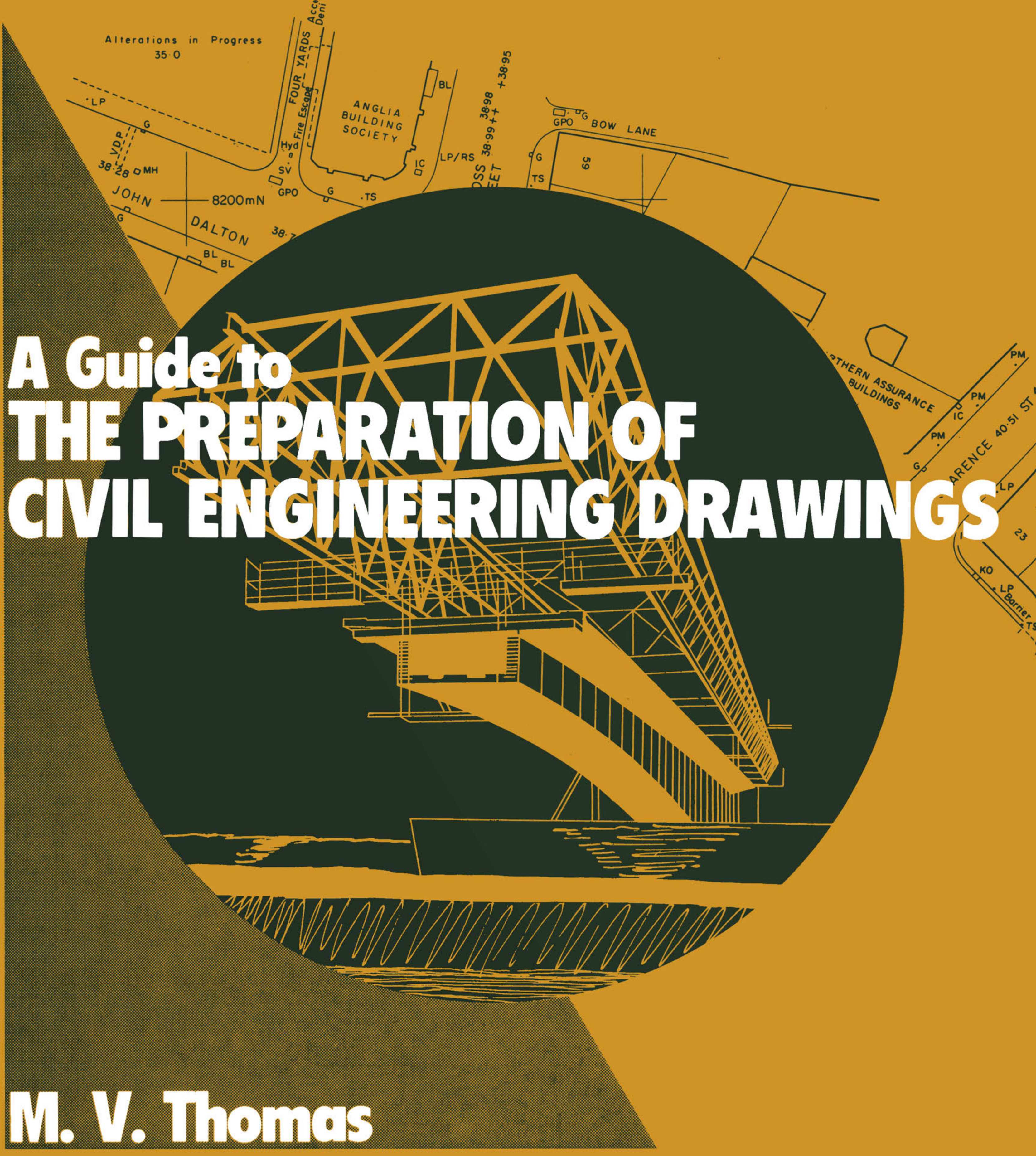
A Guide to THE PREPARATION OF CIVIL ENGINEERING DRAWINGS



M. V. Thomas

A Guide to
The Preparation of Civil Engineering Drawings

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A Guide to THE PREPARATION OF CIVIL ENGINEERING DRAWINGS

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To Glenys
Catherine
Lynette
and Clare

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INTRODUCTION

Although this book is intended primarily as an aid to the young engineer, technician or draughtsman working in a civil engineering design office, the needs of the construction student have also been strongly borne in mind.

The author's aim is not only to describe the general principles of good drawing office practice, but also to illustrate how these principles are applied in many specialised branches of civil engineering. This book should therefore prove a useful source of general reference for both the student and the more advanced reader.

As with any means of communication, drawings must be clear and capable of being interpreted correctly. This can only be achieved by the adoption of recognised standards and conventions and by giving careful attention to style, presentation and layout.

Before even putting pencil to paper, the student reader will gain a better idea of how to decide on the form and presentation of a drawing by seeking the answers to the following three basic questions.

(1) *What is the drawing intended to convey?*
The answers to this question will influence the choice of many factors including the size of the drawing, presentation and layout, the scales to be used, the degree of detail, the style, size and spacing of lettering, the drawing standards and conventions to be adopted.

(2) *Who will read it?*
Drawings may have to be studied by a large number of people each with varying degrees of technical knowledge and quite different requirements. For example, photographs, models and three-dimensional drawings may be more appropriate than detailed plans and sections for exhibitions, meetings and display in public places.

(3) *Where will the drawing be seen?*
The presentation of the drawings and charts for meetings, public enquiries and for similar purposes, requires special consideration. The size of the drawing and the lettering on it may be dictated by the distance between the drawing and the furthest point from which it will be viewed. For example, drawings may be (a) displayed on a board, (b) adapted to a form which will facilitate projection on to a screen, or (c) reproduced and copies handed to each person. Different emphasis will be given to construction drawings as opposed to presentation drawings and this emphasis is dealt with in some detail in chapters 1 and 5.

There are several stages involved with any civil engineering scheme between its inception and completion, and the drawings involved at each of these stages will be distinctly different, as described below.

(1) Preliminary Design
Sketch drawings, preliminary calculations and site investigations are carried out to assess various alternatives for achieving the basic objective. Sufficient information will be required at this stage to consider the feasibility, aesthetics and cost of each alternative.

(2) Approvals
Because of the size and scope of most civil engineering projects, and their impact on the environment and on the public in general, a large number of professional disciplines may be involved in the process of gaining approval for the whole scheme or various aspects of it. The project must receive the approval of the promoter, who may be an individual, private company, government department or Local Authority, so that the necessary funds are allocated to finance the scheme. A variety of statutory bodies, and members of the general public affected by the proposals, are likely to be among those who need to be consulted.

Considerable care must be paid to the presentation of the proposals at this stage so that the necessary approvals are gained in time to allow an adequate period for the all-important task of completing the detailed design, drawings and contract documents.

(3) Detailed Design
The planning of any project must take into account the time and resources required for the preparation of the detailed drawings. Engineering drawings will obviously need to be clear, direct, legible, unambiguous and accurate.

(4) Contract Documents
Drawings are combined with a specification and a bill of quantities which together give the contractor sufficient information to price and construct the permanent works.

(5) Construction
A very important aspect of the construction will be the temporary works required. The contractor will usually be responsible for the design and safety of the temporary works, and he must be allowed sufficient time to prepare his own detailed drawings.

(6) Information and Advertising
Information about the project will usually be given in the promoter's and contractor's own internal magazines and may be of sufficient general interest to be included in a relevant technical journal. Drawings prepared for this purpose will need to be simple and adapted to the extent of the descriptions in the text.

Perhaps because of its broad scope, civil engineering drawing practice has not yet been made the subject of a British Standard. However the revision of BS 1192 planned for 1981 is likely to contain parts more relevant to the needs of the structural and civil engineer. The recommended title for the new Standard is 'Construction Drawing Practice'. The two current Standards are

BS 308:1972 Engineering Drawing Practice – for the mechanical engineer, and

BS 1192:1969 Building Drawing Practice – for the architect and builder.

There are several standards on detailing, of which the most commonly used are probably the following.

(1) *The Standard Method of Detailing Reinforced Concrete* prepared by the Concrete Society and the Institution of Structural Engineers. Prior to this standard the many methods which were used for the detailing and scheduling of reinforcement gave rise to a great deal of confusion.
(2) *Metric Practice for Structural Steelwork* by the British Constructional Steelwork Association Limited.

This book divides broadly into four parts. The first deals with the basic general principles of drawing office practice, including recognised conventions. The second briefly describes sketching techniques and three-dimensional drawings. (A knowledge of the basic principles of perspective and sketching will be useful to any engineer, technician or draughtsman, since sketching is a commonly used form of communicating ideas during discussions on both aesthetic and technical matters.) The third deals with developments in the use of the computer for drawing and detailing. The fourth shows drawing examples typical of those prepared in some of the specialist branches of civil engineering. In order to achieve continuity and to simplify descriptions in the text, most of the detailing illustrations have been drawn from just a few typical, but small, civil engineering projects.

The author believes that the frequent references to the relationship between drawing preparation and construction practice, and photographs of a variety of civil engineering works, will promote in the student an interest in civil engineering in general and the preparation of drawings in particular.

1. GENERAL PRINCIPLES

1.1 INTRODUCTION

There are many principles associated with drawing office practice that can be applied generally to most branches of civil engineering. It is with these principles that this chapter is chiefly concerned. For ease of reference, most of the more commonly used conventions have been gathered together in section 1.3.6.

1.2 DRAWING INSTRUMENTS

Every draughtsman will need his own personal set of drawing instruments (figure 1.1) which will probably include small set squares, ruling and lettering pens, compasses, protractor and pocket scales. Other instruments and materials will usually be provided by the employer.

The reader is advised to be selective and to buy the best quality instruments that he can afford. Every draughtsman will have his own ideas about the number and type of drawing instruments he will need. It would be impossible to describe here all the different instruments available and the following selection reflects the author's own preference.

1.2.1 Pump Bow Compasses (figure 1.2)

This pair of compasses is used for very small circles up to approximately 10 mm in diameter and its vertically adjustable

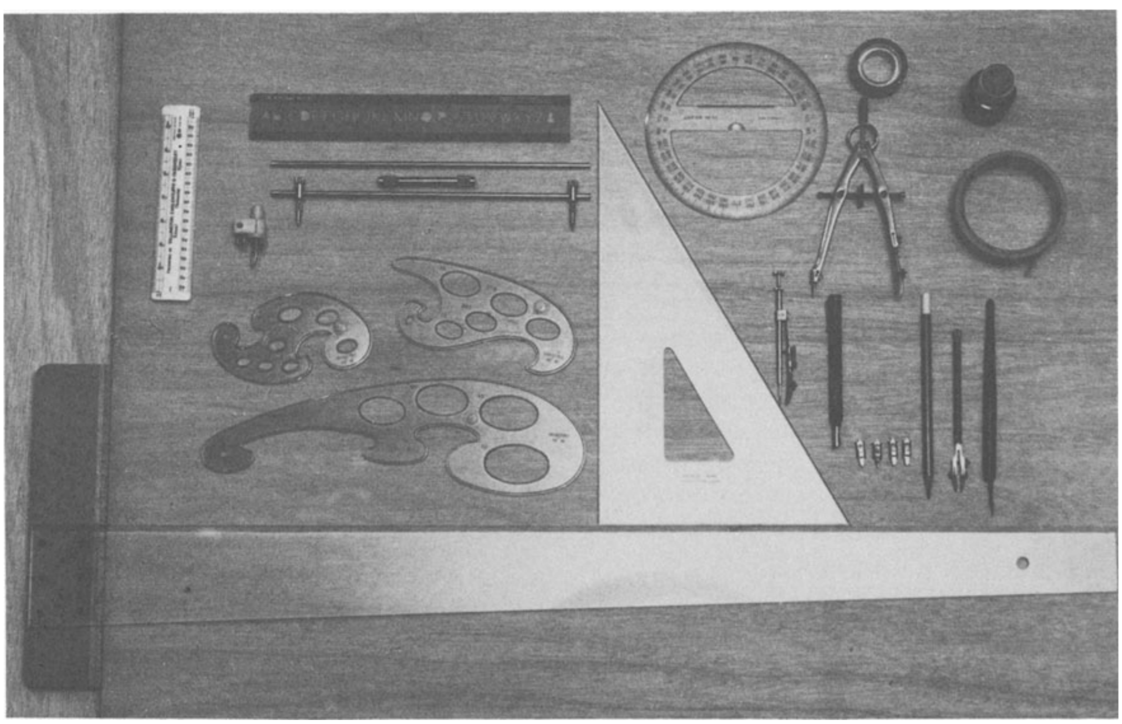


Figure 1.1 Drawing instruments for personal use

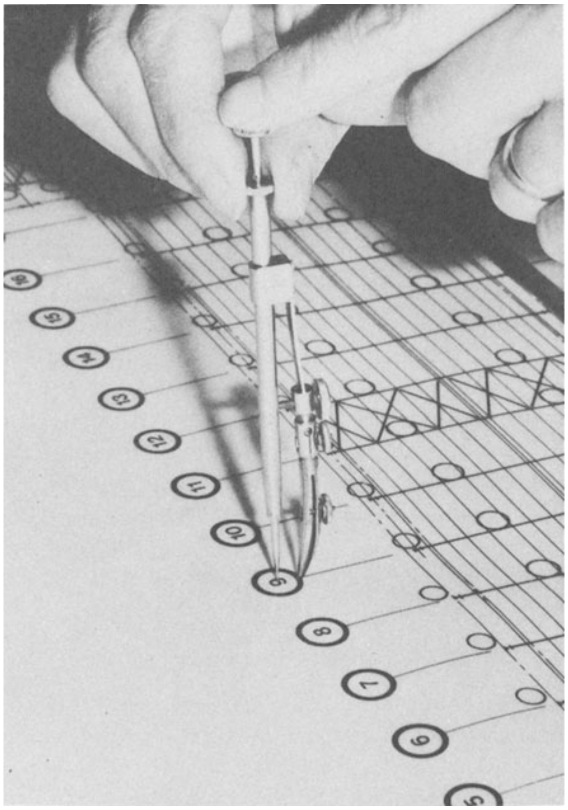


Figure 1.2 Pump bow compasses

compass point allows the pencil or ink blade to be raised above the drawing sheet while the point is located at the required circle centre.

1.2.2 Large Spring Bow Compasses (figure 1.3)

The knee joint on the blade arm enables the blade to be set perpendicular to the drawing sheet. This pair of compasses is used for small circles between approximately 10 mm and 200 mm diameter.

Note that with the pump bow and spring bow compasses the arms are positively held apart by the spindle of the adjusting screw, thus preventing movement of the arms while the circle is being drawn.

1.2.3 Beam Compasses (figure 1.4)

Beam compasses give a range of radii between 200 mm and 1200 mm and have the advantage that both the point arm and blade arm are not only positively held but remain at right angles to the sheet no matter how large the arc.

