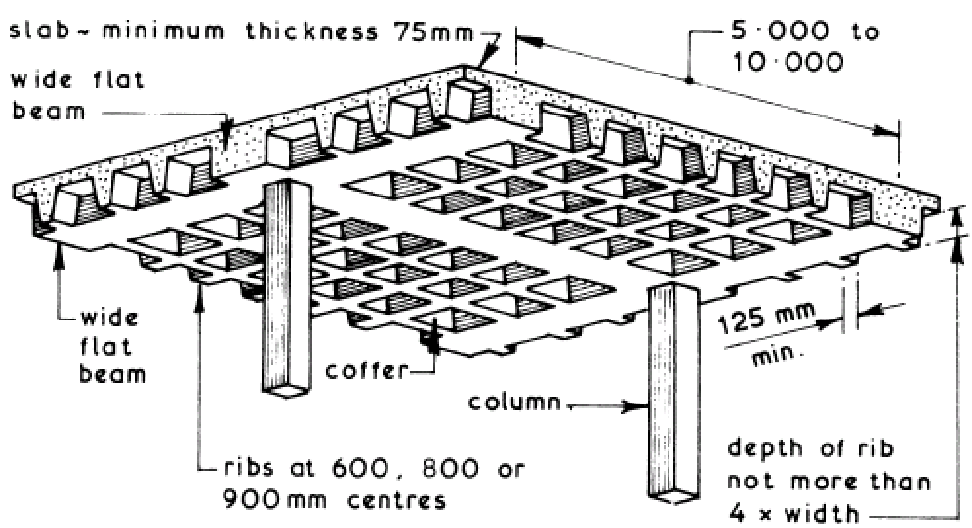


Fig. 5.2.4 Waffle slab flooring

E. Drop slab flooring

A floor slab which is thickened between columns in the form of a shallow but wide beam. This will reduced dead weight of the slab, make it cheaper and the drop panel will make the slab strong against punching shear near columns (support).

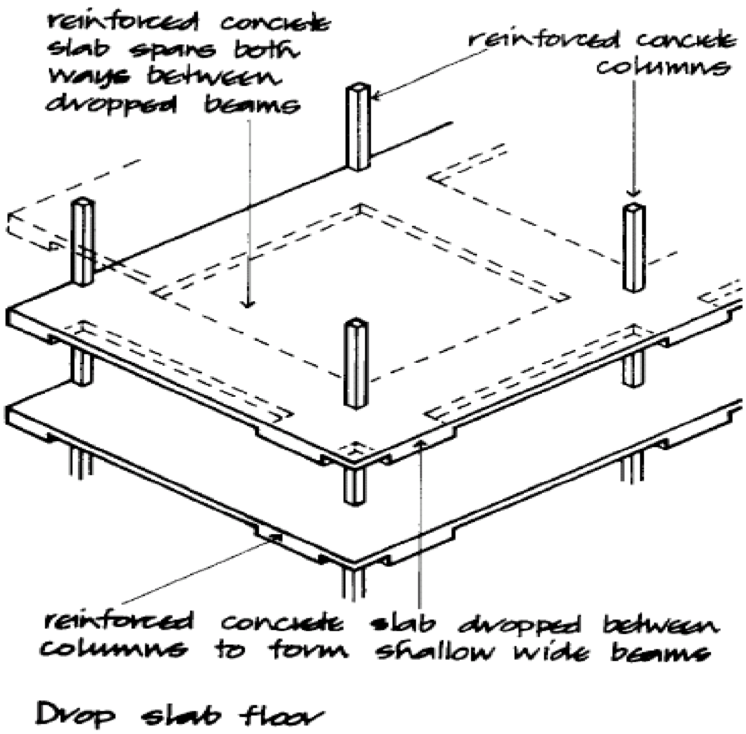
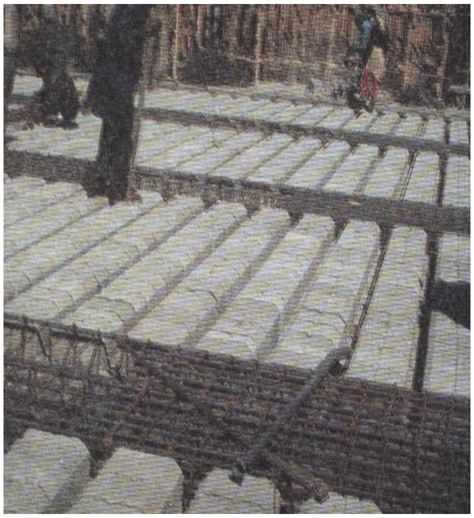


Fig. 5.2.5 Drop slab flooring

F. Ribbed slab flooring

Ribbed slab flooring is a floor system consisting of closely spaced secondary beams (ribs) which transfer load to the main beam/girder that will in turn transfer the load to columns or walls. The hollow space between the ribs is mostly filled with light weight hollow concrete blocks so as to have flat surface in the soffit of the slab. Some of the advantages of ribbed slab are:

- They are light in weight.
- They provide better thermal insulation.
- They have better sound proofing qualities.
- They have better fire resistance.
- Convenient installation of electrical and plumbing



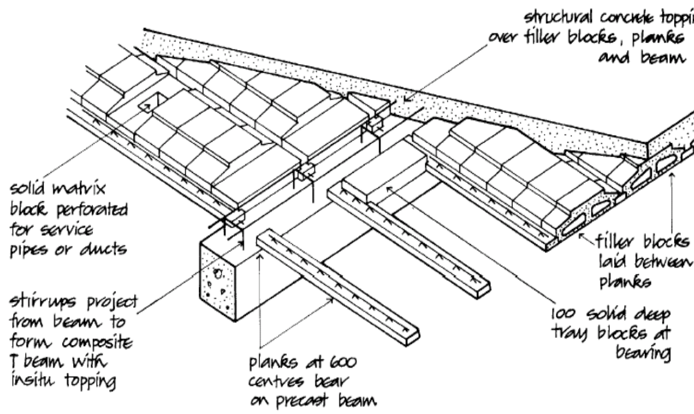


Fig. 5.2.5 Ribbed slab flooring

5.2.4.3.2 Precast Concrete Floors

Precast concrete floors are designed primarily with the object of eliminating formwork and wet poring, which make the installation of an in situ floor rather a slow process. Precast concrete floors can be erected rapidly and they are lighter in weight. They also eliminate curing time in the site, result in superior quality and can be erected at every weather condition. But they have some disadvantages such as; less flexibility in design, problems at connections, requirement for lifting device, and high degree of site accuracy is required.

5.2.4.4 Timber Floors

The fact that wood can be glued, laminated or bonded to metal or plates make it versatile construction material. Timber floors essentially consist of boarding supported on timber joists called floor joists. The structural element of timber floors is the joist. The joists are designed to carry the necessary load across the span, and the floor planking adds to the rigidity of the floor. Timber floors though quite light in weight, have poor fire resistance and sound insulation properties. The resistance of wood to fire and insects can be improved by coating. Care also should be taken in moisture flow.

5.2.5 Floor finishes

The choice of floor finishes depends on the use to which the floor is likely to be employed. The following are the factors that affect the choice of flooring materials:

- **Initial cost**: The cost of the material should be in conformity with the type of building, and its likely use.
- **Appearance**: covering should give pleasing appearance, and it should produce a desired color effect and architectural beauty.
- **Cleanliness**: the flooring should be capable of being cleaned easily, and it should be non absorbent.
- **Durability**: the flooring should have sufficient resistance to wear, temperature changes, disintegration with time and decay.
- **Damp resistance**: flooring should offer sufficient resistance against dampness.
- **Thermal insulation**: the flooring should offer reasonably good thermal insulation.
- **Sound insulation**: flooring should insulate the noise. It should not be such that noise is produced when users walk on it.
- **Fire resistance**: Flooring material should offer sufficient fire resistance so that fire barriers are obtained between different levels of building.
- **Smoothness**: the flooring material should be smooth, and should have even surface. However it should not be slippery.
- **Hardness**: It should be sufficiently hard so as to have resistance to indentation marks, in prints etc.
- **Maintenance**: the flooring material should require least maintenance. However, whenever repairs are required, it should be such that repairs can be done easily with least expenditure.

5.2.5.1 Brick Flooring

Brick flooring is used in cheap constructions, especially where good bricks are available. It is specially suited for warehouses, stores, pedestrian walk ways, etc. Good quality bricks of various shapes and colors can be used.

Base course:

- Sub grade is compacted properly and a 7.5 cm thick layer of sand is spread.

- 10-15cm thick layer of lean concrete is laid over the prepared sub grade.
- Slopes shall be properly provided

Construction:

- Bricks shall be socked and wetted
- The joints are rendered, flushed and finished
- The brick flooring shall be cured for 3-7 days to improve the durability.

Fig. 5.2.6 Brick flooring

5.2.5.2 Flag Stone Flooring

Dressed stone having rectangular or square sizes or any shapes are used for making floors. Stone flooring can be used for garages, entrance corridors, pedestrian walkways, etc.

Base course:

- properly compacted ground or concrete base

Construction:

- Joints are pointed and cured
- Provision of slope is necessary

Advantages:

- Hard, durable and resistant to wear and tear
- Easy in construction and maintenance

But it is not suitable in places like residential building or important public building.

5.2.5.3 Cement Concrete Flooring

Cement concrete flooring is suitable for residential, commercial buildings, industrial buildings, laboratories, garage, and ware houses.

Properties:

- Moderately cheap, durable and easy to construct
- Moderately resistant to oil and weak acids

Components:

- Base concrete and toping (wearing) surface.

Construction:

- The components can be constructed monolithically or independently
- Monolithically casted: the topping may be damaged during subsequent operation, hair cracks may also be developed plus the work progress is low.
- Independently casted: base surface is covered with slurry, mix 1:2:4
- In both cases the floor should be cured properly (at least for 7 days).

5.2.5.4 Granolithic Flooring

Granolithic finish consists of rich concrete made with very hard and tough quality coarse aggregates such as granite, basalt, and quartzite. They are suitable where hard resistant to wearing and durable floor is needed.

Mix proportion:

- 1:1:2 to 1:1:3 for heavy duty floors
- 1:2:3 for public buildings

Thickness of finish:

- Minimum of 25mm when laid monolithically with the top concrete
- Minimum of 35mm when laid over hardened surface.

Construction:

- Shall be laid before the base coarse has set
- Surface is tamped and floated
- Smoothened by steel trowel
- Grinding and polishing is done after curing

5.2.5.5 Tiled Flooring

Tiled flooring are suitable for residential houses, offices, schools and other public buildings

Properties:

- Made of cement, clay, concrete or terrazzo
- Constructed in Square, hexagonal or other shapes and many colors.

Construction:

- Similar to laying stone or brick floor
- Over a concrete base, a 25 to 30 mm thick layer of mortar is spread
- Neat cement slurry is spread over the bedding mortar
- Cement grouting of the joints
- The flooring need to be cured for 7 days
- Grinding and polishing

Fig. 5.2.7 Tiled flooring

5.2.5.6 Wooden/Timber (Parquet) Flooring

Timber is one of the oldest materials for floor finishing. It is suitable for living and dining rooms, bed rooms, dance halls, auditoriums etc...

Properties:

- Must have hard, Resistant to wear and durable surface
- Selection shall be based on texture, color, defects and grain
- Available in various shapes, sizes, texture and color
- Shall be avoided in moist areas

Sub-base: Cement screed finished concrete base

Construction:

- Can be glued to concrete floors
- Can be joined by nails
- Protective coating like varnish, lacquer, wax shall be applied for long service periods.

Fig. 5.2.8 Wooden/ Timber flooring

5.2.5.7 Terrazzo Flooring

Terrazzo is concrete containing white and/or coloured cement and marble chips as an aggregate in proportion of 1:2 to 1:3. This flooring is suitable for residential, Offices and other public buildings

Properties:

- Marble Chips exposed by grinding, may vary from 3-6 mm
- Decorative and high wearing resistance
- Can be found in market as precast terrazzo in the form of tiles (20-30 cm, t = 2-3cm) even for Stair Treads and Risers or as cast in situ.

Sub-base: concrete base

Construction:

- Shall be casted with the required mix proportion
- Grinding in three levels and then cement grout to seal holes
- Mirror - Polishing

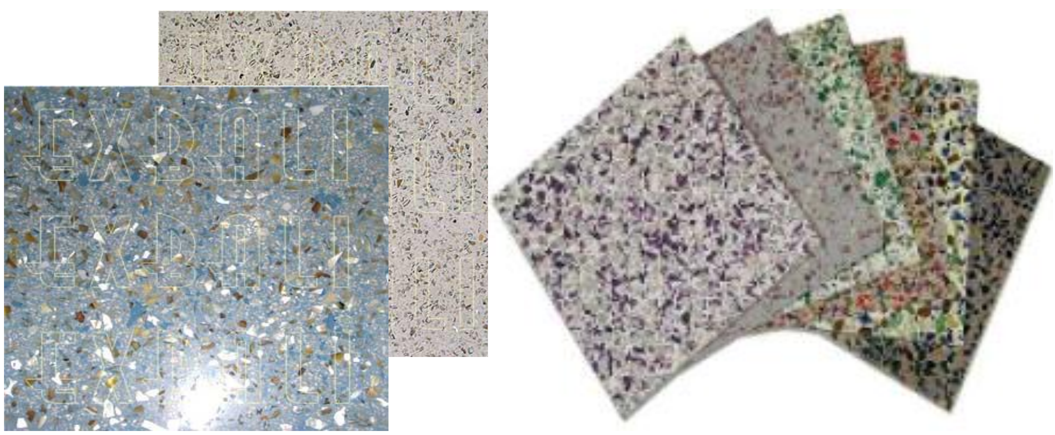


Fig. 5.2.9 Terrazzo flooring

5.2.5.8 Mosaic flooring

Mosaic flooring is made of small pieces of broken tiles of china glazed or of cement, or of marble arranged in different pattern. This flooring is suitable for walls, floors, both internal and external, Stairs.

Properties:

- Glazed or Unglazed
- Impervious to water and have dense structure.

Types:

- **Porcelain** - made by dust press method from ceramic materials with vitreous body, resistant to freezing and thawing and abrasive wear.
- **Natural Clay (Ceramic)** – made of natural clays or shale, which produce a strong longwearing structure with slightly textured surface.

Sub-base: concrete base

Construction:

- Concrete base made of mortar– mortar is spread & leveled to a depth of 5 to 8 cm.
- 3mm thick suitable cementing material in the form of paste is spread
- Mosaics are arranged in different pattern and hammered
- Stone roller about 30 cm in dia. and 45-60 cm long is passed
- White cement grout of creamy consistency is applied as a filler

Fig. 5.2.10 Mosaic flooring

5.2.5.9 Plastic (PVC) Flooring

It is made of plastic material, called Poly-Vinyl-chloride (PVC). It is suitable for residential as well as non residential buildings.

Properties:

- Fabricated in rolls or tiles with different colors
- Resilient, smooth, good looking and cleanable
- Easily damaged by heat or chemicals

Sub-base:

- concrete base (smoothly finished cement screed)

Construction:

- Adhesive shall be applied to the cement screed surface
- Tiles are then pressed gently using lightweight rollers
- Floor is washed with warm soap water

Fig. 5.2.11 Plastic (PVC) flooring

5.2.5.10 Marble Flooring

Marble flooring is one of the most expensive floor finishes. This flooring is suitable for residential buildings (Stairs, Corridor, and Kitchens), Public and Worship places.

Properties:

- Made of sedimentary rocks
- Different sources – Granite, Marble

- Durable, Water proof but expensive

Sub-base:

- concrete base

Construction:

- Similar to tile and terrazzo flooring
- Has to be cured and cleaned before use
- Mirror - Polishing

Fig. 5.2.12 Marble flooring

5.2.5.11 ASPHALT FLOORING

Asphalt floorings are of many types and are used where wear resistance and durability are the main design factor. It is mainly used in garages, stores, roof etc.

Properties:

- Wear resistance and durable
- Resilient, sound proof, non-absorbent and moisture proof
- Used for basement floors, ground floors, floors exposed to external weather condition

Sub-base:

- concrete base
- Wooden base (for asphaltic tiles only)

Types:

- **Asphalt mastic**: Made of sand and asphalt mixed hot and laid in continuous sheets.

- **Asphalt Tiles** – made of asphalt and other ingredients such as asbestos fibers, by pressing the mix in different sizes, with thickness varying usually from 3 to 6 mm.

- **Asphalt Mosaic** – similar to mastic but made with marble chips in the place of sand.

Construction:

- The mix is poured on the concrete base
- Spread by means of trowel to get a level surface
- A thin layer of sand is spread which is then rubbed with a trowel
- Asphalt tiles are simply glued to the base surface

Fig. 5.2.12 Asphalt flooring

5.2.5.12 Rubber Flooring

It consists of sheets or tiles of rubber, in variety of patterns and colors. This flooring is suitable for offices or public building like hospitals, schools, gym etc.

Properties:

- It is manufactured by mixing pure rubber with fillers such as cotton fiber, granulated cork or asbestos fiber.
- Resilient and noise proof however they are costly

Sub-base:

- concrete base or wood

Construction:

- Fixed to the floor by means of appropriate adhesive or easily laid on the base surface



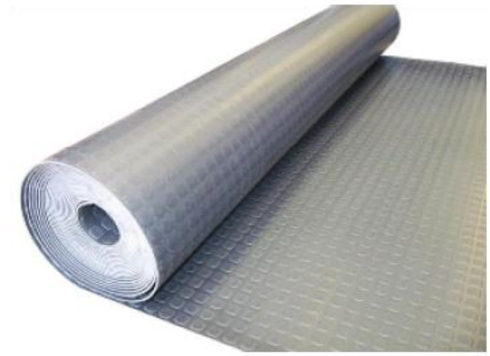


Fig. 5.2.13 Rubber flooring

5.2.5.13 Cork flooring

Cork flooring manufactured by baking cork granules with phenolic or other resin binders under pressure. This flooring is suitable for areas where quiet and comfort is of paramount importance such as libraries, theaters, art galleries, broadcasting stations, etc.

Properties:

- Perfectly noiseless
- They are available in various sizes, thickness, and shades [size= 10x10cm to 30x90cm, Thickness= 5 to 15mm]

Sub-base:

- concrete base or wood

Construction:

- Fixed to concrete base by inserting a layer of saturated felt
- By using fixing mechanism (suspended cork)

Fig. 5.2.14 Cork flooring

5.2.5.14 Glass Flooring

This is a special purpose flooring used in circumstances where it is desired to transmit light from upper floor to lower floor. It is suitable for basement and upper floor where light has to be transmitted. Glass flooring is very costly and not commonly used.

Properties:

- Structural glass, in the form of tiles or slabs (t = 12 to 30 mm)

Sub-base:

- Steel Frames

Construction:

- Suspended on closely placed frames
- Care should be taken to avoid joint failures

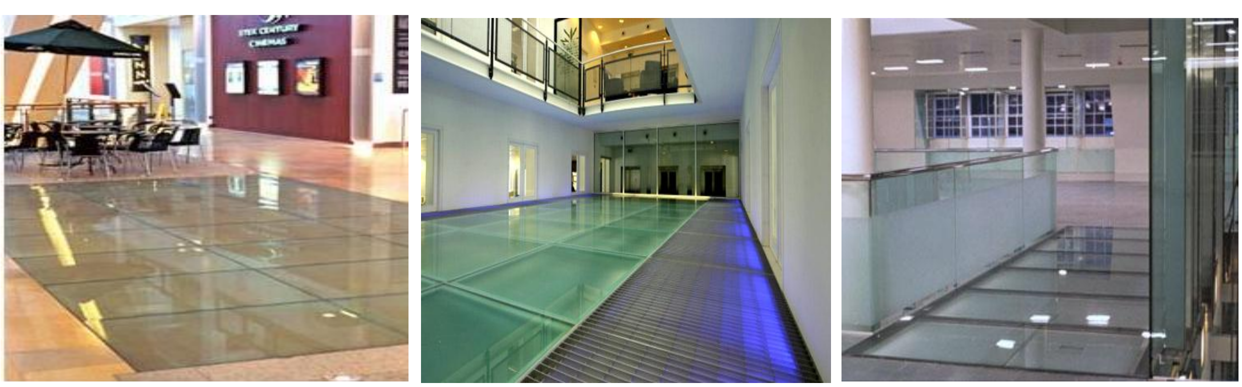


Fig. 5.2.15 Glass flooring

5.2.5.15 Linoleum Flooring

Linoleum sheets or tiles are manufactured by mixing oxidized linseed oil in gum, resins, pigments, wood flour, cork dust and other filler materials. It is suitable for residential buildings except for Bath rooms, kitchens, etc.

Properties:

- Seasoned in ovens for 2-4 weeks (given several coats of lacquer for greater stain and spot resistance)
- Attractive, resilient, durable, cheap and easily cleanable
- Subjected to rotting when kept wet or moist for some time
- The sheets are either plain or printed.
- Available in 2-6mm thickness and 2-4m wide roll.

Sub-base:

- Concrete or wood base

Construction:

- Linoleum sheets are easily spread or
- Fixed or glued to base in various patterns

Fig. 5.2.16 Linoleum flooring

5.2.5.16 Carpet Flooring

Carpet flooring is a textile floor covering consisting of an upper layer of "pile" attached to a backing. This flooring is suitable for passage ways, Bed Rooms, Hall ways, meeting rooms, etc.

Properties:

- The pile is generally either made from wool or a manmade fiber such as polypropylene, and usually consists of twisted tufts which are often heat-treated to maintain their structure.

Sub-base:

- Concrete or wood base

Construction:

- Carpets and carpet tiles can be laid loose, stuck with a suitable adhesive or in the case of carpets edge fixed using special grip strips.

Fig. 5.2.17 Carpet flooring

5.2.6 Review questions

1. Explain in brief, the essential requirements of a floor.
2. Discuss the requirements that must be fulfilled for a floor to serve its function.
3. In what occasions are suspended floor is recommended over solid ground floor?
4. Enumerate various types of upper floors?
5. Explain with sketches the various types of RCC floors. Where do you use flat slab floor?
6. What are the advantages that precast floors have over cast in situ concrete floors?
7. Enumerate the advantages of ribbed slab floor system.
8. Briefly discuss the different factors which affect the choice of floor finishing.
9. Explain the method of laying the following types of flooring (a) Flag stone flooring (b) Brick flooring (c) Marble flooring
10. Explain the method of constructing cement concrete flooring. What is the use of granolithic finish and how it is made?
11. Explain the procedure of constructing the following types of flooring (a)Terrazzo flooring (b)mosaic flooring (c) PVC flooring.
12. Write short notes on the following types of flooring (i) Asphaltic flooring (a) Linoleum flooring (b) Cork flooring (c) Rubber flooring.
13. Explain with reasons what type of floor finishing will be required for (a) Operation theatre (b) dancing hall (c) library (d) ware house (e) factory hall/workshop (f)Testing laboratory (g) hostel.

5.3 WALL SYSTEMS

5.3.1 Introduction

By definition a wall is a continuous, usually vertical structure of brick, stone, block, concrete, timber, or metal thin in proportion to its height and length. Wall is one of the most essential components of a building. The primary function of wall is:

- To enclose or divide space of a building to make it more functional and useful.
- To provide privacy and afford security
- Give protection against heat, cold, sun and rain
- Also to provide support to floors and roofs.

The functional requirements of a wall are:

- Strength and stability
- Resistance to weather
- Durability and freedom from maintenance
- Fire resistance
- Resistance to passage of heat
- Resistance to passage of sound

5.3.2 Types of Walls

A distinction between various types of wall can be made in two different ways:

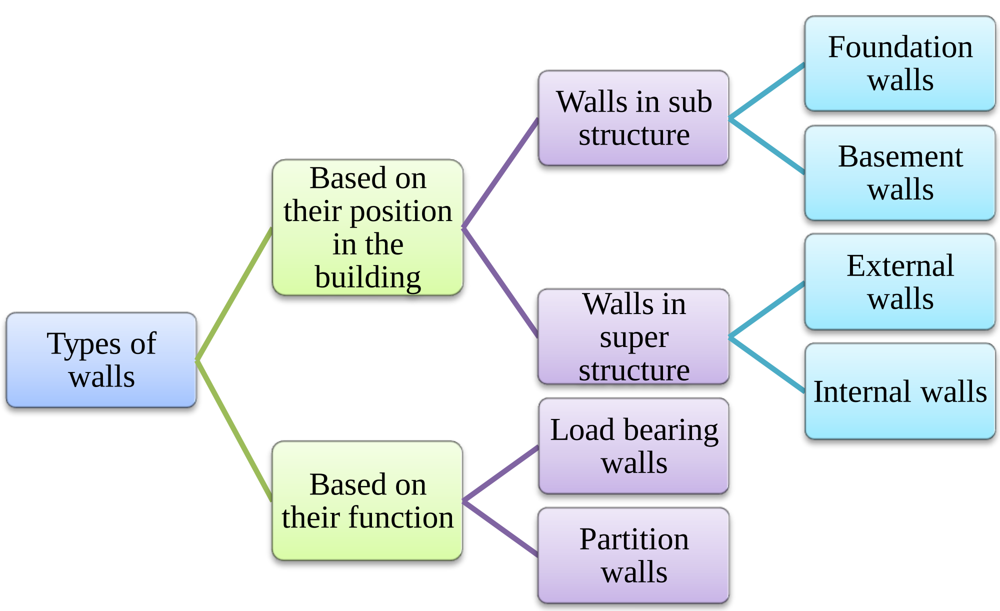


Fig. 5.3.1 Classification of walls

Foundation walls - The function of foundation wall is to transmit loads coming from the super structure. Load bearing capacity and resistance against effect of the underground, such as swelling pressure, uplift pressure and chemical attack should be taken into consideration.

Basement walls - The function of basement wall is to support vertical loads (if load bearing), resist lateral loads, and protect the building from dampness.

External walls - They must provide protection against wind and rain, should insulate heat, be water repellent, fire resisting and capable of sound insulation.

Internal walls - Internal walls are basically required to separate rooms. They should have sufficient sound and heat insulating capacity and should be water repellent.

Load bearing walls - The strength must be sufficient to carry the loads placed on it. The loads are calculated from the live and dead loads on the structure supported by the wall. Wind pressure must also be taken into account.

5.3.3 External Walls

5.3.3.1 Materials for external walls

Different materials are employed for the construction of external walls such as: brick, stone, HCB, RCC, glass, metals and plastics, “chika”, etc. The materials employed depend on several factors such as:

- Local availability of the material
- The standard of the house planned
- Climatic conditions
- Cost of the material
- Aesthetic requirements
- Skilled labour availability
- Function of the wall to be constructed
- Fire resistance requirement

5.3.3.2 Types of External Walls

External walls can be classified in different groups according to their ***structural functions*** and ***physical nature***.

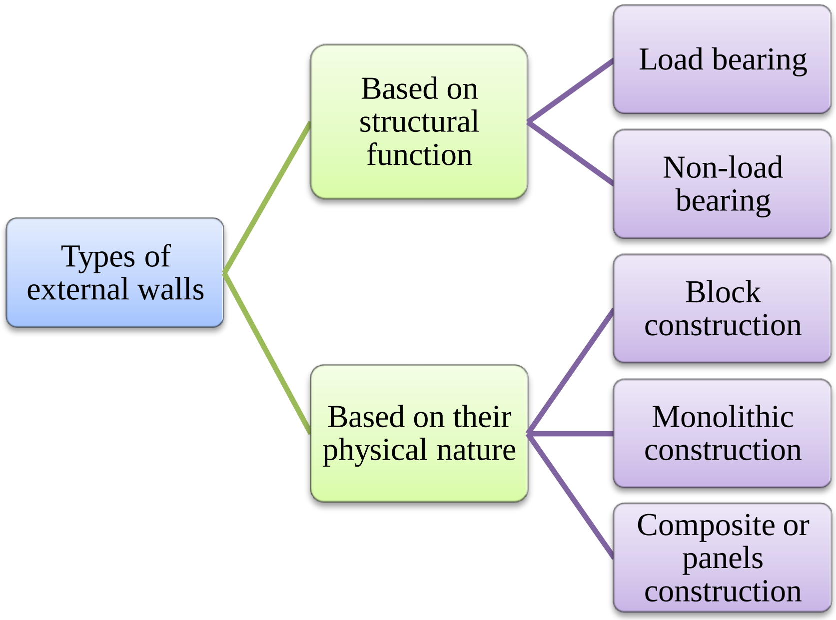


Fig. 5.3.2 Types of external walls

5.3.3.2.1 Walls of Block Construction

Walls composed of stones, bricks or HCB are of block construction. They are formed from fairly small units set in matrix of cement mortar. The properties and strength of such wall depend on quality of masonry material, quality of mortar and method of bonding used.

A. Brick walls

Brick walls are widely used both as load bearing and as non-load bearing walls. Brick is a very old building material. The production of bricks for various purposes has advanced significantly and it is now excellent building material all over the world having different shapes, sizes, color and characteristics.

The practice of using bricks for construction in Ethiopia is not that old. The process of brick production in Ethiopia is far from accurate and doesn't benefit from the current advances in brick technology.

A.1 Manufacturing of clay bricks

Brick is manufactured from clay. Clay is a fine grained soil, which has resulted from weathering of rocks. Clay for the production of brick must possess some specific properties:

- ***Plasticity***: which permits it to be shaped or moulded,
- ***Sufficient tensile strength***: to maintain its shape after forming,
- ***Must fuse together*** when subjected to rising temperature.

Clay occurs in three principal forms having similar chemical composition but different physical characteristics. They are:

- ***Surface clay***: recent sedimentary formation
- ***Shale***: clay that have been subjected to high pressure
- ***Fire clay***: mined at deeper levels and have refractory qualities

Chemically all the three forms are compounds of silica and alumina with varying amounts of metallic oxides and other impurities.

- ***Metallic oxides***: acts as fluxes promoting fusion at lower temp.
- ***Iron, magnesium and calcium***: influence the color
- ***Silicates:*** contribute for the strength and durability

There are generally four basic stages in brick manufacturing:

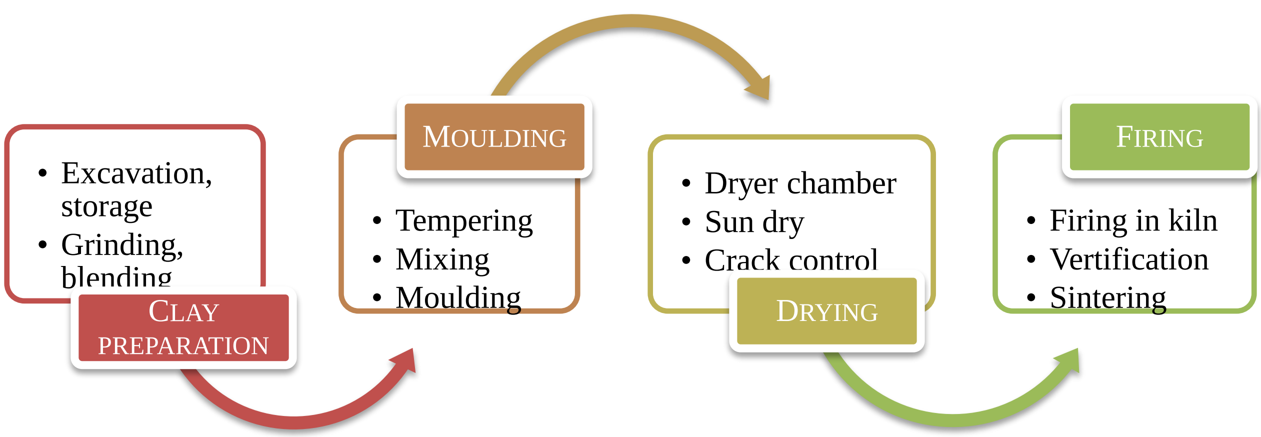


Fig. 5.3.3 Stages of brick manufacturing

A.2 Types of clay bricks

Different types of bricks can be produced depending on the ***types of clay***, ***the moulding*** and ***firing process:***

i. **Common bricks**
   - They are ordinary bricks
   - They are not designed to provide good finished appearance & highest strength
   - They are the cheapest bricks

ii. **Facing bricks**
   - They are designed to give attractive appearance
   - They are free from imperfections such as cracks & size variations

iii. **Engineering bricks**
   - They are designed for strength & durability
   - They have high density & well fired

iv. **Fire bricks**
   - They are made of special fire clay
   - They are used for lining in fire places, furnaces, etc. where high temperatures are prevalent.

A.3 Tests for bricks

i. **Field test for soils**
   - Balls of about 8cm are moulded with hands & allowed to dry.
   - Moulding bricks of standard size

ii. **Field test for burnt clay bricks**
   - **Appearance**: shape, plainness, color checks
   - **Hammer test**: properly burnt & free from cracks brick emits a metallic ring.
   - **Hardness test**: scratching surface with a knife.

iii. **Laboratory tests**
   - **Compressive strength**: direction of loading same as that to be applied in practice.
   - **Water absorption**: 24 hrs cold water or 5 hrs boiling water tests.
   - **Efflorescence**: results from dissolved salts & spoils the appearance.

Table 5.3.1 Minimum compressive strength of brick (ES C.D4.001)

Class	Average of 5 brick [MPa]	Individual brick [MPa]
A	20	17.5
B	15	12.5
C	10	7.5
D	7.5	5.5

Table 5.3.2 Maximum water absorption (ES C.D4.001)

Class	24-hrs immersion (%)		5-hrs immersion (%)	
	Avg. of 5 bricks	Individual brick	Avg. of 5 bricks	Individual brick
A	21	23	22	24
B	22	24	23	24
C,D	No limit	No limit	No limit	No limit

A.4 Brick masonry

Brick masonry is sometimes preferred over other types of masonry for the following reasons:

- Bricks are of uniform size and shape, and hence they can be laid in any definite pattern.
- Bricks are light in weight and small in size. Hence they can be easily handled.
- Brick do not need any dressing.
- The art of brick laying can be understood easily.
- Ornamental works can be easily done with bricks.
- Light partition walls can be easily constructed in brick masonry.

A.4.1 Terminologies

- **Course:** A course is a horizontal layer of masonry units.
- **Stretcher**: A stretcher is the longer face of a brick as seen in the elevation of the wall.
- **Header**: A header is the shorter face of a brick as seen in the elevation of the wall.
- **Lap**: Lap is the horizontal distance between the vertical joints of successive brick courses.

- **Bed**: Bed is the lower surface of the brick when laid flat.
- **Closer**: It is a portion of the brick with the cut made longitudinally and is used to close up bond at the end of the course.
    - **Queen closer**: It is a portion of a brick obtained by cutting a brick length wise into two portions.
    - **King closer**: It is obtained by cutting the triangular piece between the center of one end and the center of the other side.
    - **Bevelled closer**: A special form of king closer in which half width is maintained at one end and full width is maintained at the other end.
    - **Mitred closer**: It is a portion of a brick whose one end is cut splayed or mitred for full width.
- **Bat**: It is the portion of the brick cut across the width. Thus, a bat is smaller in length than the full brick.
    - ***Half bat***: equal to half the length of the original brick
    - ***A three-quarter-bat:*** its length equal to three-quarters
    - ***Bevelled bat***: A bat with its width bevelled
- **Racking back**: It is the termination of a wall in a stepped fashion.
- **Toothing**: It is the termination of the wall in such a fashion that each alternate course at the end projects.

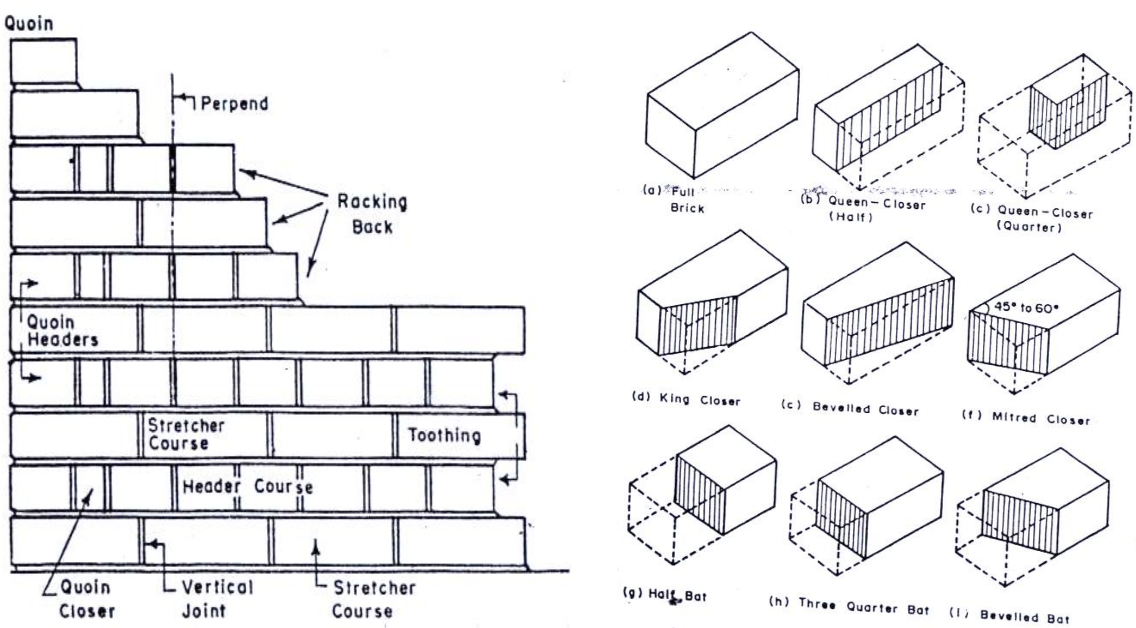


Fig. 5.3.4 Brick masonry terminologies

A.4.2 Rules for bonding

For getting good bond, the following rules should be observed:

i. The brick should be of uniform size. The length of the brick should be twice its width plus one joint.
ii. The amount of lap should be minimum ¼ brick along the length of the wall and ½ brick across the thickness of the wall.
iii. Use of brick bats should be discouraged, except in special locations.
iv. In alternate courses, the center line of header should coincide with the center line of the stretcher, in the course below or above it.
v. The vertical joints in the alternate courses should be along the same perpend.
vi. It is preferable to provide every sixth course as header course on both sides of the wall.

A.4.3 Types of brick bonds

Bond is the system of laying bricks in such a manner that there is no vertical joint in any row or course immediately above or below the one considered.

I. Stretcher bond

It is a brick bond type in which all the bricks are laid as stretchers on the faces of the wall. This pattern is used only for those walls which have thickness of half brick. Used as partition walls, sleeper walls, chimney stacks, etc

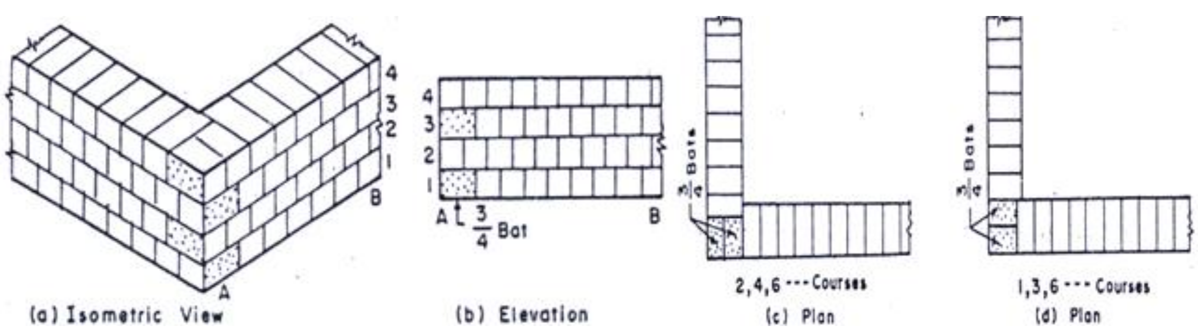


Fig. 5.3.5 Stretcher bond

II. Header bond

In this type of brick bond, all the bricks are laid as headers on the faces of walls. The width of the brick is along the direction of the wall. The pattern is used only when the thickness of the wall is equal to one brick. This bond does not transmit pressure in the direction of the length of the wall. Thus it is unsuitable for load bearing walls.

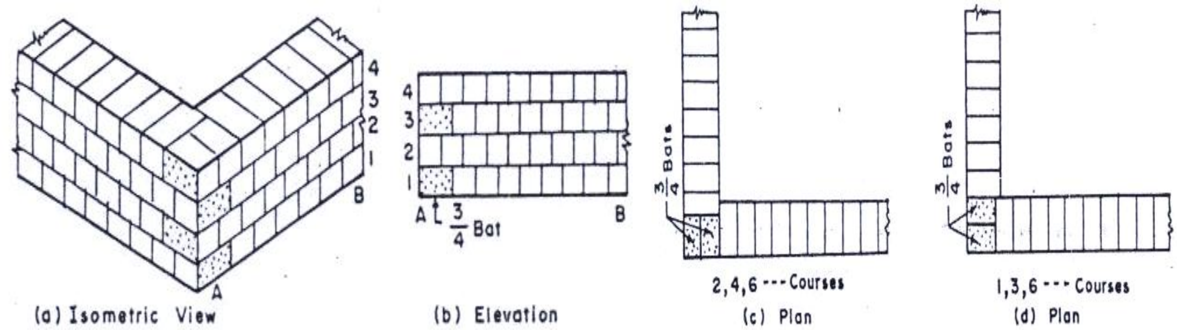


Fig. 5.3.6 Header bond

III. English bond

This is the most commonly used bond, for all wall thickness. And it is considered to be the strongest. The bond consists of alternate courses of headers and stretchers. The vertical joints of the header courses come over each other, the same goes for stretcher courses.

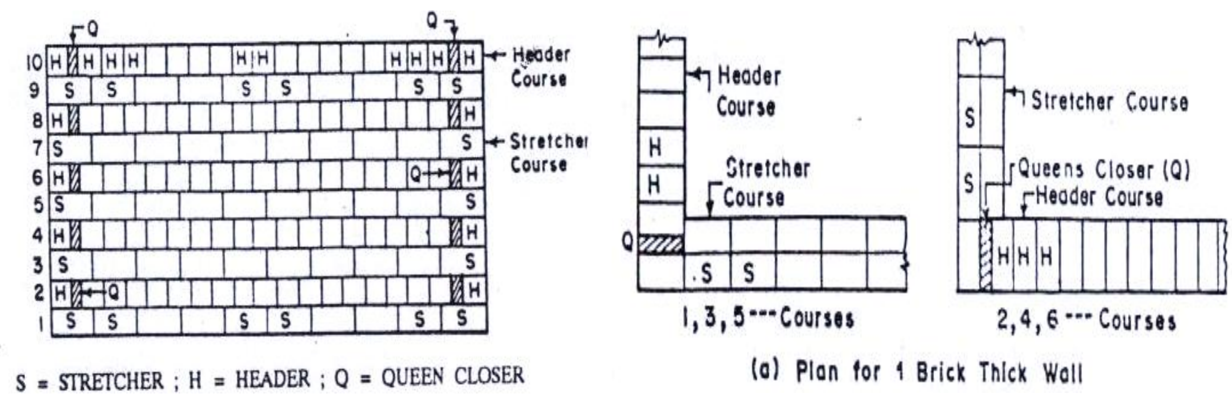


Fig. 5.3.7 English bond

IV. Flemish bond

In this bond, each course is comprised of alternate headers and stretchers. Every alternate course starts with a header at the corner (i.e. Quoin header). Quoin closers are placed next to the quoin header in alternate courses to develop the face lap. Every header is centrally supported over the stretcher below it. Flemish bond can be of two types; double and single Flemish bond.

Double Flemish bond: each course presents the same appearance both in the front face as well as in the back face. Alternate headers and stretchers are laid in each course. And It presents better appearance than English bond.

Single Flemish bond: Comprised of double Flemish bond facing and English bond backing and hearting in each course. It combines the strength of English bond and appearance of Flemish bond.

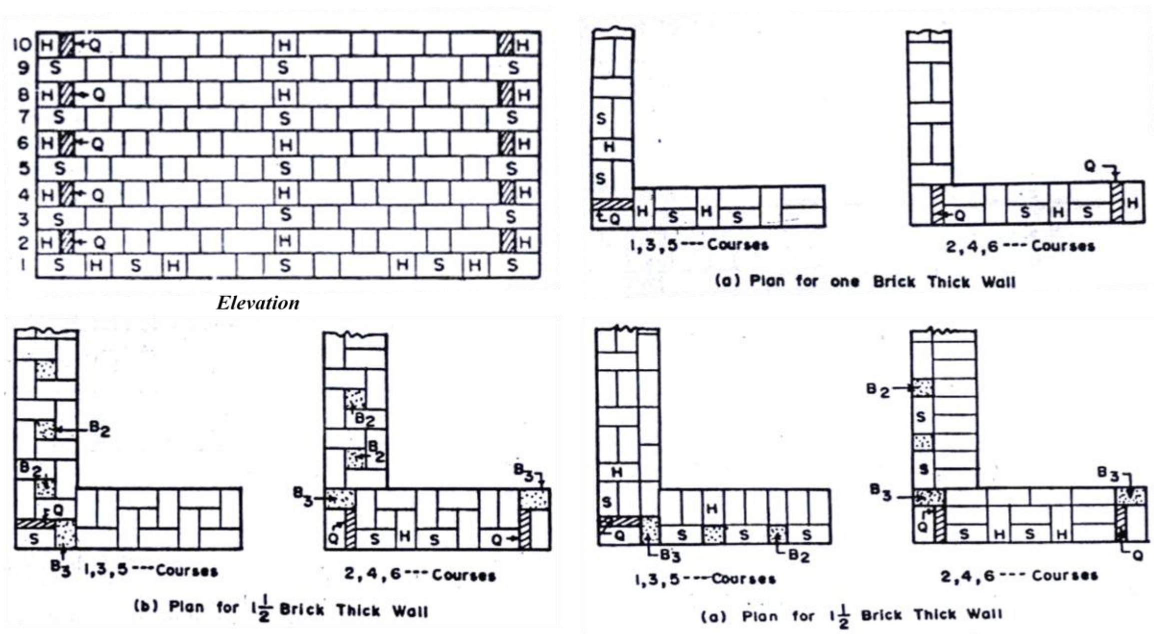


Fig. 5.3.8 Flemish bond

V. English cross bond

This is the modification of English bond used to improve the appearance of the wall. It combines the requirements of beauty and strength. Alternate courses of headers and stretchers are provided, and queen closers are placed next to quoin headers. A header is introduced next to the quoin stretcher in every alternate stretcher course.

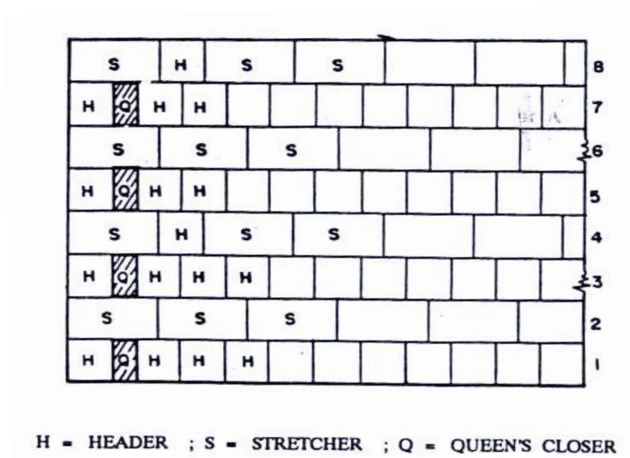


Fig. 5.3.9 English cross bond

VI. Dutch bond

This is another modified form of English bond. In this bond the corners of the wall are strengthened. Alternate courses of headers and stretchers are provided. Every stretcher course starts at the quoin with the three quarter bat. In every alternate stretcher course, a header is placed next to the three-quarter brick bat provided at the quoin.