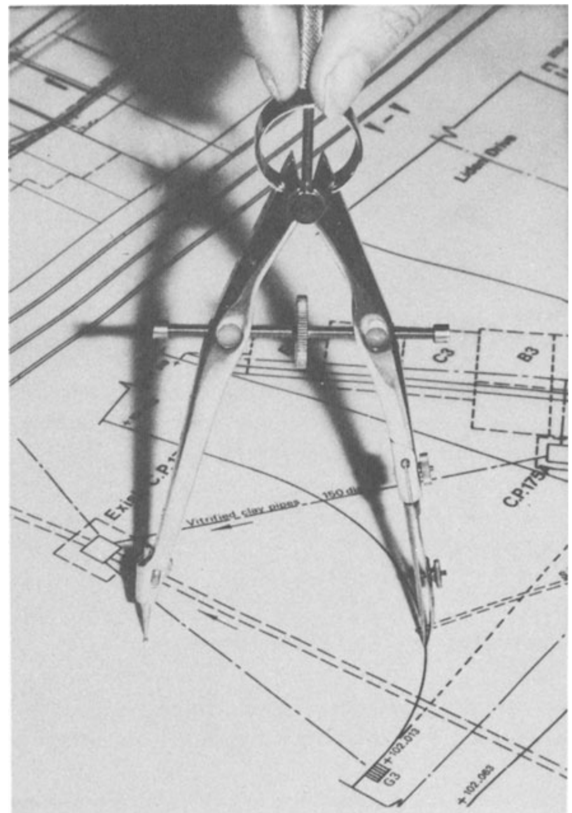


Figure 1.3 Large spring bow compasses

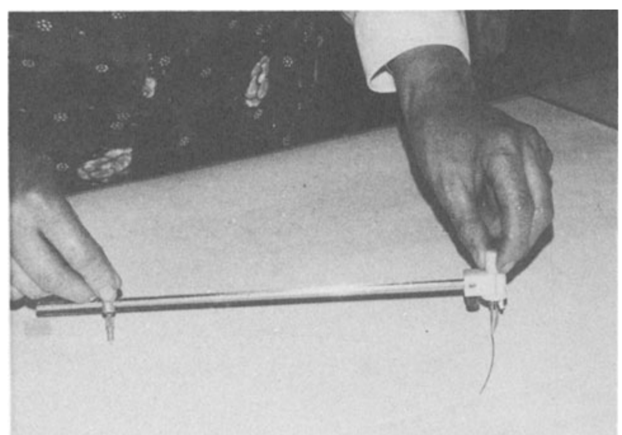


Figure 1.4 Beam compasses

1.2.4 Drawing Pens

Adjustable-blade ruling pens have generally been replaced by pens with interchangeable nibs. There are two basic types:

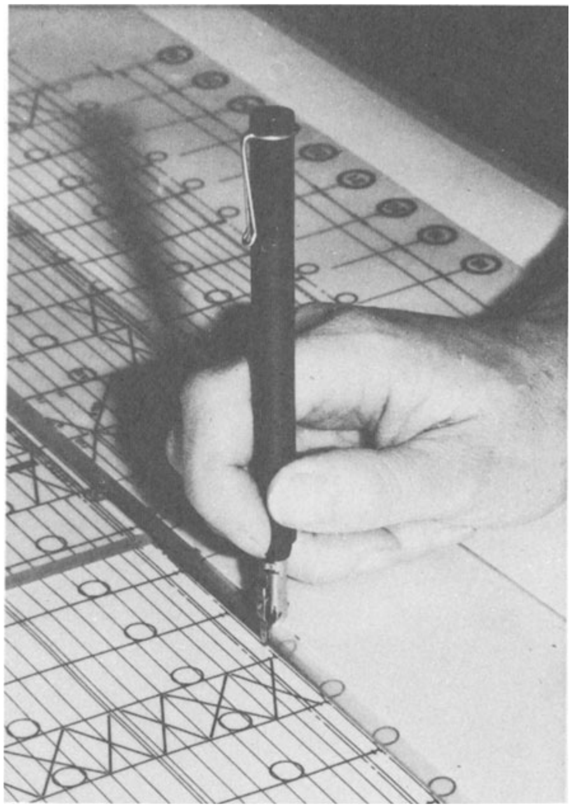


Figure 1.5 Rotring Graphos drawing pen

one has nibs with tubular points, and the other has both nibs with pivoted blades for ruling and nibs for lettering. The Rotring 'Graphos' pen (figure 1.5) can be fitted with 3 nib styles and a total of 25 different nibs.

1.2.5 Proportional Dividers

These are used for transferring dimensions from one drawing to another of differing scale.

1.2.6 Set Squares

A large (300 mm long at least) 45° set square, a 30/60° set square for pencil and ink work, and a large adjustable type for pencil work will be indispensable. Most draughtsmen will probably prefer the single bevel-edged Perspex type, with the bevel facing the drawing sheet for ink work. However, square-edged set squares, with some attachment for raising the edge slightly above the surface of the drawing sheet, may be more suitable for use in conjunction with parallel motion straight edges.

1.2.7 Tee Squares

A large number of drawing offices now have either drawing boards fitted with parallel motion straight edges, or draughting machines. These have generally superseded tee squares, which are more difficult to manipulate and less efficient. Tee squares will, however, be found useful for home and site office use and in college classrooms where space may be limited. The author recommends a single bevel-edged, transparent Perspex type with the blade fixed to the handle with countersunk screws. Tee squares will need to be checked frequently for straightness and squareness.

1.2.8 Protractors

A fully divided, complete-circle type of at least 150 mm diameter is recommended.

1.2.9 Scales

Scale rules should preferably be fully graduated. The oval-section four-scale type will be adequate for most purposes. For plotting and measuring survey and similar small detail, however, a narrow-edged scale graduated on one side only and flat on the other is more suitable. The graduations will then be close to the drawing sheet, the scale can be held more firmly against the sheet, and the figures are less likely to be worn off through abrasion. (Scales are intended for measurement only and should not be used as a paper knife or for drawing lines.)

1.2.10 French Curves

Smooth, non-circular and irregularly shaped curves are best drawn by means of French curves.

The following drawing instruments will probably be supplied by the employer for the use of the drawing office as a whole.

1.2.11 Steel Straight Edges

Steel straight edges are important items of drawing office equipment and should be cleaned after every use and returned to a closed box. They are durable and less susceptible to temperature changes and humidity than other straight edges, and are therefore useful for very accurate drawing measurements and for checking the straightness of set squares, tee squares and drawing board surfaces and edges.

If a steel straight edge is required for cutting then it should be used only for this purpose, a separate straight edge being reserved for drawing. Only the thick square edge should be used for cutting. (The tip of many a finger has been sliced off using a cutter against the bevel side of a straight edge.)

1.2.12 Railway Curves

Railway curves are circular curve templates, each of which has been formed to a different radius in regular increments. They are commonly used in road and railway design.

Pencils, rubbers, erasers, sand-paper blocks, stencils, large beam compasses, and flexible rules are among the equipment usually supplied for general office use.

1.3 DRAWING OFFICE PRACTICE

The two British Standards relating to drawing practice have been referred to in the Introduction. Basic practice will vary in some respects between one organisation and another, depending on the nature of the work undertaken. The recommendations of BS 1192 may, for example, be adopted throughout an organisation which deals principally with the design of buildings. Most civil engineering drawings will probably combine recommendations given in both Standards until the revised BS 1192 is available.

Practice may also vary in other respects. Where drawings will only be required for relatively short periods, the practice may be to draw in pencil directly on to tracing paper for subsequent reproduction. Alternatively, in another office, drawings may be prepared first in pencil on cartridge paper, and then traced in ink on to sheets of polyester film or tracing paper.

1.3.1 Drawing Sizes

Recommended drawing sheet sizes are shown in table 1.1. Commonly used sizes are A0 and A1, although smaller sizes may be preferred for small standard or typical details and for ease of handling on the site of the construction works.

Table 1.1 Drawing sheet sizes

Designation	Size (mm)
A0	841 × 1189
A1	594 × 841
A2	420 × 594
A3	297 × 420
A4	210 × 297

An A0 sheet has an area of 1 m^2. All sheets in the A series have sides in the proportion $1:\sqrt{2}$. The sides of 35 mm film have the same proportions, which facilitates microfilming.

1.3.2 Scale Ratios

The correct choice of scale is an important factor which is decided after a careful consideration of the amount and form of the information to be conveyed on the drawing. Once the content and layout of the drawing have been established, clarity then becomes the predominant factor in the choice of the scale.

When a drawing is to be reproduced in a reduced or enlarged form (for example, microfilming or photocopying) it may be advisable to draw a diagram scale on the original drawing or negative. Examples of scale ratios used are shown in table 1.2.

Table 1.2 Scale ratios

Type of Drawing	Recommended Scale Ratios
Location plans	1:5000, 1:10 000, 1:10 560
Site plans	1:2500, 1:1250, 1:500
Road and sewerage layout plans	1:1250, 1:500, 1:200, 1:100
Road and sewerage longitudinal sections	Vertical – 1:5, 1:10, 1:20, 1:50 Horizontal – 1:1250, 1:500, 1:200, 1:100
General arrangement drawings	1:200, 1:100, 1:50
Detail drawings	1:20, 1:10, 1:5, 1:25, 1:1

1.3.3 Line Types and Thicknesses

The line types recommended in BS 308 and BS 1192 should be adopted where applicable (figure 1.6). Line types relating to reinforced concrete detailing are shown in chapter 7.

When drawings are to be microfilmed, wherever possible a line thickness should be chosen so that the thinnest line on the smallest print to be made from the microfilm will have a width of not less than 0.25 mm. Lines should be so spaced that in the smallest print to be made from the microfilm they will not be less than 0.5 mm apart.

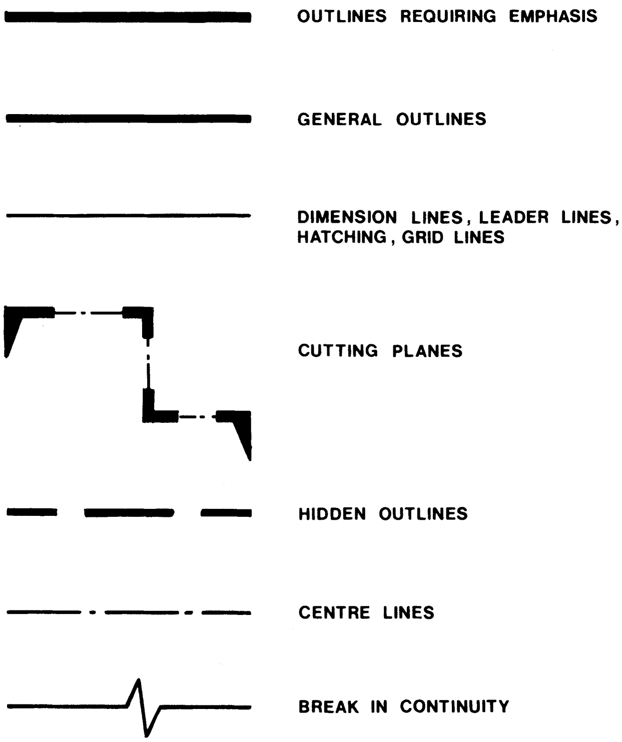


Figure 1.6 Types of line

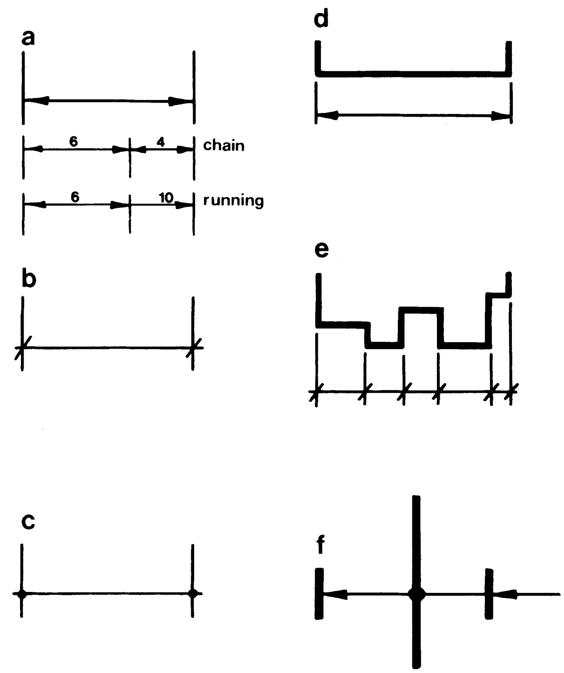


Figure 1.7 Types of dimension line

1.3.4 Dimensioning

There are three common methods of representing the ends of dimension lines (figure 1.7). The 'arrow' shown in figures 1.7a and d is recommended for civil engineering drawings. The 'dash' shown in figures 1.7b and e has particular advantages where there are a large number of short dimension lines on a drawing. The 'dot' shown in figure 1.7c is not recommended and should be confined to leader lines as shown in figure 1.7f. Note that figures on running dimension lines are shown next to the arrowhead.

Clear, consistent and well-arranged dimensioning is particularly important on detail drawings. The recommendations of BS 308 should be strictly followed when detailing machined metal components which need to be manufactured to fine tolerances. In addition to the accuracy of the dimensions themselves, the method of arranging the dimensions on the various views could also have an effect on the accuracy of the finished product. Chain dimensioning should not be used on such drawings. Three datum planes, from which all dimensions are taken, should be decided for each separate component, or in some cases, a series of components. These planes will usually be coincident with the outermost sides or, in the case of circular and other symmetrical parts, the centre lines of the component.

Generally the following conventions should be adopted.

(1) The least number of dimensions for the complete definition of the finished product should be shown, but each should generally appear only once on the drawing. However there are exceptions as in (4) below.
(2) It should not be necessary to deduce any dimensions. Dimensions relating to a particular feature should preferably be placed adjacent to a single view rather than on several.
(3) Generally, dimensions should be given in millimetres if less than 1 m, and in metres and decimals of a metre if greater than 1 m. Dimensions on reinforced concrete and structural steelwork details are generally shown wholly in millimetres. Metres should be written to three places of decimals.