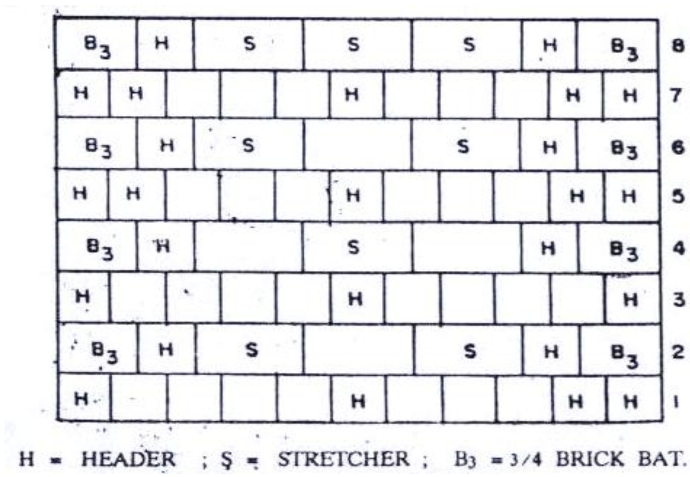


Fig. 5.3.10 Dutch bond

VII. Raking bond

The bonding bricks are kept at an inclination to the direction of the wall. And it is used in thick walls. The inclination should be in opposite direction in alternate courses of raking bond. It is provided at a regular interval of 4-8 courses in the height of a wall Raking bonds are of two types: ***Diagonal bond*** and ***Herring-bone bond***.

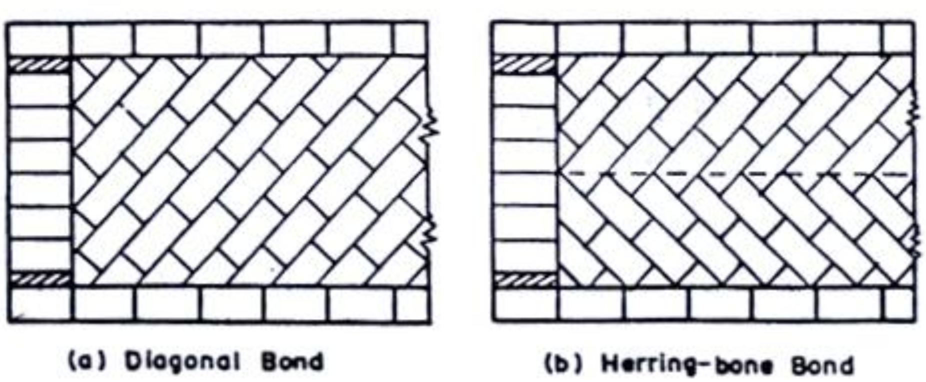


Fig. 5.3.11 Raking bond

VIII. Zigzag bond

This bond is similar to herring-bone bond, except that the bricks are laid in zigzag fashion. It is commonly used for making ornamental panels in the brick flooring.

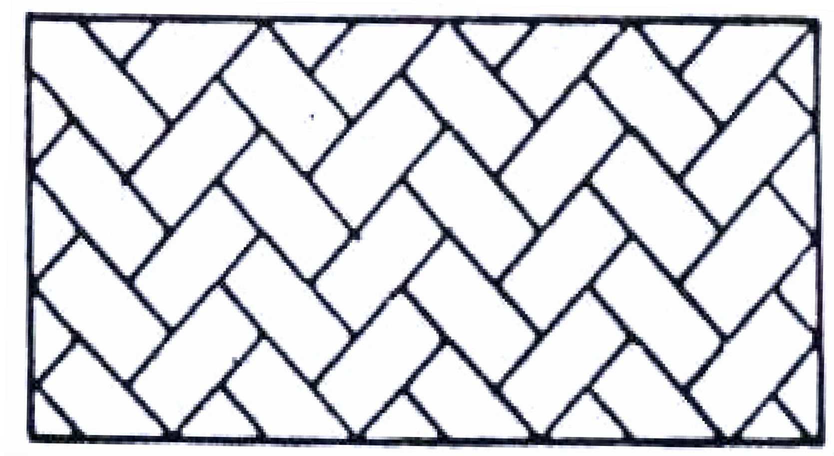


Fig. 5.3.12 Zigzag bond

IX. Garden wall bond

This bond is used for the construction of garden walls, boundary walls, compound walls where the thickness is one brick and the height doesn't exceed 2m. It is not as strong as English bond, but is more attractive. Garden walls are of three types:

- ***Garden wall English bond***: The header course is provided only after 3-5 stretcher courses.
- ***Garden wall Flemish bond***: Each course contains one header after 3-5 stretchers continuously placed, throughout the length of the course.
- ***Garden wall monk bond***: Type of garden wall Flemish bond in which each course contains one header after two successive stretchers.

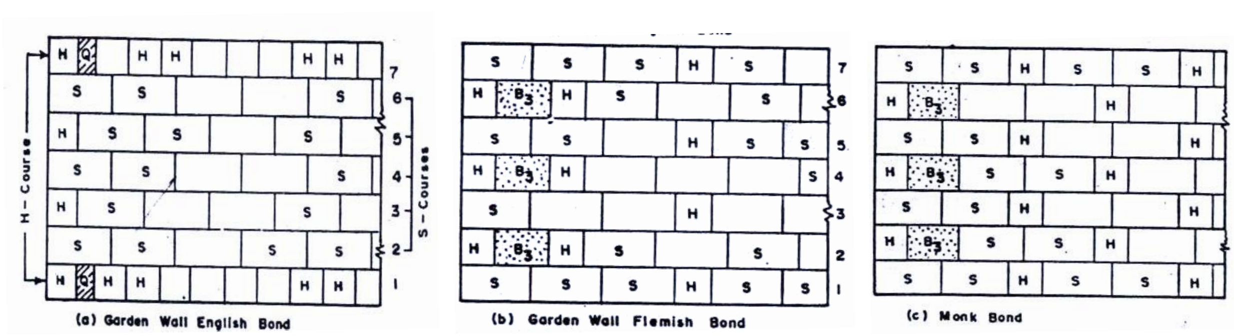


Fig. 5.3.13 Garden wall bond

A.5 Strength of brick masonry

The main factors governing the strength of brick structure are:

- **Type and quality of bricks**: The strength of brick masonry primarily depends upon the type and class of bricks used and the basic compressive strength of bricks.
- **Mortar mix proportion**: It is essential that the mortar should be specified and prepared in relation to the brick with which it is to be used, and should be comparable in strength and density with the brick itself.
- **Size and shape of masonry construction**: The strength of brick masonry depends upon **slenderness ratio** of masonry and **shape factor**.
    - **Slenderness ratio**: Effective height or length of the wall divided by its thickness whichever is less.
    - **Shape factor**: takes into account the effect of shape of the brick, i.e. Ratio of its height to thickness.

A.6 Joints in brickwork

Joints are the weakest part of a masonry structure and they require special care in laying and finishing. The purpose of finishing joints is to improve the appearance of brickwork and to make it more water proof. The finishing of joints as the brickwork proceeds is termed as **jointing** whereas finishing of joints after the brickwork has been completed is called **pointing**.

A.6.1 Types of pointing finishes

Generally, brickwork is jointed by striking, raking or rubbing the mortar while it is green. Pointing consists of raking out the green mortar in the joint to a depth of about 20mm and then refilling the joint with fresh mortar.

- **Flush or flat pointing**: are formed by pressing mortar in the raked joint and by finishing off flush with the edges of masonry unit. This type of pointing does not give good appearance; however, it is more durable since it does not provide any space for the accumulation of dust, water, etc.
- **Struck pointing**: this is a modification of flush pointing in which the face of pointing is kept inclined, with its upper edge pressed inside. The point permits water to drop off from the face off the brickwork. The appearance is not satisfactory.

- **Recessed pointing**: is done by pressing the mortar back from the edges by 5mm or more. The face of pointing is kept vertical by a suitable tool. The pointing gives very good appearance in face-work for good textured bricks and good quality of mortar.
- **Concave pointing (keyed)**: It is formed by a round jointer and it gives a very attractive appearance to the brickwork.
- **V-pointing**: It is made in a manner similar to concave pointing by forming V-groove in the flush-finishing face.
- **Projecting pointing**: a special type of pointing formed by a suitable slighted steel rod. Such type of pointing gives good appearance but is liable to damage easily.

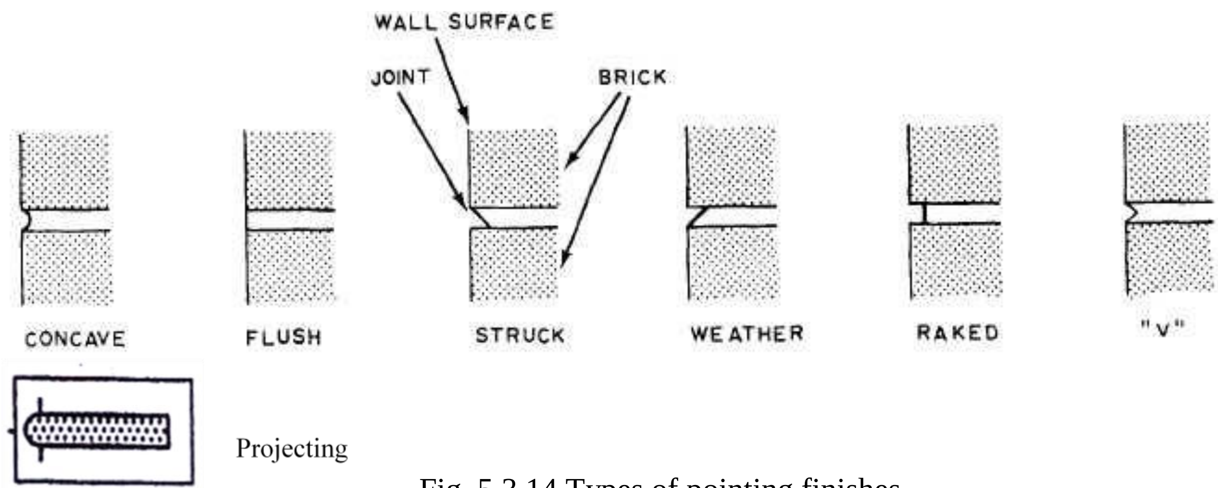


Fig. 5.3.14 Types of pointing finishes

A.7 Reinforced brickwork

Reinforced brick work is the one in which the brick masonry is strengthened by the provision of mild steel flats, hoop iron, expanded mesh or bars. It is adopted or used for the following circumstances:

- When the brick work has to bear tensile and shear stresses.
- When it is required to increase the longitudinal bond.
- When the brick work is supported on soil which is susceptible to large settlement
- When the brick work is supposed to act as a beam or lintel over openings
- When the brick work is to resist lateral loads, such as retaining walls etc.
- When the brick wall is to carry heavy compressive loads.
- When the brick work is to be used in seismic areas.

Brickwork can be reinforced in one of the following way:

i. Reinforcement may consist of iron bars of expanded metal mesh. Usually the metal mesh is provided at every third course.

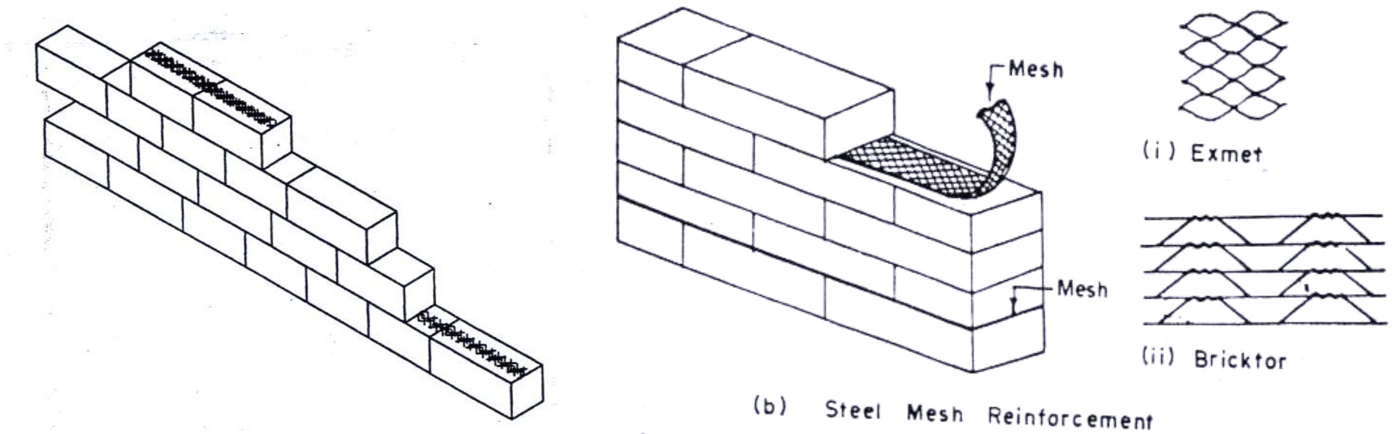


Fig. 5.3.15 Steel mesh reinforced brickwork

ii. Another type of reinforcement is hoop iron. These are steel flats about 2.5-3 cm in width and are from 1.5-2.5 mm in thickness. Two strips of hoop iron are used for header bricks and one hoop iron for stretcher bricks, and every sixth coarse is reinforced

iii. For walls that have to withstand pressure vertical reinforcement passing through openings made in special types of brick is employed.

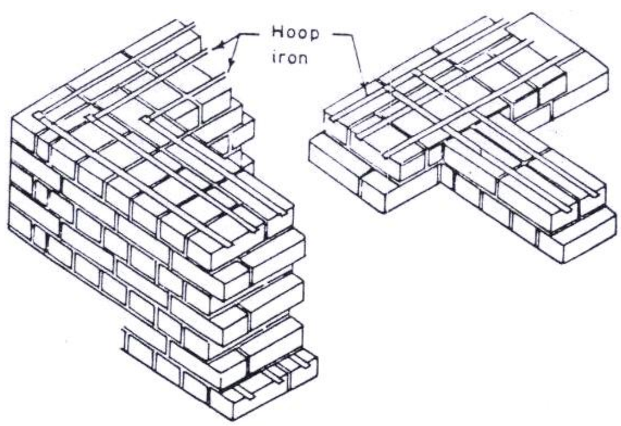


Fig. 5.3.16 Hoop iron reinforced brickwork

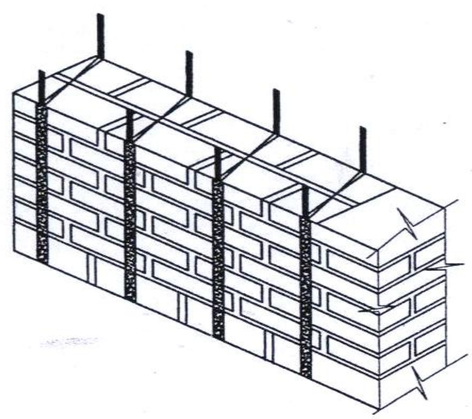


Fig. 5.3.17 Reinforced brickwork retaining wall

A.8 Causes of failure of brick masonry

Brick masonry may fail due to the following three major causes:

i. By crushing if it is overloaded - can be prevented by providing adequate dimensions
ii. By shearing along any horizontal plane - can be prevented by providing a strong mortar
iii. By rupture along a vertical joint under vertical loads - Can be prevented by breaking vertical joints in brickwork

A.8 Defects in brick masonry

Brick masonry may develop the defects due to the following reasons:

- Sulphate attack
- Crystallization of salts from bricks
- Corrosion of embedded fixtures
- Drying shrinkage

Maintenance of brickwork

Brick walls can be maintained using alternative methods among which the following are widely used in practice:

i. Re-pointing old brickwork
ii. Repainting brickwork
iii. Cleaning brickwork
iv. Removal of efflorescence

B. Stone walls

The stones used for masonry should be **hard**, **durable**, **tough** and **sound** and free from weathering, decay or defects like cavities, cracks, sand holes, injurious veins, patches of loose or soft materials etc. Rocks, from which building stones are obtained, are divided into three groups:

i. ***Igneous rock***: the chief building stones in this class are trachyte, basalt, granite, etc.
ii. ***Sedimentary rocks***: The principal building stones in this group are lime stones and sand stones. These are used in floors, steps, facing works, columns, walls etc.

iii. ***Metamorphic rocks***: the common building stones are slate and marble. Since marble is costly it is not used for masonry but used for flooring, facing work, steps, ornamental works etc.

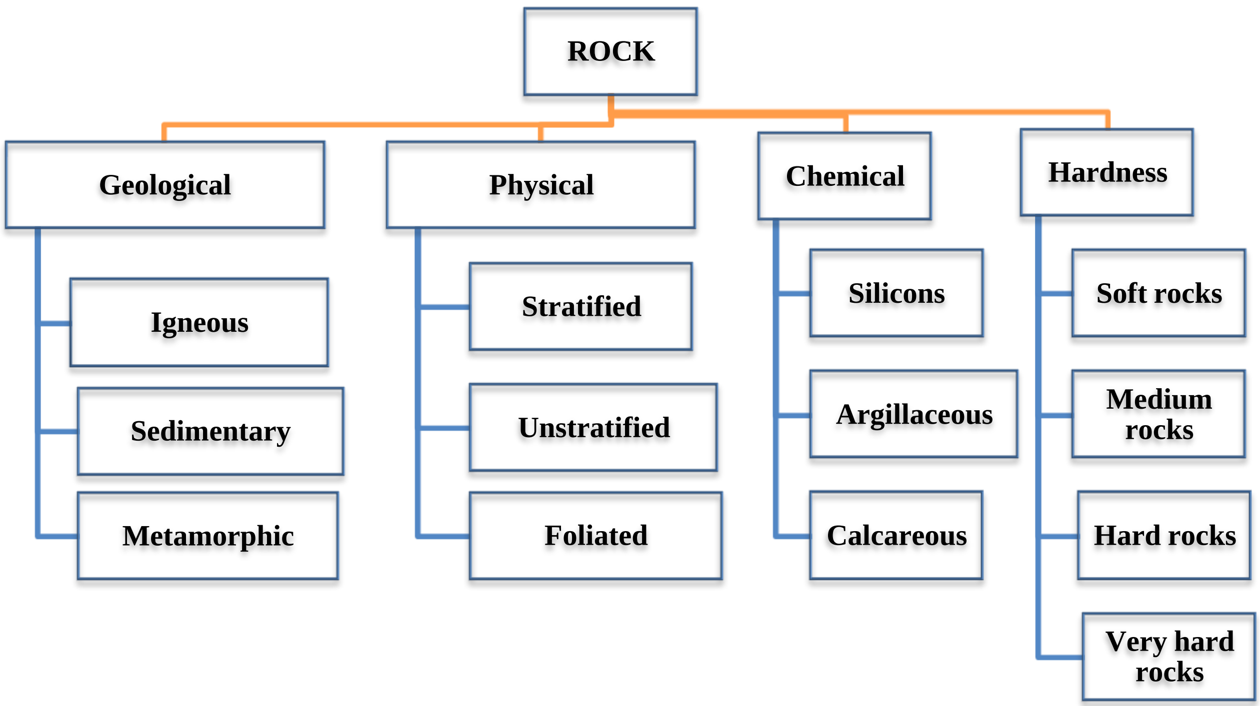


Fig. 5.3.18 Classification of rocks

B.1 Tests for stones

The building stones are tested for their different properties:

i. ***Attrition test***: This test is carried out to find out the rate of wear of stones (Daval's attrition test machine).

ii. ***Crushing test***: The compressive strength of stone can be found out with the help of this test.

iii. ***Hardness test***: To determine the hardness of a stone (Dorry's testing machine). Coefficient of hardness is determined.

iv. ***Impact test***: to determine the toughness of a stone. Toughness index is determined.

v. ***Water absorption test***: to determine the water absorption capacity of a stone.

B.2 Qualities of good building stone

A good building stone should posses the following qualities.

i. ***Crushing strength***: The crushing strength of stone should be greater than 100 N/mm^2.
ii. ***Appearance***: stones for face work should be decent in appearance, capable of preserving their color uniformly and free from clay holes, spots of other colors etc.
iii. ***Durability***: A good building stone should be durable which depends up on its chemical composition, texture, resistance to environment and positioning.
iv. ***Facility of dressing***: It should be such that they are easily carved, moulded, cut and dressed.
v. ***Hardness***: The coefficient of hardness should be more than 17.
vi. ***Percentage wear***: The wear of stone should be maximum 3%.
vii. ***Specific gravity***: specific gravity of good stone should be minimum 2.7.
viii. ***Texture***: It should have compact fine texture free from cavities, cracks and soft fragments.
ix. ***Toughness index***: T.I. > 19 good stones, T.I < 13 poor stones.
x. ***Water absorption***: Different stones have different water absorption depending upon the porosity.
xi. ***Weathering***: A good stone should be able to resist the environment attack.
xii. ***Fire resistance***: A good stone must preserve its shape in case of fire.

B.3 Classification of stone masonry

Depending upon the ***arrangement of stones*** in the construction, ***degree of refinement*** used in shaping the stone and ***finishing adopted*** stone masonry can be classified as:

I. Rubble masonry
II. Ashlar masonry

I. Rubble masonry

The blocks of stones used are either ***undressed*** or ***comparatively rough dressed***. The masonry has ***wide joints***, since stones of ***irregular sizes*** are used.

I.1. Random rubble: Un-coursed - This is the **roughest** and **cheapest** form of stone walling. The stones used are of widely **different sizes** and **shapes**. Greater care has to be exercised in arranging the stones in such a way that they adequately distribute the pressure over the maximum area at the same time long continuous vertical joints are avoided.

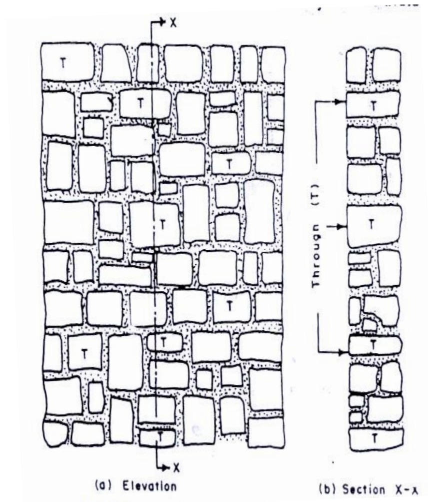


Fig. 5.3.19 Random rubble: un-coursed masonry

I.2. Random rubble: Built to courses - The work is roughly levelled up to form courses varying from 30-40 cm thick. All the courses are not of the same height. Quoins are built first and line (string) is stretched between the tops of quoins.

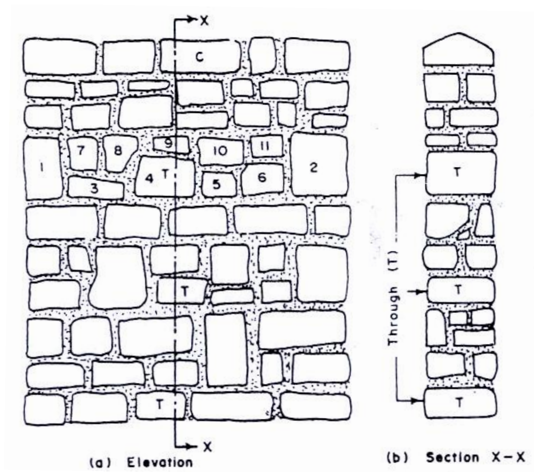


Fig. 5.3.20 Random rubble: built to course masonry

I.3. Square rubble: Un-coursed (square-snecked rubble) - Square rubble masonry uses stones having straight bed and sides. The stones are usually squared and brought to hammer dressed or straight cut finish. The stones with straight edges and sides are available in different sizes (heights) and are arranged on face in several irregular pattern.

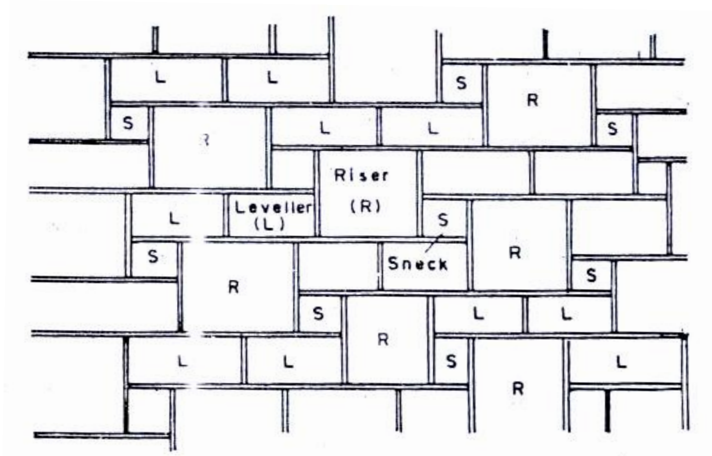


Fig. 5.3.21 Square rubble: un-coursed masonry

I.4. Square rubble: Built to courses - Use the same stone as used for un-coursed square but the work is levelled up to courses of varying depth. The courses are of different heights.

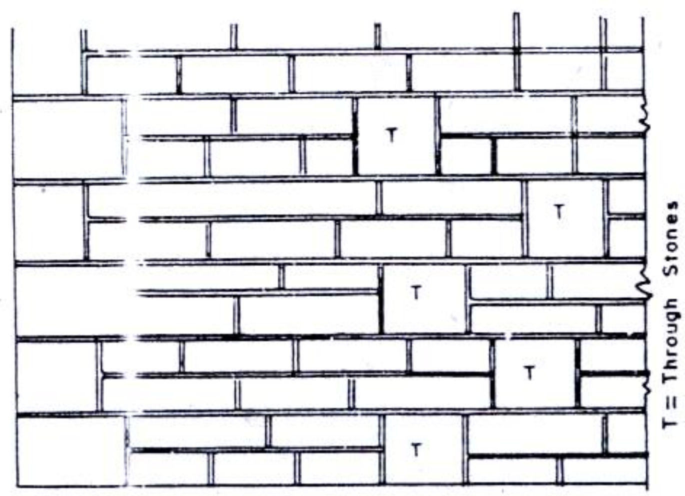


Fig. 5.3.22 Square rubble: built to course masonry

I.5. Square rubble: Regular coursed

The wall consists of various courses of varying heights, but the height of stones in one particular course is the same.

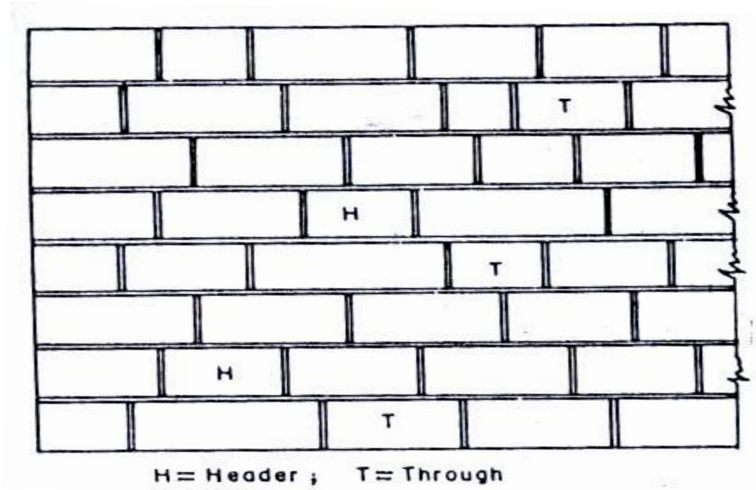


Fig. 5.3.23 Square rubble: regular coursed

I.6. Polygonal walling: Polygonal rubble masonry

The stones are hammered finished on face to an irregular polygonal shape. These stones are bedded in position to show face joints running irregularly in all directions. There are two types of polygonal walling: ***rough picked*** and ***close picked***.

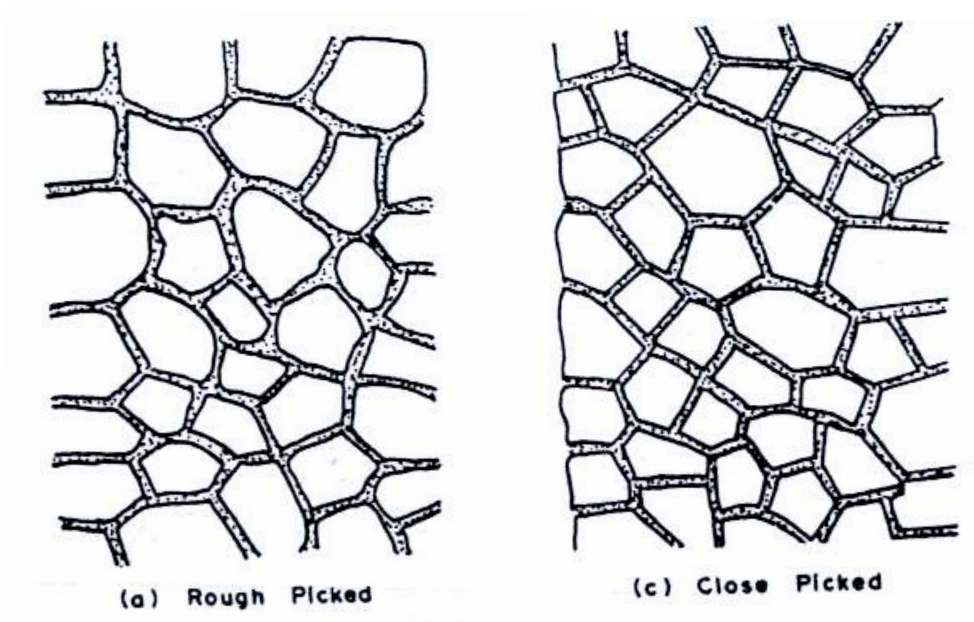


Fig. 5.3.24 Polygonal walling: polygonal rubble masonry

I.7. Flint walling: Flint rubble masonry

The stones used are **flints** or **cobbles**, which vary in width and thickness from 7.5-15 cm and in length from 15-30 cm. The face arrangement of the cobbles may be either ***coursed*** or ***un-coursed*** or ***built to courses***. The strength may be increased by introducing ***lacing courses***.

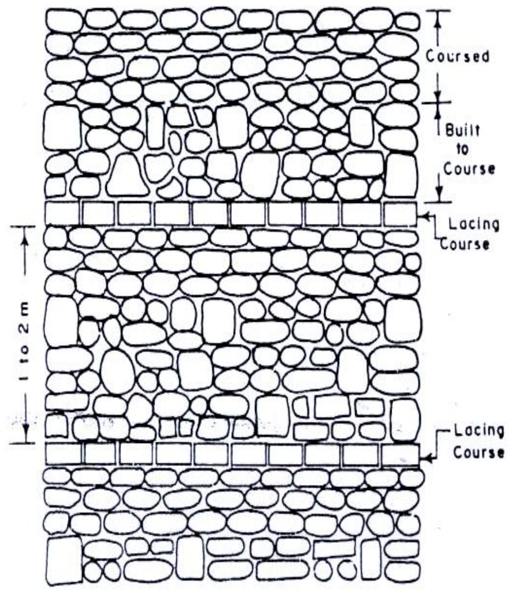


Fig. 5.3.25 flint walling: flint rubble masonry

I.8. Dry rubble masonry

Dry rubble masonry is that rubble masonry, made to courses, in which mortar is not used in the joints. This type of construction is the cheapest, and requires more skill in construction. This may be used for non load bearing walls, such as ***compound wall*** etc.

II. Ashlar masonry

Ashlar masonry consists of blocks of ***accurately dressed stone*** with extremely fine bed and end joints. The blocks may be either square or rectangular shape. The height of stone varies from 25-30 cm.

II.1. Ashlar fine tooled

This is the finest type of stone masonry work. Each stone is cut to regular and required size and shape so as to have all sides rectangular. The thickness of course is generally not less than 15 cm. The width of stone is not kept less than its height.

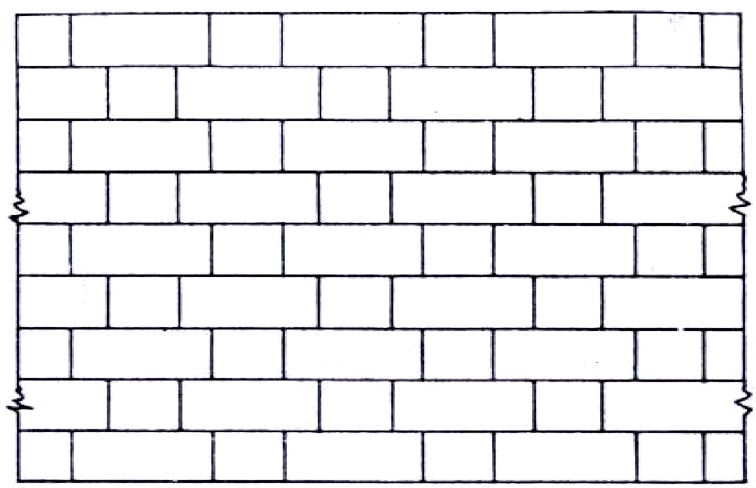


Fig. 5.3.26 Ashlar fine tooled masonry

II.2. Ashlar rough tooled (Bastard Ashlar)

The beds and sides of each stone block are finely chisel dressed just in the same manner as for Ashlar fine, but the exposed face is dressed by rough tooling. A strip, about 25mm wide and made by means of a chisel is provided around the perimeter of the rough dressed face of each stone.

II.3. Ashlar rock faced (Rustic or Quarry faced)

The exposed face of the stone is not dressed but is kept as such so as to give rock facing. A strip, about 25mm wide and made by means of a chisel is provided around the perimeter of the exposed face of every stone.

II.4. Ashlar chamfered

This is a special form of rock-faced Ashlar masonry in which the strip provided around the perimeter of the exposed face is chamfered at an angle of 45°. Due to the chamfering, a groove is formed in between adjacent blocks of stone.

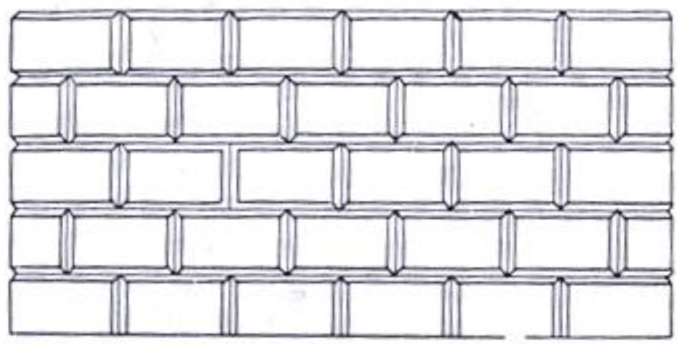


Fig. 5.3.27 Ashlar chamfered

II.5. Ashlar block in course

This type of masonry is intermediate between rubble masonry and Ashlar masonry. The vertical joints are not as straight and as fine as in Ashlar masonry. It is adopted in heavy works such as retaining walls, bridges, etc.

II.6. Ashlar facing

Ashlar facing masonry is provided along with brick or concrete block masonry, to give better appearance. The sides and beds of each block are properly dressed so as to make them true to shape.

B.4 Dressing of Stones

The surface of stones obtained from quarry is rough. The blocks are irregular in shape and non uniform in size. Hence their dressing is essential. t serves the following purposes:

- It gives desired aesthetic appearance.
- It makes transport easy and economical.
- It suits the desired requirements.
- It helps taking advantage of locally available skilled labour

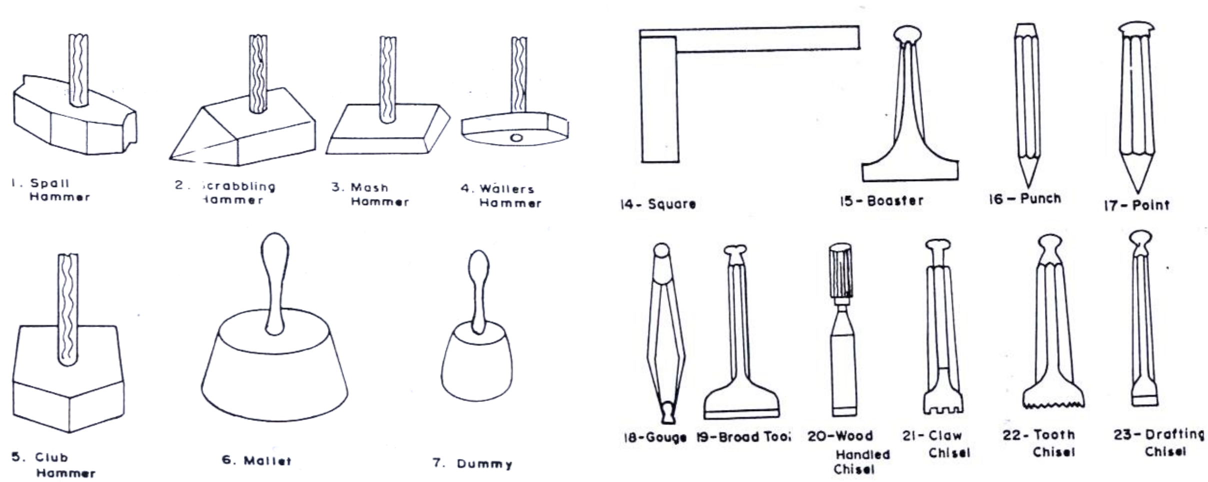


Fig. 5.3.28 Tools for dressing of stones

Dressed stones may have the following types of surface finish:

1. Rock faced or quarry faced: The exposed face of the stone is not dressed, but is kept as such, except that the bushings exceeding 80mm in projection are removed by light hammering.

2. Hammer dressed finish: The stone blocks are made roughly square or rectangular by means of Waller's hammer. The exposed face is roughly shaped by means of mash hammer.

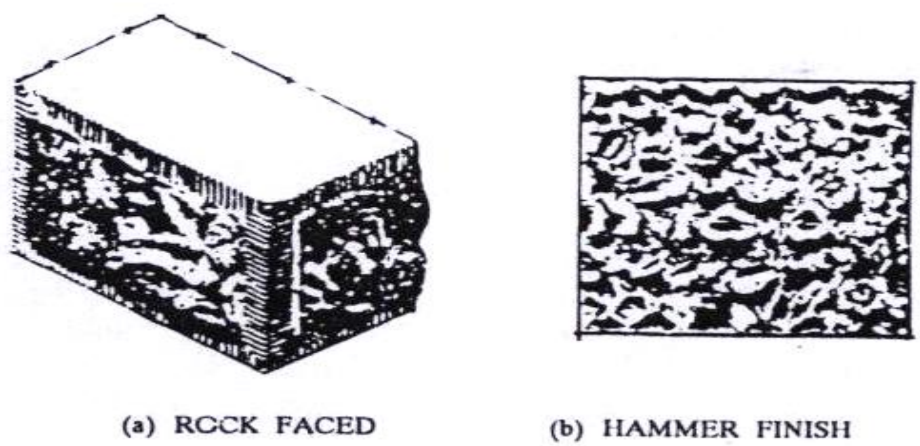


Fig. 5.3.29 Hammer dressed finish

3. Punched, broached or Stugged finish: The exposed face of the stone is dressed with the help of a punch thus making depression or punch holes at some regular distance.

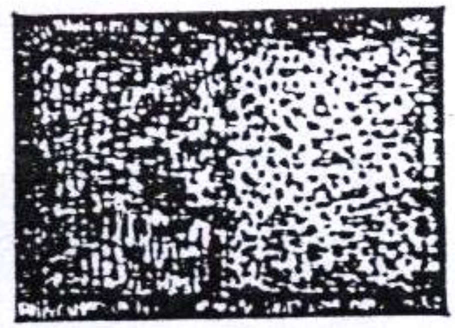


Fig. 5.3.30 Punched, broached or stugged finish

4. Picked finish: Similar to punch finish except that a point is used in the place of punch, thus forming small pits on the exposed face.

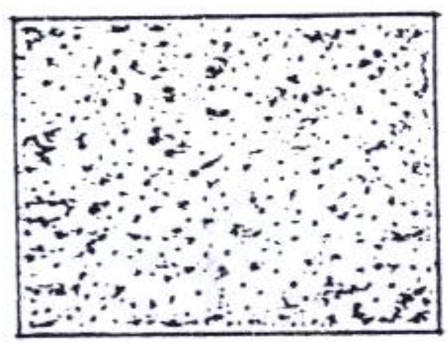


Fig. 5.3.31 Picked finish

5. Boasted or droved finish: The dressing is done to form a series of bands of more or less parallel tool marks, which cover the whole surface.

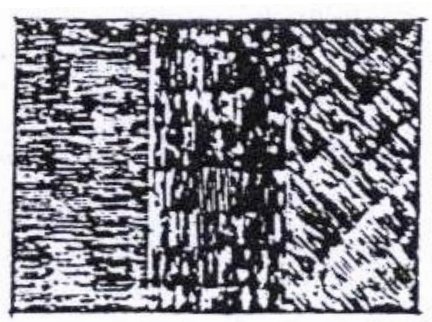


Fig. 5.3.31 Boasted or droved finish

6. Tooled or batted finish: This is done as a further step to boasting. A series of parallel fine chisel lines are formed. The lines are deeper & continuous.

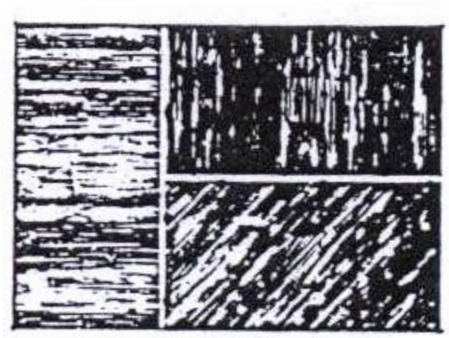


Fig. 5.3.32 Tooled or batted finish

7. Furrowed finish: After boasting the surface and then rubbing it, 6-10mm wide flutes are formed by a gauge.

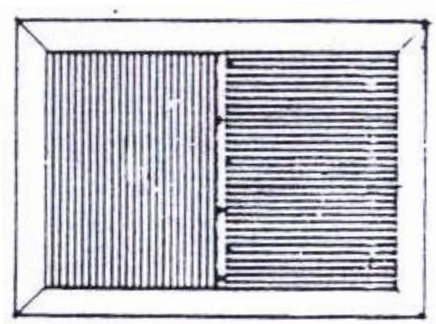


Fig. 5.3.33 Furrowed finish

8. Vermiculated finish: After having brought the face of the stone to a level and smooth finish, marginal drafts are sunk about 10mm below the surface. The finish presents worm eaten appearance.

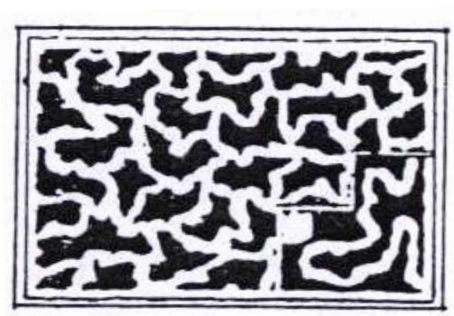


Fig. 5.3.34 Vermiculated finish

9. Reticulated finish: This is similar to vermiculated except that the ridges or veins are less winding. This are linked up to form polygonal or irregular shaped reticules.

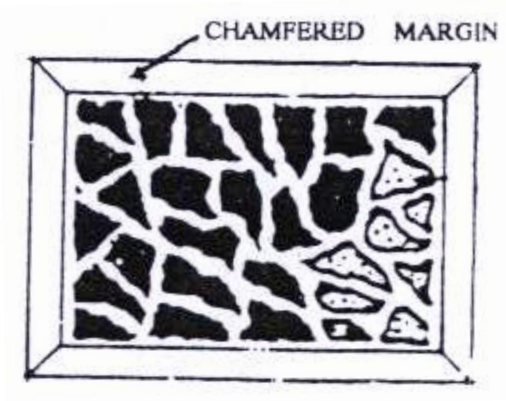


Fig. 5.3.35 Reticulated finish

10. Plain finish: The Surface is made approximately smooth with a saw or chisel.

11. Rubbed finish: This type of finish is obtained by rubbing a piece of stone on the levelled surface. The rubbing can also be done with the help of a machine.

12. Polished finish: This type of finish is used in marbles, granites etc. These are polished either manually or with the help of machines.

B.4 Dressing of Stones

Various environmental and external agencies play an important role to deteriorate the stones:

- ***Alternate heating and cooling***: Repeated contraction and expansion cause cracking of stones due to internal stresses.
- ***Alternate wetting and drying:*** repeated wetting and drying result in wearing it out quickly.
- ***Thawing and freezing:*** it results in entrapping of moisture which expand on freezing resulting in splitting of stones.
- ***Nature of mortar***: The mortar may react chemically with constituents of stone and leads to the disintegration of stones
- ***Rain water***
- ***Vegetable growth***

C. Concrete block walls

Concrete block is one of the most common masonry units. It consists of hardened cement and may be completely solid or contain single or multiple hollows. It is made from conventional cement mixes and various types of aggregates. These include: sand, gravel, crushed stone, expanded shale or clay, volcanic ciders (Pozzolana), scoria, pumice, etc. Various types of blocks are manufactured to be used for wall construction.

Fig. 5.3.36 Hollow concrete block

C.1. Advantages of hollow concrete block masonry

i. Concrete blocks are regular in size, requiring no dressing work. Hence construction is very rapid.
ii. Blocks are light and therefore easy to handle.
iii. Because of their lightness, the load transferred to foundations is much less than the stone masonry.
iv. There is a great saving in the material.
v. Because of larger size of the blocks, the number of joints in the masonry is less. This results in saving in mortar.
vi. Because of hollow space, the resulting wall has better insulating properties against sound, heat and dampness.
vii. Blocks can withstand the atmospheric actions, and do not require plaster or any other covering.

C.2. Manufacturing of concrete masonry blocks

The following points should be kept in mind while manufacturing the concrete masonry blocks:

i. The cement-aggregate ratio should not be leaner than 1:6.

ii. Blocks should be taken out from the moulds only when concrete has sufficiently set.

iii. Machine casting is preferable to hand casting, to obtain better finish.

iv. After taking the blocks out of mould they should be kept under shade for a week and should be properly cured 3 to 4 weeks.

v. Blocks should be used only after about 3-4 weeks of curing.

Fig. 5.3.37 Manufacturing of concrete masonry blocks

5.3.3.2.2 Walls of Monolithic Construction

Walls of monolithic construction could either be load bearing or not. The modern concrete wall and the primitive mud wall are composed of materials, which are placed in a plastic state into a mould. Concrete walls can be plain or reinforced. The two greatest advantages of concrete wall are strength and freedom it gives in design. Freedom of design is expressed by the ease with which it can be made to take up curved or other complex shapes. Reinforced concrete wall thickness may be from 8cm up, and the cost is generally higher but the strength of the structure is considerably higher.

5.3.3.2.3 Panel or Composite Walls

Panel walls are used whenever the load bearing function of the walls is taken over by a framework, which leaves the spaces in the uprights to be filled. Generally, they consist of two or more layers or sections each of which fulfils a specific purpose. They are principally used with the object of reducing weight. Requirements to be fulfilled are resistance to wind pressure, protection against wind and rain, and providing satisfactory appearance. Some of the materials used for panel wall construction are Aluminum panels, Gypsum panels, Glass, etc.

5.3.4 Internal Walls

An internal wall or partition wall is a thin wall which is constructed to divide the space within the building into rooms or areas. A partition wall may be either non load bearing or load bearing. Generally partition walls are non load bearing.

Requirements to be fulfilled by partition walls are:

i. Should be strong enough to carry its own load
ii. Should be strong enough to resist impact to which the occupation of the building is likely to subject them.
iii. Should be stable and strong enough to support suitable decorative surface.
iv. Should be as light as possible.
v. Should be as thin as possible
vi. Should act as sound barrier, especially when it divides two rooms.
vii. Should be fire resistance.

Types of Partition Walls

Partition walls are of the following types:

- ♠ Brick partitions
- ♠ Clay block partitions
- ♠ Concrete partitions
- ♠ Glass partitions
- ♠ Metal lath partitions
- ♠ Solid plaster partitions
- ♠ Timber partitions
- ♠ Corrugated sheet partitions

5.3.5 Cavity Walls

Cavity wall or hollow wall is the one which consists of two separate walls, called leaves or skins, with a cavity or gap in-between. The thickness of the two leaves may be equal if it is non-load bearing wall or the thickness of the inner may be increased to meet the required structural strength. The inner and the outer leaves of the wall should not be less than 10cm in thickness throughout the height of the wall.

For a cavity wall to be effective, it is essential that the leaf is entirely disconnected from the outer leaf, except for ties. The cavity varies from 4-10cm. The two leaves are securely tied together with suitable bonding steel ties or sometimes with special bonding bricks. The ties should be placed at intervals not exceeding 1m horizontally and 40 cm vertically.

5.3.5.1 Advantages of cavity walls.

i. **Damp prevention**: cavity walls are able to prevent dampness effectively.
ii. **Insulation**: cavity walls have about 25% greater insulating value than the solid walls.
iii. **Acoustic**: cavity walls reduce sound and noise pollution.
iv. **Economy**: they are cheaper and economical.
v. **Load reduction**: loads on foundations are reduced because of lesser solid thickness.

5.3.5.2 Precautions on cavity wall construction

i. Damp proof course should be built into separate widths under each leaf of the wall and divided by cavity.
ii. No mortar or any other thing should get accumulated in the cavity.
iii. Cavity should be free from projections.
iv. The contact b/n inner and outer wall should be least.
v. Head of openings should be carefully attended for damp prevention.

vi. Ties must be of rust proof materials and should be able to prevent transmission of water from inner surface to the outer surface.

5.3.6 Opening in Walls

Openings are invariably left in the walls for the provision of doors, windows cupboards, etc. These openings are bridged by the provisions of either a lintel or an arch. Both lintels and arches are structural members designed to support the loads of the portion of the wall situated above the openings.

5.3.6.1 Arches

An arch is normally a curved member of stone, concrete, steel, etc. Arches are constructed where; loads are heavy, span is large, strong abutments are available, and architectural appearance is required.

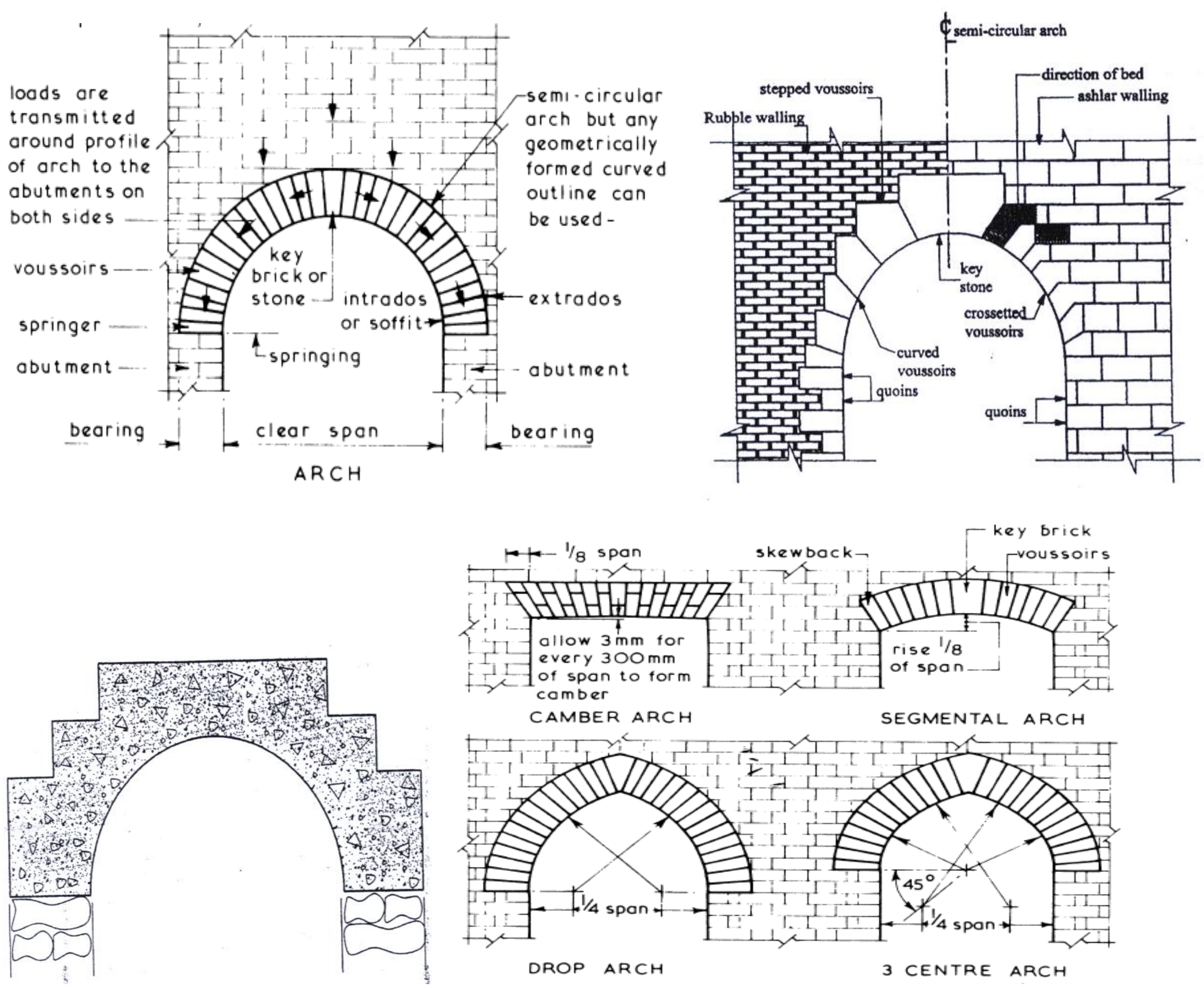


Fig. 5.3.38 Opening in walls: Arches

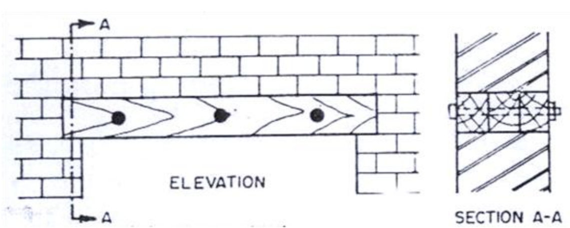
5.3.6.2 Lintels

A lintel is a horizontal member, which is placed across the opening. Lintels are easy to build and the supporting walls need not be very strong. At least 10cm length of bearing is a minimum requirement. For very long spans, the bearing for the lintel end should be equal at least to its depth.

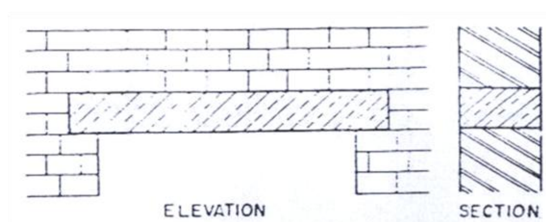
Types of lintels

Lintels are classified according to the material of their construction.

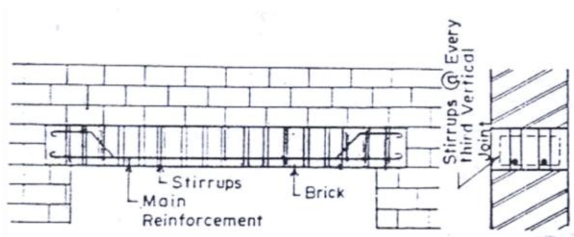
a) **Timber lintels**: are the oldest types of lintels and are not commonly used nowadays. They cannot take greater load and are vulnerable to fire and decay.
b) **Stone lintels**: not widely used as the stone used for this work is not available at all places.
c) **Brick lintels**: Plain brick lintels are not structurally strong and they are not used in large openings and where loads are heavy. Instead reinforced bricks are used.
d) **Steel lintels**: Are provided where the opening is large and where the superimposed loads are heavy.
e) **Reinforced concrete lintels**: have replaced practically all other types of lintels because of their strength, rigidity, fire resistance, economy and ease in construction. Can be used on any span and they may be cast in place or available as precast.



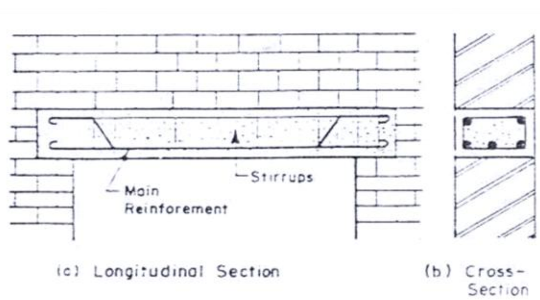
Timber lintel



Stone lintel



Reinforced brick lintel



Reinforced concrete lintel

Fig. 5.3.39 Opening in walls: Lintels

5.3.7 Review Questions

1. Explain in brief, the function of a wall.
2. Discuss the requirements that must be fulfilled for a wall to serve its function.
3. Briefly discuss the different factors which affect the choice of material for wall construction.
4. Discuss a) manufacturing process of brick, b)types of bricks and tests conduct on brick.
5. Show with the help of sketches various types of a) closer bricks b) brick bats.
6. Write short notes on a) Header bond, b)Stretcher bond, c)Dutch bond, d) Garden wall bond.
7. Differentiate and compare English bond, Flemish bond and double Flemish bond.
8. Draw plans of alternate courses of i) 1½ brick wall, and ii) 2-brick wall in a) English bond, b) Double Flemish bond.
9. Write important points connected with the supervision of brick work.
10. Write a note on a) various defects in brick work, b) failure mechanisms of brick work, c) maintenance of brick work.
11. What do you understand by ‘reinforced brick masonry’? When do you use it? Give examples.
12. Write a note on a) Classification of rocks, b) tests conduct on stone, c) qualities of good stones.
13. Classify various types of stone masonry. Draw typical sketches to illustrate the same.
14. Enumerate the different advantages that could be obtained by dressing of stones and the different types of surface finishes used in stone masonry.
15. What do you understand by concrete block masonry? State the advantages of hollow concrete block masonry. State the various points that should be kept in mind both during production and construction of concrete blocks.
16. What do you understand by a) Walls of monolithic construction, b) composite or panel walls?
17. Define a partition wall. Enumerate a) various requirements to be fulfilled by a partition wall, b) different types of partition walls.
18. Define a cavity wall. What are its advantages? Explain with the help of sketches, general features of cavity wall.
19. Distinguish clearly b/n a lintel and arch. Classify various types of lintels and their relative use.
20. Describe where arches are recommended. Explain with the help of sketches various types of arches.

5.4 STAIRS

5.4.1 Introduction

Access in buildings can be classified into categories:

i. **Moving -** An elevator, escalator, a staircase or a belt that moves by using different kinds of **electrical or hydraulic driving motors**. For example: an elevator or lift, escalator, conveyor and moving chairs for handicaps.

ii. **Stationary -** Most widely used access in buildings. There is **no any motor that drive the system**, rather it is fixed. These are stairs, different kinds of ladders, ramps, corridors.

Stairs are **set of steps** leading from one floor to another and are provided in building to afford a **means of communication** between the various floors. Set of **steps arranged in series** and placed in an **enclosure** is called **Stair Case**. Stairs should be designed properly to provide proper **ventilation and light** (natural). The location of stairs should be near main entrance for public buildings, centrally placed for easy access and should give privacy in residential buildings.

The primary functions of stairs are:

1. Provide a **means of circulation** between floor levels.
2. Establish a **safe means of travel** between floor levels.
3. Provide an **easy means of travel** between floor levels.
4. Provide a ***means of conveying*** fittings and furniture between floor levels.

5.4.2 Technical Terminologies

- **Step**: is a portion of stair which permits ascent or descent. It is comprised of a tread and a riser. A stair is composed of a set of steps.
- **Tread**: is the horizontal member of stair. The tread of public buildings must be wide enough to provide safe footing.
- **Going**: is the horizontal distance b/n the nosings or front edges of two consecutive steps. It is usually 30cm for public buildings so that it is wide enough to provide safe footings.
- **Riser**: is the vertical member of a stair.
- **Rise**: Is the vertical distance b/n the upper surface of two consecutive steps. The rise of public building is about 15cm while a higher value can be used for private buildings.

- **Nosing**: it is the projecting part of the tread beyond the face of the riser. It is usually rounded off from the architectural point of view.
- **Flight**: is a continuous set of steps b/n floors and/or landing.
- **Landing**: is a platform b/n two flights.
- **Baluster**: is the vertical member which supports the hand rail. The combined framework of hand rail and baluster is known as ***balustrade***.
- **String or stringer**: is the structural member which supports the steps and act as inclined beams.
- **Hand rail**: is a rounded or molded member of wood or metal fixed on the top of balusters.
- **Head room**: is the minimum clear vertical distance b/n the tread and overhead structure.
- **Soffit**: It is the underside of the stair.
- **Run**: it is the total length of stairs in a horizontal plane, including landings.
- **Newel post**: it is the vertical member which is placed at the ends of flight to connect the end stings and handrail.
- **Winders**: are tapering steps which are provided for changing the direction of stair.

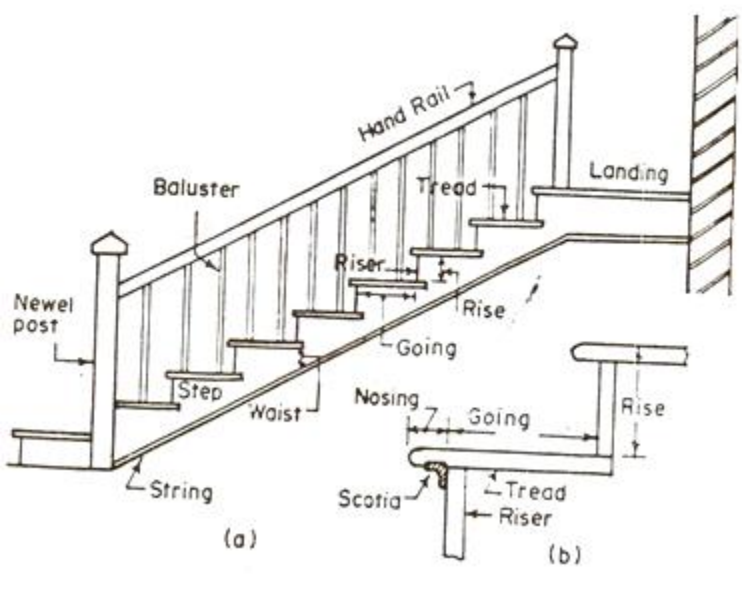


Fig. 5.4.1 Stair technical terminologies

5.4.3 Classification of Stairs

Stairs can be classified into two broad heads:

I. Straight stairs

II. Turning stair

Each of the turning stairs are of three types; Newel stairs, Well or open-newel stairs and Geometrical stairs.

I. Straight stairs

This stair runs straight b/n the two floors. It may be used for small houses where there are restrictions in available width or for the entrance of buildings**.** The stair may consist of either one single flight or more than one flight (usually two) with a landing.

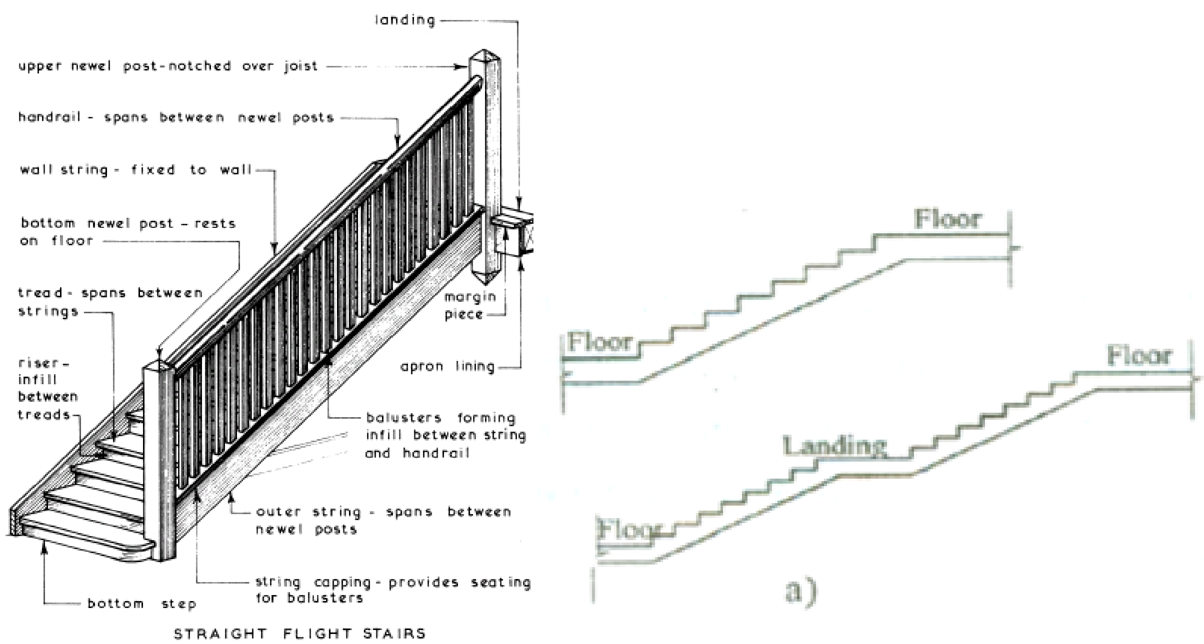


Fig. 5.4.2 Straight stair

II. Turning stairs

II.1. Quarter turn stairs

It is a stair type which changes its direction either to the left or to the right. The turn is designed either by introducing a quarter space landing or by providing winders. Quarter turn stairs are of two types:

A. Newel quarter turn stairs

B. Geometrical quarter turn stairs.

A. **Newel quarter turn stairs**

These stairs have the conspicuous newel posts at the beginning and end of each flight. At the quarter turn, there may either be quarter space landing or there may be winders.

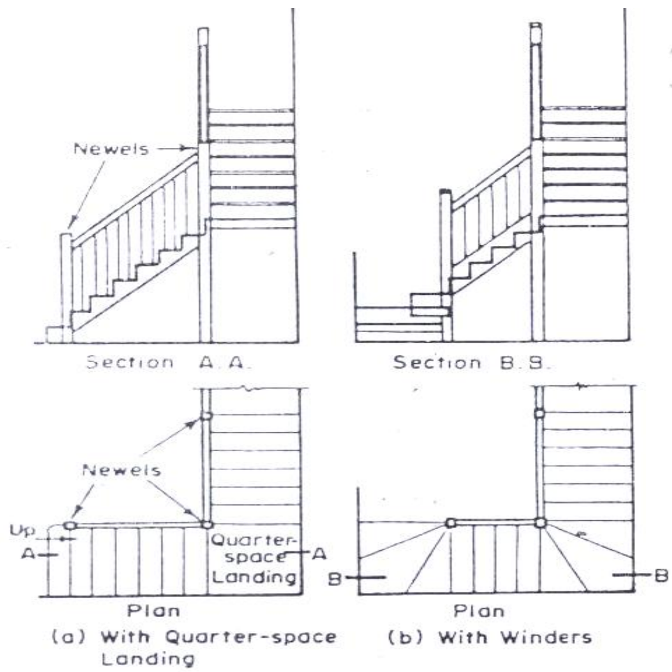


Fig. 5.4.3 Newel quarter turn stair

B. **Geometrical quarter turn stairs**

The stringer as well as the hand rail is continuous, with no newel post at the landing.

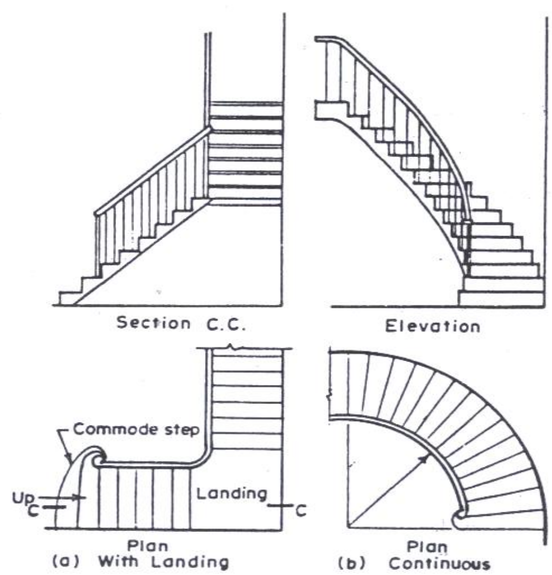


Fig. 5.4.4 Geometrical quarter turn stair

II.2. Half turn stairs:

It is the one which has its direction reversed or changed for 180°. Such stairs are quite commonly used. Half turn stairs are of three types:

- Dog-legged or newel half turn stairs
- Open newel half turn stairs
- Geometrical half turn stairs

A. Dog-legged stairs

The name is given because of its appearance in sectional elevation. It comes under the category of newel stairs in which newel posts are provided at the beginning and end of each flight. These may be of two types: with half space landing and with quarter space landing and winders.

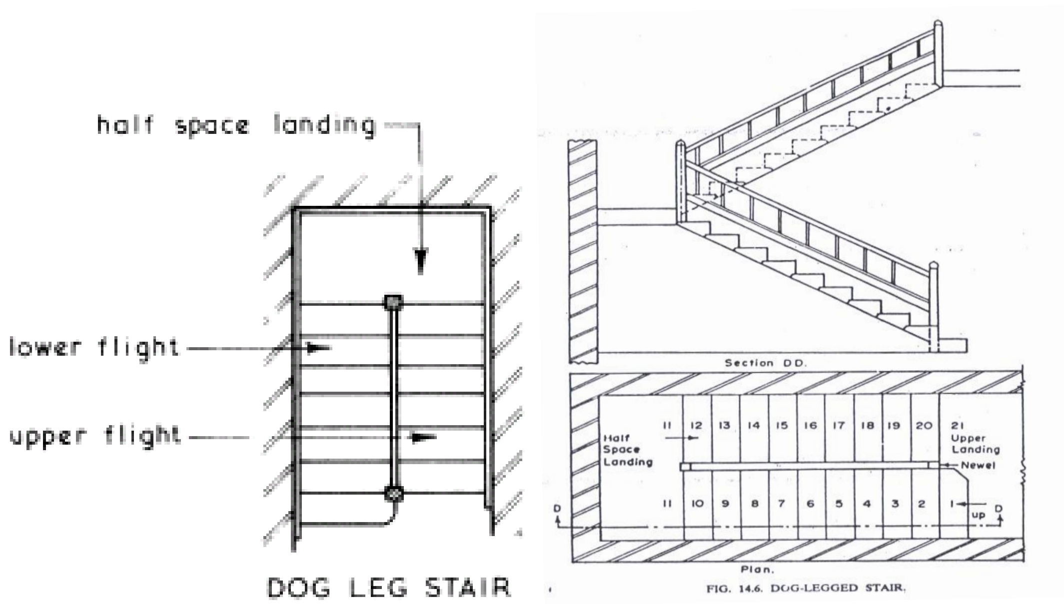


Fig. 5.4.5 Dog-legged stair

B. Open newel half turn stair

This stair type has a space or well between the outer strings. This is the only aspect in which it differs from the dog legged stairs. Additional width is required b/n the two flights. When the space provided is more, a small flight containing two to four steps may be introduced.

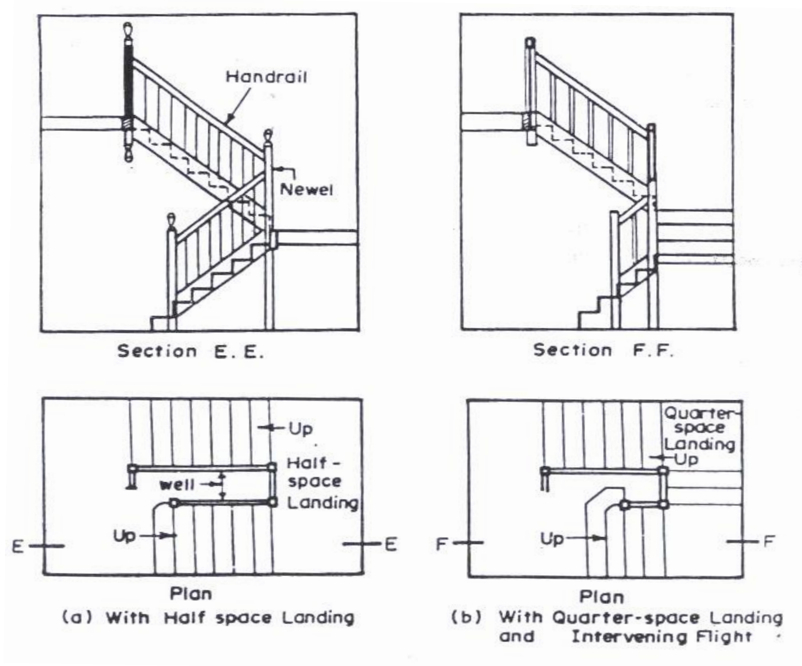


Fig. 5.4.6 Open newel half turn stair

C. Geometrical half turn stair

The essential features of such stairs are that the stringers and the hand rails are continuous, without any intervening newel post. This may be either with half-space landing or without.

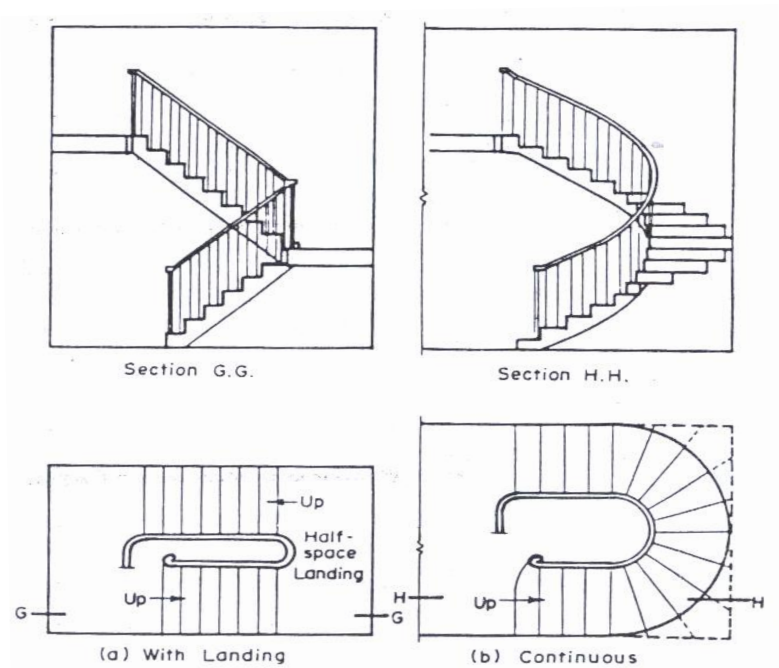


Fig. 5.4.7 Geometrical quarter turn stair

II.3. Three quarter turn stairs

It has its direction changed three times with its upper flight crossing the bottom one. It may either be newel type or open newel type. Such type of stair is used when the length of the stair room is limited and when the vertical distance b/n the two floors is quite large.

II.4. Bifurcated stairs

The stair has a wider flight at the bottom, which bifurcates into two narrow flights one turning to the left and the other to the right, at the landing. It may be either of newel type with a newel post or of geometrical type. This type of stair is commonly used in public buildings at their entrance hall.

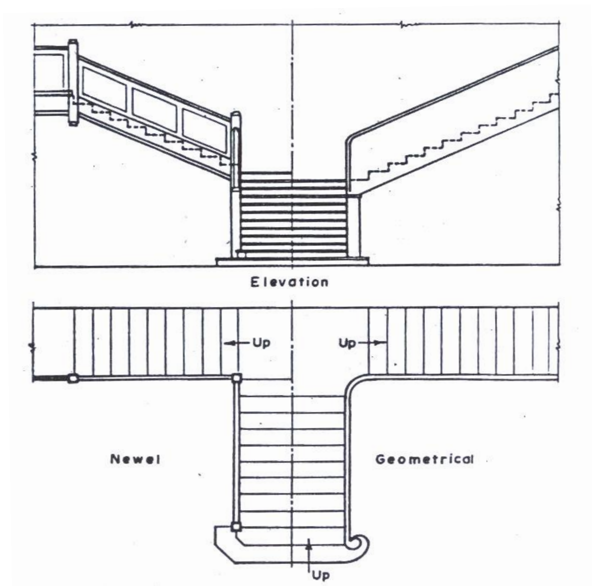


Fig. 5.4.8 Bifurcated stair

II.5. Continuous stairs

These are types of stairs which do neither have any landing nor any intermediate newel post; and they are geometrical in shape. Continuous stairs may be of three types:

A. ***Circular stairs***,
B. ***Spiral stairs***, and
C. ***Helical stairs***.

A. Circular stairs

This stair has circular plan configuration

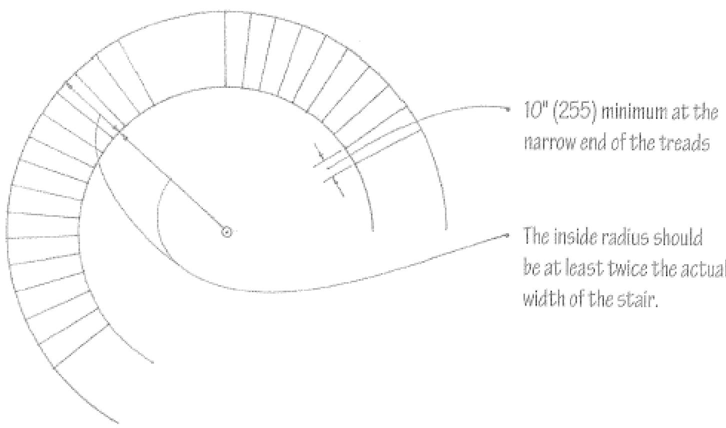


Fig. 5.4.9 Circular stair

B. **Spiral stairs**

They are usually made either of R.C.C. or metal. They are employed at a location where there are ***space limitations***. They are also used as ***emergency stairs*** and are provided at the back side of the building. All the steps are winders. Therefore they are not comfortable.

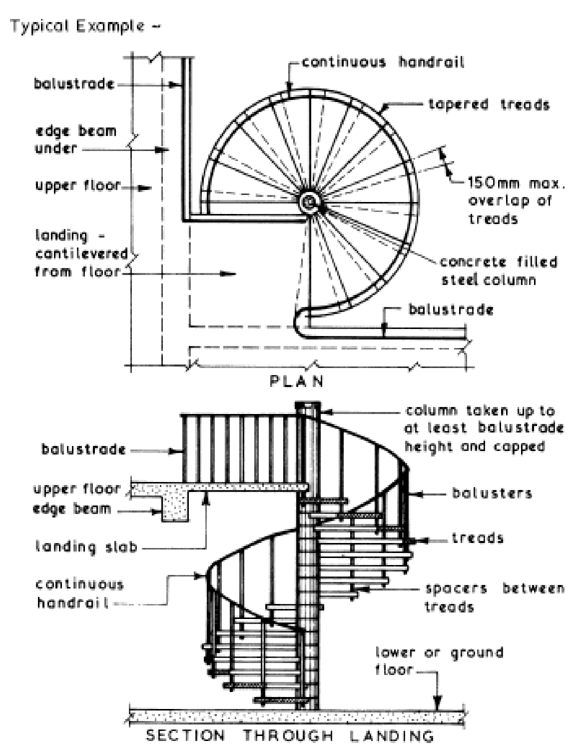


Fig. 5.4.10 Spiral stair

C. Helical stairs:

Looks very fine but its structural design and construction is very complicated. It is made of R.C.C. in which a large portion of steel is required to resist bending, shear and torsion.

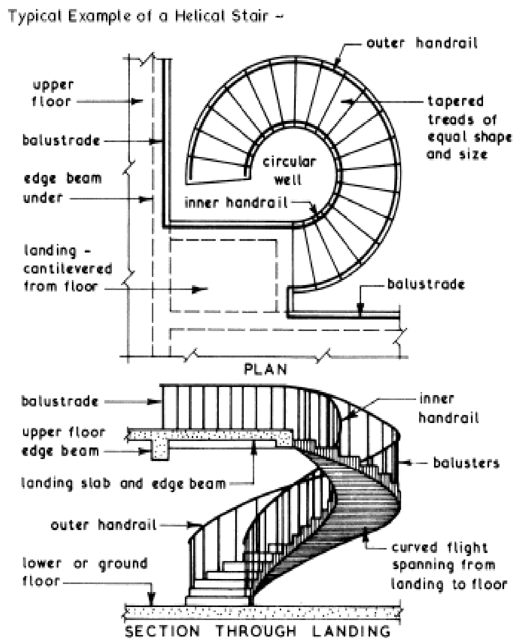


Fig. 5.4.11 Helical stair

5.4.4 Stairs of Different Materials

The selection of materials for the construction of stairs depend up on

- The availability of materials and ease of transportation
- Funds
- Desired life of building
- Aesthetical importance
- Freedom of design
- Expected fire resisting quality

Thus, stairs may be made either of timber, bricks, stones, mild steel, wrought iron, or plain and reinforced concrete.

I. Timber stairs

Timber stairs are light in weight and easy to construct. They have poor fire resistance and sound insulation. But they are unsuitable for high rise residential buildings and for public buildings. The timber to be used should be well treated before use.

II. Concrete stairs

They are most widely used for residential, public and industrial buildings. They are strong, durable, can take any desired shape and have good fire resistance. They are less noisy, can be kept clean and may have more attracting appearances if suitable finishes are used. Reinforced concrete stairs can be cast-in-situ or prefabricated.

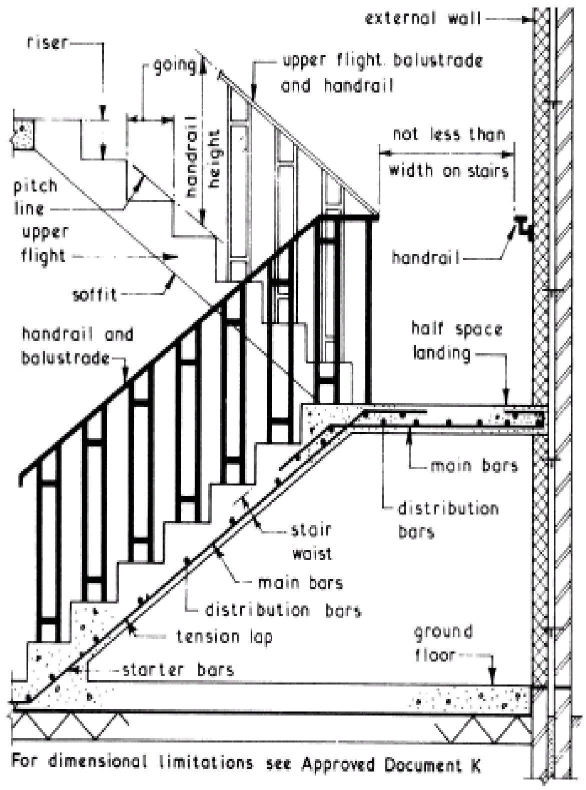


Fig. 5.4.12 Reinforced concrete stair

III. Pre-cast Concrete stairs

Pre-cast concrete stairs have the following advantages:

a) Good quality control of finished product.
b) Saving in site space since formwork fabrication and storage will not be required.
c) The stairs can be installed at any time after the floors have been completed thus giving full utilization to the stair shaft as a lifting or hoisting space if required.
d) Hoisting, positioning and fixing can usually be carried out by semi-skilled labor.

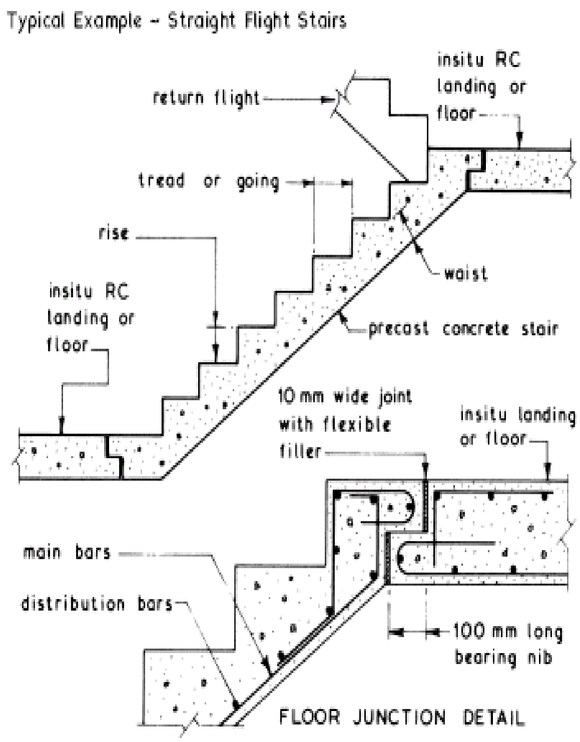


Fig. 5.4.13 Pre-cast concrete stair

IV. Metal stairs

These can be produced in cast iron, mild steel or aluminum alloy for use as escape stairs or for internal accommodation stairs. They make a lot of noise and can be built in a smaller area. They are normally manufactured in a workshop and fixed on site, which makes it faster and will be functional immediately. Their main advantage is the elimination of the need for formwork. Spiral stairs are mainly made of metal.

V. Stone stairs

They are strong and rigid and are widely used at the main entrance of public buildings. Stones for such stairs should be dressed and properly bounded to each other. Stone used for the construction of stairs should be hard, strong, and resistant to wear.

VI. Brick stairs

Similar to stone stairs, brick stairs are used at the entrance of a building. Special quality of bricks should be used for the construction of stairs. Brick steps may be plastered or pointed at all the joints. If properly made, brick stairs are durable, have good aesthetic value, but requires frequent maintenance.

5.4.5 Essential Requirements of a Good Stair

Stairs should be designed so as to provide ***easy***, ***quick*** and ***safe*** mode of communication b/n the floors. The following are the general requirements which a stair should fulfill.

A. **Location:**
   - It should be so located as to provide easy access to the occupants of the building.
   - It should be so located that it is well lighted and ventilated directly from the exterior.
   - It should be so located as to have approaches convenient and spacious.

B. **Width of stair:**
   - It should be wide enough to carry the user with out much crowd or inconvenience.
   - Width of stairs depends up to its location in the building and the type of the building itself.
   - If a domestic building, a 90cm wide stair is sufficient while in public building, 1.5-1.8m width may be required

C. Length of flight:
   - From comfort point of view, the number of steps should not more than 12 and not less than 3.

D. Pitch of stair:
   - Its ascent should be relatively easy.
   - Stairs for public building should have a pitch of 38° and for private buildings the pitch should not be more than 42°.

E. Head room:
   - The clear distance b/n the tread and soffit of the flight immediately above it should not be less than 2.1-2.3m

F. Balustrade:
   - Open well stairs should always be provided with balustrade, to provide safety to the users.
   - Wider stairs should have hand rail to both the sides.

G. Step dimensions:
   - The rise and going should be of such dimension as to provide comfort to the users.
   - Their proportion should also be such as to provide desirable pitch of the stair.
   - The going should not be less than 25cm, though the 30cm is quite comfortable.

- The rise should be b/n 10cm (for hospitals, etc) to 15cm.
- The width of landing should not be less than the width of a stair.
  - Rise + Tread ≥ 40 and ≤ 45cm
  - 2Rise + Tread ≥ 58 and ≤ 63cm
  - Rise x Tread ≥ 400 and ≤ 500cm2

5.4.6 Ladders

Ladders are used primarily in industrial construction and in utility and service areas.

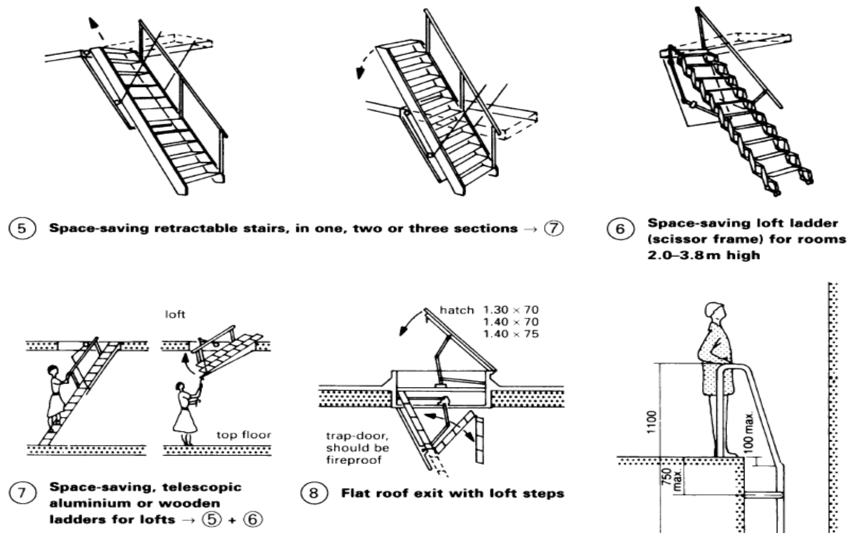


Fig. 5.4.14 Ladders

5.4.7 Ramps

Ramps shall be provided to allow wheel chair access and luggage path in hotels, for stretchers in hospitals for loading and unloading in warehouses and factories.

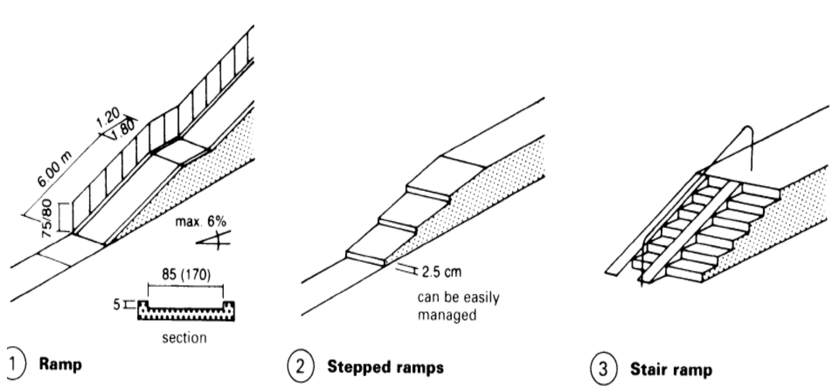


Fig. 5.4.15 Ramps

5.4.8 Elevators

Elevators travel vertically to carry passengers, equipments and freight from one level of the building to another. The two most common types are electric and hydraulic elevator.

Electric elevator: consist of a car that is mounted on guide rails supported by hoisting cables, and driven by electric hoisting machinery in a pent house.

Hydraulic elevator: consist of a car supported by a piston that is moved by or moves against a fluid under pressure.

The type, size, number, speed and arrangement of elevators are determined by:

- Type of occupancy
- Amount and tempo of traffic to be carried
- Total vertical distance of travel
- Round-trip time and speed desired.

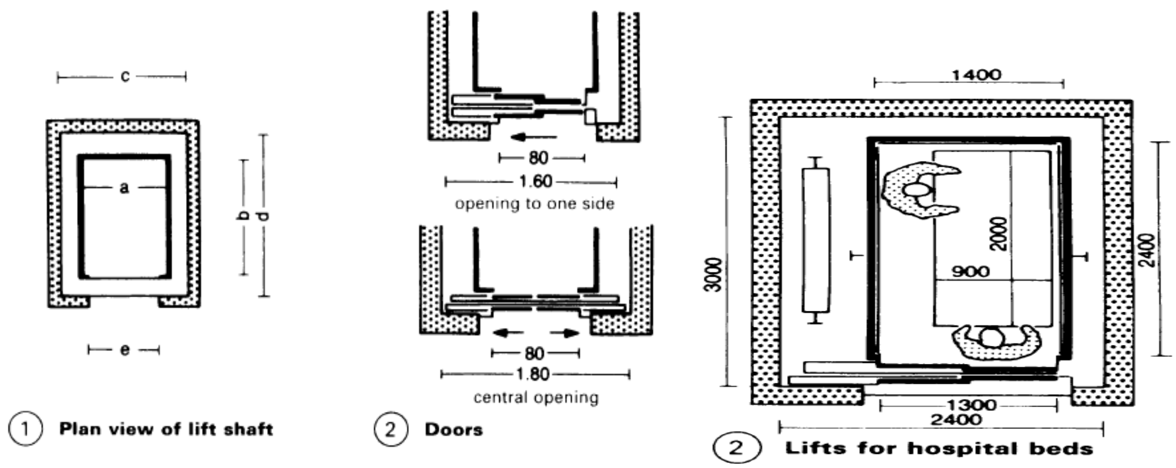


Fig. 5.4.16 Elevators

5.4.9 Escalators

Escalators are power driven stairways consisting of steps attached to continuously circulating belt. They can move a large number of people efficiently and comfortably b/n a limited number of floors, six floors are a practicably limit. Since escalator move at a constant speed, there is a practically no waiting period, but there should be adequate queuing space at each loading and discharge. The pitch varies b/n 30-35°. Escalators are usually used in public areas like airport, shopping malls, etc. Escalators are typically used in pairs with one going up and other going down.

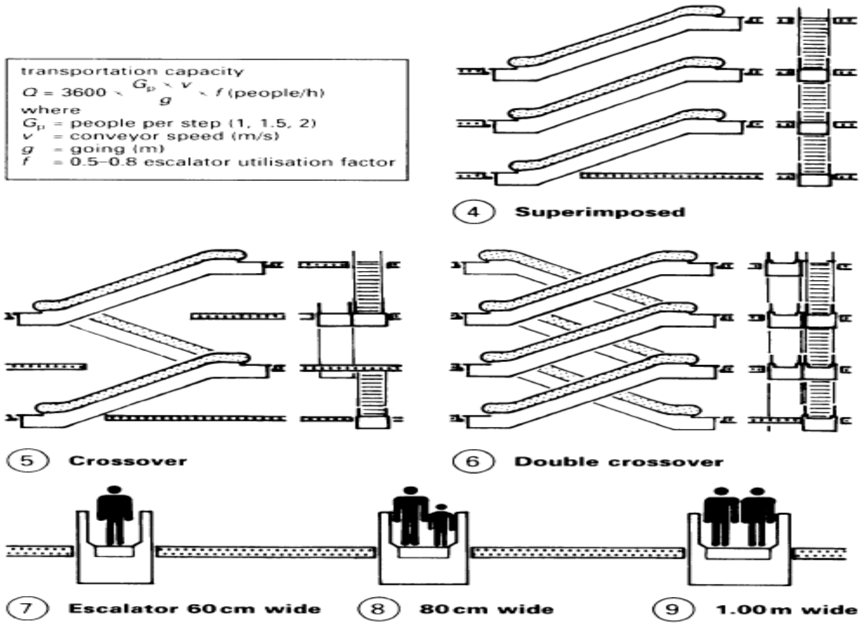


Fig. 5.4.17 Escalators

5.5 DOORS AND WINDOWS

5.5.1 DOORS

5.5.1.1 Introduction

A door is an openable barrier secured in a wall opening and is provided to give access, protection, safety and privacy to the inside of a room of a building. It serves as a connecting link b/n the various internal portions of a building. Basically a door consists of two parts door frame and door shutter.