Examples:	31.500 m	12 500	0.5 mm
	decimal point	space	zero

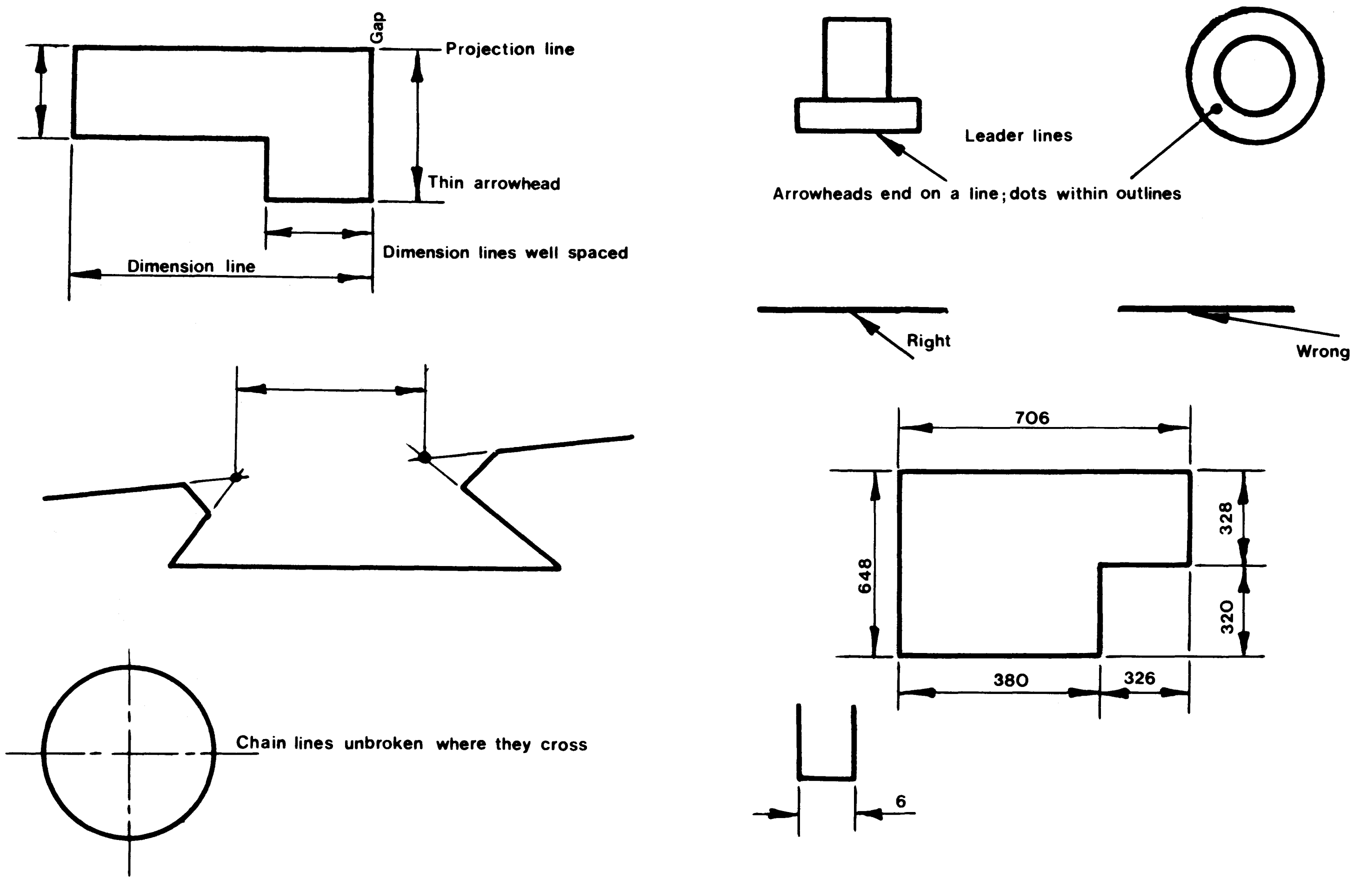


Figure 1.8 Dimensioning

Where drawings are dimensioned in one unit, the unit abbreviation may be omitted provided the drawing carries a note stating which units are used.

(4) Leader lines should not be parallel to adjacent dimension or projection lines where confusion might arise. Long leaders should be avoided even if this means repeating dimensions or notes.

(5) Dimension lines should be placed parallel to the line being dimensioned. They should not coincide with a centre line or the extension of a centre line.

(6) Projection lines should not cross other lines if this can be avoided. If they must cross, they should do so without a break. Projection lines should be broken where they conflict with an arrowhead, but not when they cross a figure.

(7) Figures and letters should be placed near the middle of (except for running dimensions) and above and clear of, the dimension line, and in such a way that they are not crossed or separated by any other line of the drawing. Figures should be placed so that they can be read from the bottom or from the right of the drawing.

The conventions described above, and other dimensioning techniques, are illustrated in figures 1.8, 1.9, 1.10 and 1.11 although these dimensioning principles need not always be strictly applied to civil engineering drawings. For example, from a consideration of accuracy alone, chain dimensioning would be a suitable method of showing the arrangement of the mains in figure 1.12. The dimensioning shown is that which is the most appropriate for the installation and location purposes. The needs of the various trades involved in the construction should be considered when a civil engineering structure is being detailed and these may necessitate more dimensions on the drawing than are absolutely necessary to define the structure.

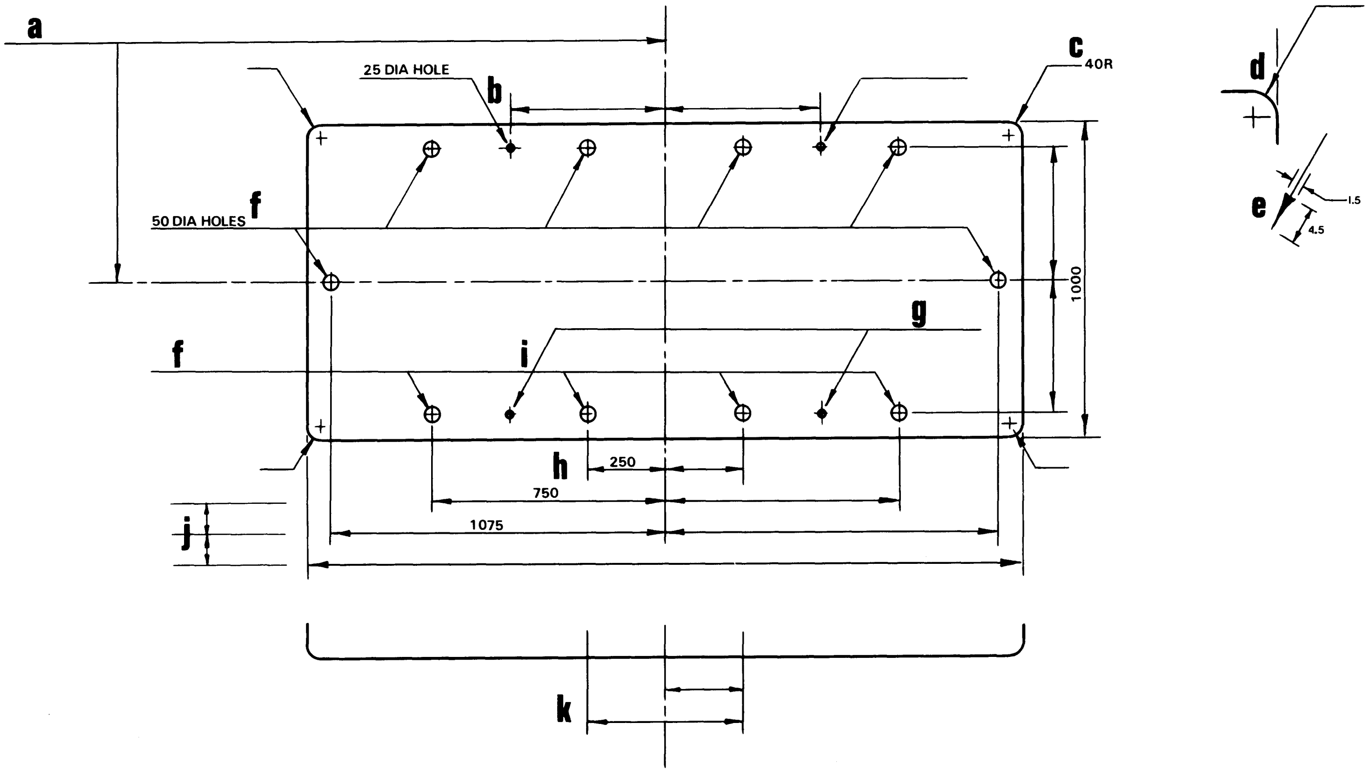


Figure 1.9 Dimensioning principles

- **a** Centre lines are the datum lines.
- **b** Single leader line to hole in order to avoid crossing other lines. Leader underlines note.
- **c** Arrowhead points towards the radius centre. Short horizontal tail to leader which extends towards the centre of the note.
- **d** Projection line broken where it crosses an arrowhead. Ends of leaders at a fixed angle of approximately 60° to the horizontal where possible gives a neater appearance to the drawing.
- **e** Narrow arrowhead.
- **f** Leaders taken within the outline of the view to avoid undue crossing of dimension lines. An alternative method of indicating the diameters would be to reference each hole with a number or letter which is then defined in the general notes. A reference at each hole would not have been necessary if all the holes had been the same size (see figure 1.13).
- **g** Direction of leader lines reversed to avoid confusion with the leaders to the large holes.
- **h** Shortest dimensions placed nearest to the outline of the view. Dimensions staggered to avoid congestion.
- **i** Leaders cross without a break.
- **j** Adequate and even spacing between dimension lines (approx. 10 mm). Over-all dimensions of plate situated so as to avoid crossing leader lines.
- **k** A more suitable method of dimensioning where a high degree of accuracy is required to locate the holes. One hole is dimensioned from the centre line of the plate and the other hole is dimensioned from the first hole.

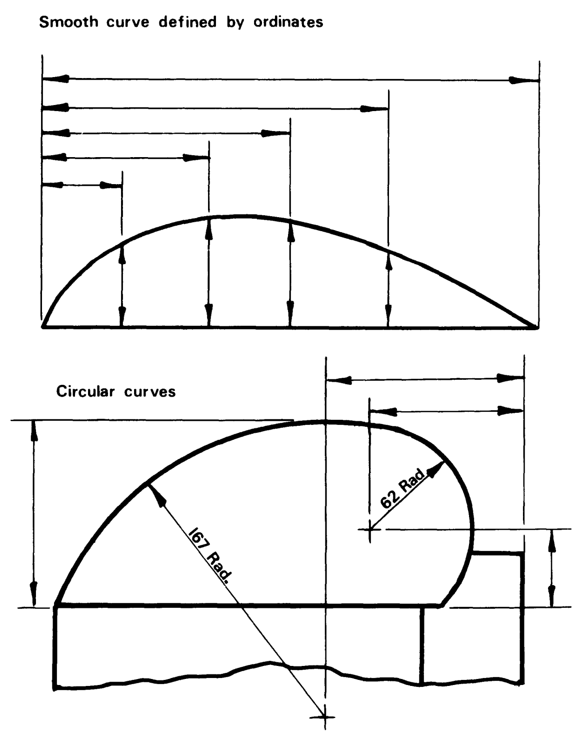
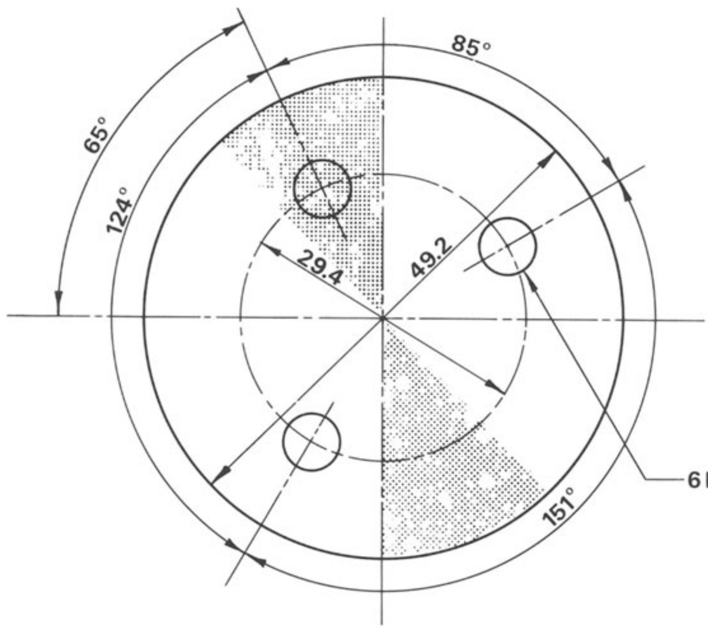
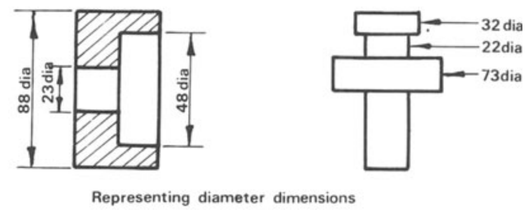


Figure 1.10 Dimensioning circular and non-circular curves



(a)



(b)

Figure 1.11 (a) Dimensioning circles; (b) diameter dimensions – diametral dimensions should not be placed within the shaded areas shown; usually whole circles are defined by the diameter, and circular arcs by the radius

1.3.5 Lettering

Lettering should be clear, simple and legible. Care should be taken with the size, shaping and spacing of individual letters, and the arrangement of notes on the drawing.

The size of lettering must be considered in relation to its purpose on the drawing. Table 1.3 shows suggested minimum character heights.

The style of lettering should be bold and in a consistent upright or sloping form (figures 1.13 and 1.14). In certain types of special presentation drawings, however, an ornamental style may be appropriate (figure 1.15).

The lettering on a finished drawing may be that of the draughtsman or a tracer. Even if a drawing is to be traced, the draughtsman must write clearly and arrange the lettering in the correct position on the original drawing.

Lettering may be formed with (1) pencil (2) ink, using stencils or pens, or (3) transfers.

1.3.6 Conventions

Although the layout and presentation of information on drawings may vary, recognised standard conventions should be adopted wherever possible.

There are standard conventions for the representation of building materials and components, geological data, land surveying information and many more. A variety of statutory bodies and other large organisations have established conventions for representing their own mains, services and plant.

Figure 1.16 shows the method of representing some commonly used constructional materials in section. Colour representation of materials is shown in table 1.4. Materials shown in section are coloured darker than those that are not sectioned.

The way in which rocks and soils are represented on geological sections and borehole logs is shown in figure 1.17.

The hatching of metal components represented in section is shown in figure 1.18. In this case, hatching is used on sections to identify different components of a product. Separated areas of a section of a single component should be hatched in an identical manner. The hatching of adjacent components should be carried out at different angles. The spacing of hatching lines should be in proportion to the size of the hatched section, thus the spacing of the lines should be greater on the larger components.