5.5.1.2 Location of doors and windows

The following points should be kept in view while locating doors and windows.

i. The number of doors in a room should be kept minimum, since larger number of doors cause obstruction, and consume more area in circulation.

ii. The location of door should meet functional requirements of a room.
   a. It should not be located in the center of the length of a wall.
   b. A door should preferably be located near the corner of a room –nearly 20cm away from the corner.

iii. If there are two doors in a room, the doors should preferably be located in opposite walls facing each other, so as to provide good ventilation.

iv. The size and number of windows should be decided on the basis of distribution of light, control of ventilation, and privacy of the occupants.

v. The location of window should also meet the functional requirements of the room, such as interior decoration, arrangement of furniture, etc

vi. A window should be located in opposite wall, facing a door or another window for cross ventilation.

vii. From the point of view of fresh air, a window should be located in the prevalent direction of wind.

viii. The sill of window should be located about 70-80 cm above the floor level of the room.

5.5.1.3 Definition of technical terms

The following are the technical terms applied to doors and windows

- **Frame**: It is an assembly of horizontal and vertical members, forming an enclosure, to which the shutters are fixed.
- **Shutters**: these are openable parts of a door or window . It is an assembly of styles, panels and rails.
- **Head**: this is the top or uppermost horizontal part of a frame.
- **Horn**: these are the horizontal projections of the head and sill of a frame to facilitate the fixing of the frame on wall opening.
- **Style**: the vertical outside member of the shutter of the door or window.
- **Top rail**: this is the top most horizontal member of a shutter.
- **Lock rail**: The middle horizontal member of a door shutter, to which locking arrangement is fixed.
- **Bottom rail**: the lower most horizontal member of a shutter.
- **Intermediate or cross rails**: additional horizontal rails, fixed b/n the top and bottom rails of a shutter.
- **Panel**: this is the area of shutter enclosed b/n the adjacent rails.
- **Mullion**: vertical member of a frame, which is employed to sub-divide a window or a door vertically.
- **Sill**: this is the lowermost or bottom horizontal part of a window frame.
- **Transom**: Horizontal member of a frame, which is employed to subdivide a window opening horizontally.
- **Hold fasts**: mild steel flats generally bent into Z shape, to fix or hold the frame to the opening.

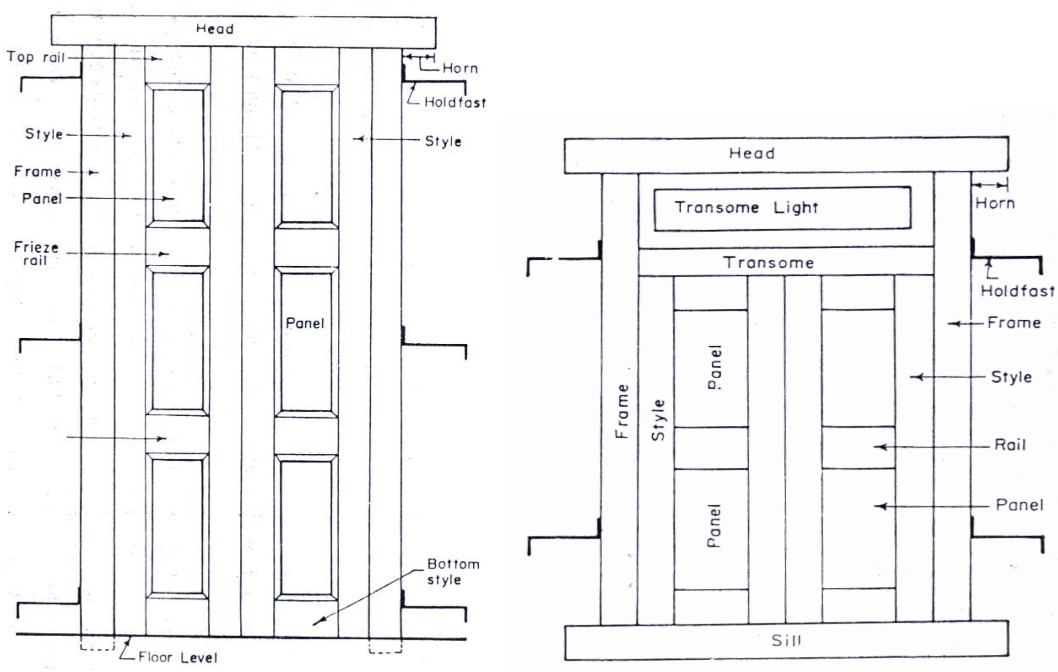


Fig. 5.5.1.1 Technical terminologies of doors and windows

5.5.1.4 Size of doors

The size of the door should be such that it would allow the movement of largest object or tallest person likely to use the door. As, a rule the height of a door should not be less than 1.8-2.0 m. The width of the door should be such that two persons can pass through it walking shoulder to shoulder. The common width height relations are:

- Width = 0.4 to 0.6 height
- Height = (width + 1.2) meters.

The following are the generally adopted size of doors for residential building:

- External door: 0.9-1.2m width and 2-2.1m height
- Internal door: 0.8-0.9m width and 2-2.1m height
- Bath room & WC 0.7-0.8m width and 2-2.1m height
- Garages for cars 2.25-2.4m width and 2-2.25m height

5.5.1.5 Door frames

A door frame is an assembly of horizontal and vertical members forming an enclosure, to which door shutters are fixed. The vertical members, one at each side, are known as **posts** while the horizontal top member connecting the posts is called **head**. The size of the frame is determined by allowing a clearance of 5mm to both the sides and the top of the opening.

The cross-sectional area of the posts and the head is generally kept the same. Door frames are made of the following materials:

i. Timber
ii. Steel section
iii. Aluminum sections
iv. Concrete, and
v. Stone

i. Timber door frames

Timber frames are more commonly used because they look much better than the other materials, and they can be polished, if desired.

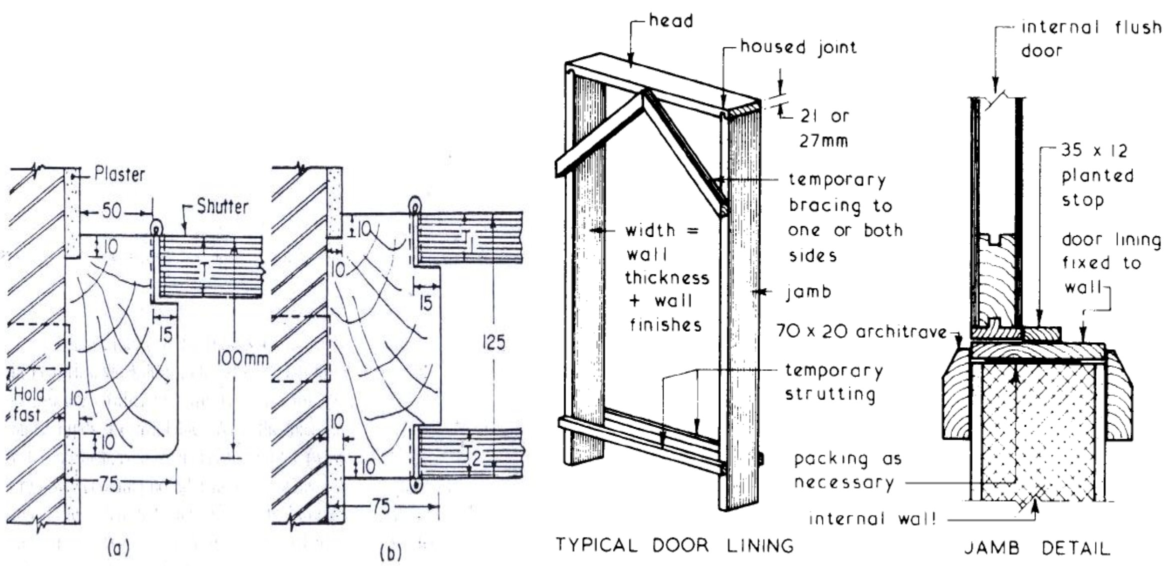


Fig. 5.5.1.2 Timber door frames

ii. Steel door frames

Steel door frames are made of any of the following sections

- Single angle iron
- Double angle iron
- T-sections
- Channel sections formed from pressing steel plates

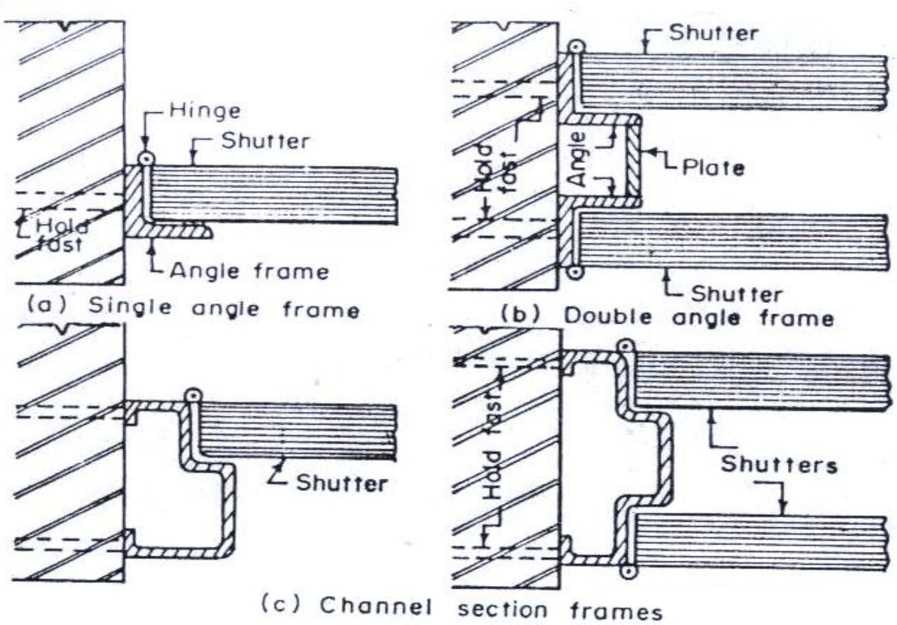


Fig. 5.5.1.3 Steel door frames

5.5.1.6 Types of doors

Doors commonly used in building are classified into the following types:

Classification based on types of material used	*Classification based on working operation*	*Classification based on method or manner of construction*	*Classification based on arrangement of components*
Wooden doors	Revolving doors	Framed and panelled doors	Battened and ledged doors
Glazed doors	Sliding doors	Glazed or sash doors	Battened, legged and braced doors
Plywood doors	Swing doors	Flush doors	Battened, legged and frame doors
Plastic doors	Folding doors	Louvered doors	Battened, legged, braced and framed doors.
Metal doors	Collapsible doors	Wire-gauged doors	

I. Classification based on types of material used

I.1 Wooden doors

It may be either hollow core or solid core. They can as well be built up of small individual pieces. Solid core doors are used as exterior doors, in location where extremely heavy service is anticipated. Hollow-core doors are used for only interior applications.

Wooden doors can take a good polish and can be given different types of moulding to produce an attractive appearance. Unless properly seasoned, wooden doors are easily attacked by vermin especially when in contact with walls built of mud masonry.

I.2 Glazed doors

Glass is used in panels of doors to admit light. Coloured glass, frosted glass and beaded glass can be used for ornamental appearance. Steel framed door with a single, two or three glass panels are mainly used in external doors for residential buildings and could also be used as internal doors in offices.

I.3 Plywood doors

The various types and quality products of plywood brought the use of ply wood skins over wooden frame works to the widespread use of the flush doors. Such doors are mainly used for internal purpose.

I.4 Plastic doors

Flush doors covered in high pressure melamine laminates are manufactured to fit in specific openings. The plastic laminate is applied to both faces of the door and comes in wide variety of colours and in many wood-grain patterns. Plastic laminate clad doors offer good resistance to impact and abrasion and usually do not need refinishing for the life of the building. The surface resists stains and can be cleaned with soap and water or other detergents.

I.5 Metal doors

Steel and aluminium doors are most popularly used as metal doors. Aluminium has a shiny colour, has light weight and provides attractive appearance and costs more than steel doors. Steel doors are used practically for any type of door opening.

Steel frames are produced in various depth and width to fit most wall conditions. Metal doors are of the following types:

- Mild steel sheet doors
- Corrugated steel sheet doors
- Hollow metal doors
- Metal covered plywood doors.

II. Classification based on working operations

II.1 Revolving doors

Revolving doors are provided in public buildings such as museums, libraries, hotels, banks, etc. where there are constant visitors. Such a door provides entrance to one and exit to the other person simultaneously and closes automatically when not in use. The door consists of a centrally placed mullion to which four radiating shutters are attached.

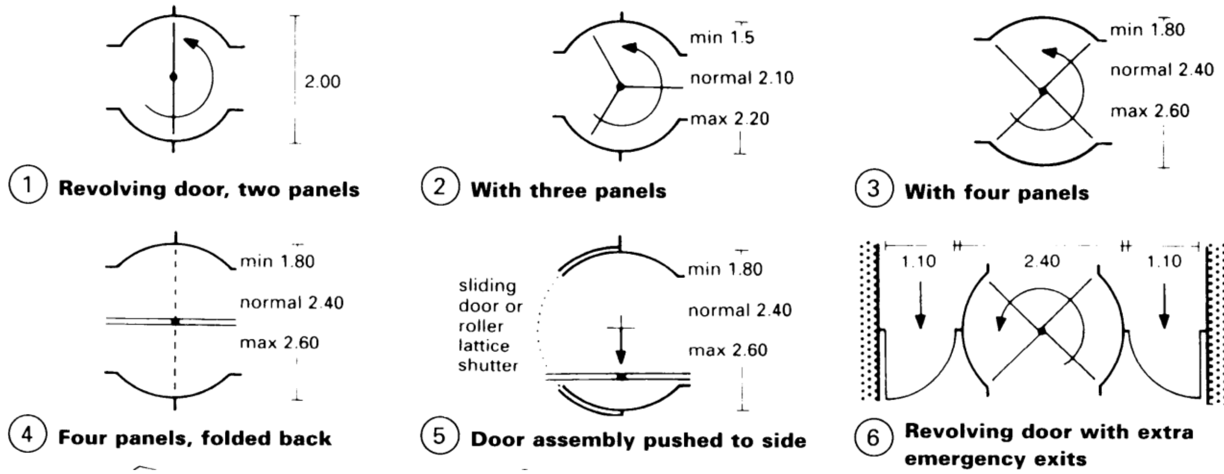


Fig. 5.5.1.4 Revolving door

II.2 Sliding doors

The shutter can slide upward, downward or sideways. The shutter slides to the sides with the help of runners and guide rails. The door may have one two or even three shutters, depending upon the size of the opening and space available on sides for sliding.

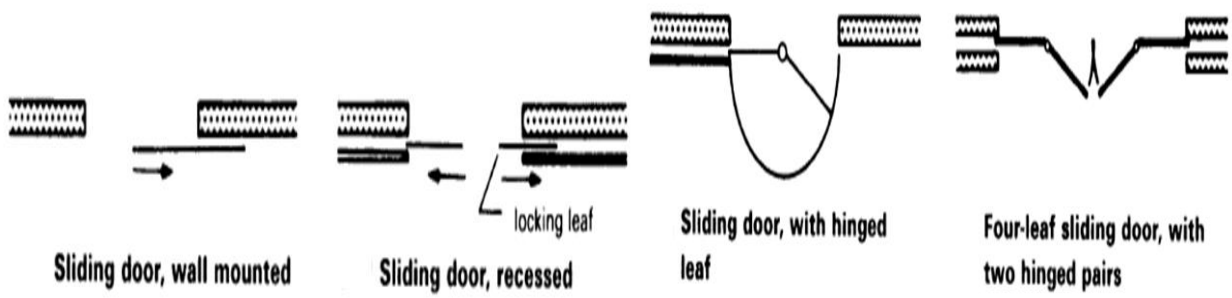


Fig. 5.5.1.5 Sliding door

II.3 Swing doors

The most common type of door movement is the swinging door either right or left, depending on which side is the hinge. Swinging doors may be hinged at the side to open and shut in one direction (single swings) or they may be double acting doors, which swing in both ways (double swinging).

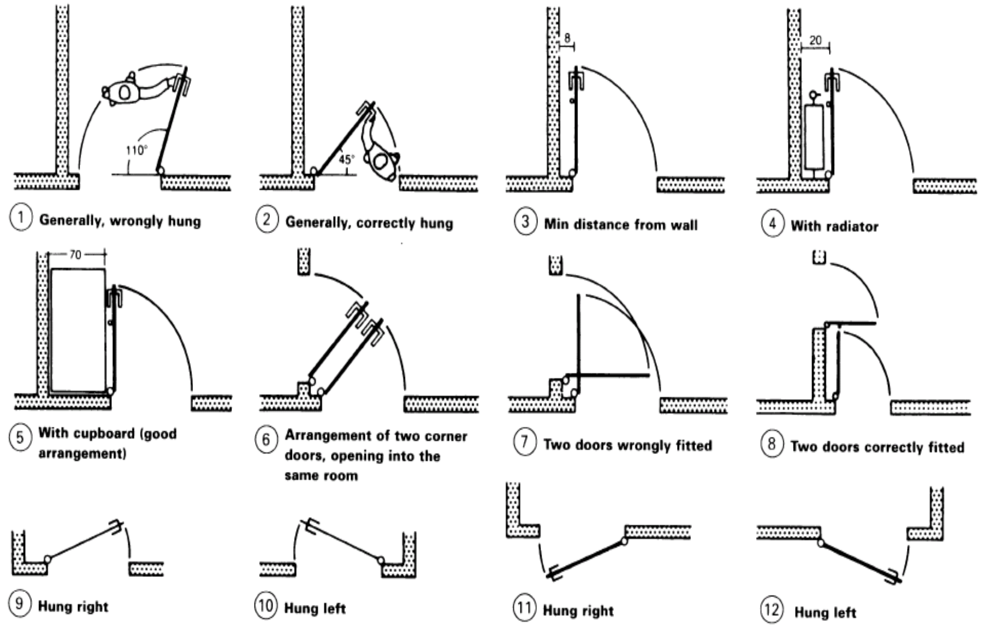


Fig. 5.5.1.6 Swing door

II.4 Collapsible steel doors

These types of doors are used in workshops, sheds, public buildings, etc for providing increased safety and protection to property. The door neither requires hinges, for opening and closing, nor any frame for hanging them. It acts like a steel curtain which can be opened or closed by horizontal push. It is used even in residential buildings where opening is large but there is no enough space to accommodate leafed shutters.

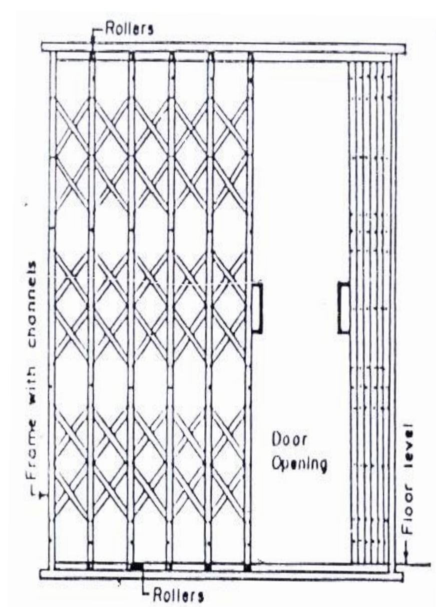


Fig. 5.5.1.7 Collapsible steel door

II.5 Rolling steel shutter doors

These doors are commonly used for garages, shop fronts, show windows etc., since they are quite strong and offer proper safety to the property. The door consists of a frame, a drum and a shutter of thin steel plates (known as laths or slates) interlocked together. Rolling shutters are of two types: Pull-push type shutters and Mechanical gear type shutters.

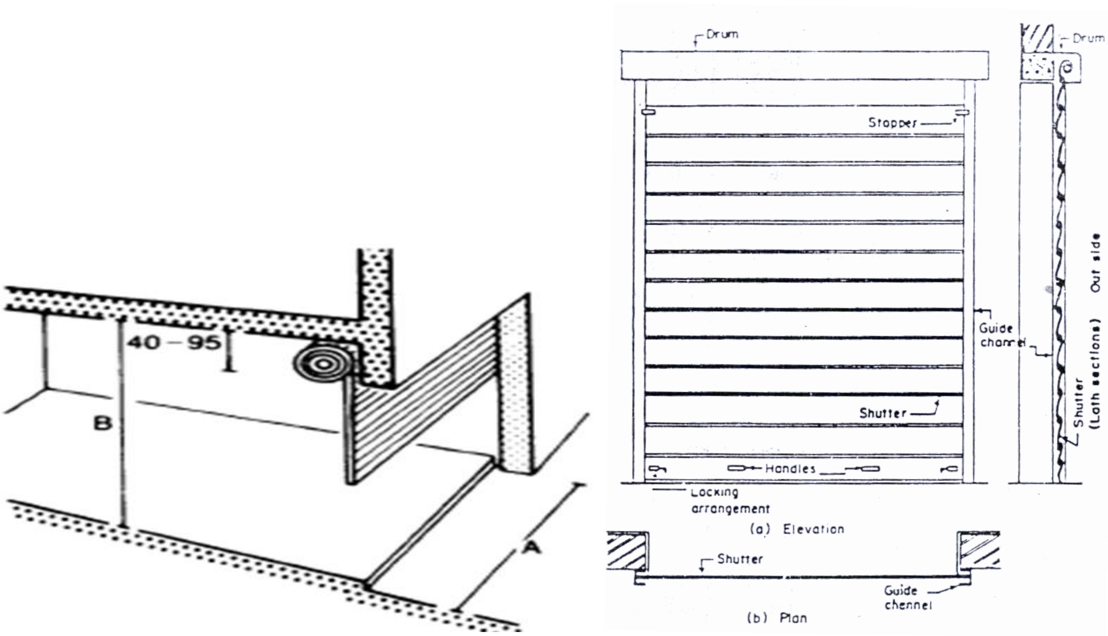


Fig. 5.5.1.8 Rolling steel shutter door

III. Classification based on working operations

III.1 Framed and panelled doors

These types of doors are widely used in almost all types of building since they are strong and give better appearance. This door consists of a frame work of vertical members (called styles) and horizontal members, called rails which are grooved along the inner edges of the frame, to receive the panels.

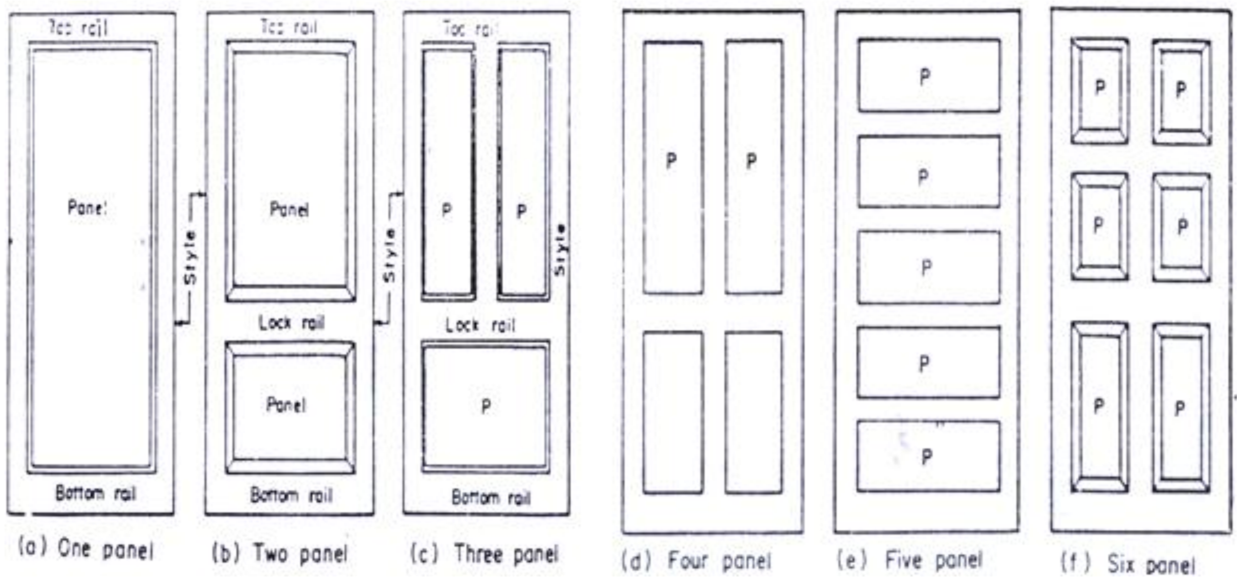


Fig. 5.5.1.9 Framed and paneled doors

III.2 Glazed doors or sash doors

They are provided where additional light is required to be admitted to the room through the door, or where the visibility of the interior of the room is required from adjacent room. They are used in residential as well as public buildings like hospitals, schools, colleges, etc. The doors may be either fully glazed, or they be partly glazed and partly panelled.

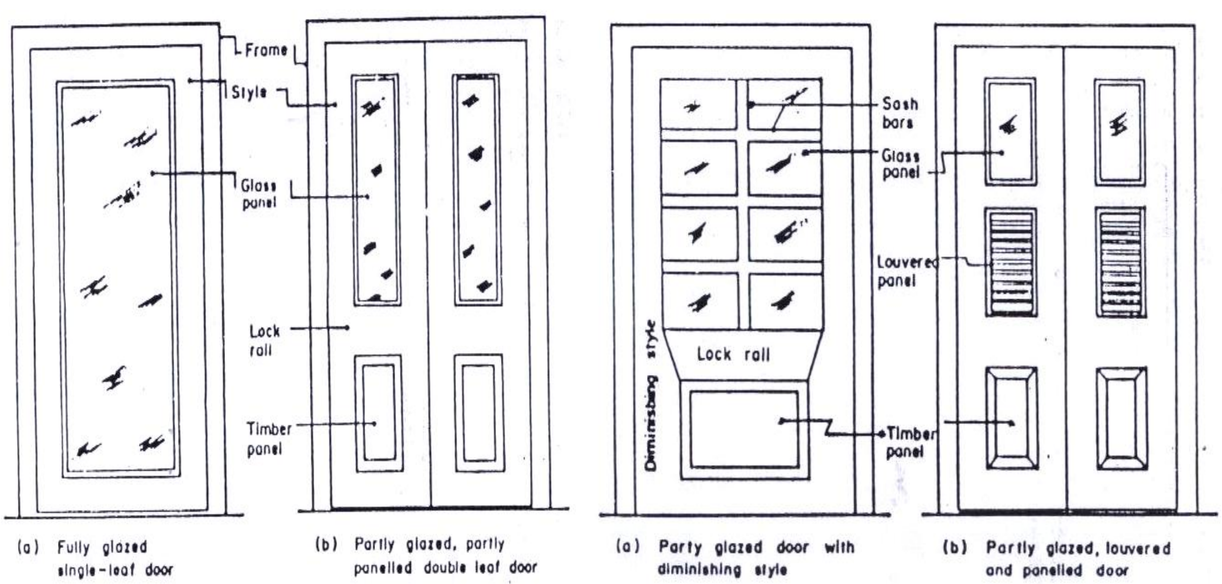


Fig. 5.5.1.10 Glazed doors

III.3 Flush doors

These doors consist of solid or semi-solid skeleton or core covered on both sides with plywood, face veneers, etc. presenting flush and joint-less surface. Flush doors are becoming increasingly popular these days because of their pleasing appearance, simplicity of construction, less cost, better strength and durability.

They are used both for residential as well as public and commercial buildings. Flush doors are of two types:

A. Solid core flush door or laminated core flush door.

B. Hollow and cellular core flush door.

A. Solid core flush door or laminated core flush door

This door consists of the wooden frame consisting of styles, and top and bottom rails are used for holding the core.

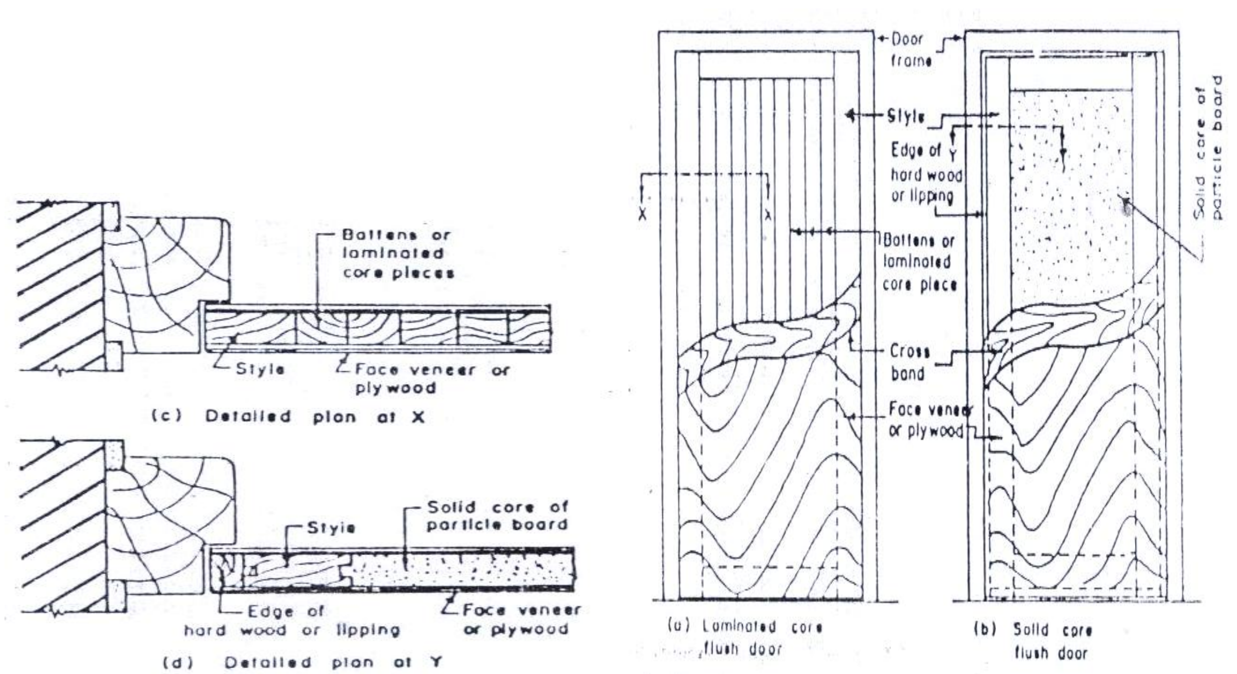


Fig. 5.5.1.11 Solid core flush door

B. Hollow core and cellular core flush door

A **hollow core flush door** consists of frame made up of styles, top rail, bottom rail and minimum two intermediate rails. The inner space of the frame is provided with equally spaced battens each of minimum 25mm width. The area of the void is limited to 500 cm^2.

A **cellular core flush door** consists of a frame of styles, top rail and bottom rail, with the void space filled with equidistant battens of wood or ply wood. The battens are so arranged that the total area of voids does not exceed 40% of the area of the shutter.

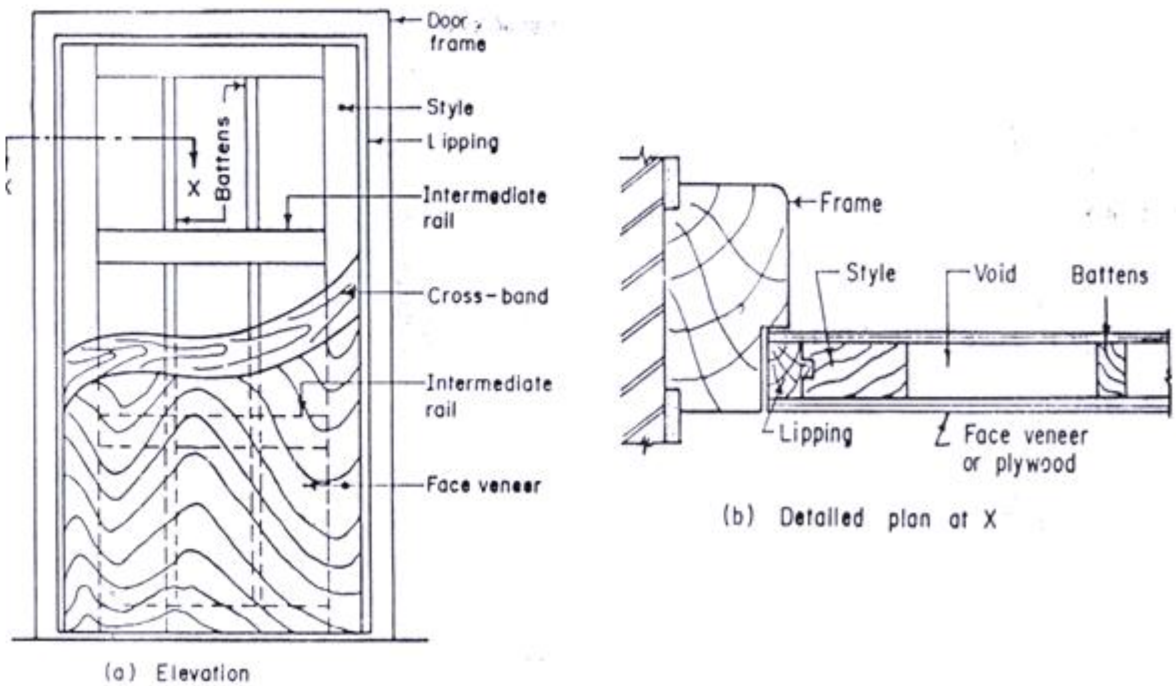


Fig. 5.5.1.12 Hollow core flush door

III.4 Louvered doors (Venetian doors)

Louvered doors permit free ventilation through them, and at the same time maintain the privacy of the room. These doors are generally used for latrines and bath rooms of residential and public buildings. The door may either be louvered to its full height, or it may be partly louvered and partly paneled. The louvers are arranged at such an inclination that the vision is obstructed while they permit the passage of air. Louvers may be either fixed or movable and they may be made of either timber or glass or ply wood.

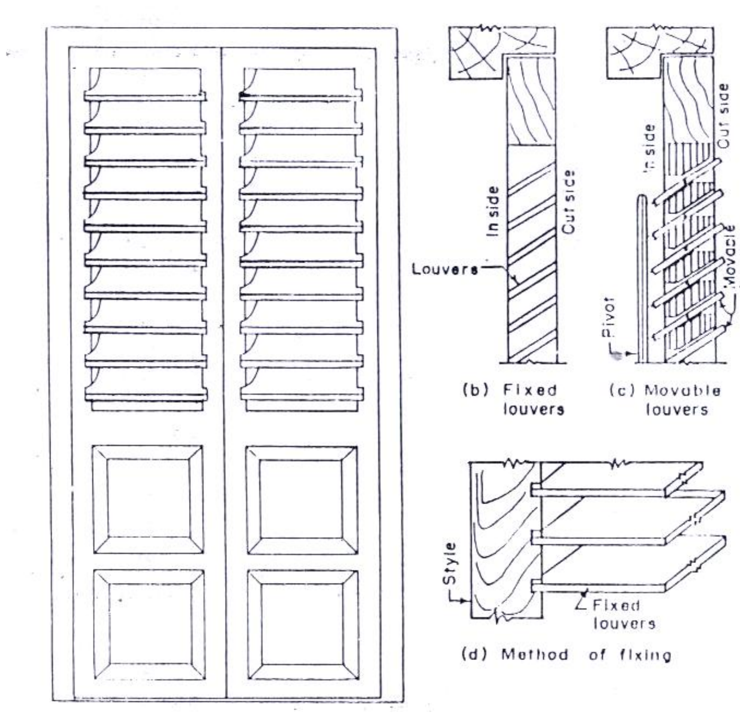


Fig. 5.5.1.13 Louvered door

III.5 Wire gauged doors

These types of doors are provided to check the entry of flies, mosquitoes, insects, etc. Wire mesh is provided in the panels, and therefore, they permit free passage of air. Such doors are commonly used for refreshment rooms, hotels, cup boards containing food and sweet shops.

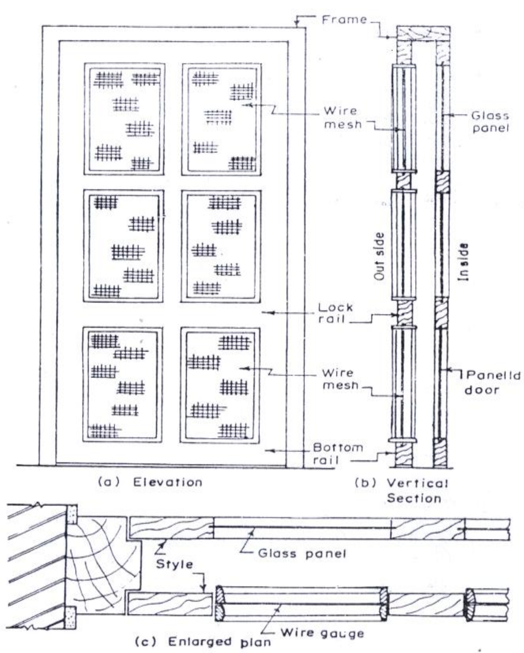


Fig. 5.5.1.14 Wire gauged door

III. Classification based on working operations

IV.1 Battened and ledged doors

This is the simplest type of door, especially suitable for narrow openings. It is formed of vertical bonds; known as **battens** which are fixed together by horizontal supports known as **ledges**.

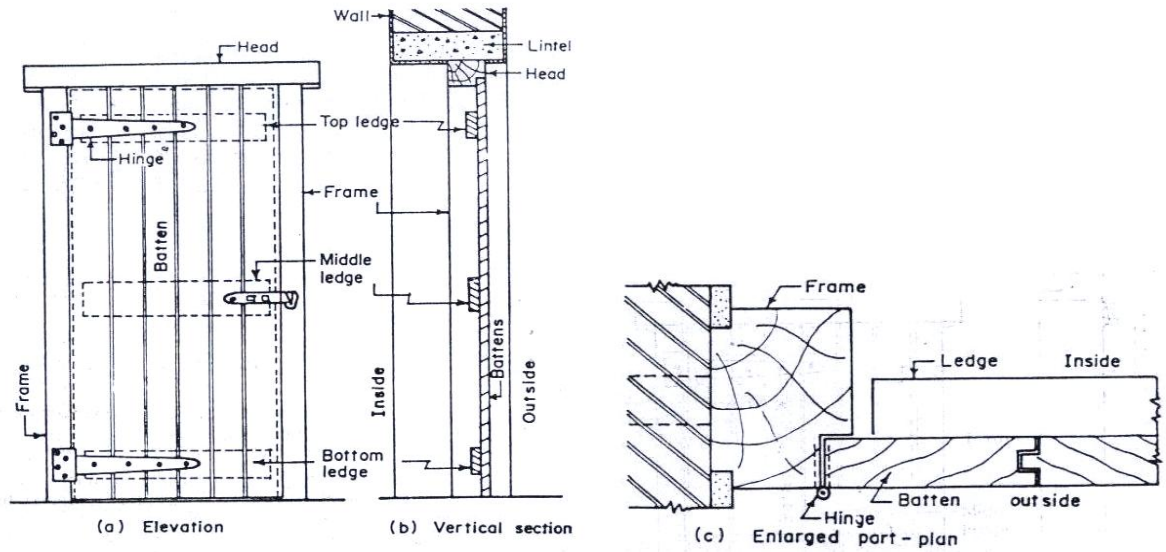


Fig. 5.5.1.15 Battened and ledged doors

IV.2 Battened, ledged and braced doors

These doors are an improved form of the previous one in which additional inclined (or diagonal) members called **braces** are provided.

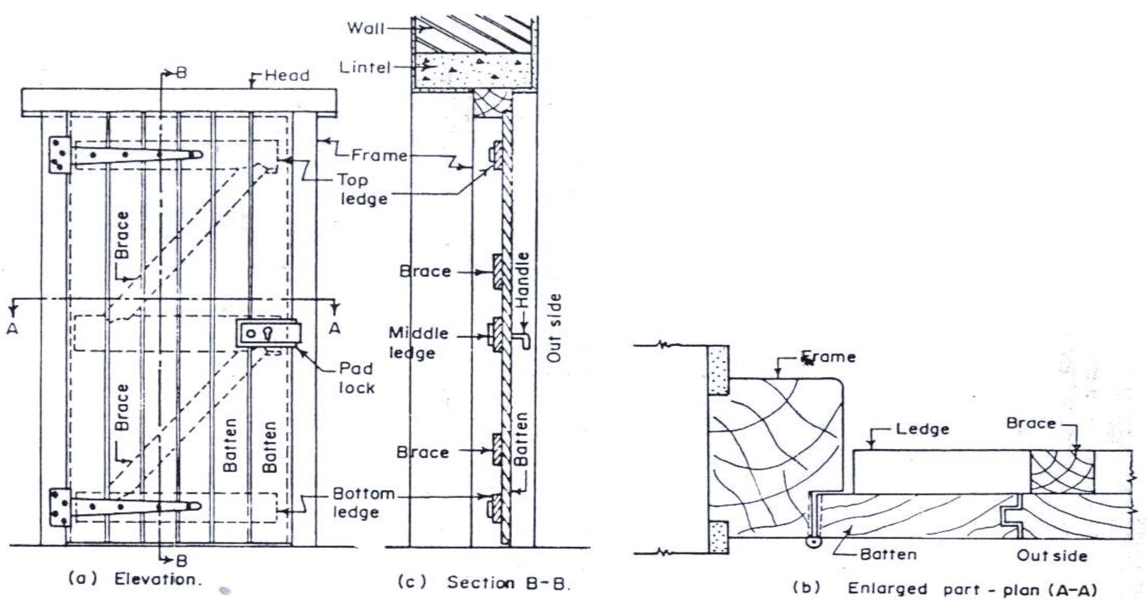


Fig. 5.5.1.16 Battened, ledged and braced doors

IV.3 Battened, ledged and frame doors

This door is also an improved form of simple battened and ledged door, in which frame work for the shutter is provided in the form of two verticals, known as **styles**.

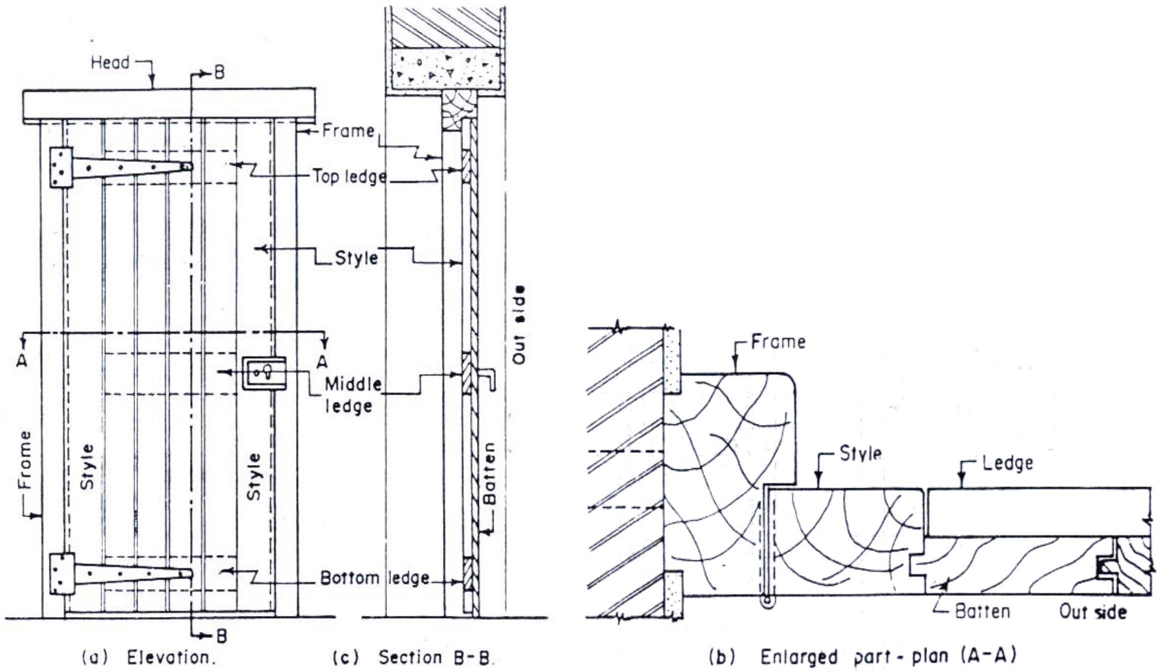


Fig. 5.5.1.17 Battened, ledged and frame doors

IV.4 Battened, ledged, braced and frame doors

This is a modification of the above, with the provision of additional braces, provided diagonally b/n the ledges to increase its **strength**, **durability** and **appearance**.

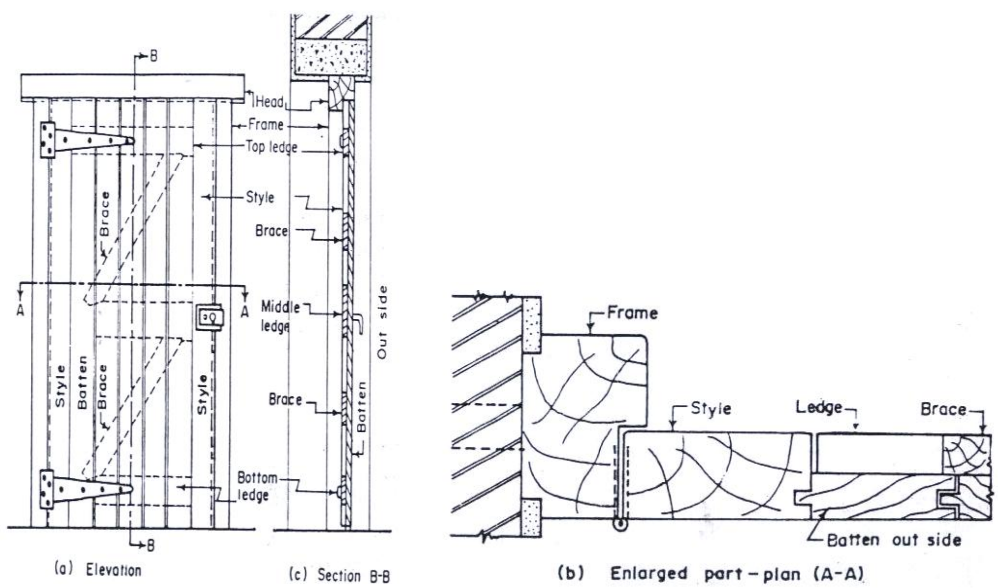


Fig. 5.5.1.18 Battened, ledged, braced and frame doors

5.5.2 WINDOWS

5.5.2.1 Introduction

Window is a vented barrier secured in a wall opening. The function of a window is to admit light and air to the building, give a view to the outside, provide insulation against heat loss, and give a measure of resistance to fire.

A window is comprised of two parts:

i. Window frame secured to the wall opening with the help of suitable hold fasts.
ii. Window shutter fixed to the window frames by means of suitable hinges.

A window must be aesthetically acceptable in the context of building design and surrounding environment.

The selection of **size**, **shape**, **location** and **number** of windows in a room depends up on the following factors:

- Size of the room
- Location of the room
- Utility of the room
- Direction of the wall
- Direction of the wind
- Climatic condition such as humidity, temperature, etc.
- Requirements of exterior view
- Architectural treatment to the exterior of the building.

Windows should be selected or designed to resist wind loadings, be easy to clean and provide for safety and security. They should be sited to provide visual contact with the outside.