In the case of large areas, the hatching may be limited to a zone following the contour of the hatched area. Where sections of the same part in parallel planes are shown side by side, the hatching lines should be similarly spaced, but offset along the dividing line between the sections. The use of

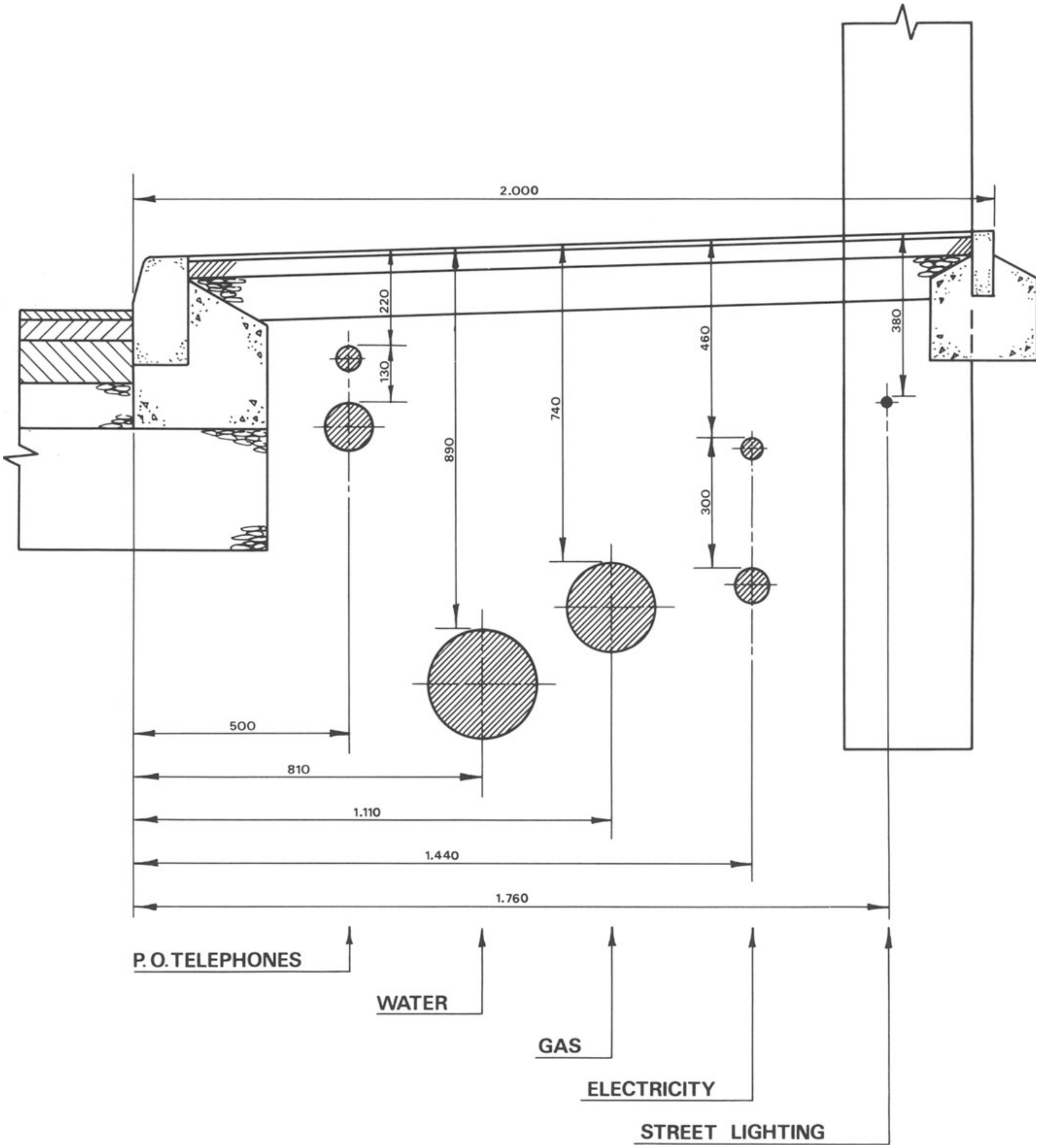


Figure 1.12 Dimensioning: typical section showing layout of Public Utilities mains

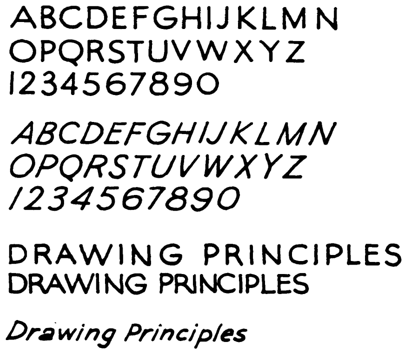


Figure 1.13 Hand lettering

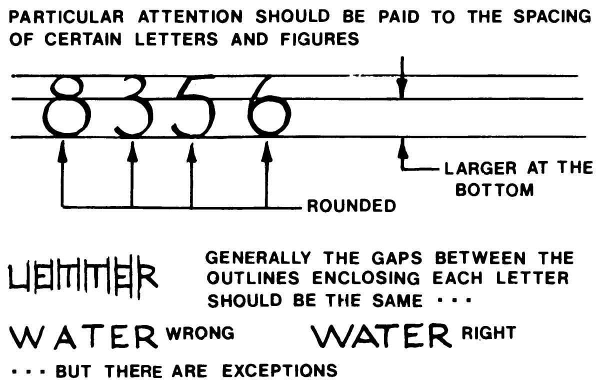


Figure 1.14 Lettering

Table 1.3 Character heights (BS 308)

Application	Drawing Sheet Size	Minimum Character Height (mm)
Drawing numbers, etc.	A0, A1, A2 and A3	7
	A4	5
Dimensions and notes	A0	3.5
	A1, A2, A3 and A4	2.5

Table 1.4 Colour representation of materials

Material	Colour
Brick	Vermilion or brick red
Concrete (in situ)	Hooker's green
Earth	Sepia or Vandyke brown
Hardcore	Chrome yellow medium
Wood (unwrot)	Raw sienna
Wood (wrot)	Burnt sienna
Concrete (precast)	Yellow
Cast iron	Payne's grey
Steelwork	Steel
Mortar, screed, render	Sap green
Glass	Pale blue

Figure 1.15 Styles of lettering

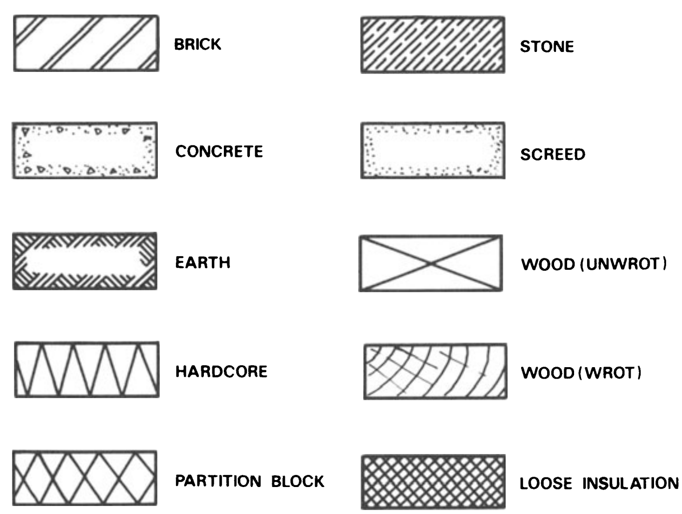


Figure 1.16 Representation of building materials in section

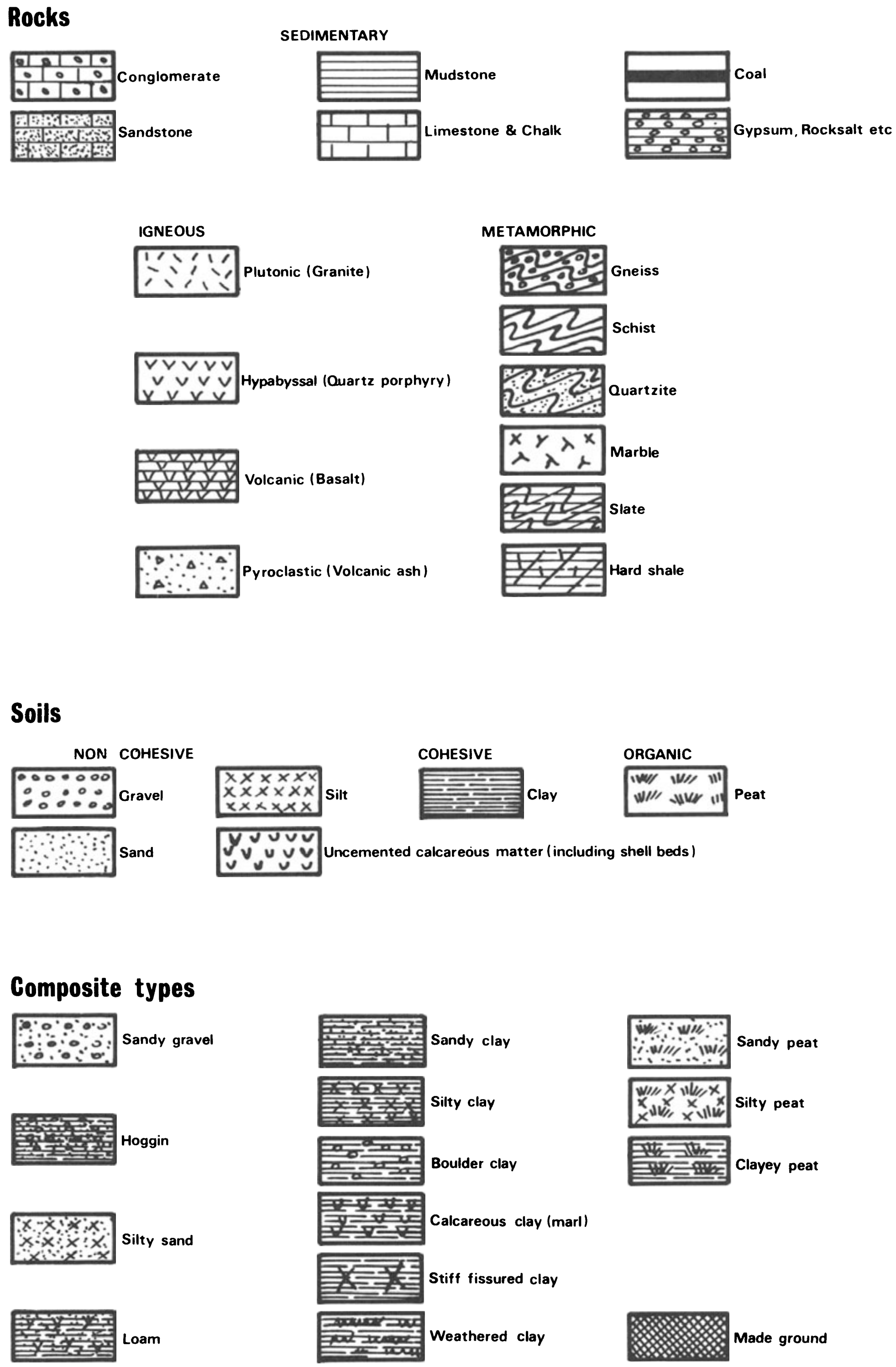


Figure 1.17 Representation of rocks and soils

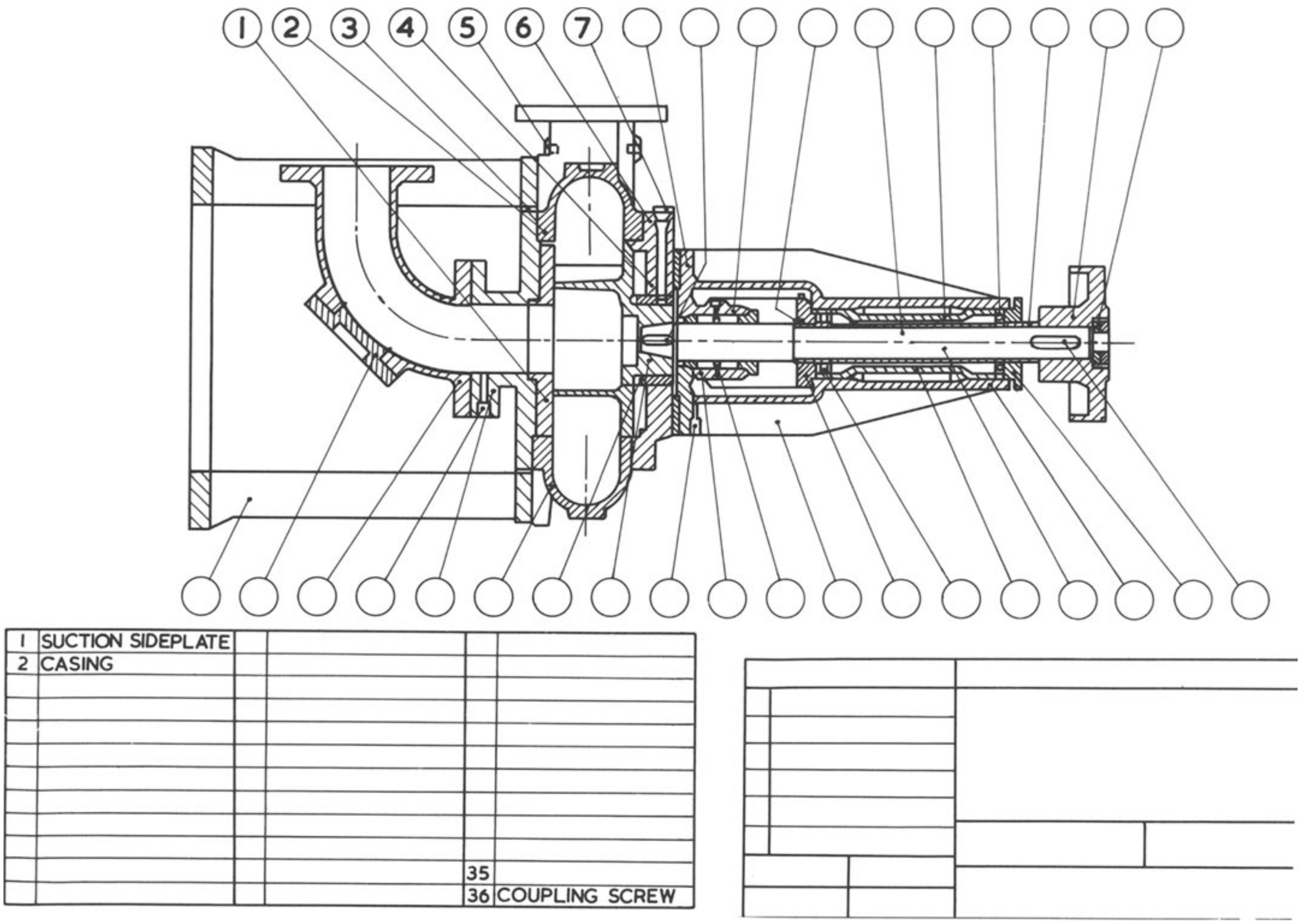


Figure 1.18 Section through a pump

hatching, leader lines to components, and a component schedule are illustrated in figure 1.18.

Commonly used abbreviations and graphical symbols are given in BS 1192. Abbreviations may be misinterpreted and should be used with care.

Recognised symbols for use on land surveying plans are shown in figure 1.19.

The importance of showing both existing and proposed gas, water, electricity, postal telecommunications, sewerage and other mains and plant clearly on drawings cannot be overstressed. The organisations that have been established by Acts of Parliament (Statutes) to provide these services are called Statutory Undertakers and a brief description of their activities and powers has been included in appendix III. It may not be possible to adopt the same conventions that these various bodies use for their own purposes when, as is often the case, information on all these mains needs to be shown on the same drawing. Where this is necessary, the following points should be considered.

(1) Use a key (as shown in table 1.5, for example) on negatives and distinguish different mains from each other by using different line types. Do not rely on colouring alone, otherwise reference will have to be made to the office copy each time a copy print is prepared.
(2) Different mains belonging to the same Undertaker can be distinguished from each other by using different line thicknesses coupled with notes describing each main at intervals along its route and either side of points at which there is a change of description.