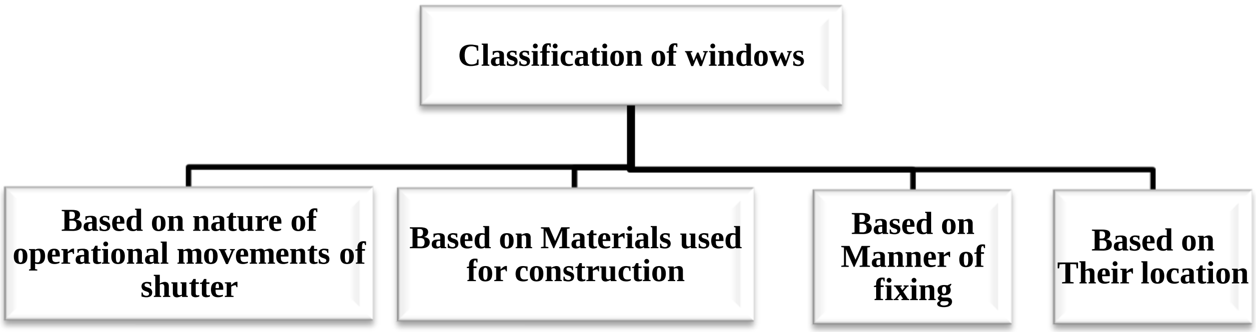
Based on the above factors, the following thumb rules are in use:

- Breadth of window = 1/8 (width of room + height of room)
- The total area of window-openings should normally vary from 10-20% of the floor area of the room, depending upon climatic conditions.
- The area of window opening should be at least one square meter for every 30-40 cubic meter of inside content of the room.
- In public buildings, the minimum area of windows should be 20% of floor area.

- For sufficient natural light, the area of glazed panels should at least be 8-10% of the floor area.

5.5.2.2 Types of windows

Windows are classified as follow:



1. Fixed Windows

These windows are provided for the sole purpose of admitting light and/or providing vision to the room. The window consists of a window frame to which shutters are fixed, and the shutters are fully glazed.

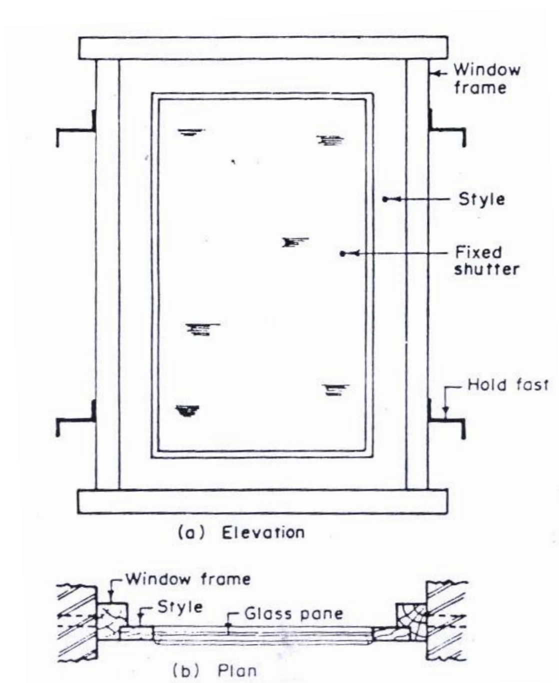


Fig. 5.5.2.1 Fixed window

2. Pivoted Windows

The shutters are allowed to swing round pivots fixed to the window frame. The frame of the window shutter is similar to that of an encasement window. The shutter can swing or rotate either horizontally, or vertically.

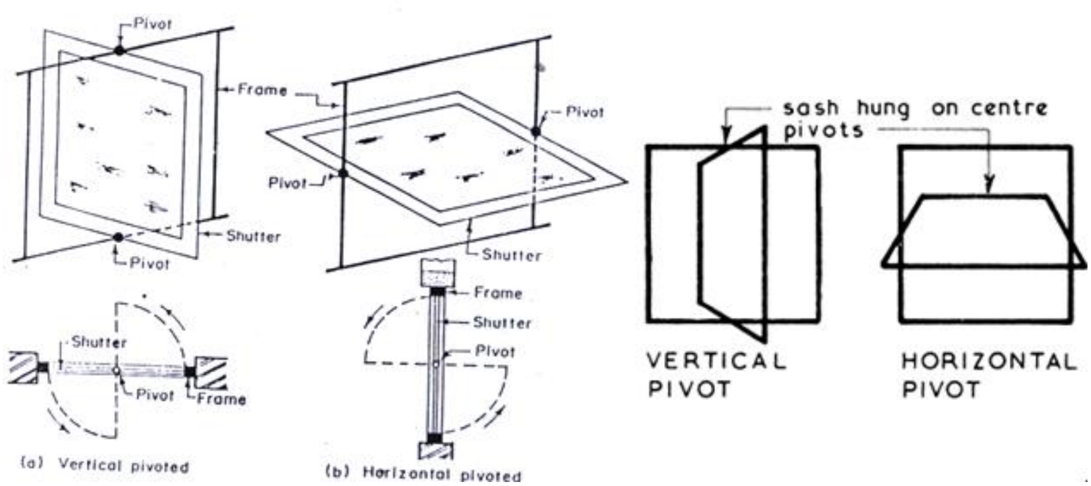


Fig. 5.5.2.2 Pivoted windows

3. Double hung windows

This type of window consists of a frame and a pair of shutters arranged one above the other, which can slide vertically within the grooves provided in the window frame. By the provision of such sliding, the windows can be cleaned effectively and at the same time ventilation can be controlled effectively.

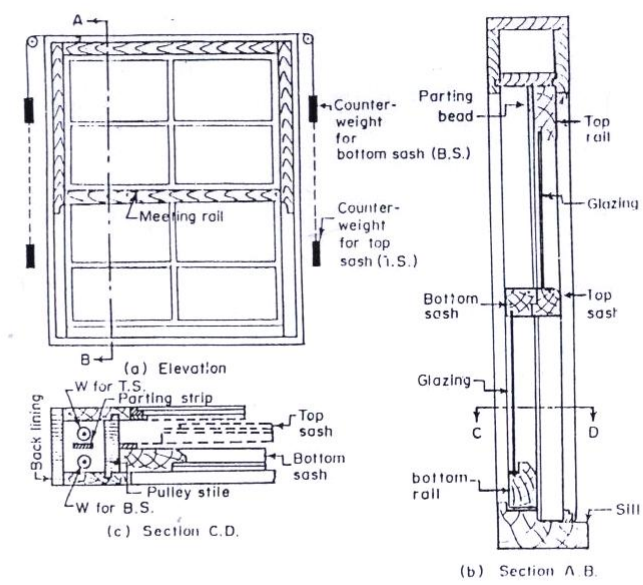


Fig. 5.5.2.3 Double hung windows

4. Sliding Windows

These windows are similar to sliding doors. The shutters move either horizontally or vertically on small roller bearings. Suitable openings or grooves are left in the frame or walls to accommodate the shutters when they are slide to open the window. They are provided in train, buses, shops and bank counters

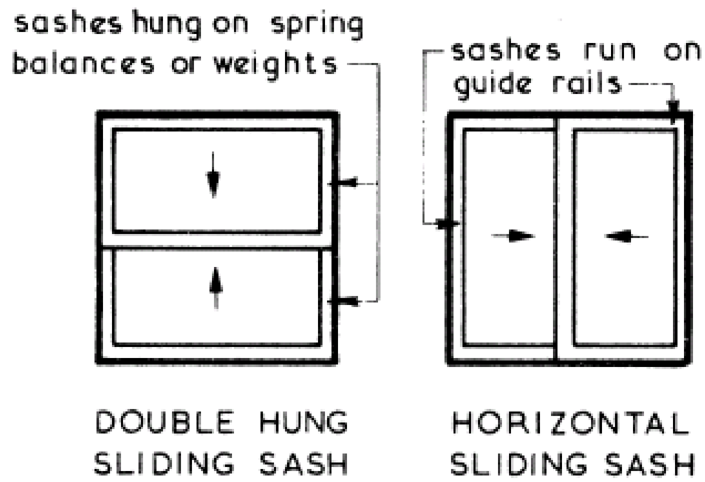


Fig. 5.5.2.4 Sliding windows

5. Casement windows

These are the main common type of windows usually provided in buildings. The shutters of the window open like the shutters of the doors. The shutters consist of styles, top rails, bottom rails, and intermediate rails thus dividing it into panels. The panels may either be glazed, or unglazed, or partly glazed and partly unglazed.

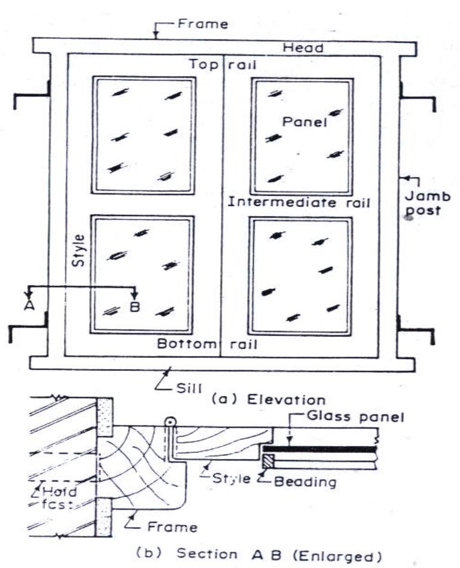


FIG. 17.27. CASEMENT WINDOWS.

Fig. 5.5.2.5 Casement windows

6. Sash or Glazed Windows

A sash window is a type of casement window in which the panels are fully glazed. The frame of each shutter consists of two vertical styles, top rail and a bottom rail. The space b/n the top and bottom rail is divided into small panels by means of small timber members placed horizontally and vertically.

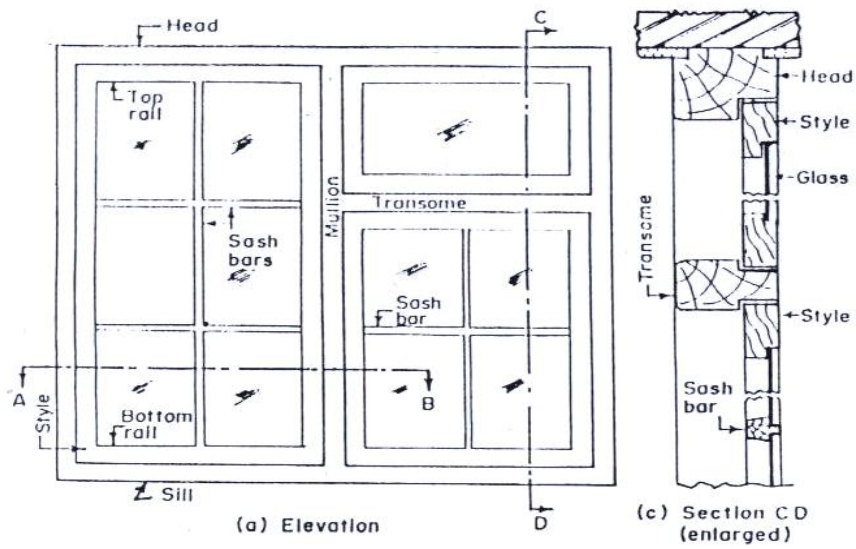


Fig. 5.5.2.6 Sash or glazed window

7. Louvered Windows

These are similar to louvered doors. Such windows are provided for the sole aim of ventilation, and they do not permit any outside vision. The shutter consists of top and bottom rails, and two styles which are grooved to receive louvers. The economical angle of inclination of the louvers is 45°. The louvers slope downward to the outside to run-off the rain water. Sometimes Venetian shutters are provided in which the louvers can open or close.

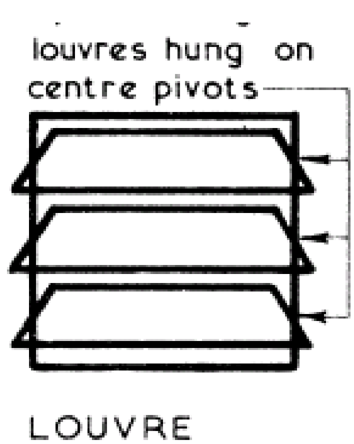


Fig. 5.5.2.7 Louvered Windows

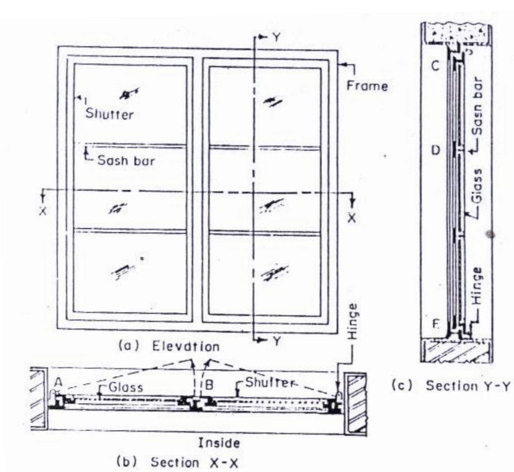
8. Metal windows

Metal windows, made of mild steel is becoming increasingly popular in private as well as public buildings, because of their strength and cost. Windows made of other metals, such as aluminum, bronze, stainless steel, etc. are used where high degree of elegance finishing is required. Aluminum windows are rust proof, durable and require no maintenance and painting.

Mild steel windows are of the cheapest, and are therefore extensively used in all types of buildings. The commonly used sections in mild steel windows are angle section, Z-sections, T-sections and channel sections.

Steel windows can be fixed either directly to the masonry opening, or it may be fixed into wooden frame already fixed in the opening. Steel windows have the following advantages over timber windows.

- Steel windows are generally manufactured in factories, with greater precision and better quality control.
- They exhibit elegant appearance and stream lined finishing.
- They are stronger and more durable than wooden windows.
- There is no contraction or expansion due to weather effects in the steel windows.
- They are rot proof and termite proof.
- They are highly fire resistant
- Since steel windows are fabricated from thin sections, they provide more effective area for light and ventilation.
- They grant better facilities for providing different types of openable parts.
- They are easy to maintain, and the cost of maintenance is almost negligible.



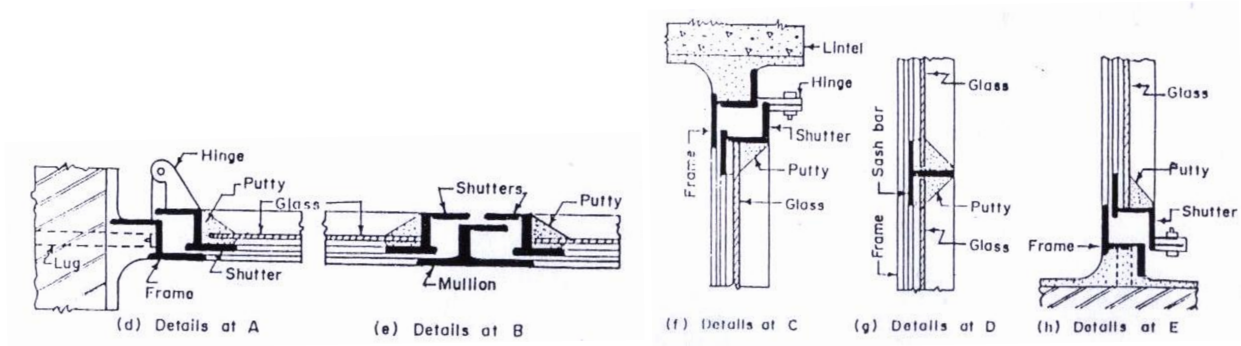


Fig. 5.5.2.8 Metal windows

9. Bay Windows

Bay windows project outside the external wall of the room. This projection may be triangular, circular, rectangular or polygonal in plan. They are provided to get an increased area of opening for admitting greater light and air. They also provide extra space in the room, and improve the overall appearance of the building.

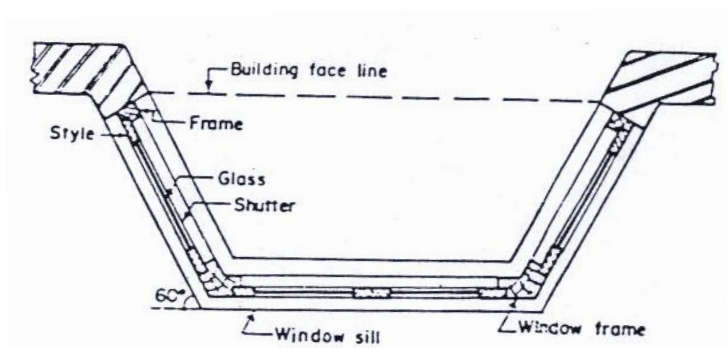


Fig. 5.5.2.9 Bay window

10. Clear-Storey Windows

These windows are provided in a room which has greater ceiling height than the surrounding rooms, or when a lean-to-roof of low height is there adjacent to the room. It is generally provided near the top of the main roof, and they open above the lean-to-roof, or roof slab of adjoining rooms.

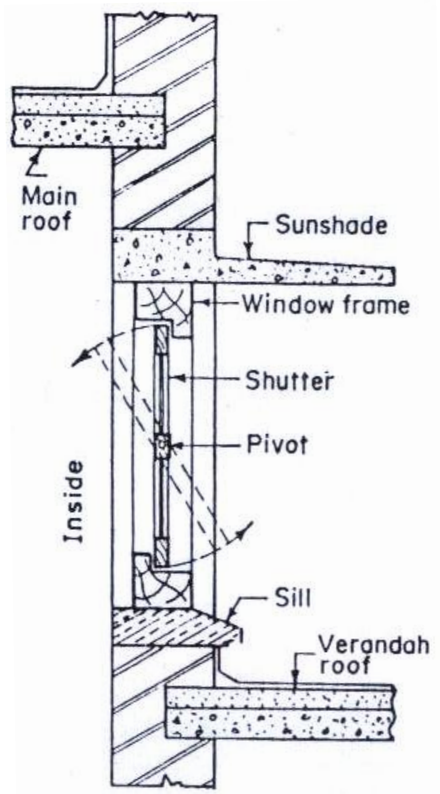


Fig. 5.5.2.10 Clear Storey window

11. Corner Windows

This is a special type of window which is provided in the corner of a room. This window has two faces in two perpendicular directions. Due to this, light and air is admitted from two directions. Such a window very much improves the elevation of the building.

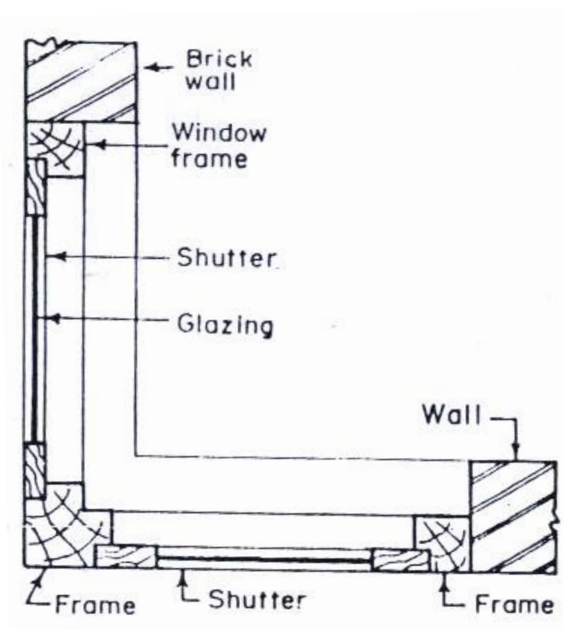


Fig. 5.5.2.11 Corner window

12. Dormer Windows

A dormer window is a vertical window provided on the slopping roof. Such windows provide ventilation and lighting to the enclosed space below the roof, and at the same time, very much improve the appearance of the building.

13. Gable Windows

It is a vertical window provided in the gable end of a pitched roof.

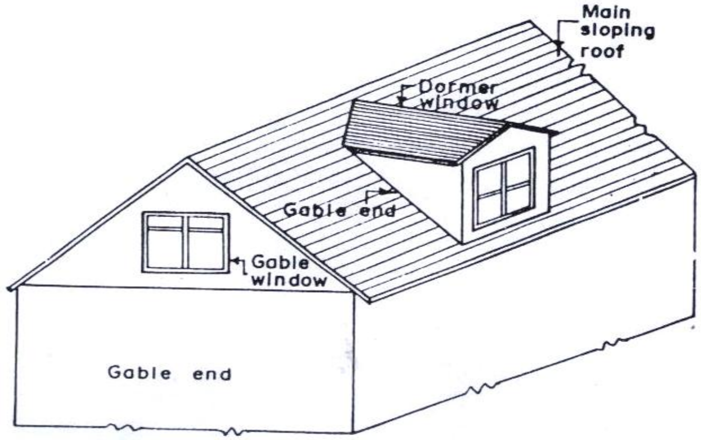


Fig. 5.5.2.12 Gable window

14. **Lantern Windows**

Such windows are provided over the flat roofs, to provide more light and air to the inner apartments/rooms of a building. They may be of several shapes in plan. They admit light either through vertical faces or inclined faces. The roof slab has an appropriate opening below the window.

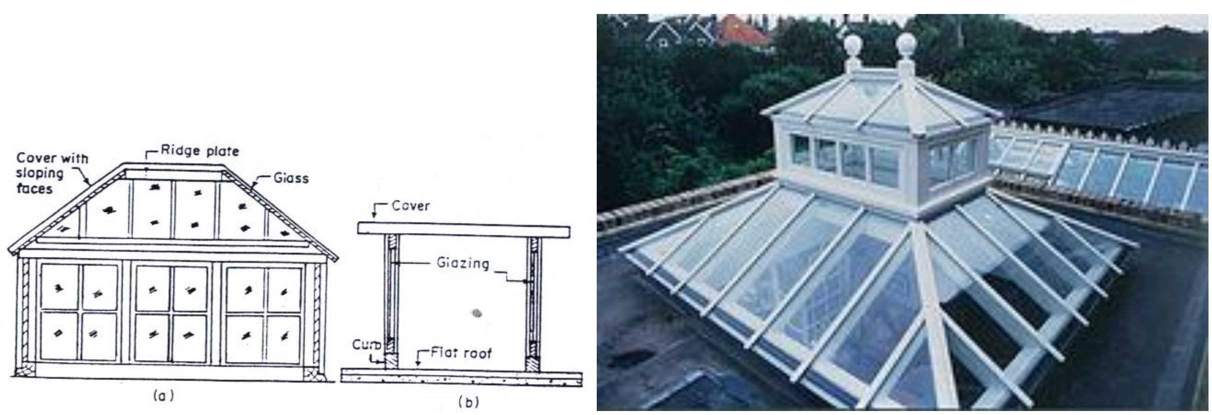


Fig. 5.5.2.13 Lantern window

15. Sky lights

A sky light is provided on a slopping roof, to admit light. The window projects above the top slopping surface and they run parallel to the sloping surface.

16. Ventilators

Ventilators are small windows, fixed at a greater height than the window, generally about 30-50cm below roof level. The ventilator has a frame and a shutter, generally glazed, which is horizontally pivoted.

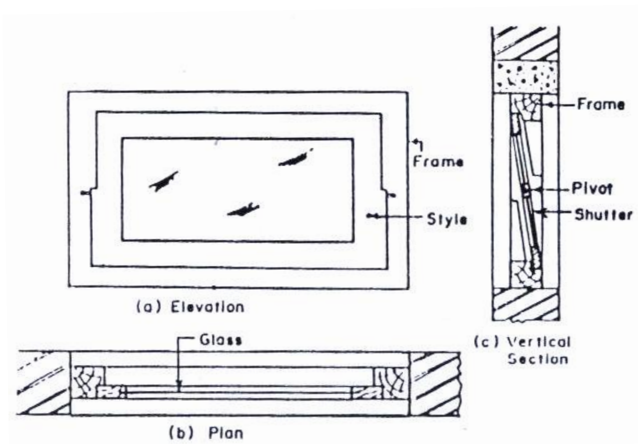


Fig. 5.5.2.14 Ventilator

17. Ventilator combined with window or door: Fan Light

Ventilators may also be provided in continuation of a window or a door, at its top. Such a ventilator is usually hinged at top and can open out. Alternatively, the ventilator shutter can be hinged at the bottom.

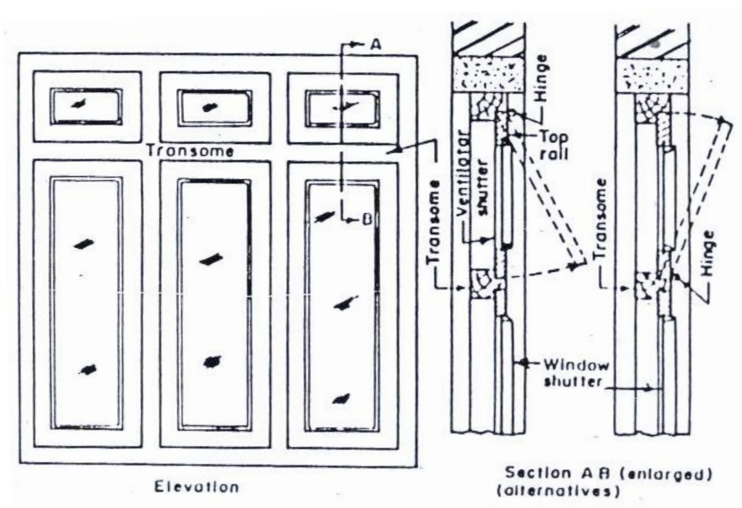


Fig. 5.5.2.15 Ventilator combined with window

5.5.2.3 Fittings for doors and windows

Generally the following four types of fixtures and fastenings are required for doors and windows:

i. Hinges
ii. Bolt
iii. Handles
iv. Locks.

i. Hinges

A hinge is a device that permits a door, window, or panel to turn or swing. Hinges are of the following types:

a. **Back flap hinge**: these hinges are used where the shutters are thin. These are fixed to the backside of the shutter and the frame, and hence the name.

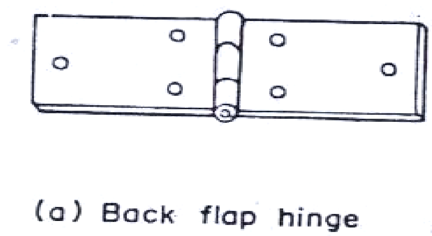


Fig. 5.5.2.16 Back flap hinge

b. **Butt hinge**: these types of hinges are commonly used for fixing doors and window shutters to the frame. The flanges of hinge are made of cast iron, malleable iron or steel, with counter sunk holes. One flange of hinge is screwed to the edge of the shutter while the other is screwed to the rebate of the frame.

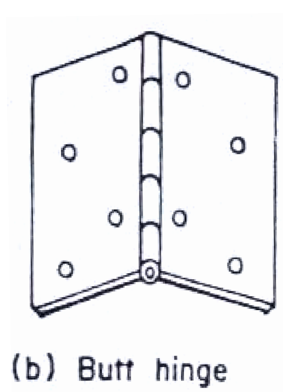


Fig. 5.5.2.17 Butt hinge

c. **Counter flap hinge**: this hinge is formed in three parts and has two centres. Hence the two centres can be folded back to back.

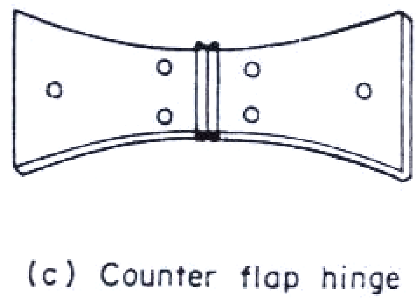


Fig. 5.5.2.18 Counter flap hinge

d. **Garnet hinge**: this type of hinge also known as T-shutter, has a long arm which is screwed to the shutter, and a short arm or plate which is screwed to the door frame. The hinge is used for ledged and battened doors, ledged and braced doors, etc.

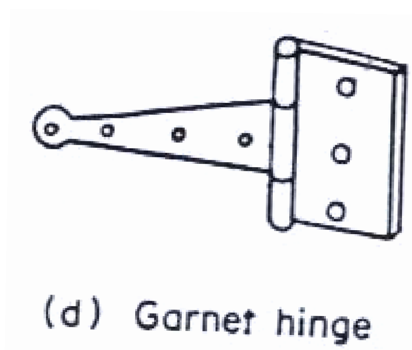


Fig. 5.5.2.19 Garnet hinge

e. **Parliamentary hinge**: these hinges permit the door shutters, when open, to rest parallel to the wall. They are used when the opening is narrow and when it is required to keep the opening free from obstruction due to door shutters.

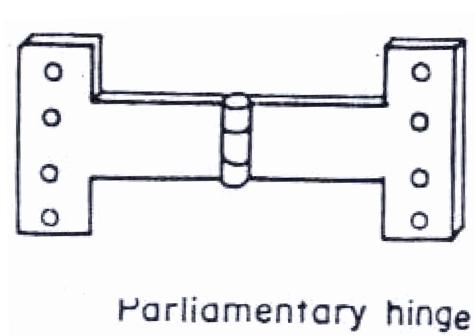


Fig. 5.5.2.20 Parliamentary hinge

f. **Pin hinge**: this is also used for heavy door shutters. The center pin of the hinge can be removed and the two leaves or straps of the hinge can be fixed separately to the frame and the shutter.

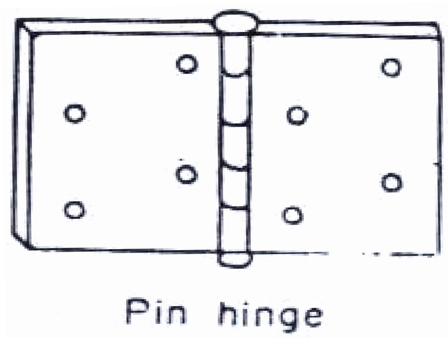


Fig. 5.5.2.21 Pin hinge

g. **Rising butt hinge**: such a hinge is provided with helical nickel joints, due to which the shutter is raised by 10mm on being opened. The door is closed automatically and they are used for doors of rooms having carpet etc.

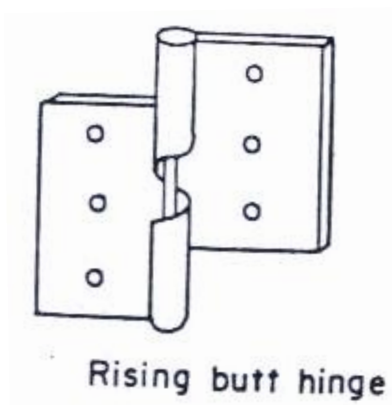


Fig. 5.5.2.22 Rising butt hinge

h. **Strap hinge**: it is a substitute of garnet or T-hinge. It is used for ledged and braced doors, and for heavy doors such as garages, stables, gates etc.

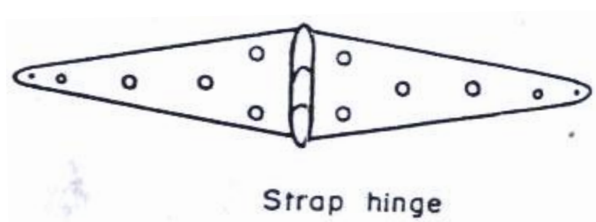


Fig. 5.5.2.23 Strap hinge

i. **Spring hinge**: single acting or double acting spring hinges are used for swinging doors. Single acting hinge is used when the door shutter opens only in one direction, while the double acting hinge is used when the shutter swings in both directions. The door close automatically due to spring action.

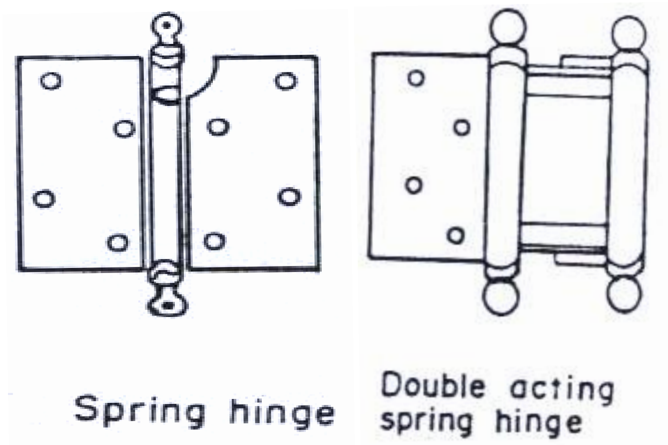


Fig. 5.5.2.24 Spring hinge

ii. Bolts

The following various types of bolts used for doors and windows.

a. **Aldrop**: it is fixed on external doors where pad locks are to be used.

b. **Barrel bolt**: it is used for fixing back faces of doors. The socket is fixed to the door frame while the plate is screwed to the inside of the shutter.

c. **Espagnolette bolt**: used for securing high doors and casement windows, the top of which can not be reached easily.

d. **Flush bolt**: used when it is desired to keep the bolt flush with the face of the door.

e. **Hasp and staple bolt**: this is also used for external doors where pad lock is to be used. The staple is fixed to the door frame, while the hasp fixed to the shutter.

f. **Latch**: this is made of malleable iron or bronze. It is fixed to the inside face of the door.

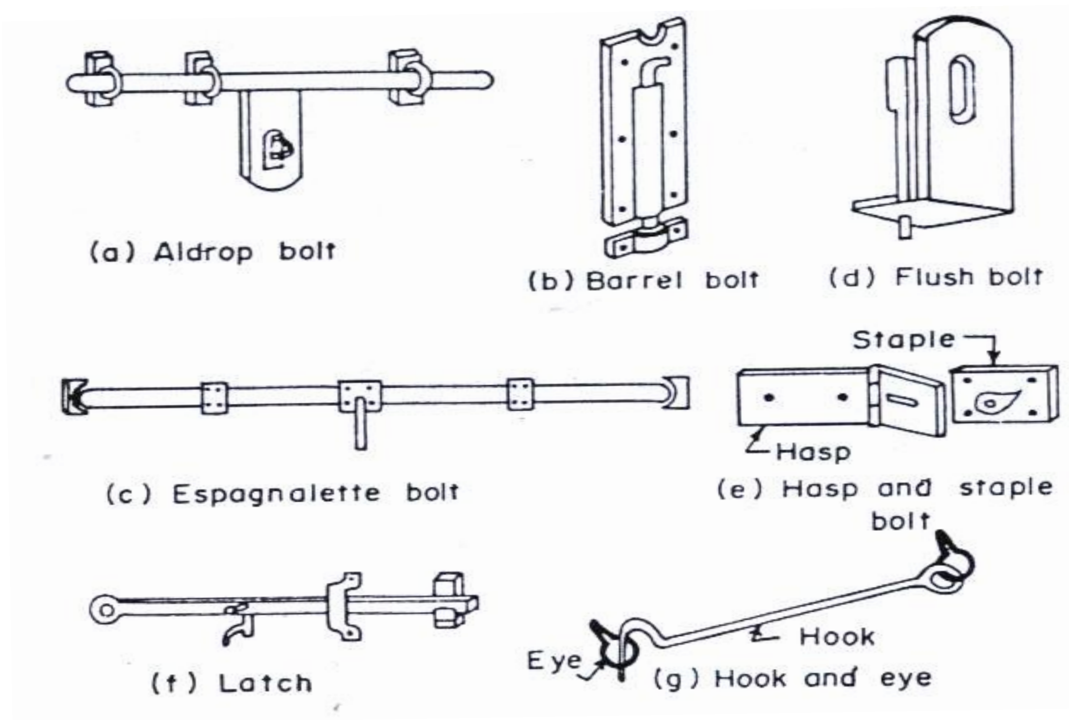


Fig. 5.5.2.25 Bolts

iii. Bolts

There are various types of handles used in windows and doors as shown in the figure below:

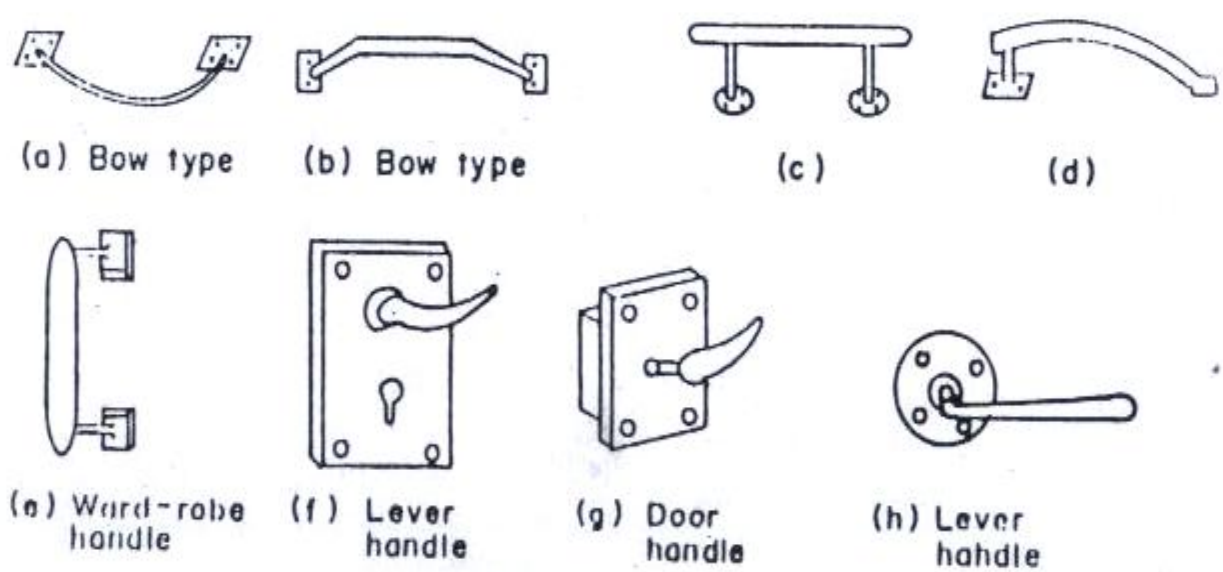


Fig. 5.5.2.26 Handles

iv. Locks

The commonly used locks are shown in the figure below:

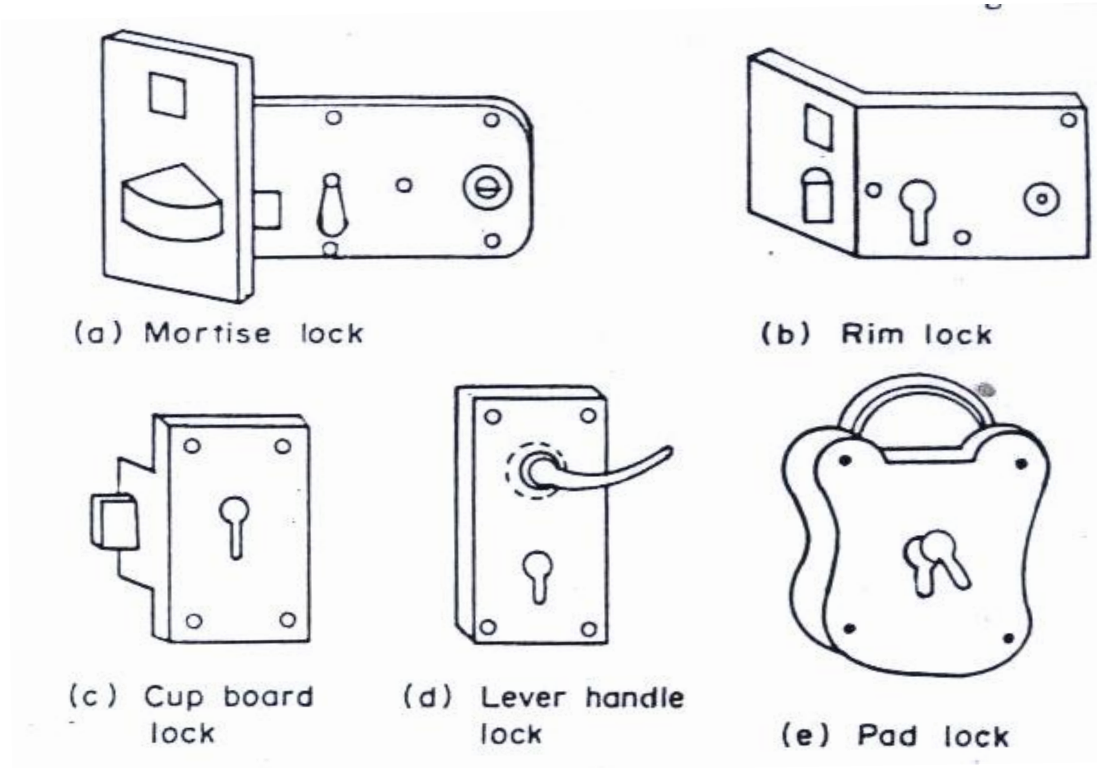


Fig. 5.5.2.27 Locks

5.5.2.4 Glass and glazing

Glass is one of four oldest materials but through modern research work it has been possible to alter the properties of glass to make it more versatile material. Glass is a super cooled liquid, one that is physically solid but un crystallized, which has sufficient viscosity to prevent the formation of crystals.

It is a thermoplastic material (it melts) that can be shaped at temperatures above 1261^0C. In its molten state, glass is a chemical compound, but if it is held too long in its molten state, the various chemicals tend to crystallize. If it is allowed to cool too slowly, the compounds will crystallize out of the solution. When crystallization takes place, the glass could be said to be frozen.

The basic materials used in the manufacture of glass for construction purposes are sand (silica), soda (sodium oxide) and lime (calcium oxide) with the addition or substitution of various other chemicals.

The physical properties of glass vary widely, depending on its chemical composition.

- Its thermal expansion is increased by the addition of sodium and potassium.
- Boron tends to reduce the thermal expansion.
- Lead increases the brilliancy of glass.
- Iron may be added to glass to produce aquamarine colouring.

There are many factors which may determine the thickness or type of glass suitable for a particular application. Properties which may need to be considered include:

- Resistance to wind loading
- Safety
- Security
- Fire resistance
- Clear vision
- Privacy
- Aesthetics (decorative glass)
- Thermal insulation
- Sound insulation
- Solar control

The various types of glass used in construction of doors and windows are:

a. **Plate glass**: plate glass is transparent and flat glass having plain polished surfaces and showing no distortion when through it objects are viewed at any angle. The thickness of plan glass varies from 3 to 6mm.
b. **Clear window glass**: Clear widow glass is transparent, having plain and smooth surface. However, small waviness of surface is present which is visible when viewed at an angle. The thickness of clear window glass varies from2.5 to 7.5mm.
c. **Obscured glass:** One side of this glass is patterned while rolling which obscures direct vision but does not obstruct light. Figured glass or rough cast glass is example of this type.
d. **Processed glass**: There are many patterns and some provide the privacy with a uniform diffusion of light. The primary functions of patterned glasses are the diffusion of light, decoration and privacy. By means of patterned glass, rooms can be adequately day lighted far from windows. Small sky lights can furnish diffused light over a wider area.

e. **Wired glass**: Rolled flat glass having wire mesh embedded in it is called wired glass. Wired glass provides safety against breakage and has better fire resistance.

f. **Prism glass:** This has prism shaped prim for deflecting light. The prisms with different angles are available to suit various needs.

g. **Quartz glass:** Quartz glass transmits ultraviolet rays and is used in hospital where maximum benefit from sun's rays is desired for the health of the patients.

h. **Bullet proof glass:** Bullet proof glass is made of laminated plate glass which may break under impact but will not shatter. The properties of glass can be controlled by adding various metallic oxides or by coating one side with metallic films, oxides or paint. The tints and coatings will filter light, conduct electricity, reflect heat and light, reduce the reflection of light, or impart brilliant colours and decorative effects.

5.6 ROOF AND ROOF COVERINGS

5.6.1 Introduction

A roof is defined as the upper most part of the building, provided as a structural covering, to protect the building from external weather exposure such as rain, sun, wind, etc. A roof consists of structural elements, which support roof coverings. The structural elements may be trusses, beams, slabs, shells or domes. The roof coverings may be corrugated metal sheets, RC slabs, tiles, etc

Requirements of a roof

The requirements of a good roof are summarised as follow:

- It should have adequate strength and stability to carry the super-imposed dead and live loads.
- It should effectively protect the building against rain, sun, wind, etc and it should be durable against the adverse effects of these agencies.
- It should be water proof and should have efficient drainage arrangements.
- It should provide adequate thermal insulation.
- It should be fire resistant.
- It should provide adequate insulation against sound.

5.6.2 Types of roofs

The selection of the type of roof depends upon:

- Shape or plan of the building,
- Climatic conditions of the area,
- Type of construction materials available.

The general types of roofs are:

- Pitched or Slopping roofs,
- Flat roofs or terraced roofs, and
- Curved roofs.

Pitched roofs: have slopping top surfaces. They are suitable in those areas where rainfall/snow fall is very heavy. They are mainly used to cover satisfactorily those buildings with limited width and simple shape

Flat roofs: considered suitable for buildings in plains or in hot regions where rainfall is moderate and snow fall is not there. They are equally applicable to buildings of any shape and size.

Curved roofs: have their top surface curved. Such roofs are provided to give architectural effects. Curved roofs include cylindrical and parabolic shells and domes

5.6.3 Sloping (pitched) roofs

Pitched roof is the most common form of roof and is generally regarded as the cheapest alternative for covering a structure. Pitched roof is almost always constructed in wood or steel. In pitched roofs a slope of less than l in 3 is generally not considered satisfactory from drainage point of view. In areas of heavy snowfall, steeper slopes (1:1.5 or1:1) are provided to reduce the incidence of snow load on the roof.

The various shapes of pitched roof depend on

- The area covered
- Materials available
- Type of lighting and ventilation needed inside
- Available appliance, etc.

5.6.3.1 Forms of sloping roofs

Slopping roofs are basically of the following forms:

a) Shed roof: it is the simplest type and slopes only in one direction. It is used for smaller span and is also known as **lean to roof**. At the upper ends, the rafters are nailed to the wooden wall plate, which may be of stone, brick or steel. At the lower end the rafters are notched and nailed to the wooden post plate.

b) Gable roof: it slopes in two directions and is commonly used. It is formed by a pair of inclined rafters with their upper ends nailed to a common ridge piece and their low ends, notched and nailed to the wooden wall plates embedded in masonry on the top of the wall on either end.

c) Hip roof: It slopes in four directions such that the end formed by intersection of slopes results in triangular and/ or trapezoidal form.

d) Butterfly roof: It slopes in two directions and intersect at the centre of the span and will have common drainage system.

e) Pyramid roof: It is similar to hip roofs, slopes in four directions and the intersections of slopes make a pyramid.

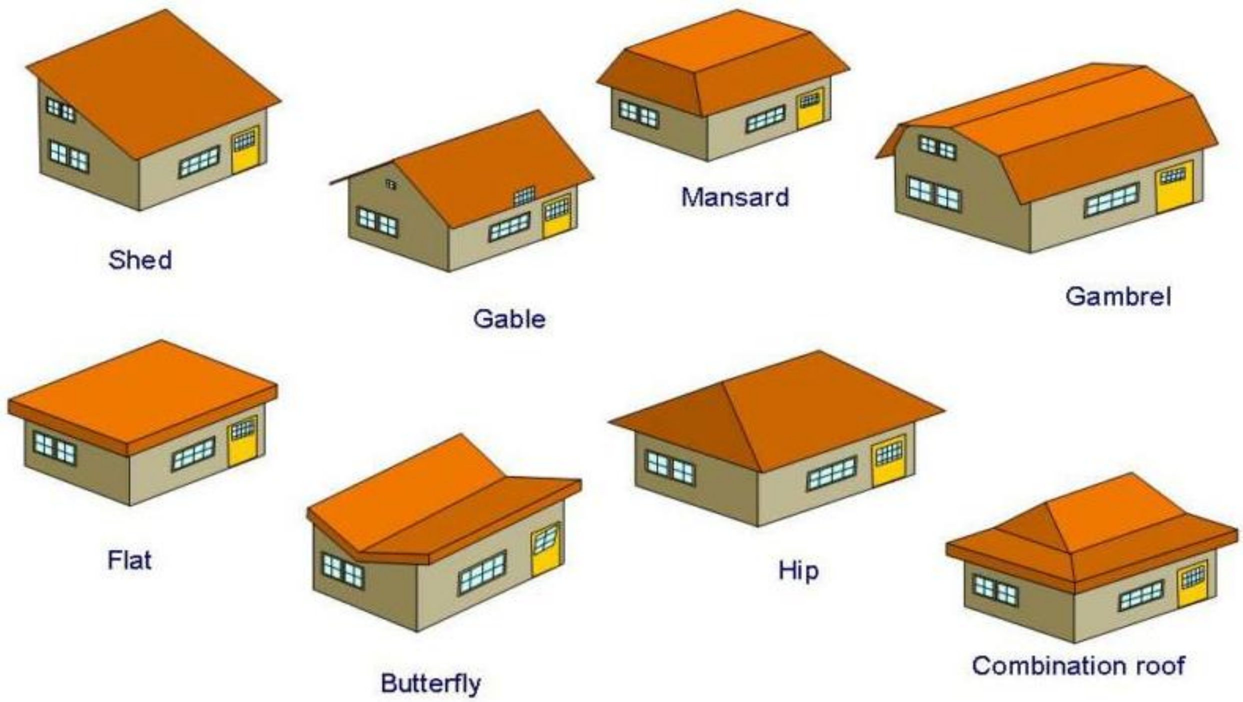


Fig. 5.6.1 Forms of sloping roofs

5.6.3.2 Elements of slopping roofs

Some of the important elements of pitched roofs are:

a) Span: It is the clear distance between the supports of an arch, beam or roof truss.

b) Rise: It is the vertical distance between the top of the ridge and the wall plate.

c) Pitch: It is the inclination of the sides of a roof to the horizontal plane. Either it is expressed in terms of angles (degrees) or as ratio of rise to span.

d) Ridge: It is defined as the apex line of the sloping roof. It is thus the apex of the angle formed by the termination of the inclined surfaces at the top of a slope.

e) Eaves: The lower edge of the inclined roof surface. From the lower edge (eaves), the rainwater from the roof surface drops down.

f) Hip: It is the ridge formed by the intersection of two sloping surfaces, where the exterior angle is greater than 180^0.

g) Valley: It is a reverse of a hip. It is formed by the intersection of two roof surfaces, making an external angle less than 180^0.

h) Hipped end: It is the sloped triangular surface formed at the end of a roof.

i) Verge: The edge of a gable, running between the eaves and ridge, is known as a verge.

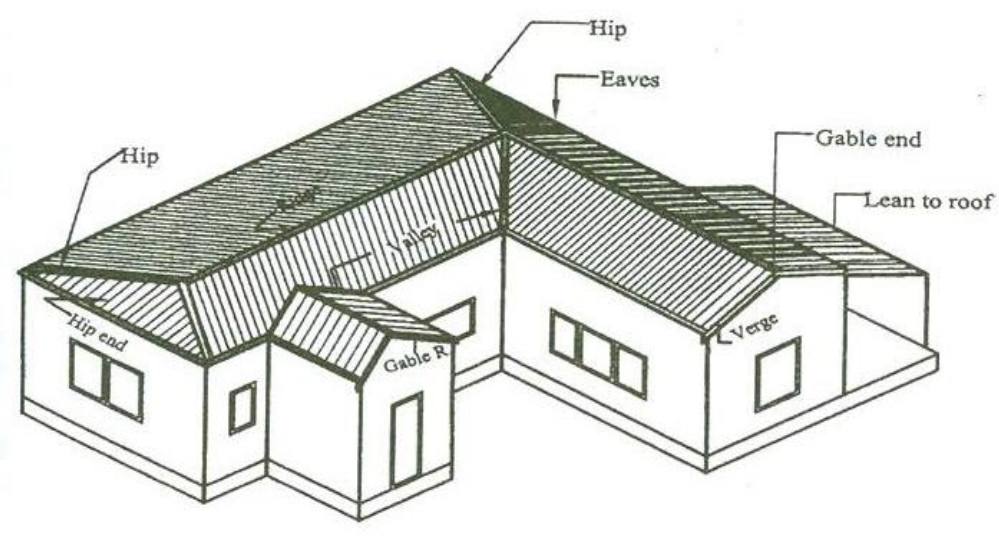
j) Rafters: These are horizontal wooden or steel members, used to support common rafters of a roof when span is large. Purlins are supported on trusses or walls.

k) Purlins: They are inclined wooden members on which roof coverings rest.

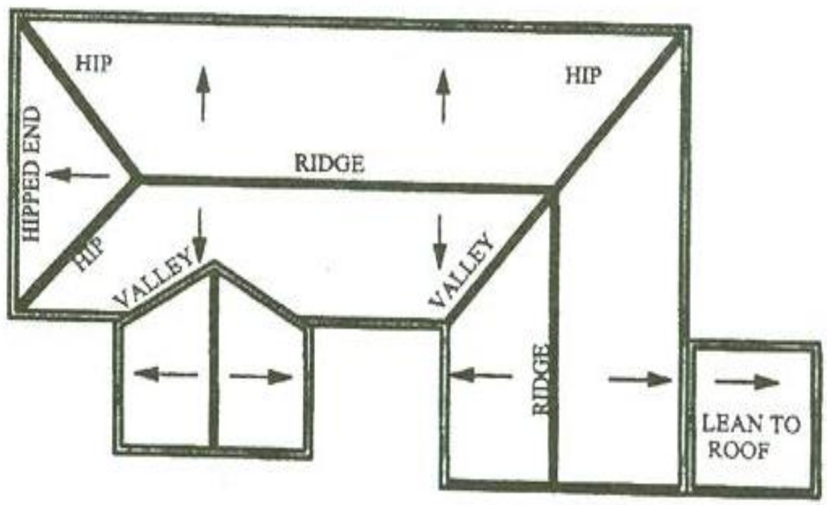
l) Eaves board: Also known as **Fascia board**. It is a wooden plank or board fixed to the feet of the common rafters at the eaves. It is usually 25mm thick and 20cm wide. The ends of lower most roof covering material rest upon it. The eaves gutter, if any, can also be secured against it.

m) Battens: These are thin strips of wood, called scantlings, which are nailed to the rafters for laying roof material above.

n) Truss: A roof truss is a framework, usually of triangles, designed to support the roof covering or ceiling over rooms.



a) View of a building with basic sloping roofs and their elements



b) Elements of pitched roof

Fig. 5.6.2 Basic elements of slopping roofs

5.6.3.3 Types of slopping roofs

Pitched roofs are basically categorised under three categories.

a. Single roof,

b. Double or purlin roofs, and

c. Tripled-member or framed or trussed roofs.

a. Single roof: This roof consists of common rafters that are secured at the ridge and wall plates. The various forms of this type are as follows:

i. Lean to roof: Is a roof, which covers the verandas of a building and projects from the main wall of the building. It is suitable for spaces up to 2.5m and is generally used for sheds, out-houses attached to the main buildings, verandas, etc.

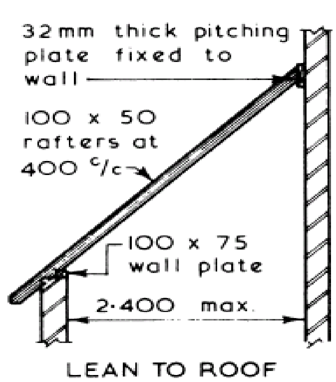


Fig. 5.6.3 Lean to roof

ii. Couple roof: each couple or pair of common rafters is made to slope upwards from the opposite walls and they are supported at the upper ends at the ridge piece or ridge board in the middle. The lower ends of the common rafters are fixed to the wall plates embedded in the masonry on the top of the walls.

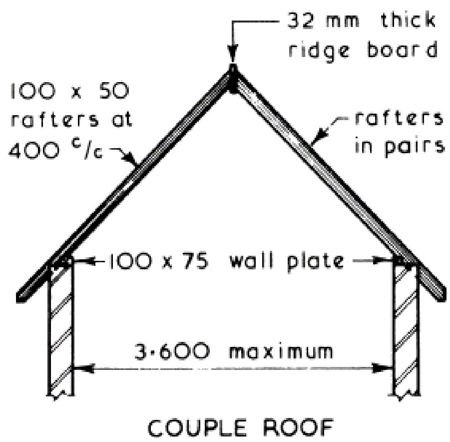


Fig. 5.6.4 Couple roof

iii. Couple-close roof: It is similar to a couple roof except that the legs of the common rafters are closed by a horizontal tie known as tie beam. This tie beam is connected at the feet of the common rafters to check their tendency of spreading out wards and hence save the walls from the danger of overturning. Under normal loading conditions, this type of roof can be used for maximum span of 4.5m.

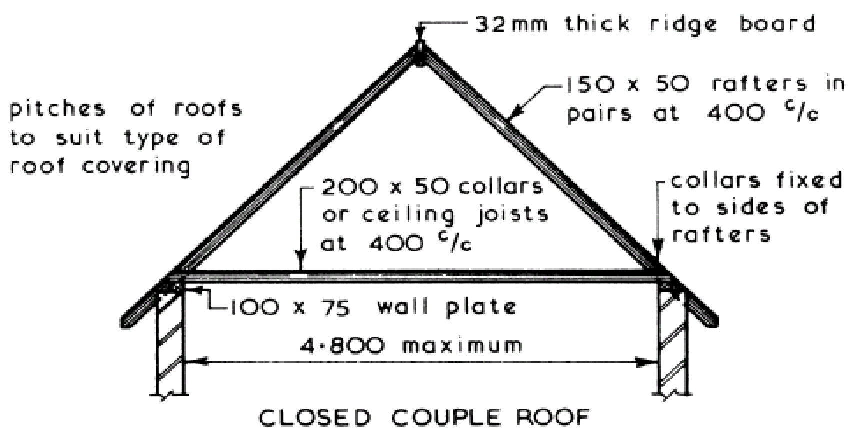


Fig. 5.6.5 Couple-close roof

iv. **Collar-beam roof**: This is similar to the couple-close roof; except that the horizontal tie is now raised up from the feet of the rafters to almost the middle of the rafters.It is considered to be suitable for spans varying 4-5.5m.

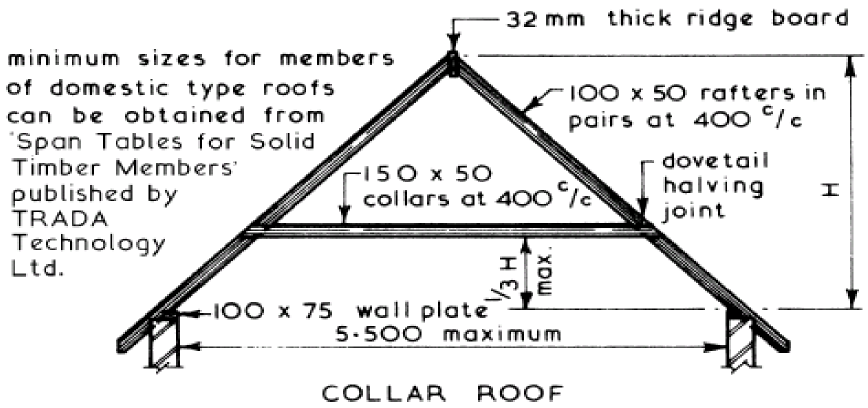


Fig. 5.6.6 Collar-beam roof

b. Double or Purlin roof: Additional members called purlins are introduced to support the common rafter at intermediate point. The purlins are used to tie the rafters together and act as intermediate support.

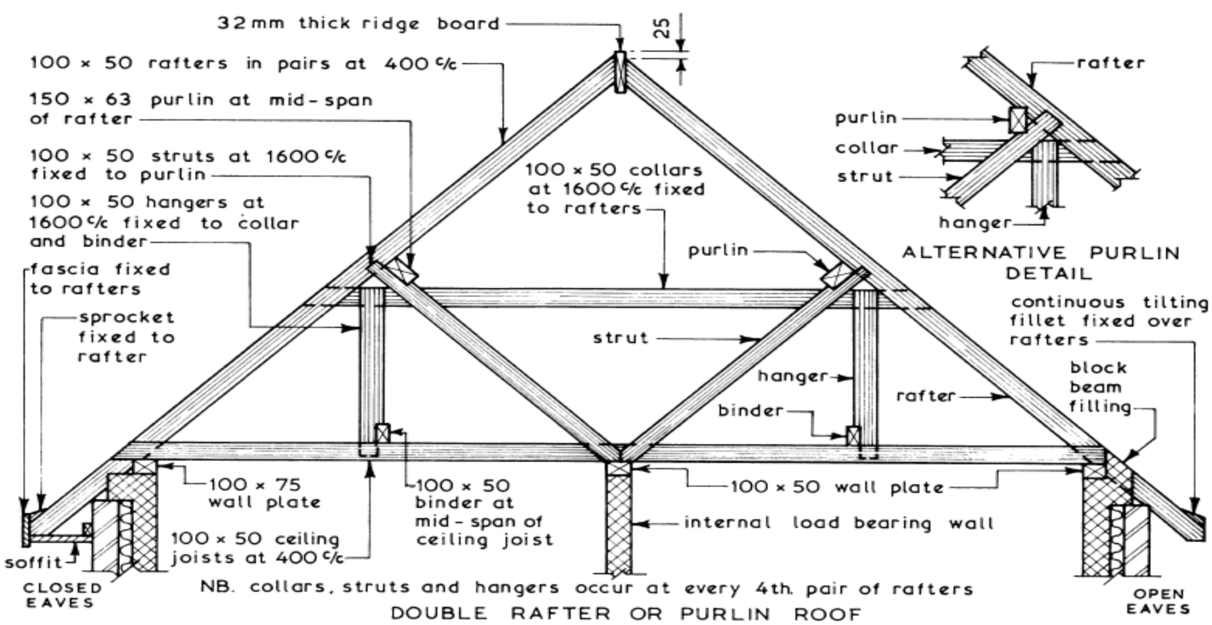


Fig. 5.6.7 Double or purlin roof

c. Trussed roof: Trussed roofs are usually used when the span exceeds 5m and where there are no inside walls to support purlins. The spacing of trusses depends upon the various factors, such as loads on roof, position of cross walls, span, material of truss, etc. and are spaced not more than 3m centre to centre. There are three elements in a trussed roof system:

- Rafters which support the roofing materials,
- Purlins to provide intermediate support to rafters, and
- Trusses to provide support to the ends of purlins.

The various types of trusses include:

i. King-post ii. Queen-post iii. Combination of king and queen

iv. Mansard v. Truncated vi. Bel-fast

vii. Composite viii. Steel

i. King-post truss: Consists of lower tie beam, two inclined principal rafters, two struts, and a king post The spacing of king post is limited to 3m. The truss is suitable for spans varying b/n 5-8m.

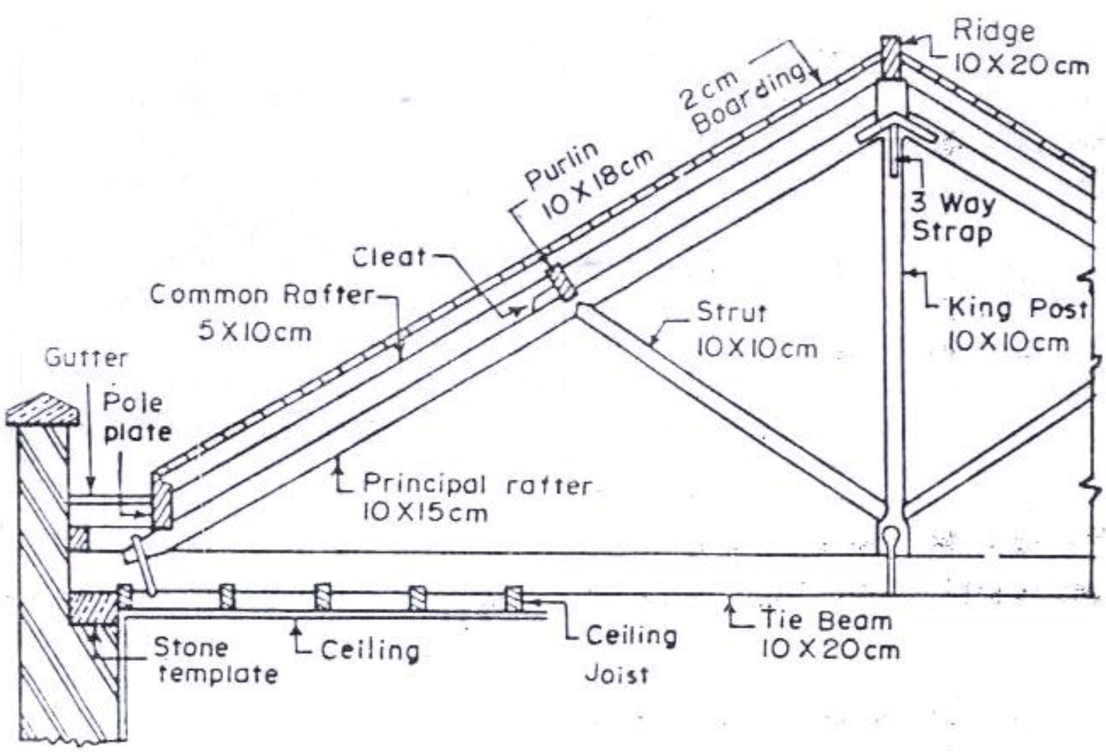


Fig. 5.6.8 King-post truss

ii. Queen-post truss: differs from a king-post truss in having two vertical posts , rather than one. The vertical posts are known as queen posts. The tops of queen post are connected by a horizontal piece known as straining beam. These trusses are suitable for spans b/n 8-12 meters.

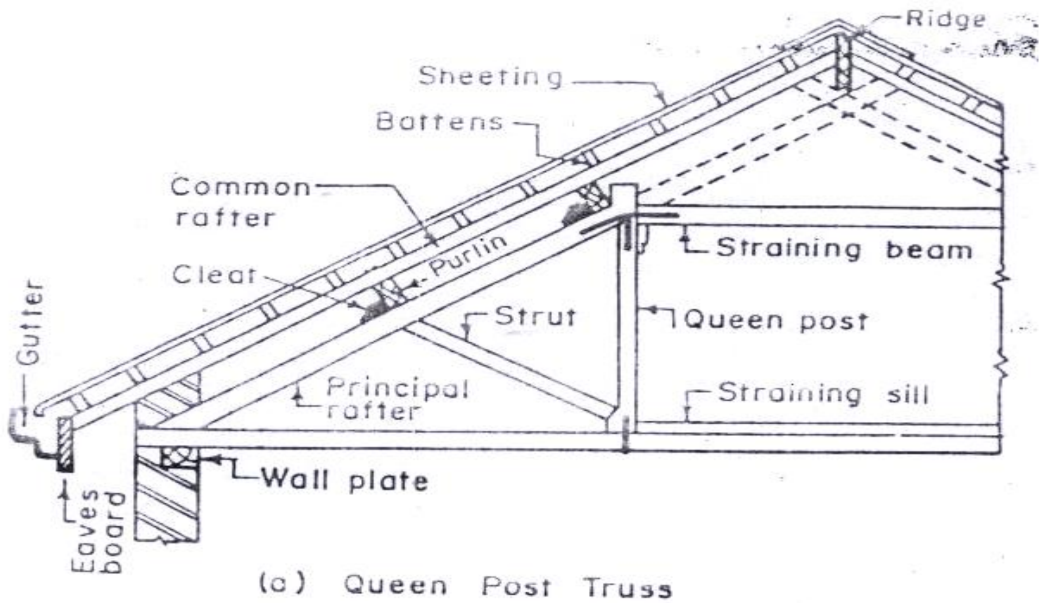


Fig. 5.6.9 Queen-post truss

iii. Combination of King-post and Queen-post trusses: For greater spans, the queen-post truss can be strengthened by one or more upright member, called princess-post to each side. They are suitable for spans up to 18m.

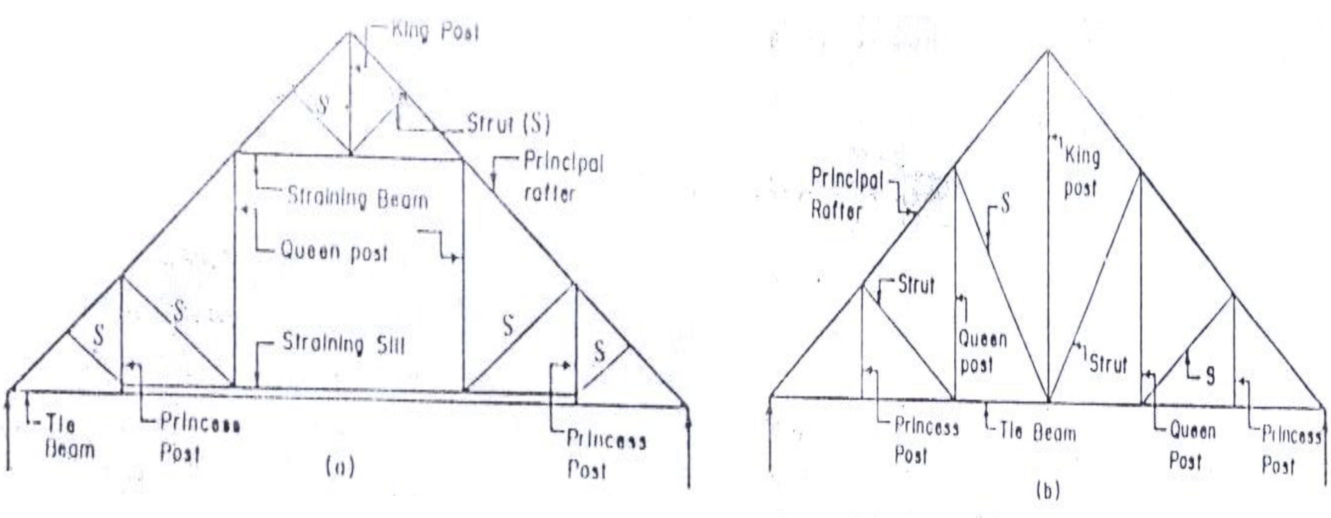


Fig. 5.6.10 Combination of king-post truss and queen-post trusses

iv. Mansard roof truss: It is a combination of king-post and queen post trusses. It is a two-storey truss, with upper portion consisting of King-post truss and the lower portion of queen post-truss. The entire truss has two pitches. The upper pitch varies from 30-40° while the lower pitch varies from 60 to 70°.

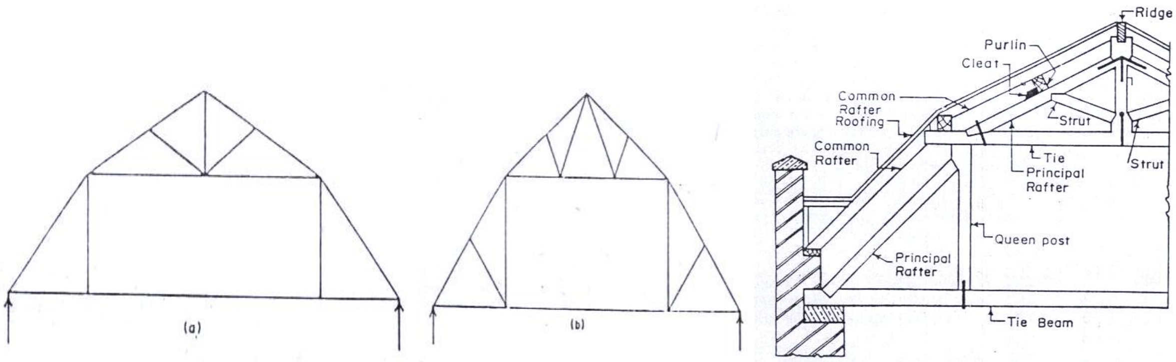
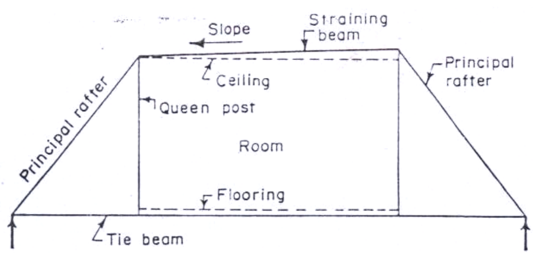


Fig. 5.6.11 Mansard roof truss

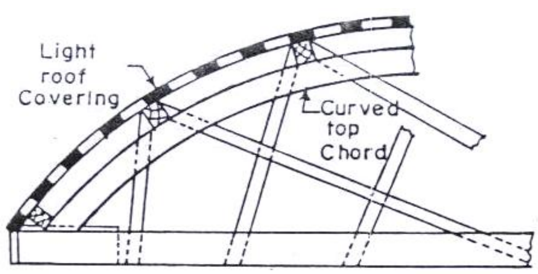
v. Truncated roof truss: It is similar to mansard truss except that its top is formed flat, with a gentle slope to one side. It is used when it is required to provide a room in the roof, b/n the two queen posts.



TRUNCATED TRUSS.

Fig. 5.6.12 Truncated roof truss

vi. Bel-fast roof truss (Bow string truss): This truss, in the form of a bow, consists of thin sections of timber, with its top curved. If the roof covering is light, this roof truss can be used up to 30m span.



BET-FAST TRUSS.

Fig. 5.6.13 Bel-fast roof truss

vii. Composite roof truss: Roof truss made of two materials are known as composite roof trusses. In a composite truss, the tension members are made of steel, while compression members are made of timber.

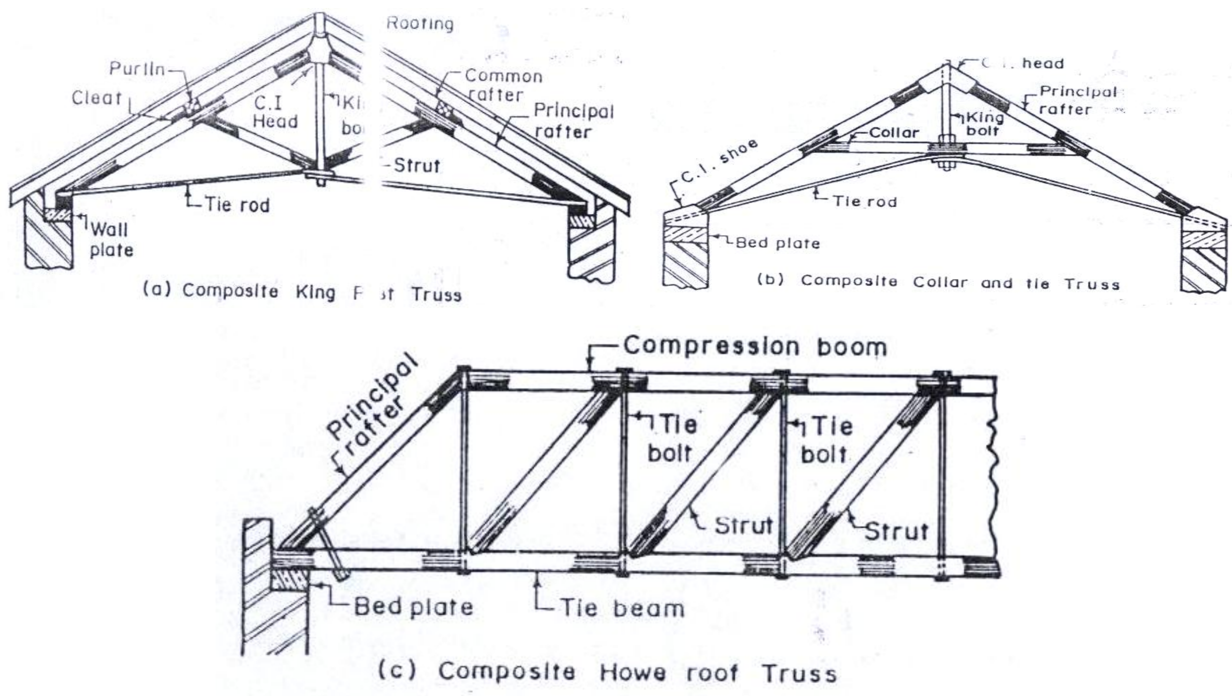


Fig. 5.6.14 Composite roof truss

viii. Steel roof trusses: When the span exceeds 10m, timber trusses become heavy and uneconomical. Steel trusses are commonly used for the following reasons:

- More economical
- Easy to construct or fabricate
- Fire proof
- More rigid and permanent.

Steel trusses are fabricated from rolled steel structural members such as channel, angles, RHS, T-sections and plates. Steel trusses may be grouped in the following categories:

♦ Open trusses ♦ North light trusses

♦ Bow string trusses ♦ Arched rib trusses

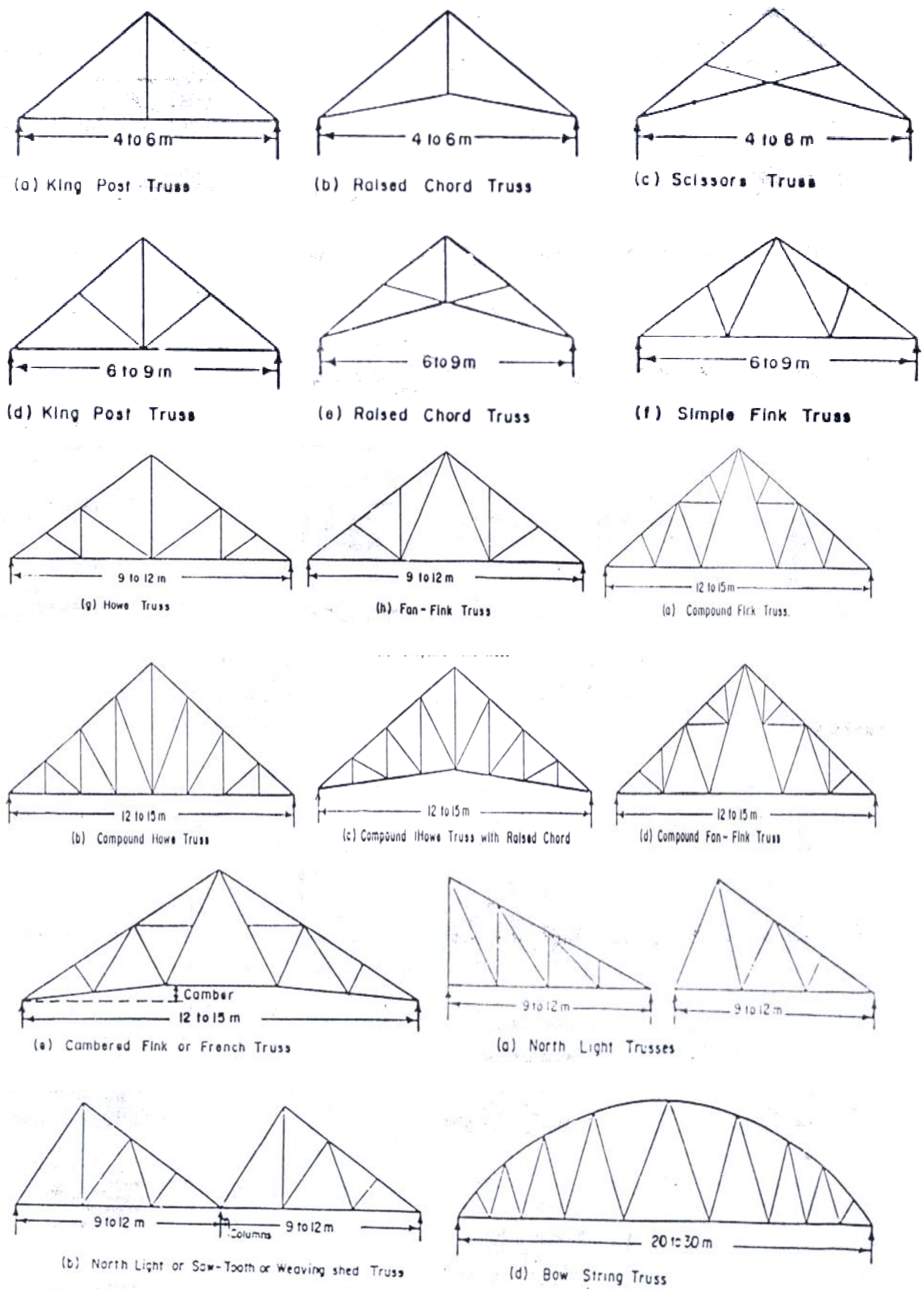


Fig. 5.6.15 Steel roof truss

Steel trusses have the following advantages over timber trusses:

- The sections comprising of a steel truss are readily available in the required dimension, resulting in minimum wastage.
- Steel trusses are light in weight, and can be fabricated in any shape depending upon structural and architectural requirement.
- Steel trusses are stronger and more rigid in comparison to timber trusses. The members are equally strong in tension and compression.
- Steel truss can be used over any span, while timber trusses are suitable only up to 15m span.
- Steel trusses are fire proof and termite proof.
- Steel trusses are most resistant to other environmental agencies.
- The fabrication of steel truss is easier and quicker.

5.6.3.4 Roof coverings for sloping roof

Roof covering is a material, which gives a protective surface to the roofing structure. The function of the covering is only to prevent ingress or egress of heat and moisture into the building. It does not withstand structural loads, which are directly taken by the roofing elements.

There are various types of coverings and the selection depends on:

- the character of the building,
- the type of roofing structure,
- Initial cost,
- Maintenance requirement,
- Fabrication facilities,
- Fabrication and special features of the locality,
- Durability, availability of the material and climate of the locality.

Some of the different types of coverings which are used for slopping roofs are:

- Thatch roof covering
- Galvanized corrugated iron/steel sheet
- Corrugated Asbestos cement Sheets
- Fiber Cement Profiled sheets

- Aluminum sheeting
- Harvey roof tile coverings
- Decra roof tiles

i. Thatch roof coverings

It is one of the most ancient types of roof covering and is mainly used in village areas. Thatch roof cover is suitable for rural buildings mainly because the cost is very low and thatch is abundantly available in those regions.

Fig. 5.6.16 Thatch roof covering

ii. Galvanised corrugated iron/steel sheet

Galvanization means that the iron/steel sheet is covered with a thin layer of zinc to protect it from rusting. The corrugation means that the sheet is made more resistant to bending stresses lengthwise. The gauge indicates the thickness G-24=0.549mm, G-26=0.457mm, G-28=0.376mm, G-30=0.315mm, G-32=0.274mm and G-35=0.2mm.

It is required that a sheet should be strong enough to carry, without buckling, the load of full grown man.

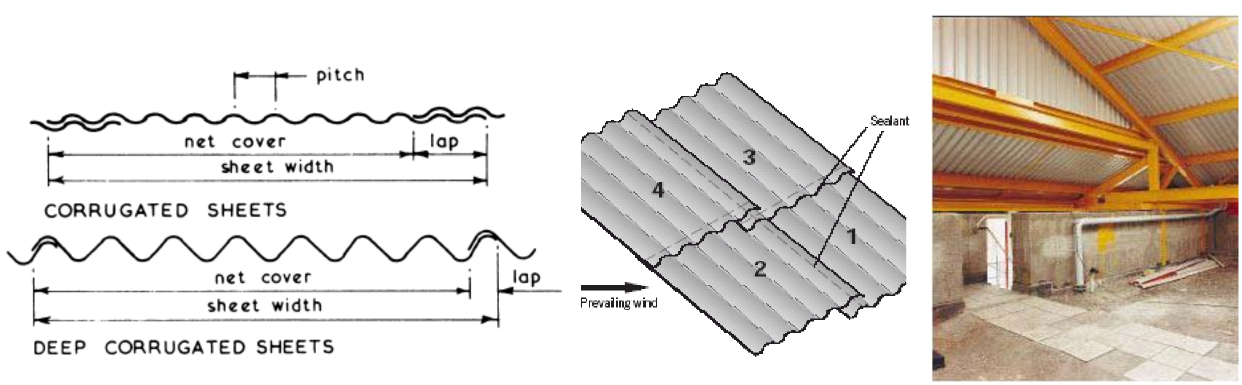


Fig. 5.6.17 Galvanized corrugated iron sheet

5.6.4 Flat roofs

Flat roof is nearly flat slab, with angles less than 10^0 for drainage purpose. This roof requires very reliable water proofing and heat insulating material. Flat roof has high initial cost

Flat roof is commonly constructed using r**einforced concrete.** Damp proofing is done through application of rich mortar mix, application of sufficient layers of bitumen coat and spreading hot mastic asphalt. The types of water proofing materials are asphalt, lead, copper, plastic etc.

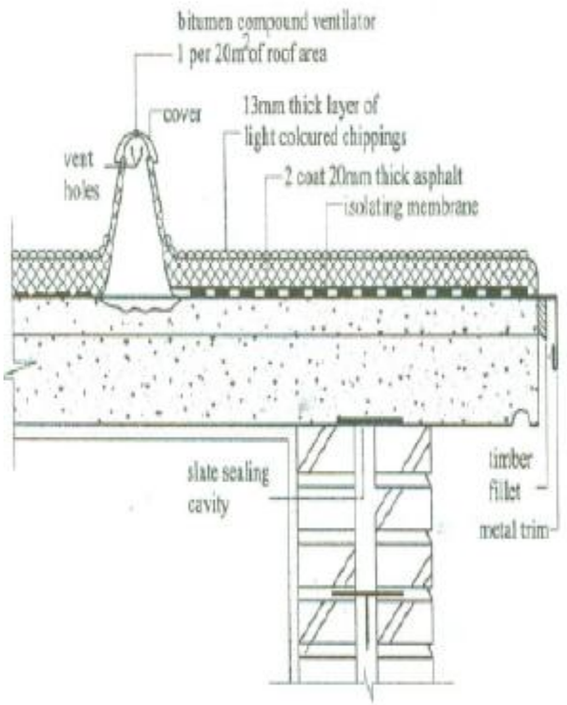


Fig. 5.6.18 Typical section of flat roof

5.6.5 Dome and shell roofs

Dome is a roof of semi-spherical or semi-elliptical shape. Materials used are stone, brick, concrete or metals (sky lights). They are common in large buildings because they don't need intermediate support. Domes are structurally different from arches as they are slabs in a different setting and they require massive or strong abutment.

5.7 FINISHING

5.7.1 Introduction

Building finishes are used to **give protective coating** to the surface which preserves and protects the materials used in building from weather effects such as rain water, heat, frost, etc. They also **provide decorative finishes** which add to the appearance of the material surfaces and building as a whole.

Types of building finish:

- Plastering,
- Pointing,
- White washing and color washing,
- Painting,
- Varnishing, and
- Distempering.

Selection of finishing type

In making the decision for the **selection** of a suitable finish, **its specifications** and **color**, the following major factors need to be considered.

- The **appearance** required,
- The **maintenance** necessary for giving the satisfactory appearance,
- The **degree of protection** against rain penetration to be provided by the finish,
- The **severity of exposure** to atmospheric and climatic agencies affecting durability,
- The **time of year** during which the finish is applied,
- The **background materials** on which the finish is to be applied, and
- The **cost**.

5.7.2 Plastering

5.7.2.2 Introduction

Plastering is the **process of covering** various surfaces of structure with a plastic material such as **cement mortar**, **lime mortar** or **composite mortar**, etc. to obtain an **even**, **smooth**, **regular**, **clean** and **durable** surface. Purposes of Plastering are:

- **Conceals inferior quality** materials and defective workmanship,
- **Provides a protective** coating against atmospheric effects
- **Provides a base** for receiving other decorative finishes

The tools used in plastering are: laying trowel, float, floating rule and gauging trowel

5.7.2.2 Plastering Materials

- **Binders** - hydrated lime, gypsum or Portland cement
- **Sand** - used to reduce shrinkage of binders, and should be free from organic matters and silt.

5.7.2.3 Background for Plastering

The durability of plastering depends not only on the properties of the mixture itself but also its adhesion with the background. A good background **must be plain enough** for suitable application of plaster and **should have enough strength**.

The usual types of backgrounds that are used for plaster work are:

a. **Solid background**: For instance brick work, concrete blocks, heavy clay blocks , etc.
b. **Lathing**: These include wood laths, expanded metal lathing , wire meshes etc.,
c. **Boards and slabs in non-mortar construction**: E.g. slabs of gypsum plaster, fiberboards, etc.

5.7.2.4 Requirement for good Plastering

Some requirements of a good plaster are:

i. It should provide **a smooth**, **non-absorbent** and **washable surface**.
ii. It **should not contract** in volume while drying and setting otherwise it will crack and give an unsightly appearance.
iii. It **should adhere firmly** to the surface and resist the effects of weather agencies such as rain, heat, etc.
iv. It should offer **good insulation against sound** and **high resistance against fire**.

v. It should provide the surface with the required **decorative effect** and **durability**.

5.7.2.5 Defects in plastering

Some of the defects in plastered work include **cracking**, **blistering**, **efflorescence** and **falling out of plaster**.

a. **Cracking in plastering**

The major causes of cracking in plastering can be:

i. Structural defects in building and discontinuity of surface,
ii. Plastering on very wet background,
iii. Old surface not being properly prepared,
iv. Movement in the background due to thermal expansion or rapid drying of backing surface,
v. Movements in the plaster itself, due to expansion as in the case of gypsum plaster or due to shrinkage of plasters coat during, drying as in the case of lime-sand plasters,
vi. Excessive shrinkage of the plaster due to thick coat,
vii. Due to faulty workmanship or method of application.

b. **Blistering or blowing of plaster**

This consists of formation of one or more **swelling in small patches** over the finished plastered surfaces. It is caused due to **faulty slaking of lime** particles in the plaster after its application.

c. **Falling out of plaster**

Some portion of the **surface comes off** (**peeling**) due to:

- Lack of adhesion,
- Excessive moisture in the background,
- Excessive thermal changes in the background,
- Rapid drying of plaster coats,
- Insufficient drying between each coat of plaster.

d. **Efflorescence**

Efflorescence is the whitish crystalline substance, which appears on the surface of walls due to the presence of salts in the lime, cements, and bricks and sometimes even in water. Efflorescence can be rectified or checked by the following measures.

i. By scrubbing with brushes. It can also be removed by applying a solution of 1:5 HC:H_2O or H_2SO_4 and spraying with clean water,
ii. By using burnt bricks and clean water, which is free from salt,
iii. Using a mortar, which is waterproof, is also useful in preventing efflorescence.

e. **Faulty workmanship**

The following points can be cited as major workmanship error in plastering:

i. Excessive trawling may cause the binder to come to the surface,
ii. The interval between successive application may be short,
iii. The coats may have been too thick,
iv. Addition of water to hydraulic lime after initial set has taken place may be harmful.

5.7.3 Pointing

Pointing is the process of finishing of mortar joints in exposed brick or stone masonry. Pointing consists of raking out the green mortar in the joint to a depth of about 15mm and then refilling the joint with fresh mortar. Pointing gives good ***appearance*** and ***water resistance***.

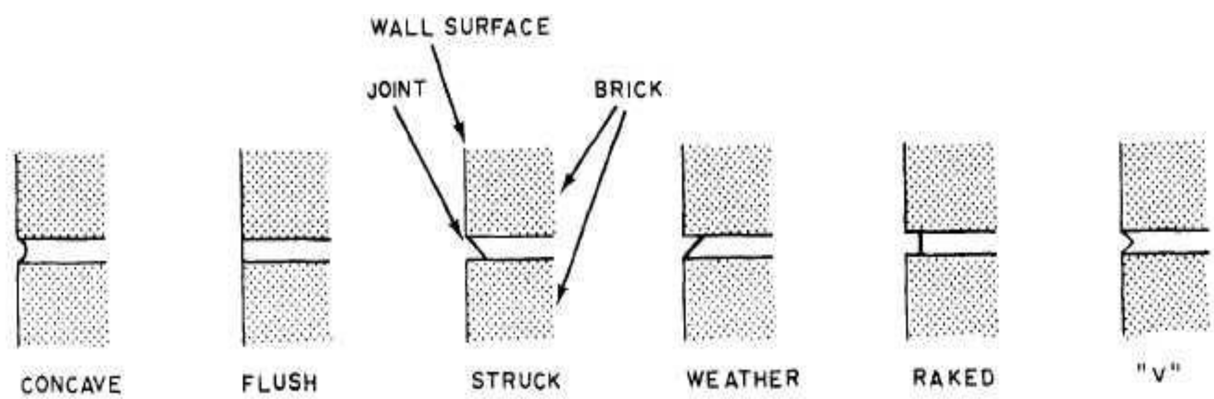


Fig. 5.7.1 Types of Pointing finishes

5.7.4 White washing

Preparation of white wash

White wash is prepared from fresh burnt shell lime or pure lime stone mixed with water. Fresh lime is slaked for two days, and after it attains consistency of thin cream it will be screened. Then clean gum dissolved in hot water is added to the white wash. Additives may be added for glaring effect

Preparation of Surface

The surface shall be clean, made free from loose materials. If surface to be coated is extra smooth, then rub by sand paper for better adhesion. Re-whiting should be done for scrapped off surfaces, holes, irregularities etc.

Application of white wash

Apply white wash in specified coats with a jute brush, usually three coats for new and one to two for old works

5.7.5 Color washing

A color wash is usually prepared by adding the necessary coloring pigments in suitable quantities to the screened whitewash or liquid mixture or whitewash.

5.7.6 Paints and painting

Paints are coating of fluid materials, which are applied as a final finish to all surfaces such as walls, ceilings, woodwork, metalwork, etc. The process of application of paint as a coating is termed as painting.

5.7.6.1 Objects of painting

The objects of painting can be summarized as to:

- **Protect the surface** from weathering effects of the atmosphere,
- **Protect** the **decay** of wood and **corrosion** of metals,
- **Provide a decorative finish** to obtain a clean, colorful and pleasing surface.

5.7.6.2 Characteristic of a good paint

- A good paint should have such a **consistency** that it can be applied easily and freely on the surface with a brush or spray,
- A good paint should be in **initial cost** and prove **economical** in the long run,
- The paint color should **neither fade nor change** by atmospheric influences in its designed service life, and
- A good paint **should not show any signs** such as brush marks, shrinkage marks, cracks, patches, etc. on drying.

5.7.6.3 Types of Paint

Some of the painting types used in buildings are:

- Aluminum paint
- Anti corrosive paint
- Asbestos paint
- Bituminous and tar paint
- Cellulose paint
- Cement paint
- Oil paint
- Plastic paint
- Quartz paint
- Synthetic rubber paint

5.7.6.4 Defects in Painting Work

Some of the usual defects in paining works are:

a. **Blistering:** This defect occurs by **formation of bubbles** under the paint film. It is generally caused due to **excess of oil** in final coat and imperfect seasoning of timber.
b. **Crawling:** This occurs due to application of **too thick coat**. It can be rectified by sandpapering the surface.
c. **Grinning:** This is **clear reflection of the background** due to lack of opacity of final coat of paint.
d. **Fading:** This is the **loss of paint color** due to the effect of sunlight on pigments of paint.
e. **Flashing:** This is **appearance or reflection of glossy patches** on the painted surface due to either workmanship or cheap paint used or due to weather effect.
f. **Saponification:** This is the **chemical formation of soap patches** on the painted surface due to chemical action of alkalis

5.7.7 Varnish and varnishing

Varnish is a solution of **resinous substance** in oil, turpentine or alcohol. The varnish solution on drying or evaporation forms or leaves a **hard**, **transparent** and **glossy film** of resin on the varnish surface.

Varnishing is the process of applying varnish to the wooden surfaces and also to the painted surface in order to improve their appearance and protect them from atmospheric action.

5.7.7.1 Objects of varnishing

The objects of varnishing are to:

- **Brighten** the ornamental appearance of the grains of the unpainted wood surfaces,

- **Protect** the structural wooden surfaces from atmospheric action,
- **Give brilliancy** to the painted surface and also to papered walls and
- **Protect the painted surface** from atmospheric actions in order to increase the durability of the paint film.