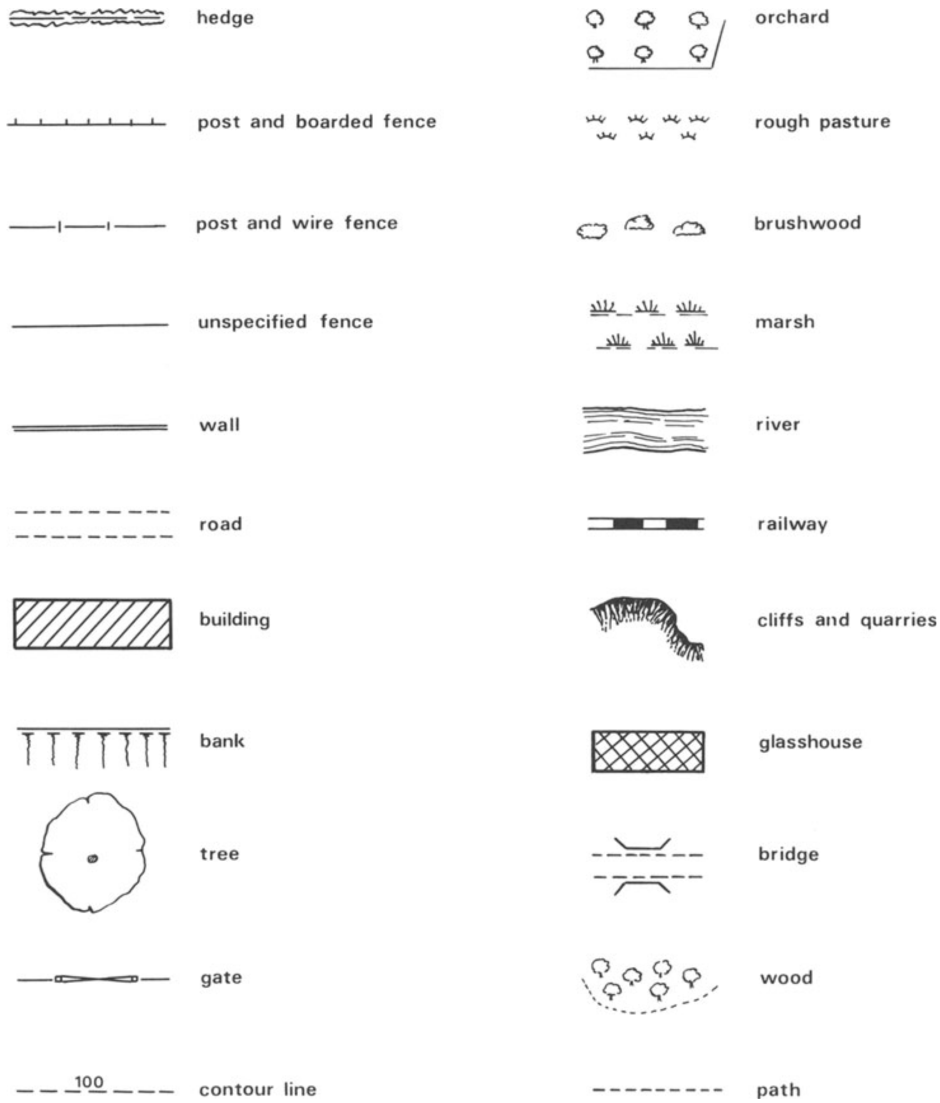


Figure 1.19 Symbols used on land surveying plans

(3) Ensure that the line type proposed cannot be confused with other features, for example, fences and kerb lines. This can be achieved, if necessary, by adjusting the line thicknesses and spacing.

(4) Standardise on the colours used to represent each of the Undertakers' mains and plant. Use contrasting colours.

There are limits to standardisation, and the adoption of the above suggestions may not be desirable or possible in every case.

Table 1.5 Representation of Statutory Undertakers' mains

MAIN	LINE TYPE	COLOUR
ELECTRICITY	——— - - ——— - - ——— - -	PURPLE
	——— - - Street lighting - - ———	MAUVE
WATER	——— - ——— - ——— - -	GREEN
GAS	——— ——— ——— ———	ORANGE
POST OFFICE	——— - - - ——— - - - -	BROWN
FOUL WATER SEWER	●———————————●	RED
SURFACE WATER SEWER	○— — — — — — — ○	BLUE
DISUSED MAIN	—✕— —✕— —✕— —✕—	

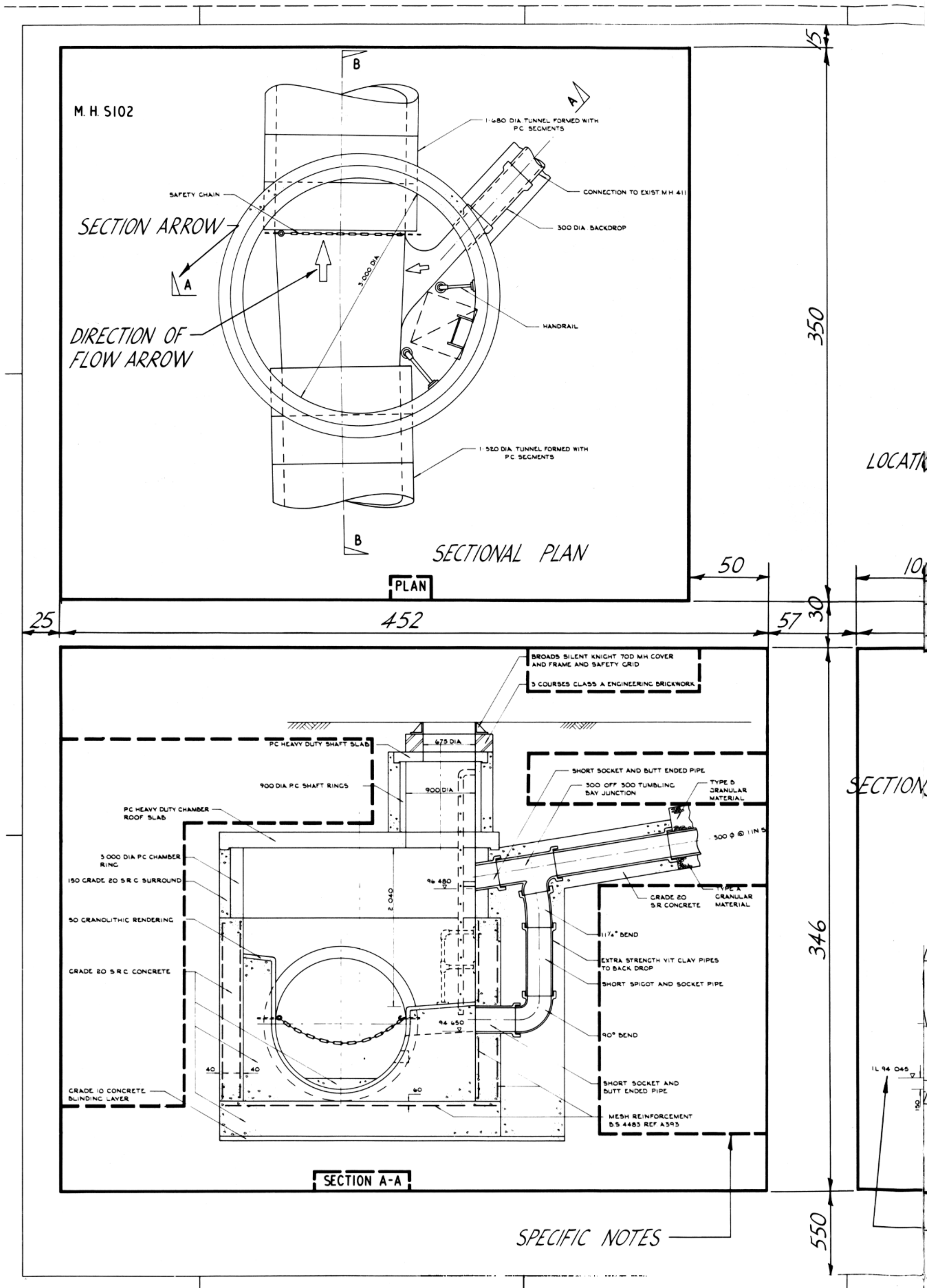
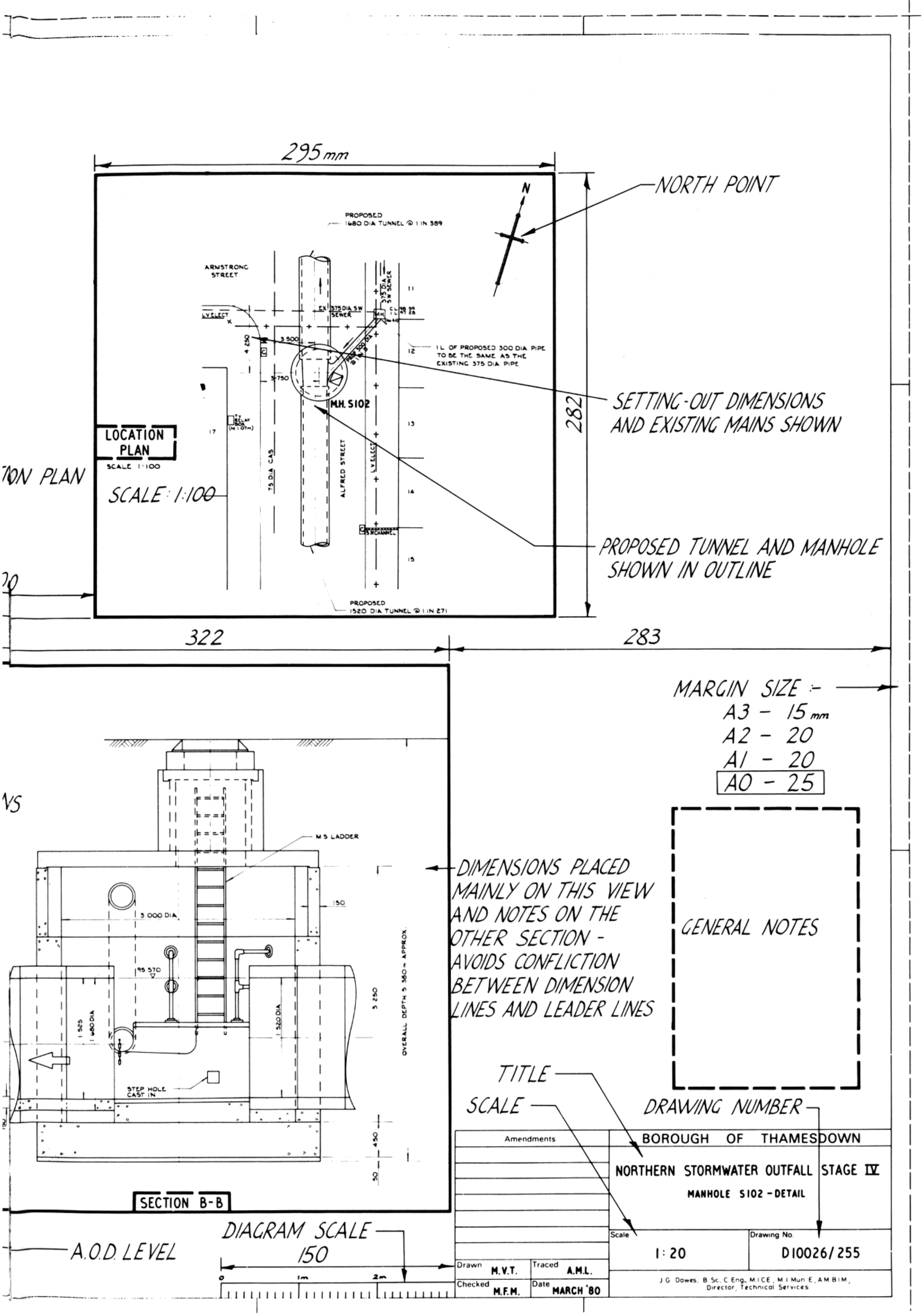


Figure 1.20 Layout of views


295 mm
NORTH POINT
N
PROPOSED 1680 DIA TUNNEL @ 1 IN 389
ARMSTRONG STREET
LOCATION PLAN
SCALE 1:100
M.H. S102
ALFRED STREET
75 DIA GAS
LV ELECT
I.L. OF PROPOSED 300 DIA PIPE TO BE THE SAME AS THE EXISTING 375 DIA PIPE
PROPOSED 1520 DIA TUNNEL @ 1 IN 271
SETTING-OUT DIMENSIONS AND EXISTING MAINS SHOWN
282
PROPOSED TUNNEL AND MANHOLE SHOWN IN OUTLINE
SCALE: 1:100
322
283
MARGIN SIZE :-
A3 - 15 mm
A2 - 20
A1 - 20
A0 - 25
M S LADDER
3 000 DIA
95 570
1 525
1 680 DIA
1 520 DIA
5 250
OVERALL DEPTH 5 380m APPROX
STEP HOLE CAST IN
150
450
50
SECTION B-B
DIMENSIONS PLACED MAINLY ON THIS VIEW AND NOTES ON THE OTHER SECTION - AVOIDS CONFLICTION BETWEEN DIMENSION LINES AND LEADER LINES
GENERAL NOTES
TITLE
SCALE
DRAWING NUMBER
Amendments
BOROUGH OF THAMESDOWN
NORTHERN STORMWATER OUTFALL STAGE IV
MANHOLE S102 - DETAIL
Scale
1:20
Drawing No.
D10026/255
Drawn M.V.T.
Traced A.M.L.
Checked M.F.M.
Date MARCH '80
J.G. Dowes, B.Sc., C.Eng., M.I.C.E., M.I.Mun.E., A.M.B.I.M., Director, Technical Services
A.O.D. LEVEL
DIAGRAM SCALE
150
0
1m
2m

1.4 HEALTH AND ENVIRONMENT

Before dealing with the mechanical techniques of drawing, the various needs of the draughtsman will be discussed. The health of the draughtsman must be considered to be of paramount importance. Eye strain, back ache and foot complaints are the obvious ailments which can result from working under poor lighting conditions with equipment that requires an unsatisfactory working posture.

Equipment should be provided that permits comfortable working at all points of the drawing board with the minimum of hand movement, and which allows the draughtsman to change his position without loss of efficiency. An upright drawing board, which can be adjusted in both height and angle of tilt, will make for the greatest efficiency and comfort. The use of tee squares and set squares on large detailed drawings can be particularly fatiguing and inconvenient when working at the right-hand side of the board.

Horizontal boards necessitate a bad working posture, and can result in a greater number of draughting errors near the top of the drawing where the maintenance of a convenient working position is most fatiguing. Survey plotting and similar intricate work, for which illuminated boards are often used, must be done on a horizontal surface – the periods during which this type of work is carried out should not be prolonged.

Basic equipment may, however, be quite adequate for those engineers who do not spend long periods at the drawing board, and who might in fact consider draughting machines to be an encumbrance when they are not drawing.

Ventilation, temperature and lighting must be carefully considered. Natural light is better than artificial light. There should be a good over-all standard of lighting throughout an office, while use of diffusers and screens may sometimes be necessary to reduce glare.

A reference bench large enough to accommodate A0 sized drawings should, if possible, be provided adjacent to each drawing board. In addition to this there should be sufficient space available for placing drawing instruments when not in use. Reference facilities at the side of the drawing board, rather than behind the draughtsman, will be far more convenient.

It should be borne in mind that some people may put physiological and safety considerations at the bottom of their list of priorities if other needs are being met – the fact that no one in an office is complaining may not necessarily mean that the working conditions are satisfactory.

1.5 LAYOUT

The clarity of a drawing will depend to a major extent on the correct choice of scale, and the layout of the views, lettering and dimensions.

The student draughtsman may be tempted immediately to start drawing in the detail of the views before first giving careful thought to their arrangement on the drawing. Such a mistake is likely to lead to a complete redrawing of all the details. Ten minutes spent in calculating the positions of views, notes and dimensions may save several hours of redrawing (see figure 1.20).

The following procedure is suggested in order to achieve a good result at the first attempt.

(1) Determine the scale ratio or alternative ratios that will be required to show all the details on the drawing clearly. Use as a guide the recommendations given previously in this chapter and in chapter 7.

(2) Decide on the amount of information that should be shown on the drawing. If a set of drawings for the same structure is required, the information to be shown on each drawing should be determined, if possible, before the layout on any of the drawings is finalised.

(3) Calculate the over-all dimensions of the sheet required to enable all the views, dimensions and notes to be shown clearly. Consider only the rectangles touching the extremities of each view and allow for the positioning of dimension lines, title and notes, and for ample space between the views. Standardisation of the drawing size may be desirable for ease of filing and handling. The content of each drawing will then also be influenced by this consideration.