5.7.7.2 Requirements of a good varnish

A good varnish should have the following characteristics or qualities:

- It should **dry rapidly** or quickly.
- On drying, it **should form a protective film**, which should be hard, tough, resistance to wear or durable.
- It should **exhibit a glassy surface**.
- The finished surface should be **uniform in nature** and **pleasing in appearance**.
- The color of the varnish **should not fade** or change when exposed to atmospheric action.
- It **should not crack in drying** and should have **sufficient elasticity**.

5.7.8 Distemper and Distempering

Distempering is the process of applying distempers over the various surfaces more easily and with less cost than paints and varnishes, to safeguard them against weather effects and improve their appearance. Distempers are considered to water paints, consisting of whiting (i.e. powdered chalk), glue or casein as a binder, and suitable proportion of coloring pigments if desired. Distempers form a **cheap**, **durable** and **easily applied decoration** for internal use on plastered, cement concrete and various wall board surfaces.

5.7.9 Miscellaneous finish

i. **Wall tilling:** It is the process of lining or finishing the walls with special tiles either for height varying from 60 to 120 cm above the floor level or up to the ceiling.
ii. **Papering:** It is the process of pasting the papers on the walls and ceilings for improving the aesthetic values of the interior of rooms.
iii. **Whitening:** It is the process of whitening the walls and ceilings by a mixture of white fine powder, glue and water.
iv. **Coal tarring:** it is the process of applying the coating of local tar to woodwork or iron work for preserving them.

v. **Wax-polishing:** It is done on varnished surface to improve their elegance and also to protect the under coats.
vi. **Wood oiling:** It is normally used as a substitute for paining on woodwork not exposed to weather,
vii. **Glazing:** It is the work of fixing panels of glass in window, door and other frames.

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5.7.10 Other External Finish

The following external finishes are considered to be important in the application of various finishing qualities.

i. **Pebble-dash or dry-dash:** This is the finish in which small pebbles or crushed stone of suitable sizes are thrown on to a freshly applied final coat of mortar and left exposed.
ii. **Rough cast:** This is a finish in which the final coat containing a proposition of fairly coarse aggregate is thrown as a wet mix and is left in a wet condition.
iii. **Scarped finishes:** In this type of finishes the final coat of mortar, after being leveled and allowed to stiffen, is scraped with a steel straight edge so as to give a rough surface**.**
iv. **Textured finishes:** with the aid of suitable tools, ribbed stucco or fun textures can be created in the final coat.
v. **Smooth finish:** this type of finish has got a level and a smooth surface. The wooden float normally used as a steel float, gives surface much more liable to craze.
vi. **Machine applied finishes:** A variety of finishes in which the final coat is applied by machine, which throws or spatters the material on the wall.
vii. **Board marked concrete:** A variety of surface textures and overall patterned effects can be achieved by casting concrete against suitably prepared rough sawn boards.
viii. **Exposed aggregate concrete finishes:** Removal of the cement-Sand mortar from the surface of concrete to reveal the underling coarse aggregate produces a durable textured finishes.
ix. **Tooled concrete finishes:** By tooling hardened concrete, the outer surface is broken away to leave a rough textured durable finishes.

5.7.11. Review Questions

Provide short and precise answers for the following questions

1. a) What are the major purposes of building finishes?

   b) What are the major factors that need to be considered in making the decision for the selection of a suitable finish, its specifications and color?

2. a) What is plastering and explain in brief the objects of plastering?

   b) Describe the requirements of a good plaster.

   c) Mention at least four defects in plastered work.

3. Enumerate at least three characteristics of a good paint.
4. Briefly describe at least three defects in painting.
5. a) What are the objects of varnishing?

   b) List at least four characteristics of a good varnish.

5.8 DAMP PREVENTION

5.8.1 Introduction

One of the basic requirements of a building is that it should remain dry or free from moisture passing through walls, roofs or floors. Dampness is the presence of hygroscopic or gravitational moisture. It leads to unhygienic conditions affecting badly the health and comfort of the inhabitants. It also seriously deteriorates the stability of the building. Damp prevention is, therefore, one of the important items of building design.

5.8.2 Source of dampness

The following causes are considered to be the **main sources of dampness** in buildings

a. **Moisture rising up the walls from the ground**

- All the structures are founded on soils, and the substructure is embedded into it. If the soil is pervious, moisture constantly travels through it.
- This moisture may rise up into the wall and the floor through capillary action.
- Ground water rise will also result in moisture entry into the building through walls and floors.

b. **Rain travel from wall tops**

- If the wall tops are not properly protected from rain penetration, rain will enter the wall and will travel down.
- Leaking roofs will also permit water to enter.

c. **Rain Beating Against External Walls**

- Heavy showers of rain may beat against the external faces of walls and if the walls are not properly treated, moisture will enter the wall, causing dampness in the interior.
- This moisture travel would completely deface interior decoration of the wall.

d. **Condensation**

- Due to condensation of atmospheric moisture, water is deposited on the walls, floors and ceilings. The moisture may cause dampness.

e. **Miscellaneous causes**

- Moisture may also enter due to the following miscellaneous causes

- **poor drainage** at the building site,
- **Imperfect orientation**: walls getting less sunlight and heavy showers may remain damp,
- **Imperfect roof slope**: specially in the case of flat roofs,
- **Defective construction**: imperfect wall jointing, joints in roofs, defective throating etc.,
- Absorption of water from defective rainwater pipes,
- water introduced in the building during construction,
- **shrinkage of wooden frames** permits an entry of rain,
- **Poor material choice**, e.g. use of porous bricks in chimneys.

5.8.3 Effects of dampness

The following are some of the ill effects of dampness in buildings:

a. Dampness gives rise to breeding of mosquitoes and create unhealthy living conditions.
b. Travel of moisture through walls and ceiling may cause unsightly patches.
c. Moisture travel may cause softening and crumbling of plaster, especially lime plaster.
d. Wall decoration (i.e. painting, etc) is damaged, which is very difficult and costly to repair.
e. Continuous presence of moisture in the walls may cause efflorescence resulting in disintegration of bricks, stones, tiles, etc., and consequent reduction in strength.
f. The flooring gets loosened because of reduction in the adhesion when moisture enters through the floor.
g. Timber fittings, such as doors, windows, wardrobes, etc., coming in contact with damp walls, damp floors, etc, get deteriorated because of warping, buckling, dry-rotting, etc. of timber
h. Electrical fittings get deteriorated, giving rise to leakage through electrical fittings and consequent danger of short-circuiting.
i. Floor covering are damaged. On damp floors, one cannot use floor coverings.
j. Dampness promotes and accelerates growth of termites.
k. Dampness together with warmth and darkness breeds germs of dangerous diseases. Occupants may even be asthmatic.

l. Moisture causes rusting and corrosion of metal fittings attached to walls, floors and ceilings.

5.8.4 Method of damp proofing

The following methods are used to make a building damp proof :

a. Use of damp proofing course (D.P.C): membrane damp proofing
b. Integral damp proofing
c. Surface treatment
d. Cavity wall construction
e. Guniting
f. Pressure grouting

a. **Membrane damp proofing: use of D.P.C**

This consists of introducing a water repellent membrane or damp proof course (D.P.C) between the source of dampness and the part of building adjacent to it. D.P.C may consist of flexible materials such as bitumen, mastic asphalt, bituminous felts, plastic or polyethylene sheets, metal sheets, etc. Damp proofing courses may be provided either horizontally or vertically in floors, walls, etc. The following general principles should be kept in mind while providing D.P.C.:

- The D.P.C. Course should cover the full thickness of walls, excluding rendering.
- The mortar bed supporting D.P.C. should be levelled and even, and should be free from projection, so that D.P.C. Is not damaged.
- D.P.C. should be so laid that of a continuous projection is provided.
- At junction and corners of walls, the horizontal D.P.C. should be laid continuous.
- When a horizontal D.P.C. (i.e. that of a floor) is continued to a vertical face, a cement concrete fillet of 7.5cm radius should be provided at the junction.
- D.P.C. should not be kept exposed on the wall surface otherwise it may get damaged during finishing work.

b. **Integral damp proofing**

This consists of adding certain water proofing compounds of materials to the concrete mix, so that it becomes impermeable. This water proofing compounds may be in either of the following forms:

- Compounds made from chalk, talc, fullers earth, which fill the voids of concrete under the mechanical action principle.
- Compounds like alkaline silicates, aluminium sulphate, calcium chlorides, etc., which react chemically with concrete to produce water proof concrete.
- Compounds, like soap, petroleum, oils, fatty acid compounds such as stearates calcium, sodium, ammonia, etc. Work on water repulsion principle. When these are mixed with concrete the concrete becomes water repellent.
- Commercially available compounds like Publo, Permo, silka, etc

c. **Surface treatment**

The surface treatment consists of application of layer of water repellent substances or compounds on these surfaces through which moisture enters. The use of water repellent metallic soaps such as calcium and aluminium oletes and stearates are much effective against rain water penetration. It should be noted that surface treatment is effective only when the moisture is superficial and is not under pressure. Sometimes, exposed stone or brick wall face may be sprayed with water repellent solution.

d. **Cavity wall construction**

This is an effective method of damp prevention, in which the main wall of a building is shielded by an outer skin wall, leaving a cavity between the two.

e. **Guniting**

This consists of depositing under pressure, an impervious layer of rich cement mortar over the exposed surfaces for water proofing or over pipes for resisting water pressure. Cement mortar consists of 1:3 cement sand mix, which is shot on the cleaned surface with the help of a cement gun, under high pressure. The mortar mix of desired consistency and thickness can be deposited to get an impervious layer. The layer should be properly cured.

f. **Pressure grouting**

This consists of forcing cement grout, under pressure, into cracks, voids, fissures etc. present in the structural components of the building, or in the ground. This method is quite effective in checking the seepage of raised ground water through foundations and sub-structure of a building.

5.8.5 Materials used for damp proofing course

An ideal damp proofing material should have the following characteristic:

- The material should ***be perfectly impervious*** and it should not permit any moisture penetration or travel through it.
- The material should ***be durable***, and should have the same life as that of the building.
- The material should ***be strong***, capable of resisting superimposed loads/pressure on it.
- Material should ***be flexible***, so that it can accommodate the structural movements without any fracture.
- The material should ***not be costly***.
- The material should be such that leak-proof jointing is possible.
- The material should ***remain steady*** in its position when once applied. It should not allow any movement in itself.

The following materials are commonly used for damp-proofing

1. **Hot bitumen**

This is a highly flexible material, which can be applied with a minimum thickness of 3mm. It is placed on the bedding of concrete or mortar, while in hot condition.

2. **Mastic asphalt**

Mastic asphalt is **semi rigid** material which is **quite durable** and **completely impervious**. It is obtained by heating asphalt with sand and mineral fillers. However it should be laid very carefully, by experienced persons. It can withstand only very slight distortion. It is also liable to squeeze out in very hot climate or under heavy pressure.

3. **Bituminous or asphaltic felt**

This is a flexible material which is available in rolls of various wall thicknesses. It is laid on a levelled flat layer of cement mortar. An overlap of 10cm is provided at joints and full width overlap is provided at angles, junctions and crossings. The laps should be sealed with bitumen. Bituminous felts cannot withstand heavy loads, though they can accommodate slight movements.

4. **Metal sheets**

Sheets of lead, copper and aluminium can be used as D.P.C. These sheets are of flexible type.

Lead sheets - Lead sheets are quite flexible. They are laid similar to the bituminous felts.

Lead sheets - They have advantages of being completely impervious to moisture, resistant to ordinary atmospheric corrosion, and capability of taking complex shapes without fracture and resistant to sliding action.

Copper sheets - Copper sheets of minimum 3mm thickness, are embedded in lime or cement mortar. It has high durability, high resistance to dampness, high resistance to sliding, and reasonable resistance to ordinary pressure.

Aluminium sheets - If used it should be protected with a layer of bitumen. It is not as good as lead or copper sheets.

5. **Combination of sheets and bituminous felts**

Lead foil sandwiched between asphaltic or bituminous felts can be effectively used as D.P.C. The combination, known as lead core possesses characteristics of easy laying, durability, efficiency, economy and resistance to cracking.

6. **Bricks**

Special bricks, which have less water absorption capacity, may be used as D.P.C. in locations where damp is not excessive. This bricks are laid in two to four courses in cement mortar.

7. **Stones**

Dense and sound stones, such as granite, can be laid in cement mortar (1:3) in two courses or layers to form effective D.P.C. The stones should extend to the full width of the wall.

8. **Mortar**

Cement mortar (1:3) is used as bedding layer for housing with other D.P.C. materials.

9. **Cement concrete**

Cement concrete of 1:2:4 mix or 1:1½:3 mix is generally provided at plinth level to work as D.P.C. The thickness may vary from 4cm to 15 cm. Such a layer can effectively check the water rise due to capillary action. Where dampness is more, two coats of hot bitumen paint may be applied on it.

10. **Plastic sheets**

This relatively a new type of D.P.C. material made of black polyethylene, 0.5 to 1mm thick in the usual walling width and wall length of 30m. The treatment is cheaper but is not permanent.

5.9 FIRE PLACES

5.9.1 Introduction

A **fireplace** is an architectural structure that contains a fire for heating. A fire is contained in a firebox or fire pit; a chimney or other flue directs gas and particulate exhaust to escape. A fire place is a framed opening in a chimney to hold an open fire. It must be designed and constructed to:

- Sustain the combustion of fuel.
- Draw properly to carry smoke and other combustive by-products to the outside.
- Radiate the maximum amount of heat comfortably in to the room.
- Ensure proper distances from combustible materials.

The dimension and proportion of a fireplace, its flue and the arrangement of its components are subject to:

- The laws of nature,
- The requirement of the building, and
- The prevalent building codes.

5.9.2 Terminologies

The following terminologies are used in connection with chimneys and fire places

a) **Chimney flue**: this is a shaft, which carries gases from a fire place through the building to the atmosphere. Normally this flue is not less than $400cm^2$ in sectional area and is constructed in brickwork or stone masonry.

b) **Chimney back**: this term applies to the back of a fire place opening.

c) **Chimney jambs**: these are the vertical sides of a fireplace opening.

d) **Chimney bar**: this is a metallic bar, which ties the jambs of chimney together.

e) **Chimney cowl**: this is a cap or fitting to a chimney and promotes an upward draught in the chimney.

f) **Chimney breast**: this is the opening of chimney or fire place projecting outside the wall face.

g) **Chimney gutter**: this is suitably shaped piece of metal, which collects and diverts water which otherwise would penetrate the roof at the back of the chimney stack.

h) **Chimney lining**: this is the rendering on the inner side of a flue, may be of special fire proof material.

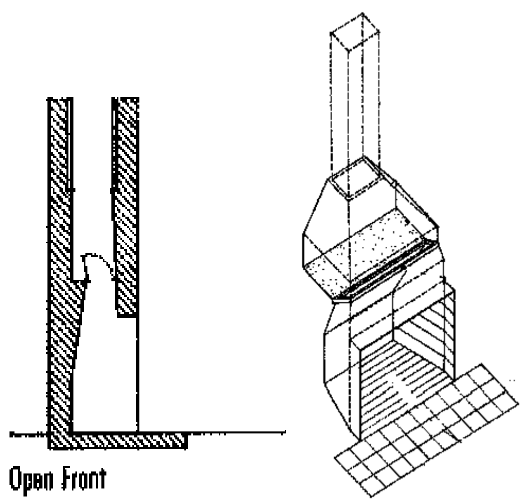
i) **Chimney piece or mantle piece**: this is an ornamental surrounding to a fire place.

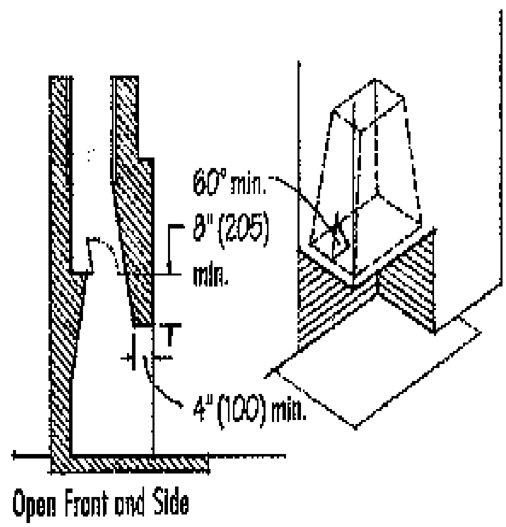
j) **Chimney pot**: this is a terracotta unit at the top of a chimney stack. It increases the height and prevents down draught.

5.9.3 Types of fire-places

There are basically three types of fire places. These are:

- Open front
- Open front and side
- Open front and back





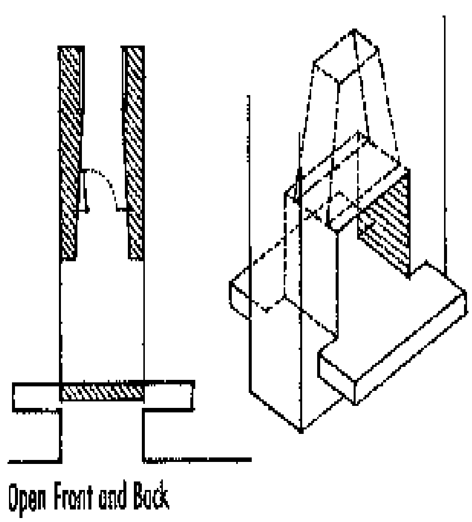


Fig. 5.9.1 Types of Fire Places

5.9.4 Function and components of a chimney

When chimneys, fireplaces and flues are constructed as an integral part of the structure, they have to fulfill the same requirements as the wall in which they are incorporated. They must fulfill the requirements of weather exclusion, thermal insulation, sound insulation and fire protection, at least to the same degree as the wall or the partition of which they form a part. The major components of a chimney include the foundation, chimney breast, flues and chimney stacks.

A. **Foundations**

The foundation of a chimney shall be properly designed and should be at least as deep as the adjacent walls. The chimney should be properly bonded to the wall and it will sometimes be necessary to make special calculations for strength and stability of the chimney. The chimney is often wider than the wall and thus it will be necessary to make the foundations larger.

B. **Chimney breast**

A fire place generally needs greater depth than the thickness of a wall. Hence the chimney is accommodated in the chimney breast. This projection can be avoided if chimney is provided in external walls where the projection can be provided on the outer side. The fire place opening will depend on the size of the room or the type of fireplace. The smallest room may need a fireplace opening of 50cm width.

C. **Flues**

The purpose of the flue from a fireplace is to provide an outlet for the products of combustion and also to include the airflow through the fire necessary for the burning of the fuel. It commonly draws air from the room in which the fire is situated, there by inducing ventilation. All open fire depends on the suction developed by the flue to provide sufficient air for combustion.

The suction exerted by the flue depends on the difference in pressure b/n the column of warm gas it contains and the column of cool air of equal height. The taller the flue the higher the temperature of the flue gas and the greater will be the velocity in the flue. The amount of ventilation induced in a room is greatly influenced by the volume of air drawn up the flue. The greater the air change, the greater will be heat loss and thus care should be taken in designing flue sizes depending on room sizes.

Flues have a minimum size of 20cm by 20cm and should be uniform in section throughout their height. However a throating i.e. reduced opening may be made at the end. The inside of a flue is plastered or rendered with mortar to prevent escape of flame or smoke through cracks or open joints. The materials used for the flues must be incombustible and durable. Special circular, rectangular, or square fire clay flue linings may be available

Chimneys whose outlets are in high pressure areas will be more likely to give rise to down draught and smokiness at the appliances. When flue is designed to be on internal wall, two advantages can be obtained

- Heat loss to the outside air is avoided and it will contribute towards warming the rooms; and
- The heat loss will be less and the flue gas temperature will be maintained, consequently improving the flow and reducing the risk of down draught.

D. **Chimney stacks:**

The chimney breasts are reduced in width when they penetrate above the roofs. According to many countries building codes, the chimney stacks must be carried up to a height of at least 1m above the highest point of the adjoining roof. To prevent down draught, the chimney stack is generally taken at least one meter above the ridge. Special considerations should be given to prevent the rain water coming down the walls.

5.9.5 Typical fire-place dimensions

Typical Fireplace Dimensions in Inches (mm)

Width (A)	Height (B)	Depth (C)	(D)	(E)	(F)	(G)	Flue Size
Open Front							
36 (915)	29 (735)	20 (510)	23 (560)	14 (355)	23 (560)	44 (1120)	12 x 12 (305 x 305)
42 (1065)	32 (815)	20 (510)	29 (735)	16 (405)	24 (610)	50 (1270)	16 x 16 (405 x 405)
48 (1220)	32 (815)	20 (510)	33 (840)	16 (405)	24 (610)	56 (1420)	16 x 16 (405 x 405)
54 (1370)	37 (940)	20 (510)	37 (940)	16 (405)	29 (735)	68 (1725)	16 x 16 (405 x 405)
60 (1525)	40 (1015)	22 (560)	42 (1065)	18 (455)	30 (760)	72 (1830)	16 x 20 (405 x 510)
72 (1830)	40 (1015)	22 (560)	54 (1370)	18 (455)	30 (760)	84 (2135)	20 x 20 (510 x 510)
Open Front and Side							
28 (710)	24 (610)	16 (405)		Multifaced fireplaces are especially sensitive to drafts in a room; avoid placing their openings opposite an exterior door.			12 x 12 (305 x 305)
32 (815)	28 (710)	18 (455)					12 x 16 (305 x 405)
36 (915)	30 (760)	20 (510)					12 x 16 (305 x 405)
48 (1220)	32 (815)	22 (559)					16 x 16 (405 x 405)
Open Front and Back							
28 (710)	24 (610)	16 (405)					12 x 12 (305 x 305)
32 (815)	28 (710)	16 (405)					12 x 16 (305 x 405)
36 (915)	30 (760)	17 (430)					12 x 16 (305 x 405)
48 (1220)	32 (815)	19 (485)					16 x 16 (405 x 405)

5.9.6 Materials for chimney and fire-place construction

The major building materials used for the construction of chimneys and fire places include bricks, concrete, masonry stones, and some metals.

A. **Brick chimneys**

- Brick is the traditional material used for building chimneys.
- The height of unsupported brick stack or shaft should not exceed six times its least horizontal dimension.
- Where the height is exceeded, the stack requires to be braced, or the thickness calculated to withstand wind pressure.
- The application of damp proof courses are necessary at the base of the chimneys to prevent rising dampness.

- Since brick chimneys are very heavy, care has to be taken during the design of foundations.

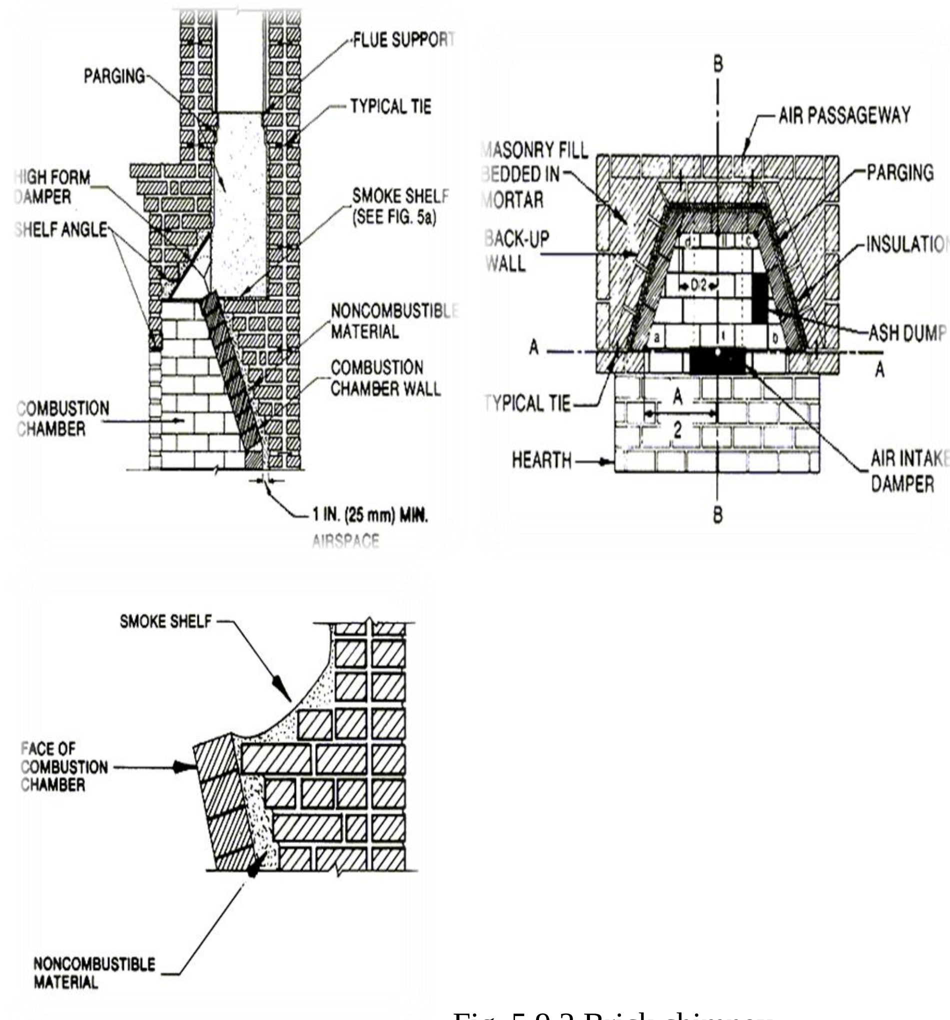


Fig. 5.9.2 Brick chimney

B. **Concrete chimneys:**

- Concrete chimneys are becoming more popular nowadays due to their better appearance and economical consideration both initially and during maintenance.
- Concrete chimneys can be formed either by using precast units or cast in situ, or a combination of both methods.
- When reinforced concrete is used the reinforcement should have a proper cover.
- The application of damp proof courses are necessary at the base of the chimneys to prevent rising dampness.

C. **Hollow blocks:**

- Hollow clay or concrete blocks are generally unsuitable for building flues unless the blocks are specially made for the purpose.

D. **Stone masonry chimneys:**

- The conditions of exposure for chimney stacks above the roof, together with the risk of condensation of the products of combustion, limit the choice of stone.
- The temperatures normally prevailing in a domestic flue are not sufficiently high to damage good building stone except in the immediate vicinity of fire.
- On this situation, the stone has either to be sand stone or has to be protected by fire brick.
- The same precautions against damp prevention have to be taken for masonry as those taken in brick chimney.

Fig. 5.9.3 Stone masonry chimney

E. **Metal flues:**

- The use of free-standing metal flues in buildings is restricted. However, steel or cast-iron can be used to produce metal flues.

- Though metal chimneys are light in weight, they require careful maintenance and large initial expenses.
- Free standing-flues of metal have to be frequently supported, usually at every section, as recommended by the codes of practice.
- Allowance should be made for the expansion and contraction of the pipes at the joints and at supports so that the whole stack may move.

5.10 FORMWORK

5.10.1 Introduction

Formwork, sometimes known as shuttering or casing, is the boarding or sheeting which is erected to contain and mould the wet concrete during placing and the initial hardening period.

- Formwork is a temporary structure that is required to support and form concrete members.
- False work is the complete structure erected to support the wet concrete.

In most of the project formwork activity accounts for 30% to 60% of the cost of the concrete skeleton and extends 40% to 60% of the total project duration. Proper selection of formwork has greater influence:

- On reducing materials and labor cost,
- Improving the quality of the produced concrete and
- Saving time leading to smooth running of the projects.

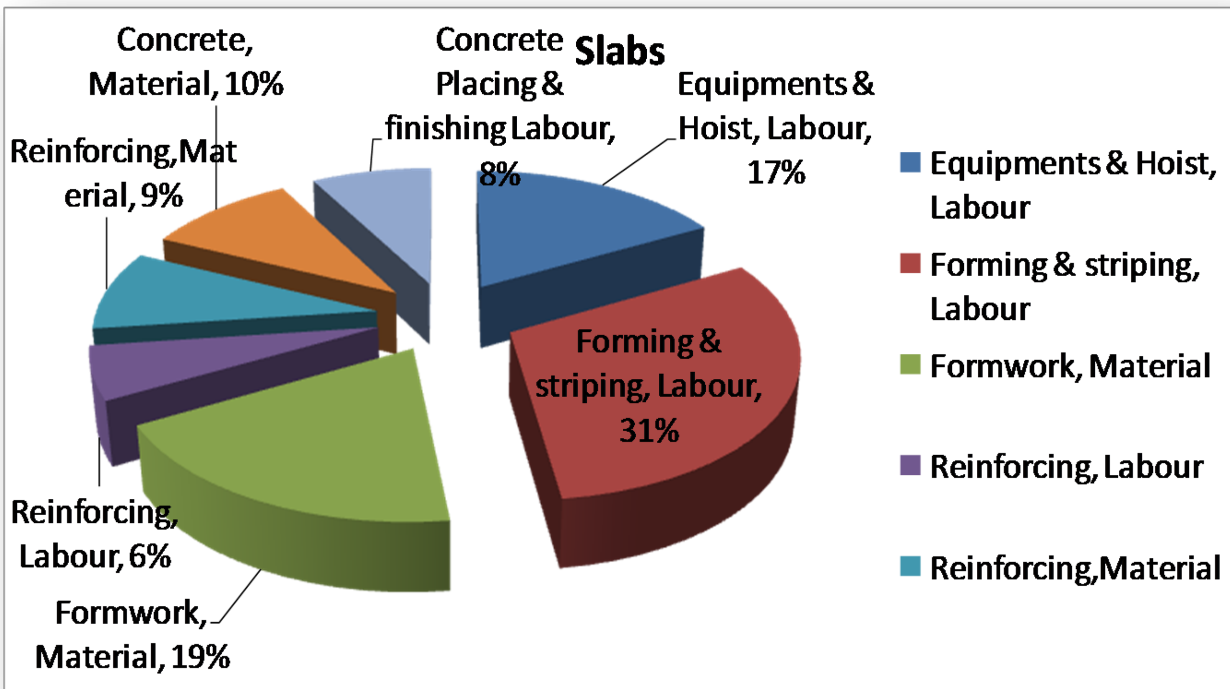


Fig. 5.10.1 Typical cost breakdown of concrete slabs

5.10.2 Requirements of a good formwork

Basic objectives of a good formwork are:

i. **Quality** - desired size, shape and finish of the concrete is achieved.

ii. **Safety** - capable of supporting all dead and live loads without collapsing or danger to workmen and to the concrete structure.

iii. **Economy** - efficient, saving time and money for contractor and owner

A good formwork should satisfy the following:

i. it should be strong enough to withstand all types of dead and live loads such as:
   - Self weight,
   - Weight of reinforcement,
   - Weight of wet concrete,
   - Loads due to workmen,
   - Construction equipment,
   - Other incidental loads and forces caused by placement and consolidation of concrete imposed upon it during and after casting of concrete.

ii. It should be rigidly constructed and efficiently propped and braced both horizontally and vertically so as to retain its shape without undue deflection.

iii. The joints in the formwork should be tight against leakage of cement grout.

iv. It should be constructed in such a manner that it may permit the removal of various parts in desired sequence without damaging the concrete.

v. The material of the formwork should be cheap, easily available and should be suitable for reuse several times.

vi. It should be set accurately to the desired line and levels and should have plain surfaces.

vii. It should be as light as possible.

viii. The material of formwork should not warp or get distorted when exposed to sun, rain or water during concreting.

ix. All joints of the formwork should be stiff so that lateral deformation under loads is minimal. Also the joints should be leak proof.

In other words a good formwork should satisfy the following:

- Containment;
- Strength ;
- Rigidity;
- Tightness;
- Good alignment;
- Surface finish;
- Durability;
- Resistance to leakage;
- Accuracy;
- Ease of handling;
- Finish and re-use potential;
- Access for concrete;
- Economy, and
- Ease of stripping and economy.

5.10.3 Materials for formwork

Formwork can be mainly made up of;

- Timber,
- Plywood,
- Steel
- Aluminium
- Precast concrete or fibreglass, used separately or in combination.

a. **TIMBER FORMWORK**

The timber used for the formwork should satisfy the following requirements:

- It should be well seasoned,
- It should be light in weight,
- It should be easily workable with nails without splitting, and
- It should be free from knots.

Timber used for shuttering exposed concrete work should have smooth and even surface on all faces, which are to come in contact with concrete. In situations where concrete surfaces are not exposed, as in the case of foundations, undressed timber can be used to reduce cost.

b. **Plywood formwork**

Use of plywood instead of timber planks is getting popular these days. Resin bonded plywood sheets are attached to timber frames to make up panels of required sizes. It ensures quality surface finish and is especially recommended in works where large exposed areas of the concrete are to be constructed such as floor slab, faces of retaining walls, etc. Generally, the number of reuses of plywood formwork is more as compared with timber shuttering.

c. **Steel formwork**

This consists of panels fabricated out thin steel angles. The panels can be fabricated in large numbers in any desired modular shape or size. Although steel shuttering costs more initially, it may work out to be economical in the long run due to its large number of reuses of the same shuttering.

The advantages of steel formwork over timber formwork include:

- It is stronger, more durable and have longer life as compared with timber forms
- It can be put to sufficient large number of reuses, as high as 100 cycles.
- It can be installed and dismantled with greater ease and speed.
- The quality of exposed concrete surface obtained by use of steel form is excellent and most of the time it need no further treatment.
- There is no danger of the formwork absorbing water from the concrete and hence the chances of honeycombing are minimised.
- They are not liable to shrink or distort and hence it is possible to achieve better workmanship and higher accuracy by use of steel forms.

d. **Aluminium formwork**

This formwork enables the walls and slab to be placed monolithically in the same operation. Consistent concrete shapes and finishes are obtained using this formwork. The smooth finish of the concrete greatly reduces or eliminates the need for costly plastering.

5.10.4 Factors affecting selection of formwork

Formwork for building nearly account for 25% of RCC work. Selection of formwork material to be used should be based on maximum economy to the contractor consistent with safety and quality required in the finished work. Proper selection of formwork has greater influence:

- On reducing materials and labor cost,
- Improving the quality of the produced concrete and
- Saving time leading to smooth running of the projects.

Factors to be considered at the time of selection:

- Strength
- Economic use
- Ease of handling, erection and dismantling
- Ability to form the desired shape
- Concrete quality and finish required

For a given set of circumstances and as a result of certain specific requirements each material may have some particular attribute that will resolve a particular constructional problem on a work

Decision making Principles

i. **Knowledge base evaluation** - Factors considered are:

- Type of finish
- Re-use for good finish
- Re-use for rough finish
- Formwork component applied
- Shuttering shapes
- Likely concrete defects
- Area practice
- Where fabricated
- Noise produced
- Fire resistance
- Liability of shuttering damage
- Formwork repairs

  - Ease of making openings
  - Insulation properties

ii. **Project data** -

- Contract specialty
  - Contract type
  - Contract conditions
  - Project duration
  - Type of concrete finish
- Building Specialty
  - Building type (commercial, residential, industrial)
  - Structural systems and details
  - Building scale (shape, length, width, height and no. of floors)
  - Building area(total, floor-wise and phase-wise)
- Site Specialty
  - Access to site
  - Site size
  - Site surroundings and its relationships
  - Space for formwork fabrications
- Contractor Specialty
  - Contractor's experience with different formwork systems
  - Formwork available with contractor
- Construction Specialty
  - Labor available and productivity
  - Construction equipments used and frequency of use
  - Construction sequence/ program
- Site Specialty

Table 5.9.1 Properties of formworks made of different materials

No.	**Formwork material**	**Surface finish**	**Re-use for good finish**	**Re-use for rough finish**	**Formwork component applied**	**Shuttering shapes**	**Likely concrete defects**	**Area Practice**	**Where Fabricatable**
1	Timber	Normal/ plain finish	1 to 2	10 to 12	Sheeting, shutter frame props	Flat	Uneven surfaces	yes	site/offsite
2	Plywood	High class/fine finish	2 to 4	20 to 25	Sheeting	Flat/ reasonably curved	Ply pieces sticking to concrete	yes	site/offsite
3	Steel	High class/fine finish	45 to 50	100 to 200	Sheeting, shutter frame props, accessories	Any	Blowholes	yes	offsite
4	Fibre glass	High class/fine finish	85 to 100	120 to 150	sheeting	Any	Blowholes	yes	Offsite
5	Concrete	High class/fine finish	1	-	sheeting	Any	Edges chip off	yes	site/offsite
6	Polypropylene	High class/fine finish	100 - 120	150 to 180	sheeting	Any	Blowholes	No	Offsite
7	Hardboard	Rough/basic finish	1 to 2	2 To 10	sheeting	Flat to slightly curved	Hardboard pieces sticking to concrete	Rarely	site/offsite
8	Polystyrene	High class/fine finish	1	-	sheeting	Generally flat/ curve possible	Sticking to concrete	Occasionally	site/offsite
9	Rubber	High class/superfine finish	10 to 12	15 to 20	sheeting	Any	Poor rubber may differ shape of concrete	No	Offsite
10	Plaster of Paris	High class/superfine finish	1	-	sheeting	Any	Give uneven concrete surface finish if it cracks	Rarely	Offsite
11	Aluminum	High class/fine finish	20 to 40	80 to 100	Sheeting, shutter frame props	Any	Alkali in conc. can react to Al, if moisture present	Occasionally	Offsite

5.10.5 Construction of formwork

The construction of formwork normally involves the following operations

i. **Propping and centring**

The props used for centring may be of steel or timber plates. In case of wooden posts are used as props, they should rest squarely on wooden sole plates. The wooden plates should have an area of at least 0.1m2 and 40mm thickness.

ii. **Shuttering**

The shuttering can be made up of timber planks, or it may be in the form of panel unit made by either by fixing plywood to timber frames or by welding steel plates to angle framing. The shuttering joints should be tight against leakage of cement grout.

iii. **Provision of camber and cleaning**

It is desirable to give an upward camber in the horizontal member of the concrete structure, especially in members having long span, to counteract the effect of deflection. The provision of desired camber should be in the formwork itself during its erection.

iv. **Surface treatment**

The shuttering can be made up of timber planks, or it may be in the form of panel unit made by either by fixing plywood to timber frames or by welding steel plates to angle framing. Before laying concrete the formwork should be cleaned of all rubbish particles. All surface of timber shuttering that are to come in contact with concrete should be well wetted with water. All surface of shuttering should be given a good coating of a releasing agent.

Formwork for foundation

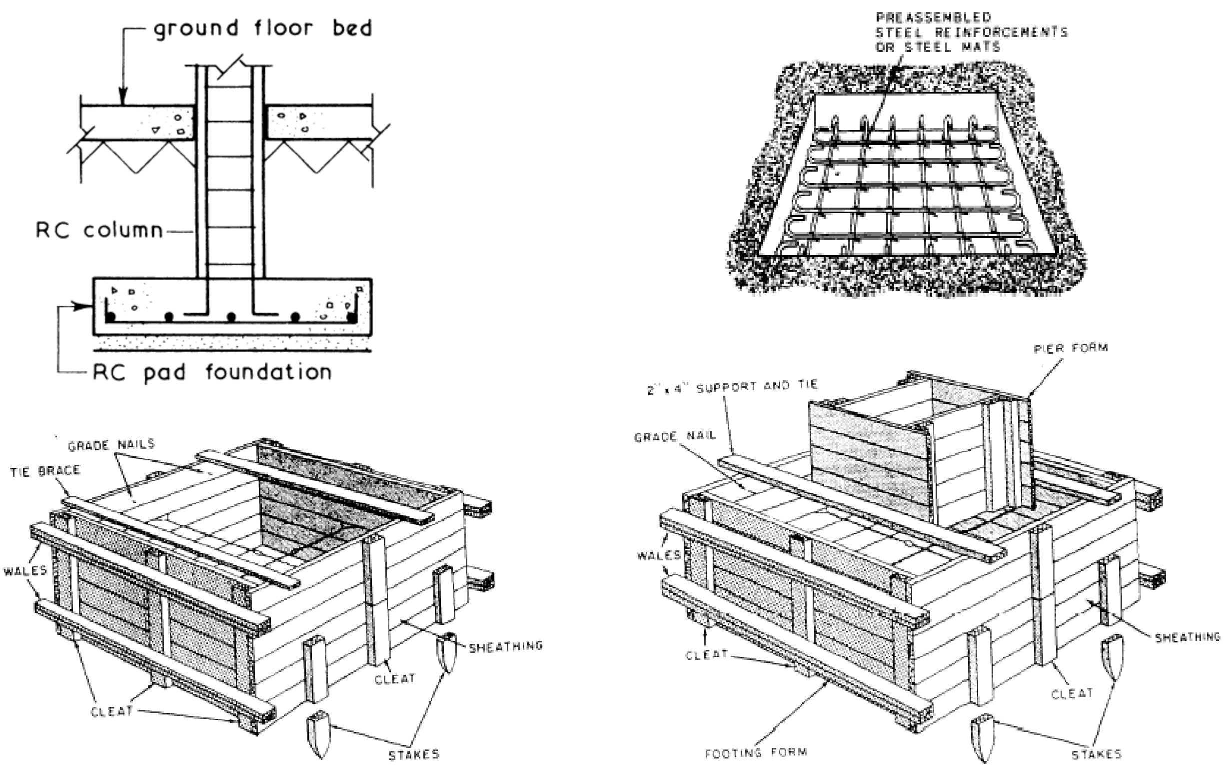
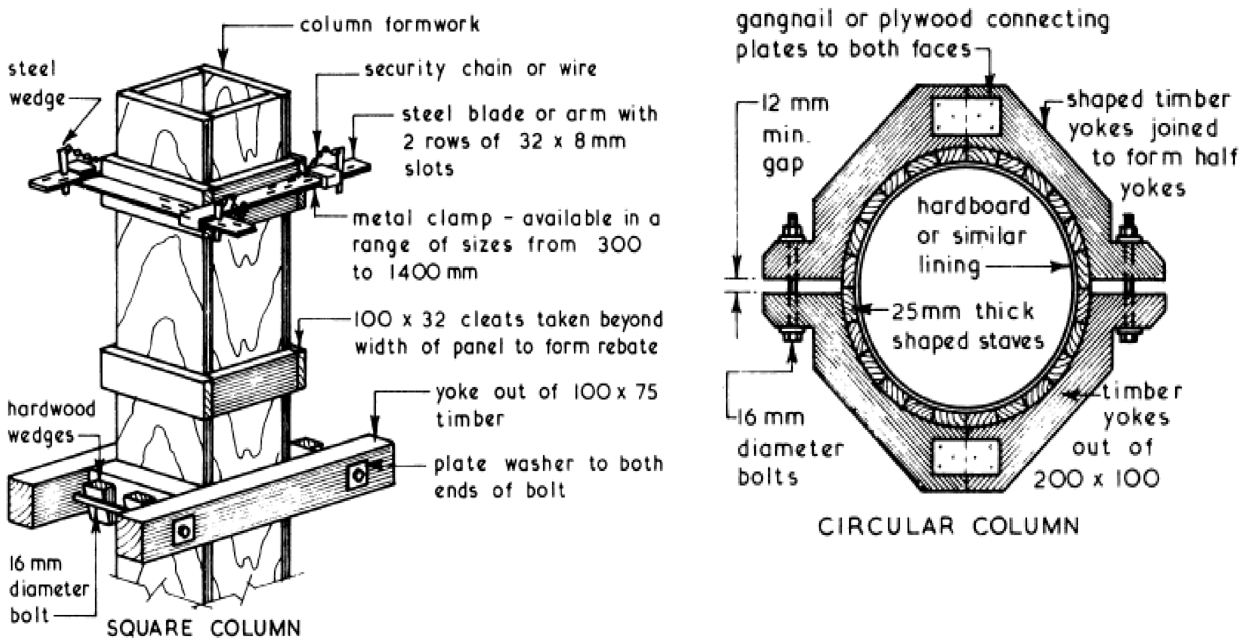


Fig. 5.10.2 Formwork for foundation

Formwork for columns

Columns are usually square or circular in section. The shuttering must be able to withstand the hydraulic pressure exerted on it by the poured concrete. For this reason, the column shutter supports near the base of the form should be closer.

To prevent segregation of the concrete when pouring high columns, it may be necessary to incorporate a ***trap door*** in the shuttering at approximately the midpoint in height of the column, thereby allowing concrete to be placed without it dropping full height. The alternative is pouring the concrete from the top of the form using a ***termite pipe***.



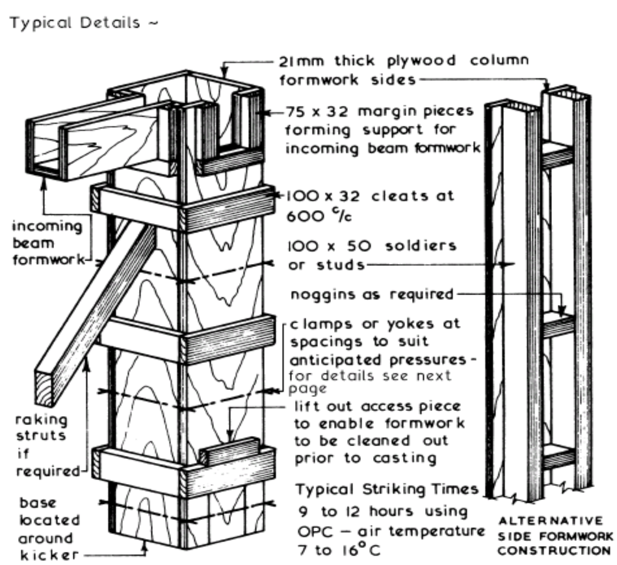


Fig. 5.10.3 Formwork for columns

Formwork for beams

This is basically a three sided box supported and propped in the correct position and to the desired level. The beam formwork sides have to retain the wet concrete in the required shape and be able to withstand the initial hydrostatic pressure of the wet concrete; whereas the formwork soffit apart from retaining the concrete has to support the initial load of the wet concrete and finally the set concrete until it has gained sufficient strength to be self supporting.

It is essential that all joints in the formwork are constructed to prevent the escape of grout which could result in honeycombing and/or feather edging in the cast beam. The design of the shuttering should allow the slab and beam side forms to be removed while the beam soffit remains supported.

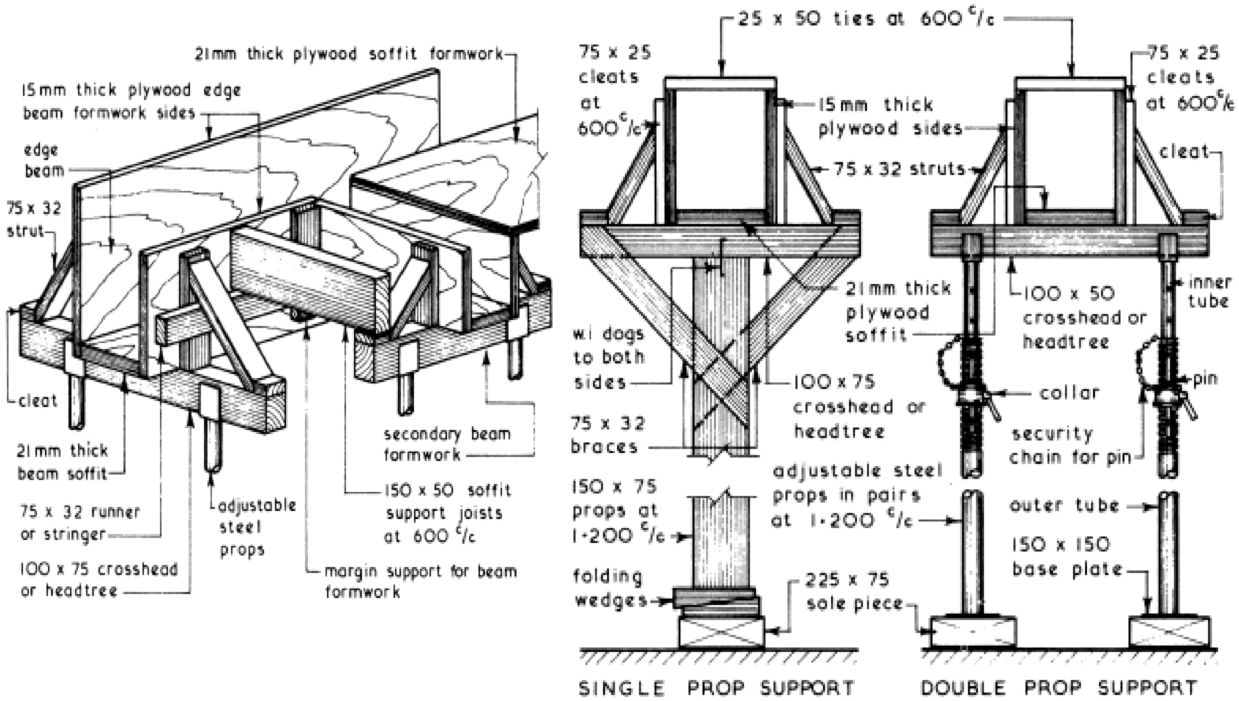


Fig. 5.10.4 Formwork for beams

Formwork for slabs

Formwork to suspended slabs is similar to that for beams, except that the soffit shuttering is far wider.