(4) Draw in feintly the basic outlines of the views, dimension lines and any centre lines. List all the notes that will be required, separating those that are specific to a particular part of the structure from the general notes. Arrange the position of the notes on the drawing by means of feint guidelines only. Sketch out the basic arrangement on scrap, or cheap detail paper, together with the complete written descriptions of all the notes, titles and dimensions, and place it at the side of the board for reference.

(5) Complete the details, then the dimensions, followed by the notes and titles.

Careful consideration should be given to the description and composition of titles, and their arrangement in the title block. Figure 1.21 shows a typical title block arrangement using both stencils and transfers.

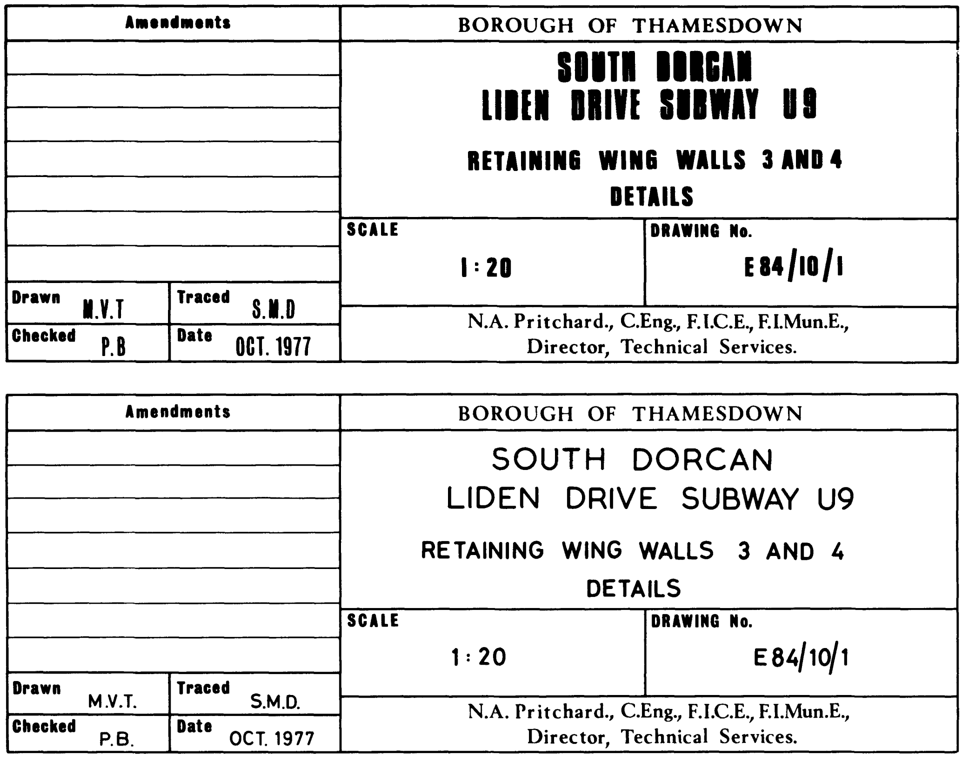


Figure 1.21 Title block

Notes on drawings should be as brief as possible consistent with clarity. General notes should be collected together and arranged in a panel at the edge of the drawing. Specific notes should be situated near the detail to which they relate.

1.6 DRAUGHTING, TRACING AND COLOURING

Most civil engineering drawings are produced in negative form to facilitate reproduction. The quality of the final print will depend on

(1) the graphic presentation ability of the draughtsman and tracer
(2) the quality of the drawing materials and equipment used
(3) the method of reproduction used.

The drawing process may involve either a pencil draught on paper which is then traced in either ink or pencil, or a pencil or ink drawing directly on to the negative.

Specialist tracers and detailers are employed in many offices. Although the standard of the linework and lettering on a final drawing may be those of the tracer, the draughtsman is usually responsible for the correct arrangement of the views, dimensions and notes. In the case of structural steelwork and reinforced concrete in particular, the detailers will translate the rough designs into practical details – a process which also involves an element of design.

There are three basic types of drawing equipment

(1) drawing board and tee squares
(2) drawing board fitted with parallel motion equipment
(3) draughting machine.

The parallel motion equipment consists of a straight edge fixed to a weighted wire cable arrangement which enables the straight edge to be moved up and down parallel to the lower edge of the board (figure 1.22).

Draughting machines consist of a straight edge fixed to horizontal rails which enable the straight edge to be moved sideways parallel to the sides of the board (figure 1.23). A draughting head, which slides on the straight edge, has two arms set at right angles which can be rotated to a set angle and positioned anywhere on the board by means of the horizontal movement and vertical carriage, both of which are

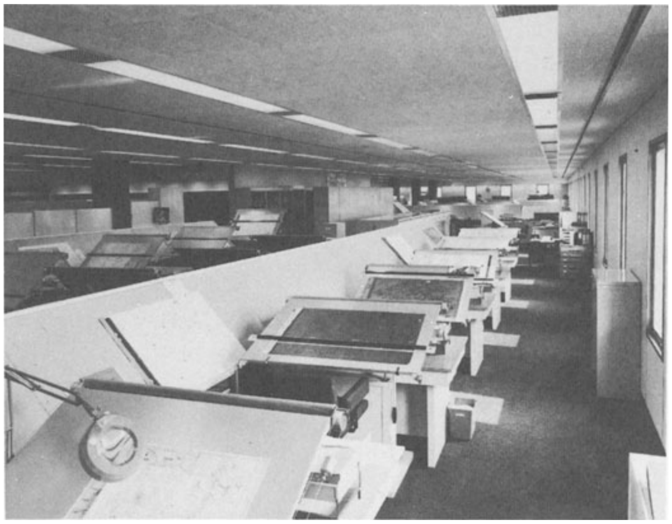


Figure 1.22 Office with parallel motion equipment (Courtesy of the Elite Manufacturing Co. Ltd)

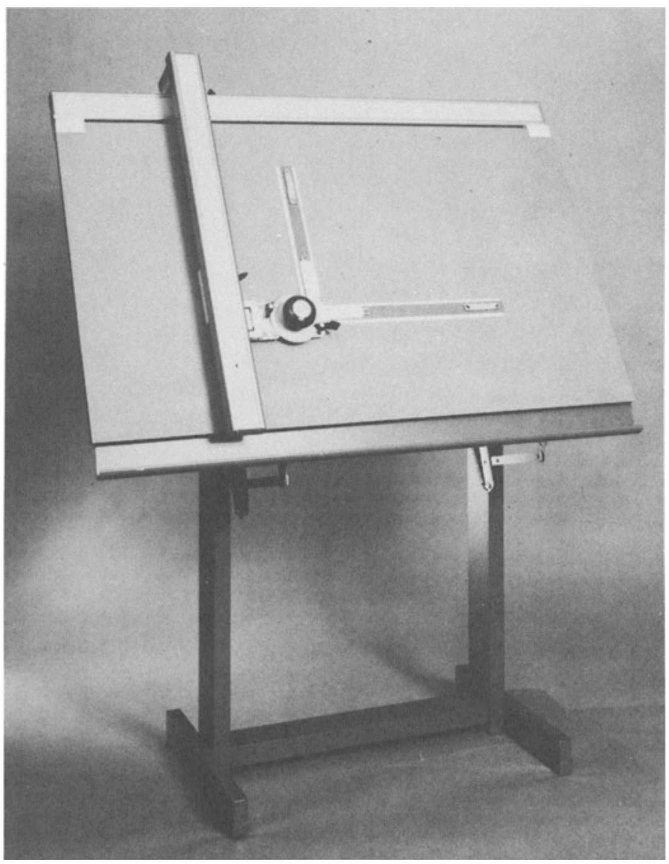


Figure 1.23 Draughting machine (Courtesy of the Elite Manufacturing Co. Ltd)

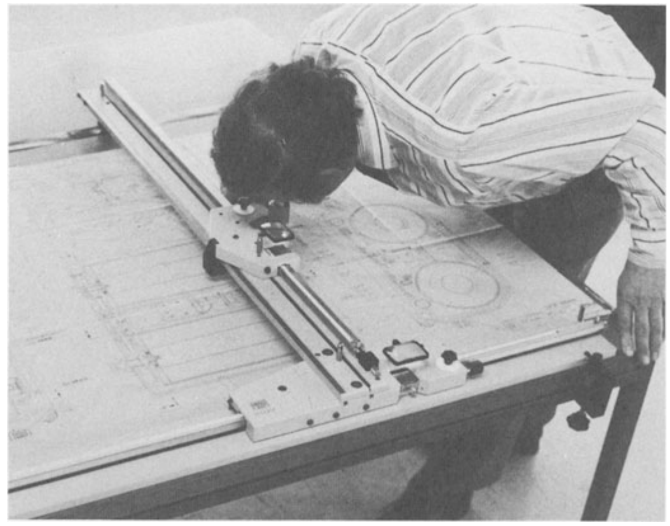


Figure 1.24 Rectangular coordinatograph (Courtesy of R. and A. Rost, Vienna)

lockable. Different scales can be fitted to the arms. Draughting heads can also be fitted to parallel motion straight edges. The addition of a lower extension rail will enable the whole of the board surface to be used.

For intricate work, glass boards with internal illumination are available.

Precision equipment is available for plotting orthographic and polar coordinates, and is used mainly for survey work. Note that this equipment must be used on a level board. The rectangular coordinatograph is shown in figure 1.24. The *X* and *Y*-carriages run on ball-bearings on cold-drawn profile rails. The plotting and measuring of coordinate values is carried out by an interchangeable pricking unit and reading microscope.

The polar coordinatograph shown in figure 1.25 is designed for high-accuracy plotting of tacheometric surveys. Both the rotary movement of the graduated circle and the distance carriage run on ball-bearings in ground profile rails to ensure an accuracy of 1′ = 0.04 mm in distance, and an angular accuracy of 1′. The instrument has a covered graduated metal circle, with a scaled reference ring, a centring device and a fine adjustment to the vernier and zero-point stop.

If a large number of the drawings being produced in an office are relatively small and have a graphic form, a board incorporating a rotating table (figure 1.26) may be an advantage. In this case all the drawing can be carried out from the one seated position with the board tilted to a near horizontal position, which is better for scaling dimensions. The equipment is portable and this is clearly an advantage

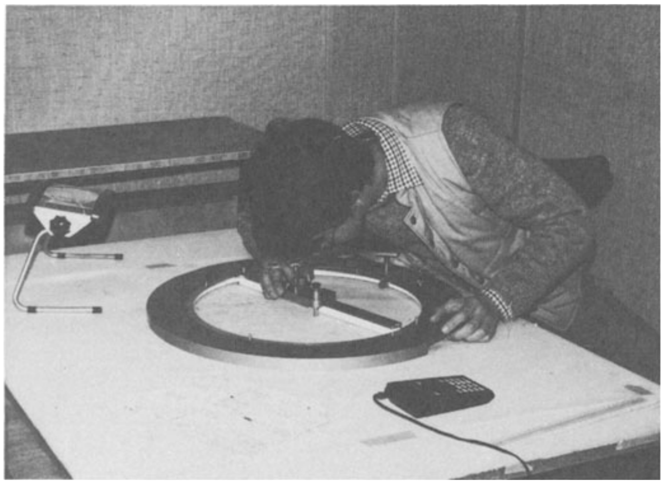


Figure 1.25 Polar coordinatograph

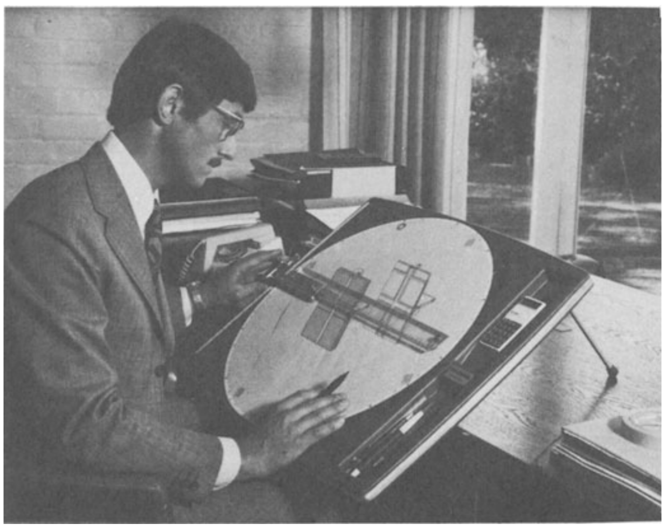


Figure 1.26 Rotobord (Courtesy of Rotobord Ltd)

where there are space limitations. The board can be adjusted in height or slope. The straight edge is fitted to a unit which slides up and down freely by pushing a knob, which, if turned when depressed, also locks the unit in position. There is a facility for enabling the straight edge to be moved up the board at a pre-set increment each time a second knob on the unit is depressed; this is particularly useful for hatching. Large vertical movements of the calibrated straight edge can be measured using the fixed vertical scale and an adjustable pointer on the unit. The rotary table can be locked in any position and there are click stops at 0, 30, 45 and 60° angles – thus set squares are not necessary. Angles can be set using the large protractor scale, combined with the vernier scale attached to the base of the board. A larger model, fitted with a parallel motion arrangement, is also available.

1.6.1 Drawing Media

A wide range of high-quality papers, cloths and film is available to the draughtsman for drawing and tracing. The factors that will influence the choice of material include cost, durability, opacity, surface texture, translucency for diazo printing, weight, stiffness, pencil and ink acceptance, dimensional stability and the effects of heat, damp and erasures.

Cartridge paper is a frequently used medium for drawing, and can be obtained in a variety of colours, thicknesses and surface textures.

Detail paper, which is semi-transparent and has a surface with good pencil and ink acceptance, is suitable for many purposes, particularly preliminary draft sketches. The material can be either rag or wood pulp based and is rendered translucent by the application of specially formulated synthetic resins to the surface. Several grades can be obtained, varying in weight from between 50 and 95 g/m^2 approximately.

Natural tracing paper has a higher transparency than detail paper and is therefore more suitable where good-quality diazo prints are required. The surface can be matt or smooth and the grades vary between 63 and 112 g/m^2 approximately. Tracing and detail papers have a number of disadvantages: they tear easily if the edges are not protected with binding tape, they need careful handling and they are susceptible to weather changes.

Tracing linen is more durable than tracing and detail paper but does not accept pencil; it shrinks and expands under the effects of heat and damp. Clear diazo prints can be obtained from the very good ink tracings which are possible on linen. Tracing linen is, however, very expensive and is now almost unobtainable.

Polyester film has all the advantages, and none of the disadvantages, of tracing linen. The base material of the film was developed by Du Pont in the United States under the trade name Mylar, and by ICI under the name Melinex. Melinex sheet has a glossy, tough and impervious surface which requires special treatment to make it receptive to ink or pencil. The usual method of achieving a suitable draughting surface is by applying a special coating to either one or both sides of the sheet. The advantages of a double coating are that the coating on one side counteracts the pull of the coating on the other side so that the sheet lies flat at all times, the tendency for the sheet to stretch or shrink is minimised and dimensional stability is also improved; pre-printing can be carried out on the reverse side, thus avoiding the risk of removing the pre-printed images if erasures are made on the face side.

Addressograph–Multigraph Ltd have developed two materials, under the trade names Permatrace and Super Permatrace, which have a matt surface (either on one side or on both sides of the sheet) that is mechanically produced by shot blasting. The base material of Super Permatrace is a silicate-filled polyester which, despite repeated erasure, leaves a surface with good ink and pencil acceptance. Because these materials have a surface that is an integral part of the base material, they do not crack or peel, and retain a high translucency enabling high-quality copies to be made using slow-speed dyeline materials.