Fig. 5.10.5 Formwork for slabs

Formwork for walls

This type of form work consists of timber sheeting supported by vertical studs or posts and horizontal struts or walls.

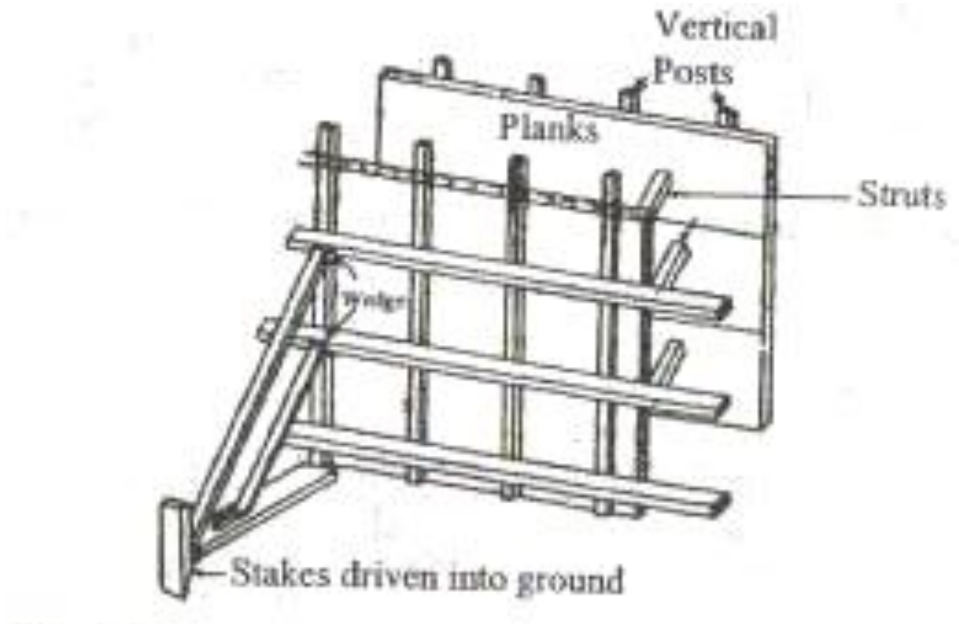


Fig. 5.10.6 Formwork for walls

Formwork for stairs

The landing is first set in position. The process for constructing the landing is the same as that of floors. After the landing has been set, the flight will be constructed.

Fig. 5.10.7 Formwork for stairs

5.10.6 Formwork striking

Removal of formwork is also important as erecting it. Before formwork can be removed the concrete must have sufficient:

- Strength to support itself
- Surface hardness to resist damage
- Curing.

Factors affecting formwork are:

- Ambient Temperature
- Layout of concrete - horizontal, vertical or inclined
- Type of cement used
- Grade of concrete
- Use of retarders, plasticizers, etc.
- Feasibility of removal with props left under
- Feasibility with re-propping
- Standards of finish required
- Structural configuration e.g. simply supported or cantilever
- Curing procedures adopted.

Factors to be considered in producing required concrete finishes of uniform color and texture

- The right concrete mix
- Consistency of the concrete
- Use of a constant rate of placing
- Uniformity of compaction
- Uniformity of face contact material
- Correct choice of formwork pre-treatment and release agents
- Correct curing procedures

Table 5.10.2 Formwork stripping periods

OPC CONCRETE (FROM BS 8110)		
	Surface temperature of concrete	
	7^0 C	16^0 C and above
Formwork for columns, walls	18 hours	12 hours
Soffit formwork to slabs	6 days	4 days
Soffit formwork to beams and props to slabs	15 days	10 days
Props to beams	21 days	14 days

OPC CONCRETE (FROM EBCS 1995)	
	Stripping time
Formwork for columns, walls	18 hours
Soffit formwork to slabs	7days
Props to slabs	14days
Soffit formwork for beams	14days
Props to beams	21days

Method of removing formwork

Formwork should be planned and constructed in such a manner that it is possible to remove the different components in the following order of sequence:

i. Shuttering forming vertical faces of walls, of beams and columns sides, which bear no load but are used only to retain the concrete, should be removed first.
ii. Shuttering forming soffit of slabs should be removed next, and
iii. Shuttering forming soffit of beams, girders or other heavily loaded shuttering should be removed in the end.

5.10.7 Formwork Economy

Formwork is the single largest component of concrete building. Considering the impact of formwork on the total cost, the engineer should design the formwork so that the maximum economy can be obtained. Economy of formwork begins with the design development of the structure itself.

The following point should be considered while designing formwork for a building structure.

- While designing the structure, consider the material and tools that will be required to make, erect, and remove the formwork.

- Design the structure with standard dimensions that will be unit multiple of forms and centering sheets.
- Use the same size of columns from the foundation to the roof, this will permit the use of column forms without alteration.
- Use beams of the same depth and spacing in every floor; this will permit the reuse of beam forms without alteration.
- Specify the same for columns and column-support girders in order to reduce or eliminate the cutting and fitting of girder forms into column forms.

Some of the important points to achieve economy in formwork expenditure are as follows:

- While designing formwork, maximum usage of material should be achieved.
- High quality finish on concrete surface is not required for sides that will not be exposed.
- When planning forms, consider the sequence and methods of striping.
- Use prefabricated panels wherever possible.
- Strip forms as soon as it is safe in order to facilitate maximum reuse of forms.
- Create cost awareness among carpenters and other workers involved in formwork construction.
- Use long length timber or plywood without cutting, where their extending beyond the working area is not objectionable.
- After removal clean panels and store them at a safe place so that they can be reused.

5.10.8 Releasing agent

Releasing agent facilitate the striking or removal of the formwork. It prevents the concrete adhering to the form face. Most oils will fulfill the function of a release agent, but different oils can produce ***blow holes*** or ***variations in the color*** of concrete, affect ***efflorescence***, or ***retard the hardening*** of the surface.

5.10.9 Formwork design principle

The person designing the formwork for a project is doing much more than planning the containers with in which the in situ concrete will be cast. Formwork design includes design of the formwork support structure, and the formwork deck and connection details.

The design of formwork will involve decisions on the location of construction joints, which may impose on reinforcement detailing, and will certainly relate to the volume of concrete to be placed in one pour. It will also be necessary for the designer to take into account the skills available, both quantitatively and qualitatively, for fabricating and handling the formwork.

Loads on formwork

a. **Wind loading** - Vertical elements must be fully braced to resist lateral load due to wind. Wind loading will vary depending on size of form, nature of the form, wind speed, and wind direction.
b. **Concrete Loading -** The force exerted by concrete is complex, because concrete starts off acting as though it were a fluid

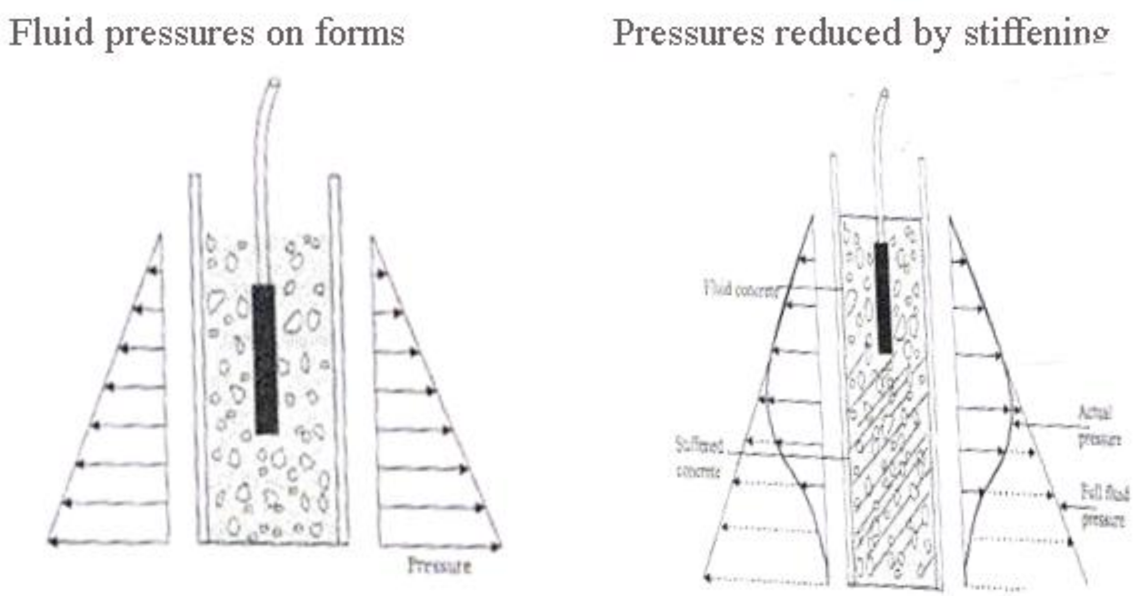


Fig. 5.10.8 Pressure of fresh concrete on formwork

Factors affecting pressure

- Concrete density,
- Rate of rise,

- Height of section cast,
- Concrete temperature,
- Cement type, admixtures, latent hydraulic binders and shape and plan area of the section.

5.10.10 Failure of formwork

The failure of formwork is always embarrassing and expensive for everyone involved in the project. Failure may occur due to collapse of entire formwork or part of it.

Some of the reasons for the failure of formwork are given below:

- Improper or inadequate shoring
- Inadequate bracing of members
- Lack of control of placement of concrete
- Improper connection
- Premature striping of formwork
- Improper design
- Failure to follow codes and standards
- Negligence of workers or supervisors

In order to prevent failure of formwork the following precautions should be taken:

- The formwork should be designed properly
- Erection and stripping should be done only under engineering supervision
- The sequence of removal should be pre-designed and correctly executed.

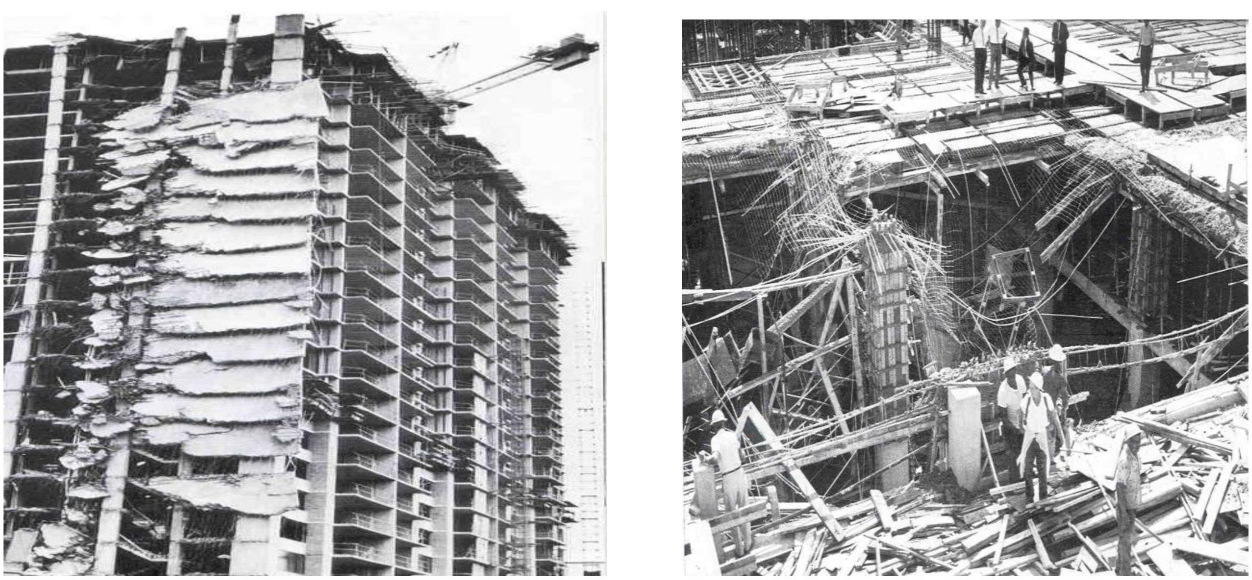


Fig. 5.10.8 Failure of formwork

5.10.11 Scaffolds and false works

A safe and suitable scaffold shall be provided and maintained or other equally safe and suitable provisions should be made, where work cannot safely be done on or from the ground or from part of a building or other permanent structure. It is essential that scaffolds should be provided with safe means of access, such as stairs, ladders or ramps.

Material for scaffolds

In the construction of scaffolds, sufficient, suitable and sound materials should be used. Where timber is used in the construction of scaffolds, it should be straight grained, sound, and free from large knots, worm holes and other defects likely to affect its strength. The mechanical properties of fastening on wooden scaffolds should conform to the national regulations and code of practices or be approved by the concerned authority.

Inspection and Maintenance of scaffolds

Scaffolds should be inspected at periodic intervals as prescribed by national standards or code of practices, and the results recorded by a competent person. Inspection by the competent person should more particularly ascertain that:

- The scaffold is of suitable type and adequate for the job,
- Materials used in its construction are sound and of sufficient strength,
- It is of sound construction and stable, and
- That the required safeguards are in position.

Fig. 5.10.8 Scaffolds

CHAPTER-6

SAFETY AND HEALTH AT CONSTRUCTION SITE

6.1 Introduction

Health and safety are the responsibility of everyone at work. Construction industry, in general, is comparatively less organized and involves participation of major percentage of unskilled labor as compared to other industrial sectors. As a major employment generator in many parts of the world, construction is also a sector associated with a proportionately high number of job-related accidents and diseases.

Despite mechanization, the industry is still largely labor-intensive, while working environments are frequently changing and involve many different parties. It is of particular importance to the construction industry, where it is one of the major employers of the work force in Ethiopia. Statistics indicate that injuries and death due to construction related accidents are increasing.

According to ILO estimates:

- Each year there are at least **60,000** fatal accidents on construction sites around the world.
- In many industrialized countries, as many as ***25% to 40%*** of work-related deaths are occurred in on construction sites, even though the sector employees only ***6% to 10%*** of the workforce.
- In some countries, it is estimated that ***30%*** of construction workers suffer from back pains or other muscular disorders.

Accidents are generally unavoidable in construction projects but the number and gravity of accidents can be reduced considerably if proper safety measures are taken beforehand. Health and safety in the context of construction industry are the discipline of preserving the heath of those who build, operate, maintain and demolish engineering works, and others involved in those works.

The term ***safety*** generally applies to the protection from risk of injury and from avoidable accidents. The term ***health*** refers to the well-being from the immediate and long-term effects of exposure to unhealthy working condition. Health and safety are not only confined to construction works on-site.

Engineers, architects and surveyors are exposed to hazards during the investigatory stage of a project and while carrying out inspection tasks during the construction phase and on completed works. Designers, in particular, carry both a moral responsibility and a duty of care for the safety of construction works, maintenance staff, demolition workers and the general public.

6.2 The problem of safety and health

Construction industry accidents in Ethiopia have not been well recorded. Nevertheless, it is reported that many people lost their lives on construction sites and many more seriously injured. Not only are construction workers who suffer injuries and death but also people and children who are not employed in the industry.

Besides human tragedies, accidents could substantial economic cost to the industry due to the fact it could also cause:

- Damage to plant and equipment
- Damage to work already completed
- Loss of productive work time while debris is cleared and damaged work rebuilt
- Increased insurance premiums, and,
- Loss of confidence and reputation.

6.3 Safety and health in international and local practice

Considering the importance of health and safety of construction workers in the industry, different countries have designed their own norms, which fit their specific objectives. The International Labor Organization (ILO) provides specific guidelines on health and safety in construction activities.

The general objectives of health and safety norms/codes in any country construction industry can be summarized as:

- To help prevent accidents and harmful effects on the health of those employed in construction industry.
- To provide guidelines in the appropriate deign, selection, installation and safe operation of equipment, and process related to civil engineering work.
- To provide guidance in establishing administrative, legal and educational frameworks within which preventive and remedial measures can be implemented
- To promote consultation and cooperation between concerned government authority, employer's organization and worker's organization in the improvement of safety and health in the construction industry.

Local practices

In the case of Ethiopia, the Ministry of Labor and Social Affairs is authorized by law for the full responsibility of consulting, monitoring and other works related to occupational health and safety topics. Even though it is difficult to obtain accurate statistics since many accidents go ***undetected*** and ***unreported***, the number of construction accidents occurring in Ethiopia, is increasing from time to time.

In constructions under-taken in Ethiopia, the construction contract agreement (i.e.) General Conditions of Contract (clause 21 - 25) and FIDIC (clause 19 - 25) states the responsibilities of the involved parties. These are like provisions of ***insurance***, taking other ***safety measures***, etc.

6.4 Cause of construction site accidents

The key to control safety and health is to predict the hazards and thus be in a position to eliminate them.

The main causes of accident could be basically categorized based on type into:

- Falls
- Stepping on or striking against objects
- Lifting and carrying-over exertion
- Machinery
- Electricity
- Transport
- Fires and explosions

Causes of accident at construction sites are broadly classified as:

i. Processes related
ii. Root causes

Process prone to accidents

Some of the processes prone to accidents are:

- Excavation
- Scaffolding/Working at Height
- Shaft work
- False work
- Erection of Structural Framework

- Tunneling
- Use of Cranes
- Transportation & Mobile Plants
- Sewer Works
- Demolition
- Road works in hilly terrain

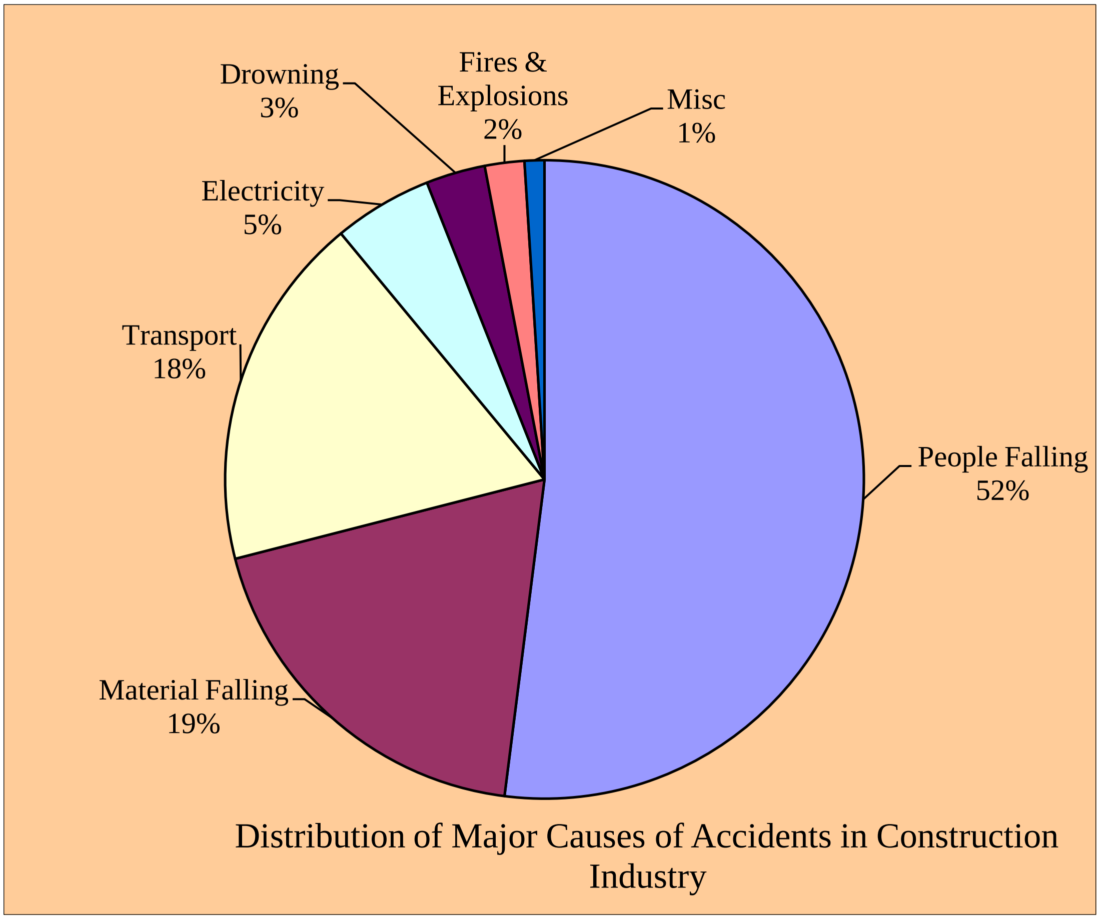


Fig. 6.1 Distribution of major causes of accidents in construction industry

6.4.1 Process related causes of accidents

A. **Falls**

Falling from heights is number one construction killer in most countries, and it is principally due to the lack of proper edge in a variety of construction sites.

I. **Person falling**

a) **From scaffolds**

Most falls from scaffolds occur through personnel overbalancing, tripping or slipping. The rest may be attributable to general defects in the scaffolding such as boards slipping or breaking, the absence of guard rails, insecure foundations etc.

b) **From ladder**

Most falls are caused by the person slipping or overbalancing and falling from the ladder, a considerable number caused by movement of the ladder (either the bottom slips outward or the top slip sideways). A number of accidents also arise out of defects (e.g. missing or broken rungs) in the ladder or, in some cases, by the breaking of the ladder

c) **From structure and other heights**

Such falls occur in a variety of ways; for example falls from shuttering (often as a result of a collapse of the shuttering on which persons are standing), and falls through unprotected openings and fragile roofs - and are almost always the result of the individuals concerned.

d) **From plant**

Fall from plant are surprisingly frequent on construction sites. The majority of such falls occur when drivers are climbing on to, or descending from, their machines.

e) **Into excavations and manholes**

In the main, falls in to excavation usually occur when personnel slip while trying to jump to climb out of them by means other than a ladder. A surprising number of personnel fall into uncovered manholes (particularly those which have became obscured by vegetation) while walking across the site.

II. Fall of Materials

Materials or other objects, whether heavy or comparatively light, gather tremendous energy in falling.

For example, a brick dropped by a man on his own foot can fracture a bone. Something very much lighter- a 20mm nut, dropped from a height of 20m, can penetrate a man's skull and kill him.

a) From heights or into excavations

All sorts of things ranging from small tools to wheelbarrows, scaffold members and girders - fall from heights. Mostly, the falls occur from working positions such as scaffolds or from structures where personnel are working, faces of excavations, or from lorries and dumpers.

Around 50% of all injuries suffered by such are the result of falling debris.

b) On the level

Most accidents result from presumed dropping materials on their own (or other people's) feet, often during loading or unloading operations. A substantial number of accidents also arise from the collapse of unstable stacks of materials such as pipes.

6.4.2 Root causes of accidents

Accidents are primarily caused by people and not by process. Many safety experts have an opinion that the root causes an accident lies in reason for the mistake having been made.

The following root causes of accident may be cited as being the most common:

a) Ignorance and luck of training

The majority of plant equipment related accidents stem directly on the operator’s misuse of such things. There are numerous reasons for the incorrect usage of plant and equipment, the most common is operator’s ignorance of the correct method of usage.

b) Ignorance and luck of training

The **“it cannot happen to me!”** attitude is regarded as the biggest single root cause of construction related or any other types of accidents.

c) Carelessness

Carelessness wills always be the prime contender for the role of “root causes” in any accident in construction especially involving young people. A substantial number of potential accidents can be avoided instilling in such people that the earliest possible opportunity the need to take care in what event they are doing by apprising what will happen if they don't.

d) **Lack of discipline**

This is also another common case of accident involving young person at construction site.

e) **Distraction**

Accidents resulting from distraction are numerous and ranges from the comparatively minor variety to serious and possibly fatal instances.

f) **communication**

There are two rules regarding communication

i. Ensure that all instructions are clear and unambiguous
ii. By way of ensuring that what was heard what was meant, check that the instructions have been fully understood

g) **Management indifference**

As a root cause of accident management indifference to safety is less common in the case of large well known construction companies. However, the reverse is becoming increasingly the case with smaller once which gives less priority for the safety of their employees on account of the cost involved safety.

6.4.3 Accidents related to plant, machinery and transport

a) **Striking personnel, collisions and overturning**

The majority or plant - or transport- related accidents fall within this category.

b) **Lifting appliances**

The majority of such accident consists either of personnel being struck by swinging loads or of variety sustained in sliding operations or while using pulley blocks.

c) **Pneumatic and power tools**

Most accidents in this category occur either through the misuse of tools or a lack of concentration on the part of the user.

d) **Others**

This section comprises plant and machinery related accident types which do not fit into any of the previous three sub-categories.

6.4.4 Miscellaneous Causes (others)

a) **Stepping on, or striking against, objects**

Around 50% of the injuries from accident in this category result from people inadvertently stepping on nail protruding from timber. The remainder results from a variety of causes such as striking against protruding scaffold members or reinforcing bars, or handling broken pipes, glass or similar sharp -edged materials without gloves.

b) **Hand tools**

The majority of such accidents are caused by personnel striking themselves, or other with picks, shovels and suchlike. Many accidents also result from defective tools or from misuse of tools.

c) **Collapse of excavation**

Such accidents, which are almost exclusively due to inadequate support-work, are usually serious and often fatal. Other factors which contribute to such accidents are the movement of plant, stacking of materials, too close edges of excavations. Erosion of the sides of which should not be overlooked.

d) **Electricity**

Electricity is also one source of enormous potential danger. Electricity regularly accounts for between 5% - 10% of fatalities in the construction industry due to coming in to contact with overhead lines, or from excavators or personnel cutting through buried cables, and the use of defective or badly maintained electrical hand-tools.

d) **Hazardous substances**

Hazardous substances have a serious impact on construction site workers health. These may come in the form of liquid, gases, vapors, fumes or dusts. They are contained in variety of commonly used products and material in construction. The main exposure through inhaling them, but substances such as solvents can also be absorbed through the skin. Very often, workers are not aware of what chemicals are contained in the products they use, and are not told about the health hazards and how to avoid them.

Renal, hepatic, cardio-vascular problems and central nervous system disorders can result from exposure to hazardous chemicals. Respiratory illness, bronchitis, asthma, fibrosis and cancer may also be caused by exposure to certain materials on site.

6.5 Safety precautions

6.5.1. Safety precautions

a) **From scaffolds**

- Suitable and sufficient scaffolds shall be provided and erected for all construction work.
- Erection and dismantling of scaffolds should be carried out efficiently by experienced personnel.
- Timber used for the construction of scaffolds shall be of suitable quality, be in good condition
- Ensure that walkways have sufficient width and keep them free from obstructions.
- Do not overload scaffolds
- Provide proper access of scaffolding to avoid personal slipping.
- Ensure that the foundations are secured and leveled
- Provide guardrails to stop persons falling.
- Scaffolds should be properly maintained to avoid accidental displacement.

b) **From ladders**

- Every ladder shall be securely fixed.
- Suitable footholds and hand-holds shall be provided on the ladder.
- Shall be given an inclination not steeper than 1/4 to 1.
- Stand ladder on a firm level base.
- Ensure a correct angle of repose
- Avoid carrying materials when using a ladder.
- Check ladders regularly for defects.

c) **From working platforms**

- Working platform passageways and stairways should be so constructed that they should not sag unduly or unequally.
- If the height of the platform or the gangway or the stair way is more than 3.66m above ground level or floor level, they should be closely boarded, and should have adequate width and should be suitably fastened.
- All roof and floor edges should be fitted with barriers.
- Warning notices on fragile roof and floor levels should also be displayed.
- Every opening in the floor of a building or to all working platforms shall be provided with suitable means to prevent the fall of persons or materials.

d) **From Plants**

- Prohibit the carrying of passages when there is a safe space seat
- Prohibit the carriage of passage by plant which is not intended for such purpose
- Instruct drivers accordingly and ensure that appropriate warning notices are displayed wherever necessary.

e) **Into excavation and manholes**

- All trenches meters or more in depth at all times should be supplied with at least one ladder for each 30m or fraction thereof.
- Ladder shall be extended from bottom of the trench to 90cm above the surface of the ground.

f) **On the level**

- Warn personnel to look where they are going.
- Ensure that walkways are free of materials and other obstructions which cause falls.

6.5.2 Safety precautions to prevent fall of materials

a) **From heights or into excavations**

- Provide tool boxes for tools.
- Provide some form of over protection where necessary.
- Don't place materials, plant or spoil tools near the edges of excavations.
- Provide batters for the work face of excavation
- Lower materials and other object properly, don't throw
- Take particular care with demolish works.
- Encourage the wearing of safety helmets.

b) **On the level**

- Ensure that stacks of material are stable
- Institute a safe working procedure when materials are being moved or stacked.
- To facilitate withdrawal of materials, ensure that material stack is not too high.
- Don't stack materials near overhead power lines.
- Encourage the wearing of safety boots(appropriate types of shoes)

6.5.3 Safety precautions to prevent accidents by agency of plant, machine and transport

a) **Striking personnel, collision and overturning**

- Position personnel and plant to avoid to former being struck by the latter.
- Erect barrier around workman if they are in the vicinity of moving plant or transport.
- Don't track moving plant too near the edges of excavations
- Prohibit racing and other dangerous driving
- Instruct plant operators in the correct and safe use of their machines

b) **Lifting appliances (Hoisting machines)**

- These should be of good mechanical construction, sound material and adequate strength and free from patent defect.
- Every rope used in hoisting and lowering materials or as a means of suspension shall be of durable quality and adequate strength and free from patent defects.
- Every hoisting appliance operator shall be properly qualified (i.e.) he should be able to operate the appliance efficiently and correctly.

- Never exceed the safe load of the appliance.
- Motors gearing, transmission, electric wiring, and other dangerous parts of hoisting appliances should be provided with efficient safeguards.
- Never use a crane when the wind speed is high (exceeds 300mph) at higher elevation.
- Always site the appliance on the firm level ground.
- Position personnel to avoid them being struck by swinging loads

c) **Pneumatic materials and power tools**

- Ensure that operator knows what he is doing
- Provide the appropriate safety clothing and/or equipment (i.e. safety goggles, safety boots etc.) where necessary.
- Ensure that there is sufficient obstruction, free working space around each tool.
- Protect compressed air hoses from damage.
- Instill the need for job concentration in operators.

6.5.4 Safety precautions for other causes

a) **Stepping on or against objects**

- Keep the site tidy and free from unnecessary rubbish
- Remove nails from timber.
- Ensure workers sufficient workspace.
- Provide protector clothing (e.g. safety boots, googols and gloves).

b) **Hand tools**

- Use the right tools for the job and instruct personnel in the correct usage
- Position personnel to avoid them from struck by picks, shovels and others.
- Inspect handholds regularly and take defective tools out of use until repaired.
- Load wheelbarrows evenly and not over load.

c) **Collapse of excavation**

- The side of the trenches shall be stepped back to give suitable slope or held by timber bracing or any other support
- The excavated material shall not be placed within 1.5m of the edges of the trench.

- Cutting shall be done from top to bottom.

d) **Electricity**

- All power tools should be effectively earthed.
- Wherever possible use insulated caplets to carry power.
- Avoid working high plant near overhead lines.
- Be aware of buried cables when using excavating part or trenches by hand.

6.5.5 Preventive measures for demolition works

Before any demolition work is commenced and also during the process of the work, the following safety measures shall be taken.

- All roads and open areas adjacent to the work site shall either be closed or suitably protected.
- No electric cable or apparatus which is liable to be a source of danger or a cable or apparatus used by the operator shall remain electrically charged.
- All practical steps shall be taken to prevent danger to person from risk of fire or explosion or flooding.

6.5.6 Preventive measures for hazardous substances

Principle of preventing accidents under this category involves:

- **Elimination**: Where a work activity involves the use of a hazardous substance that is not essential, the hazardous substance should be eliminated wherever practicable.
- **Substitution**: includes substituting hazardous substance with less hazardous substance.
- **Isolation**: Isolation involves separation of the process from people by distance or the use of barriers to prevent exposure.
- **Engineering controls**: these are plant or processes which minimize the generation of hazardous substances.
- **Safety work practices**: administrative practices which require people to work in safer ways.
- **Personal safety protective equipments**:

6.6 Occupational health hazards

Occupational health hazards (OHH) are those hazards which are inherent with the specific occupation. There are some jobs in which the risk of the hazards is more and inborn. It is mandatory to list the possible occupational health hazards whenever a job specification is prepared

OSHA (Occupational Safety and Health Administration) has laid down the possible OHH with most kinds of the jobs and also their safety measures Since construction industry too has a high risk of accidents, it is important to know the types of OHH.

Types of health hazards

- **Physical Health Hazard**
  - Noise
  - Vibration
  - Working Environment
  - Ionizing Radiation
  - Air Pressure Variation
  - Ergonomics
- **Chemical Health Hazard**
  - Solids
  - Liquids
  - Vapors, Aerosols & Gases
- **Biological Health Hazard**
  - Bacteria, Fungi, Parasites

6.6.1 Physical health hazard

a) **Noise**

This is excessive noise leads to Sensory Hearing Loss. Noise regulatory levels are as follows:

- Continuous noise
  - 85 dBA, 8 hours-Action level (AL)
  - 90 dBA, 8 hours-Permissible exposure level (PEL)
- Impact Noise
  - No Exposures above 140 dBA shall be permitted

Table 6.1 Noise levels

Type of Work	Manual machine, Tools	Handsaw	Tractor	Electric Drill	Wood working Class
Noise Level	80	85	90	95	100
Type of Work	Power Saw	Pneumatic Drills	Hammer on Nail Impact	Chain Saw	Jackhammer
Noise Level	110	120	120	125	130

b) **Vibration**

The most common injury is caused by continued exposure of the hands to high frequencies of vibration from tools such as pneumatic hammers, concrete breakers, drills and chipping hammers. It is usually known as vibration white fingers. It starts with a slight numbness in fingers and eventually causes whiteness to the tips. Attacks may last for an hour and end with a sudden rush of blood to the affected tips, often causing considerable pain. To avoid this one must use vibration isolators.

c) **Working environment**

Heat stress gives rise to number of symptoms like fatigue, loss of concentration, rapid pulse etc. which hamper the work as well as health of the worker. Providing canopies or awnings over sections of the site as well as regular breaks can be used to overcome heat stress

Table 6.2 Optimum working environment temperature and rest period

Temperature	**Rest Period/Hour**
35-40	**5 min**
> 40	**7.5 min**

Extreme cold, biting winds and rain affect the mental stability as well as slower muscle reaction leading to accidents as well as diseases like Bronchitis, Arthritis, etc

d) **Ionizing radiation**

Sealed radioactive sources are widely used in the industry to check welded joints in pipeline and trusses. The effect of radiation can cause radiological dermatitis, skin burns, loss of hair and bone cancer. Lead and concrete shielding can be used to avoid the contact with radiation. Use of shield layers in the personal protective equipments is also necessary. Specific safe distance should be maintained from the radiation source as its intensity decreases as per inverse square law

e) **Compressed air**

Working at pressures above atmospheric pressure may result in compressed air illness. e.g. Tunneling, Caissons etc. This may cause skin irritation at lower exposures but with the more serious forms severe pains develop in the joints and dizziness, unconsciousness and even death may occur. It may cause asceptic bone narcosis. Similarly working at pressures below atmospheric pressure may result in problems in breathing, lung damage. e.g. High altitude area. A pressure balance mechanism such as decompression chamber is to be used along with the proper resting schedule in the shift.

f) **Ergonomics**

Ergonomics is the study of interaction between human beings and their working environment. Inconvenient positions and working methods cause many abnormalities and syndromes like

- Carpal tunnel Syndrome-Prolonged flexing of wrist. e.g.: Painter
- White finger-loss of adequate blood supply to fingers. e.g.: Vibrations and tight gripping of Jackhammer

- Lower back pain-back stresses due to poor lifting. e.g.: Excess weight, overhang weights

6.6.2 Chemical health hazard

The degree of hazard associated with a particular chemical will depend on:

- Its physical properties
- Its toxicity
- The way it is used
- The environment in which it is encountered

Chemicals may be found in solid, liquid, aerosol, or gas and vapor form. The degree of danger varies according to the form of the chemical and the factors discussed above

a) **Solids**

Lead- Lead can become a human health hazard if the pipe is sanded or welded, producing lead dust or fumes resulting in fatigue, anemia.

Asbestos- The demolition of buildings with asbestos insulation or lagging has the potential for the release of massive amounts of asbestos fibre when inhaled leads to asbestoses, lung cancer, mesothelioma-a type of lung cancer.

Cement- The reaction of cement with water produces large amounts of heat as well as CO_2. If proper care is not taken, this can lead to choking of the workers in congested area where mixing is done.

b) **Liquids**

Many liquids are hazardous in contact with the skin. They either damage the skin or they are easily absorbed through the skin. Paints, varnishes etc generally get deposited on workers. The chemical ingredients like Isocyanates invariably get absorbed through the skin leading to dermatitis.

Lead based paints constitute absorption of lead through skin. The contact with these liquids should be avoided. Use of protective clothing should be encouraged to counter these hazards. In case the contact is unavoidable, adequate shower facilities should be provided.

c) **Aerosols/Vapors/gas**

Silica dust can cause silicosis (scarring of lungs). Cement particles when inhaled cause asthma, and other lung diseases. Exposure to saw fumes containing terpenes, a constituent of wood also causes chronic obstructive impairment in lung function.

Chronic exposure to wood dust can cause impaired nasal mucociliary clearance and nasal cancer. Liquids with a low vapor pressure may create a low airborne concentration and those with a high vapor pressure may produce high airborne concentrations. Almost all types of solvents used in paints, paint removing solutions, industrial coatings etc. evaporate and their inhalation also causes similar breathing related diseases.

Carbon dioxide occurs in chalk and limestone. It results in oxygen deficiency. Fatal accidents may occur when workers enter manholes in surface water drainage system Hydrogen sulphide is highly present in sewers. High concentration causes death while low level causes irritation to eyes, nose, headache etc. Nitrous fumes generally emerge with the use of explosives used during demolition or excavation (Blasting). Low concentration can cause bronchitis. Gas masks depending upon the type of exposure are very suitable against these types of chemical hazard

6.7 Hazard control measures

The measures to be taken against the hazards can be classified into two groups:

- **Proactive measures:** Actions to be taken in advance, precautionary measures and its implementation
    - Safety training
    - Safety program
    - Inspection and checklist
    - Personal protective equipments (PPE)
- **Reactive measures:** Actions to be taken after accident occurs
    - Medical aid
    - Accident reporting and analysis

6.7.1 Proactive measures

a) **Safety training program**

Training aims at preventing and minimising the accidents. Education to the workers is provided. Safety measures committee is formulated. Charts, posters and show films on the need to follow safety measures should be displayed. The careless workers should be discontinued after sufficient warnings. First-Aid training to at least one worker in a team should be performed. Proper medical checkups of the workers should be done before employment and also periodically

b) **Inspection and checklist**

This is very important aspect in proactive measures. Checklists for various items of work at each stage are to be prepared and accordingly inspection is to be carried out. e.g.: extract from checklist for roofing works is shown.

6.7.1 Reactive measures

a) **Medical Aid**

First-Aid should be given to injured person as soon as possible. He then should be immediately moved to nearest hospital in case of severe injury. A separate vehicle for this purpose is to be maintained when the number of workers is sufficiently large. Medical Insurance should be provided for those workers working in hazard susceptible zones

b) **Accident reporting analysis**

Analysis is done by the concerned engineer and he should submit the report of analysis in standard format with the details like cause of accident, responsibility, etc. A sample preliminary report is shown below.

6.8 Personal protective equipments

Personal Protective Equipments (PPE) plays a vital role in safety. Depending on the activities involved, PPE is chosen. E.g. as far as masks are concerned there are different types of masks are available but the right choice depends on the activity for which it is to be selected. Generally there are numerous PPE available out of which prominent PPEs are discussed.

Head protection

Falling objects, overhead loads and sharp projections are to be found everywhere on construction sites. Safety helmets protect the head effectively against most of the hazards. Everybody should wear a helmet whenever on site and particularly working in an area where overhead work is going on (Hard-Hat area). This area should be clearly marked with safety signs. Safety helmets have adjustable plastic or terylene head-harness.

6.2 Head protection/ safety helmet

Hearing protection

The noise level in some areas on construction sites are often above the level which causes sensory hearing loss to workers in the vicinity. The common form of protection in industry is ear defender consisting of a head band and cup. There are several types of head bands depending upon helmet attachment. Helmet muffs and ear plugs can also be used. The reductions in noise level are; ear muffs (25%), foam expanding ear plugs (50%), and Combination (75%).

6.3 Hearing protection

Eye protection

The chances of eye accidents are there in jobs like breaking, cutting, drilling, chipping, dry grinding, welding etc. While working on these jobs, goggles, safety glasses or shields are the only practical solutions. Wearing of eyewear is readily accepted, as danger from flying particles and dusts are obvious to most construction workers. Goggles, face shields, and spectacles can also be used against impact, chemicals, molten metal and gas hazards.

6.4 Eye protection

Respiratory protection

On construction sites such as rock crushing, sand blasting, asbestos insulation/dismantling, welding / cutting paint spraying, blasting etc. harmful dust, mist or gas may be present. Whenever there is a presence of toxic substances, respirator must be worn. The correct type will depend upon the hazards and the work conditions.

There are 3 types of face masks:

- Air borne particles
- Gases and fumes
- Both

The simplest mask is disposable paper type against nuisance dust.

6.5 Respiratory protection

Body protection

Skin is extremely vulnerable to all types of hazards in works like painting, welding, sewer works, demolition works, etc. leading to different types of skin diseases. Full sleeved shirts and trousers provide good protection against many of the hazards. In case of ionizing radiation use of shielding layers inside the cloths is necessary

6.5 Body protection

Hand and foot protection

Hands are most important as most of the work is done by hands. They are susceptible to wounds, abrasion, fractures, strains, and also are subjected to environmental variations. Protective gloves solve the purpose of preventing any hazards to hands. Foot injuries can be:

- Due to crushing
- Due to penetration

Safety footwear is of types like:

- Leather shoes- climbing jobs
- Normal shoes- heavy duty work

Rubber safety Wellington shoes- corrosive substances, chemicals and water (with steel toes)

6.6 Hand and foot protection

Safety belts and harness

Major accidents in construction are due to falls from heights where the provision of safe working platforms are impracticable. Wearing of a safety belt or harness and line or lanyard attached to a reliable strong point above the working position will serve the purpose of safety. Full harness is preferable to a safety belt.

Sometimes safety harness is supplemented by use of safety nets. A safety harness and lanyard must;

- limit the fall to a drop not more than 2 m
- Be strong enough to support the weight
- Be attached to strong structure through firm anchorage

In case where rescue operations may arise (underground sewer works) chest or body harnesses is compulsory for the workers.

6.7 Safety belts and harness

High visibility

High visibility of the workers and equipments in construction sites is vital. This has many advantages like:

- Preventing accidents
- Spotting or location accident victim
- Clear identification/separation of the work and equipment

The high visibility clothing maintains a contrast. They should be of vibrant colors with reflective stripes. All the types of PPE discussed so far are available with high visibility.

Some of the disadvantages of PPE:

- Wearing PPE may involve discomfort to the user and slow down the work and reduce efficiency.
- PPE is costly.

But as human life is precious, use of PPE should be mandatory

6.9 Accident costs

Every accident brings with it losses in the form of sacrifice of human life, loss of materials or equipment, injuries to workers etc. In turn accidents also lead to compensation cost. Thus accidents increase the cost of construction and decrease the margin of profit to contractors

They are broadly classified as:

- Tangible or Direct Cost:- The cost which can be easily ascertained or evaluated
- Intangible or Indirect Cost:- The cost which cannot be easily evaluated

6.9.1 Direct cost

Direct cost includes

- Temporary or permanent injury to worker
- Cost of man-hours for the work destroyed
- Loss of equipment
- Loss of material

It is possible to cover some of the direct costs through an insurance policy. If the workers are insured then in case of accident compensation to be given is covered by the insurance company. The value of other losses can be suitably computed using quantity analysis.

6.9.2 Indirect cost

It is not possible to cover the indirect costs through an insurance company. Sometimes they sum up to four times that of the direct cost.

Indirect costs include:

- Transportation: Includes cost of emergency transportation of injured person
- Wages paid to injured workers for time not worked
- Cost incurred due to delays which resulted from accident
- Cost of overtime necessitated by accident.
- Loss of efficiency of crew
- Cost of education for replacement worker
- Cost of cleanup, repair and/or replacement
- Cost for rescheduling: Includes time spent by supervisors, Engineers and foreman to review schedules and the resultant costs of adjusting to the new schedule

- Cost for safety personnel & clerical personnel in case of accidents: Typing, investigation, forwarding forms, etc.
- Cost of legal assistance
- Loss of reputation

6.10 Cost of the safety program

The cost of administering a construction safety and health program usually amounts to 2.5% of direct labor cost

These costs include:

- Salaries for safety, medical and clerical personnel
- Safety meetings
- Inspection of tools and equipments
- PPE
- Health programs such as respirator fit tests
- Miscellaneous supplies and equipments

The net savings to be expected from introducing effective safety program is 4 % of direct labor cost

6.11 Quantification of accidents

- **Injury Frequency Rate (IFR):**
  - The disabling injury means an injury which causes loss of working time beyond the shift or day during which the injury occurs
  - IFR denotes how frequently accidents occur

$$\text{IFR} = \frac{\text{No. of disabling injuries} \times 1{,}00{,}000}{\text{Total no. of Man - hours worked}}$$

- **Injury Severity Rate (ISR):**

$$\text{ISR} = \frac{\text{No. of days lost} \times 1{,}000}{\text{No. of Man - hours worked}}$$

- **Injury Index (II)**

$$\text{Injury Index} = \frac{\text{IFR} \times \text{ISR}}{1,000}$$

Example

On a particular construction project the contractor employed on an average 100 workers with 50 hrs/week. The project lasted for 35 weeks and during this period, 14 disabling injuries occurred. If the no. of days lost due to injuries is 35,

A) Calculate IFR, ISR and II

Solution

$$\text{IFR} = \frac{\text{No. of disabling injuries} \times 1,00,000}{\text{Total no. of Man-hours worked}} = \frac{14 \times 1,00,000}{100 \times 50 \times 35} = 8$$

$$\text{ISR} = \frac{\text{No. of days lost} \times 1,000}{\text{Total no. of Man-hours worked}} = \frac{35 \times 1,000}{100 \times 50 \times 35} = 0.2$$

$$\text{II} = \frac{\text{IFR} \times \text{ISR}}{1,000} = \frac{8 \times 0.2}{1,000} = 0.0016$$