Most of the above drawing media can be obtained in roll or standard plain or pre-printed sheet form. Pre-printed sectional materials, and standard sized sheets with pre-printed titles and borders, can save a great deal of draughting and design time. Grey and green are the accepted colours for sections on non-translucent materials. Red, fast red and sepia on translucent materials give good diazo reproduction; sepia and red are removed by erasure, but fast red is not. Green and blue are generally considered least likely to induce eye strain. Grey is the most unobtrusive background. Materials with blue lines, which are invisible to ultraviolet light, are used when lines are not required on diazo copies taken from the original master. Figure 1.27 shows standard sections typical of a wide range available.

Special markers are required for drawing on transparent foil, which is frequently used for diagrams that have to be projected on to a screen.

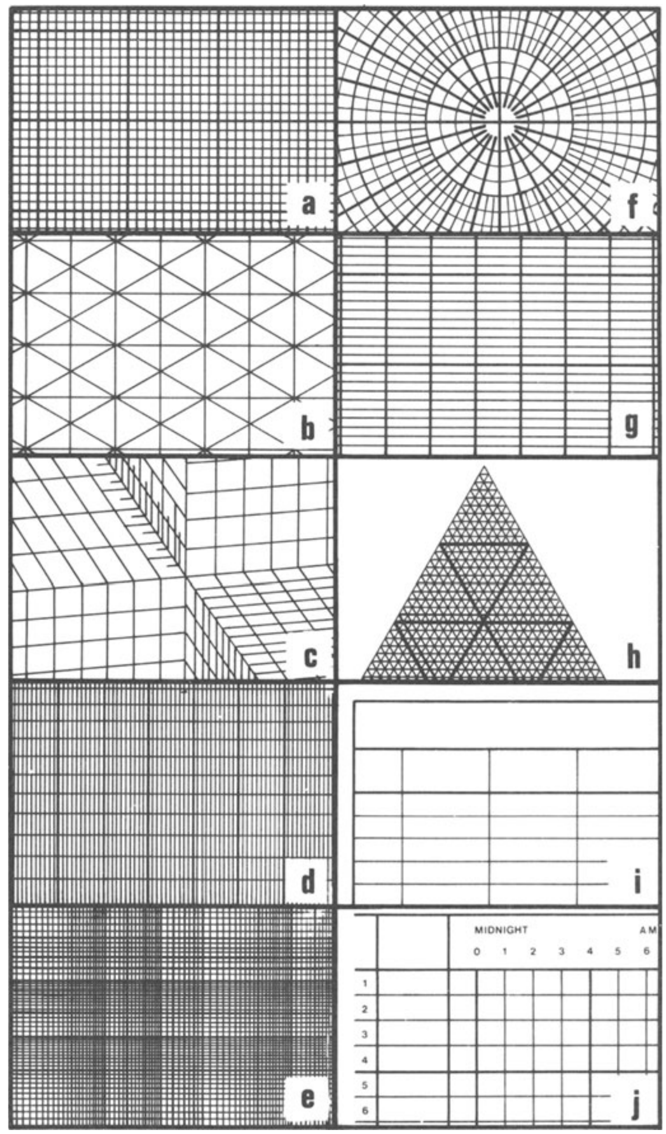


Figure 1.27 Sectional papers: (a) square coordinate, (b) isometric, (c) perspective, (d) rectangular, (e) logarithmic, (f) polar coordinate, (g) rectangular, (h) triangular, (i), (j) chart form

1.6.2 Draughting

Draughting principles, techniques and materials will vary according to the type of drawings being prepared.

Most drawings will be traced for the purpose of reproduction, in which case the original draught is sometimes discarded or microfilmed after the tracing has been completed. The paper used in this instance only needs to be of sufficient quality to allow erasure without undue disturbance of the surface, and the linework must be clear enough for the tracer to interpret. Medium-quality cartridge paper, or even detail paper, will be suitable for this purpose. The use of sectional papers may greatly simplify the task of drawing cross-sections, longitudinal sections, charts and details, etc.

When it is necessary to retain the original draught, as in survey work or where it is in fact the final drawing, a high-quality cartridge paper, linen-backed paper, or heavy-duty polyester film, all of which are durable and dimensionally stable, should be used. Survey plots made directly on heavy polyester film will facilitate print reproductions, and eliminate the inaccuracy that would result from a copy tracing (intermediate).

Most detail drawings will be produced on cartridge paper using a hard 2H or 3H pencil or even a 4H in the case of survey plots which require a high degree of accuracy. Retained survey masters should be inked in. Softer pencils, H or HB, may be necessary on tracing or detail paper in order to produce lines dense enough for dyeline reproduction. Where a drawing is being prepared in its final form directly on cartridge paper, a wide range of pencils may be used for contrast and shading. A soft pencil, although it produces a darker line that is easier to erase without disturbing the surface of the paper, is more likely to cause smudges on the drawing, and will have to be sharpened more frequently. A 3H pencil is recommended for dimension and leader lines, and a 2H pencil for outlines. A softer pencil may be preferred for the lettering which can be left until last in order to reduce smudging. Generally, pencils should be sharpened to a long fine point. If glasspaper is used for sharpening, the point should be wiped clean on a piece of scrap paper before use. A chisel point will not have to be sharpened so frequently and may be preferable for linework. The points of compasses should be bevel edged. An adjustable set square will be found useful for drawing inclined parallel lines.

If parallel straight edge boards or draughting machines are not available, a high degree of detailing accuracy can be achieved by first constructing a square grid on the drawing, using beam compasses and steel straight edge. Each section of detail can then be related to the nearest construction lines of the grid, using a tee square and set squares in the normal way.

1.6.3 Tracing Techniques

Tracings may be prepared on linen, polyester film, tracing paper or detail paper. Black ink on polyester film will facilitate the production of good diazo prints with dense black linework on a white background. Polyester film is abrasive and the use of special nibs incorporating tungsten carbide tips is advisable on this medium.

The correct choice of ink is important and will depend on the nature of the medium used.

The following sequence of operations should enable a tracing to be completed quickly and with minimal movement of drawing instruments over completed work.

(1) Fix both the original drawing and the tracing sheet, matt side uppermost, to the board with draughting tape. If artificial light is necessary, arrange for this to come from the top left-hand corner of the board. Ensure that any surface grease is removed from the sheet, applying talc if necessary.
(2) Complete centre lines first – this will make it easier to draw any outlines that are symmetrical about the centre lines.
(3) Next draw the outlines. Where circular curves and straight lines meet, draw the curves first. Mark the ends of the curves lightly in pencil so that the lines can be described in a continuous movement. Because outlines are thick they take a long time to dry. Hence, draw either (a) all the horizontal lines, starting at the top and moving progressively down the sheet, followed by all the vertical lines starting from the left hand side, or (b) all the vertical lines, followed by the horizontal lines.
(4) Hidden detail or other broken lines.
(5) Dimension lines.
(6) Lettering and arrowheads.
(7) In order to avoid crossing internal dimensions, section lines are best left until last.

Tracing is a skill that requires a great deal of practice to acquire, and if done properly, it involves more than merely copying. In addition to being capable of neat lettering and linework, a tracer should be able to

(1) visualise the information shown on the drawings, following a brief discussion with the draughtsman;
(2) draw all the lines to their correct thicknesses and understand the reasons for the different weightings;
(3) check all line lengths against the dimensions and make minor adjustments if necessary – any major discrepancies must be referred back to the draughtsman;
(4) draw lines truly vertical or horizontal where it is obvious to do so without assuming that the lines on the original drawing are perfectly correct;
(5) locate exactly the centres of circles;
(6) understand basic geometrical principles.

Careful consideration should be given to the arrangement of notes and dimensions. Pencil guidelines, or a piece of squared paper placed beneath the tracing sheet, should be used to enable the formation of consistent freehand lettering. Clear lettering can be achieved quickly using stencils. Stencils may be preferred, particularly where several tracers are working on a set of drawings, because this achieves a more uniform style of presentation. Transfers can be obtained in a very wide range of lettering types, but they take longer to use than stencils, and are liable to become partly erased after the tracing has been in use for a time. The latter objection of course does not apply to a diazo copy negative (intermediate) taken from the original. Transfers are indispensable when preparing presentation drawings.

All instruments should be thoroughly cleaned before and after use. Each time the pen is filled with ink the top should be returned to the bottle. If mistakes are made while tracing, they should be marked in pencil, and then corrected all together when the drawing has been completed. This will allow more time for the ink to dry, and erasures can then be made easily, using a hard rubber, safety razor blade, or sharp cutter. An erasing paste will probably be more suitable for rubbing out on linen.

Lines must be drawn to their correct width in accordance with their function on the drawing. Long lines should be drawn with an arm movement finishing with a short finger movement. There should be sufficient ink in the pen to complete a line in one continuous movement. If a line is very thick it is better to draw thin lines to mark the edges and then fill in the space between them.

When the tracing has been completed it should be placed on a white sheet of paper at the side of the drawing board, and carefully checked against the original draught.

1.6.4 Colouring

Drawings are rarely coloured because of the additional time and cost involved. In certain circumstances, however, drawings should be coloured in order to delineate particular features and facilitate better understanding of the information shown (for example, in legal documents and drawings for public display).

The drawing board should be slightly tilted for colouring on paper prints. A light colour wash should be worked down the sheet, using as large a brush as practicable, with the edges slightly in advance of the centre until the part has been completed. The excess wash at the bottom of the section should then be removed with the tip of a dry brush held just clear of the surface of the paper. If the part is too large to complete in one application, work down to a conveniently positioned feint pencil guideline. Note that materials represented in section are coloured darker than those that are not. A dark colour is better achieved by applying several light washes on top of each other – this will avoid patchiness. This will be even more important when colouring linen prints.

Colour linen prints in the same manner as paper, but adjust the drawing board to a near horizontal position and add a little ox-gall to the water.

2. DRAWING OFFICE LAYOUT; CONTROL AND REPRODUCTION

2.1 INTRODUCTION

The layout of a drawing office, and the system of drawing control operating within it, will depend on the structure and size of the organisation of which it forms an integral part.

The nature of the work undertaken will influence the choice of (1) filing, recording and retrieval systems for drawings, and (2) methods of reproduction and distribution.

Many large organisations will contain several specialist technical groups each with their own drawing office. All these groups will probably be serviced by one central section which deals with communications, purchasing, stores, general administration, distribution, printing, dyeline reproduction, the microfilm unit and the library. If all the drawing offices are close together, centralisation of the drawing control and filing systems may also be an advantage. Even if this is the case, however, each drawing office will still need facilities for easy reference, such as print and film filing cabinets, or a microfilm viewer.

Some of the factors that should be considered in determining the basic structure, and the drawing control and other procedures that should operate within each group, are

(1) industrial relations
(2) working conditions and ergonomics
(3) reduction of monotonous work
(4) simplification of drawing procedures
(5) standardisation
(6) efficiency in general
(7) reduction of draughting errors
(8) security
(9) communications
(10) filing, recording and retrieval methods
(11) draughting costs
(12) reproduction methods
(13) available space.

The most important consideration in any workplace is the establishment of a good industrial relations environment. A sensible management structure, adequate working conditions and a good communcations system will go a long way towards ensuring that people are happy in their work. The basic physiological needs of most people living in advanced industrialised societies have been attained and the chief remaining needs, often unfulfilled, are those which relate to self-esteem: needs for self-respect and self-confidence, autonomy, achievement, competence, knowledge, status, recognition and appreciation. It could be argued that a successful organisation is likely to be biased towards satisfying these needs.

2.2 OFFICE LAYOUT

Many new offices are being designed on the open-plan principle, which should provide for greater efficiency and flexibility, and ease communication. However, if such layouts are not carefully designed, the resulting disadvantages could outweigh the merits. Draughtsmen, in order to work efficiently, need a workplace that is quiet and free from through traffic. In an open-plan office, thought may need to be given to the provision of acoustic and free-standing screens and to ensuring that adequate light levels, both natural and artificial, exist throughout the office. It should also be borne in mind that some people may prefer to work in a small group without the feeling that they may be overlooked. Carpeting throughout the office will reduce noise, assist in providing an attractive working area, and is likely to be the cheapest form of covering in the long term.

The office of Building Design Partnership in Preston, created in 1968 within the walls of a 100-year-old biscuit factory, is a good example of what can be achieved by careful planning.

Architects, engineers and quantity surveyors, housed in two large open-plan office areas, have been arranged in small groups distributed and intermixed so that professions can act as job teams and at the same time receive stimuli from fellow professionals. Each designer has a four-sided workplace, the four sides being drawing board, reference unit with storage, desk, and additional storage with pin-up surface above formed by the back of the next person's reference unit.

Quantity surveyors and secretarial staff each have an L-shaped workplace incorporating storage and again the furniture is assembled in groups.

A considerable number of indoor plants are provided, together with free-standing screens at key points to offer some privacy to people in positions adjoining main routes through the office. See figures 2.1 and 2.2.

Secretarial staff have been sited in the centre of each large floor thus avoiding the accentuation of typing noise by reflections from hard wall surfaces.

The main ground floor office also has a gallery which accommodates the office information section and library service with direct staircase links to the centre of two of the technical floors.

Other functions including town planning, graphic design, photography and printing and the central accounts with service areas including cloakrooms and toilets are located on three separate floors of an adjoining wing. The central accounts department has a style of design consistent with the main office areas.

The ceiling and lighting of the first-floor room (figure 2.2) have been integrated in a coffered design so that the ceiling becomes the light fitting itself providing cut-off to the exposed tubes and avoiding glare conditions associated with the conventional light fitting inserted in a flat ceiling, the

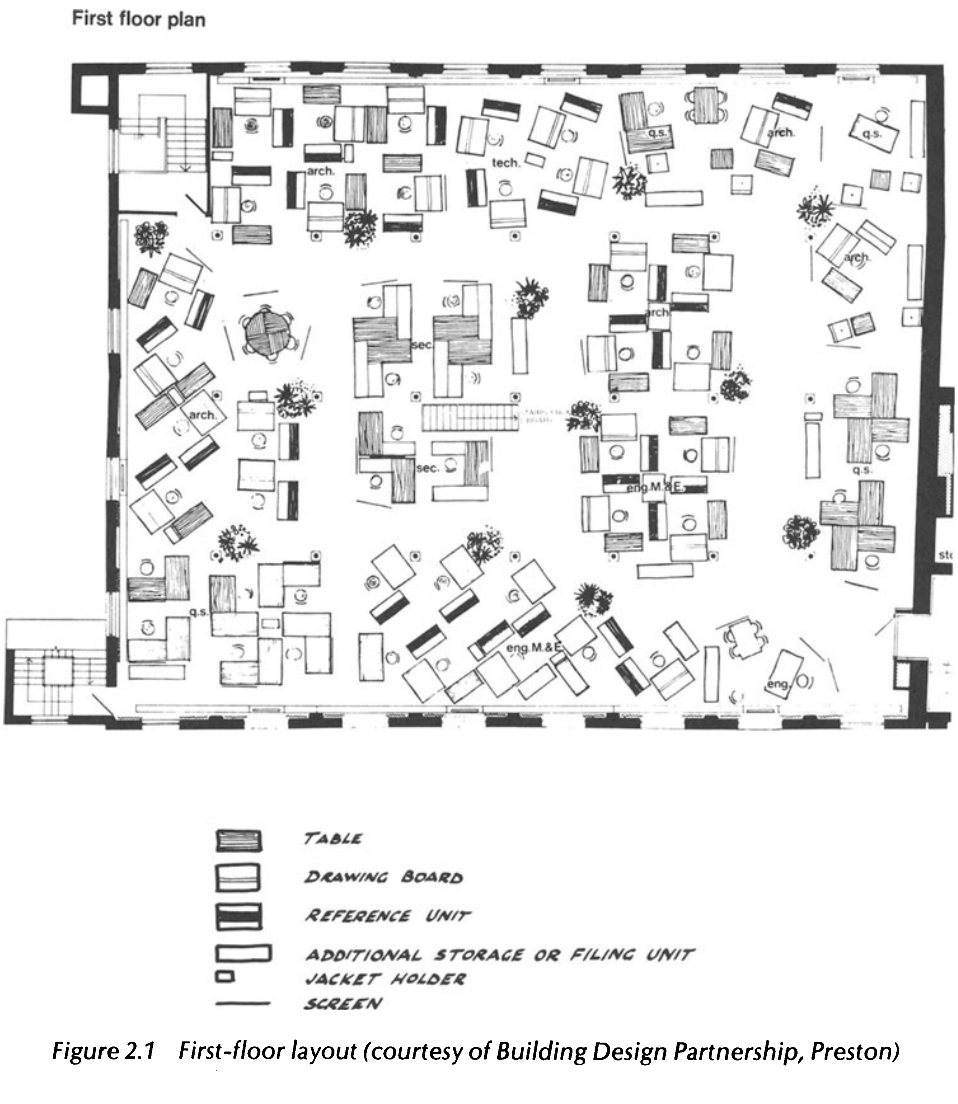


Figure 2.1 First-floor layout (courtesy of Building Design Partnership, Preston)

Figure 2.2 Open plan office (courtesy of Building Design Partnership, Preston)

slopes of the coffers being directly illuminated. An underlying design theme runs through all the items of furniture, the chief characteristic being the use of light coloured materials – Finnish birch plywood tops and white end panels, which increase reflections on to the ceiling, combine with the lime green carpeting to give good eyesight conditions and provide a cheerful atmosphere for the staff.

Chapter 1 has already referred to various types of drawing equipment and their arrangement in the office. Separate draughting machines, or parallel motion equipment with a side reference bench if possible, will usually prove to be the most suitable equipment for draughtsmen and tracers; on the other hand engineers, detailers and technicians will need both desk and drawing facilities. Seats should be well upholstered, have an adequate back rest, be adjustable in height, and have a foot rest where necessary.

Adequate space must be provided for filing, reference and storage purposes. Plan chests with drawers, located near each drawing board, will provide for both storage and reference. Generally, drawer chests should not be placed adjacent to the draughtsman or tracer, otherwise he will be disturbed each time someone else requires drawings.

2.3 DRAWING CONTROL AND FILING

2.3.1 Control

There are substantial costs involved in producing the simplest of drawings, therefore control procedures and security will be of paramount importance in any design office.

Every drawing should be given a reference number by which it is uniquely identified. This may be a simple sequential number or may have coded into it such basic information as the status of the drawing, the scheme for which it was produced, the size of the sheet and the design department.

The coding significance of the drawing number, E 84/10/1, shown in figure 1.21 is as follows

E identifies the department
84 identifies the scheme
10 is the sequential master reference number (negative number)
1 is the sequential number of a copy taken from the original. This number is not introduced until a copy is to be distributed. Each time a change is made to the master or copy negative, or whenever the information on the print is not identical to the master, this number will change. An alternative that may be preferred when the negative is modified is to add a letter to the negative number which relates to the amendment reference letter of the title block. The oblique strokes between the numbers have the effect of reducing the number of digits which would otherwise be needed in the reference.

Other information on the drawings will include the initials of those involved in its production, the dates of completion of the original drawing and of any subsequent amendments, the title, and a standard drawn scale of at least 150 mm length giving the ratios used.

All drawings should be scheduled on a card indexing system, the prime function of which is to enable each drawing to be identified and located quickly. Similar information to that given in the drawing title blocks should be entered, and all drawings adequately cross-referenced. In addition, records should be kept of the names of all those to whom drawings have to be sent, the date of issue, and the number of copies. Amendment details may also be entered, and a statement as to whether the drawing has been microfilmed and the master destroyed.

A copy, and issue details, of each drawing distributed and all incoming drawings, should be filed. Masters can be safeguarded against excessive handling if they are kept in a separate filing compartment, and their use for reference purposes can be minimised by keeping up-to-date print copies of all drawings. An efficient and systematic drawing control system is more likely to be achieved if there is one person solely responsible for filing and general administrative office duties.

One of the main problems in drawing control concerns amendments to drawings. Some drawings, by their very nature, are likely to be added to or amended frequently, and if these can be identified at the outset, at least the fundamental requirement of providing sufficient space on the original drawings for entering details of the alterations can be met.

2.3.2 Filing

Any filing system must be readily accessible and must enable any required drawing to be located quickly. Working drawings will usually be placed in labelled horizontal drawers. Masters, office copies and incoming drawings should be stored in vertical cabinets (figure 2.3); these take up less floor

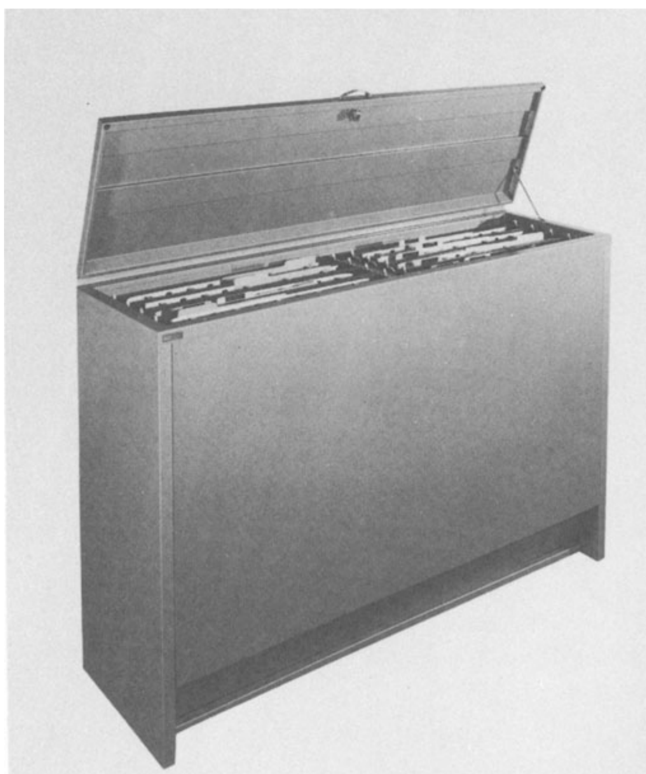


Figure 2.3 Vertical filing cabinet (courtesy of the Elite Manufacturing Co. Ltd)

Figure 2.4 Horizontal filing cabinet (courtesy of the Elite Manufacturing Co. Ltd)

space, are easy to operate, enable drawings to be filed and located quickly and afford better drawing protection.

Small drawings are difficult to store satisfactorily in horizontal drawer or vertical cabinets; they are more effectively filed in folders stored in a sectioned shutter cabinet.

If a horizontal filing system is preferred for all drawings (figure 2.4) the cabinet drawers should be as shallow as possible to reduce the amount of time searching for drawings and the consequent wear and tear caused by excessive handling.

Most organisations will at some stage experience storage problems with conventional filing systems; microfilming may then offer a solution. In addition to reducing storage requirements by as much as 95 per cent, microfilming has other benefits, such as greater security and the advantages of automated filing and retrieval facilities (see section 2.4.2).

2.4 DRAWING REPRODUCTION

The most widely used processes for drawing reproduction are dyeline (diazo) and microfilming. It should be borne in mind at the outset that reproductions will not be exact copies of the original negatives. Any drawing on a paper or linen base is subject to dimensional variation resulting from changes in humidity and temperature and from handling; all dimensions should therefore be clearly marked. Also, dimensions should not be scaled directly from a drawing. This is particularly important in the case of plans used for setting-out purposes on development sites, or for conveyance plans where land costs are high. Each print from a negative or original may introduce further dimensional error, unless polyester or other stable materials are used all the time. If dimensions are always given, any variations due to print processing will not matter so much.

2.4.1 Diazo

The three diazo processes, all of which require translucent masters and the use of copy media coated with sensitised diazonium salts, are

(1) dry or ammonia (figure 2.5)
(2) wet or chemical
(3) pressure.

The most common of these is the dry process, in which both the negative and print material are fed through a machine which first exposes them to actinic light. The sensitised areas that remain beneath the lines on the master are transferred into an azo dye by ammonia fumes when the print is passed through the developing section of the machine.

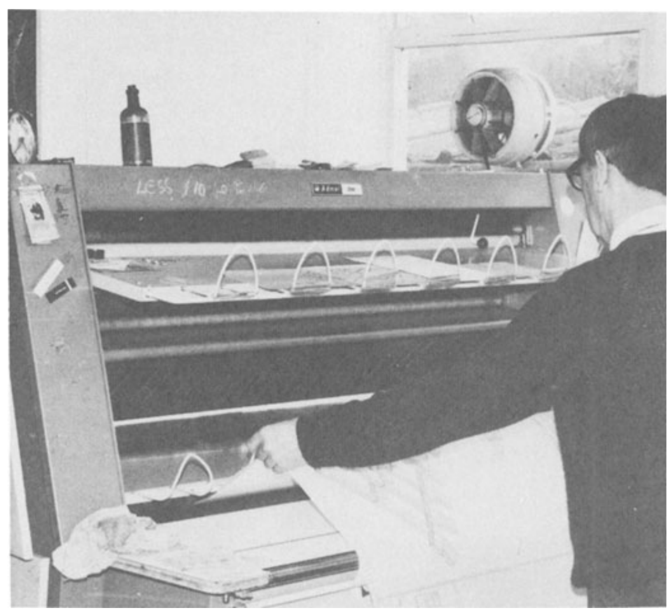


Figure 2.5 Dry or ammonia process.

In the wet process the developing stage involves immersing the print in a chemical solution.

The pressure process does not involve chemicals or ammonia gas; it is therefore advantageous where space is limited and good ventilation is difficult to provide.

The dry process provides the greatest reproduction output and permits the use of a wider range of printing media. The clarity of each reproduction depends on the nature of the sensitised coating (fast or slow), the translucency and density of linework on the master, the lighting power of the machine and the speed at which the print is fed through the machine. The extent to which a print will fade depends on the quality of the developing, the length of time that it is exposed to direct sunlight and the type of diazo material used. There are materials available that are 'ultraviolet screened' and provide a very high resistance to the fading effects of direct sunlight. The lower the material speed the higher the quality of contrast and density of line. 'High-speed' materials allow higher reproduction rates, while 'medium-speed' materials aim at a balance between quality and rate of production.

Reproductions from diazo materials can be obtained in

(1) polyester for intermediates, aluminised polyester (foil) for intermediates and overlays; also paper, linen and lacquered film paper;
(2) a variety of thicknesses;
(3) several background colours – white, red, orange, yellow, green, blue;
(4) black, blue or red linework which gives the facility for distinguishing between drawings of differing status;
(5) different weights – low-weight prints reduce postal charges and need less storage space; heavier-weight papers give better handling qualities and may be more suitable for presentation drawings that are colour washed.

2.4.2 Microfilming

The security benefits of microfilming become apparent when one attempts to establish the true value of drawings. This value may be assessed as the cost involved in preparing new drawings should the originals be lost or destroyed. This may be correct if the information required for redraughting is readily available, but what if the original drawing is the only record of data that have taken many months or even years to compile?

Documents that are the only record of a particular event are irreplaceable. The loss of a drawing could have serious financial, technical and legal implications. Also, prints from diazo processes have only a limited life because the material deteriorates with age and subsequent reproduction from them may be difficult.

Drawings can be recorded on roll film, but the most convenient method for ease of filing, retrieval and reproduction is for each drawing to be reproduced on a separate film which is then mounted in an aperture card containing a brief description of the drawing. At least two complete sets of aperture cards should be prepared – one for reference and the other for security. Exact microfilm copies can be taken from the card mounted originals for the purpose of obtaining print reproductions.

Microfilming requires

(1) a camera and processor for exposing and developing the film;
(2) inspection equipment for checking the quality of the film;
(3) mounting equipment for cutting the microfilm frames and fixing them into the aperture cards;
(4) a printer for making copies;
(5) a reader for viewing the information recorded on the microfilm;
(6) filing equipment.

A large organisation producing or receiving perhaps many thousands of documents each year may have all the equipment listed above, but the average firm will probably rely on a service company for filming and the provision of print reproductions, using aperture card files and readers for its own general reference purposes. If a service company is used, it may still be necessary to inspect and check film quality to ensure long-term information retrieval needs.

Although it may be decided to microfilm all drawings, original negatives that are in constant use may be kept so that cheap full-size diazo prints can be produced. If full-size prints are unnecessary, smaller copies obtained from microfilm may be cheaper and may also reduce postage costs. It is important to ensure that the information shown at the reduced size is still comprehensible and the standard scale is easily readable so that rough measurements of any undimensioned areas can be made. Supplement No. 1 to BS 308 gives guidance on the preparation of drawings suitable for microfilming. BS 4210, 5525 and parts of 3429 are also relevant for preparing standard drawing sheets.

The main advantages of microfilming are

(1) reduction of filing space;
(2) security against fire, theft or damage;
(3) low operating costs;
(4) low print costs if drawings smaller than original size are adequate;

(5) lower postage costs in distributing small aperture cards and prints;
(6) quick duplication of aperture cards;
(7) quick and convenient reference to drawings by means of a viewer;
(8) faster retrieval from single-sized small-drawer filing systems;
(9) reduced wear and tear on drawings;
(10) punched aperture cards facilitate automatic coding, sorting and retrieval of drawings;
(11) long life, at high quality, if film has been produced to standard.

Ink drawings provide the best results for microfilm recording. Rotring drawing pens that are suitable for microfilming carry the symbol m̅. The line thicknesses are graduated in accordance with the A series drawing sizes. The letter sizes of stencils carrying the symbol m̅ are graduated in the same proportion and the lettering system conforms to the international standard ISO 3098/1.

Figures 2.6 to 2.10 illustrate a range of microfilm equipment installed in the offices of the London Borough of Ealing. The microfilm is stored in an automated filing and retrieval unit (figure 2.6), controlled by a single operator who is able to retrieve any one of thousands of microfilm cards at the touch of a button. A large electrostatic printing unit accommodates any drawing up to 900 mm wide. The drawing can be copied at between 100 per cent down to 45 per cent of its original size. The finished print from the machine has a maximum width of 450 mm. The machine can print on ordinary paper, tracing paper or special polyester map or transparent films. The input can be on any material up to 4 mm hardboard. The machine works within a tolerance of 0.5 per cent which, compared with the error on normal dyeline printing of some 5 to 6 per cent, enables more accurate copies to be produced for master work, such as Ordnance Survey sheets. (Machines with variable reduction and enlargement facilities – from 45 to 145 per cent of original size – are available.)

By careful planning of the drawing process, it is possible to eliminate the tracing stage and also to incorporate parts of all the drawings where only the dyeline print exists (figure 2.7).

The printer (figure 2.8) enables print copies to be made of

Figure 2.6 Automated microfilm filing and retrieval unit (courtesy of the London Borough of Ealing)

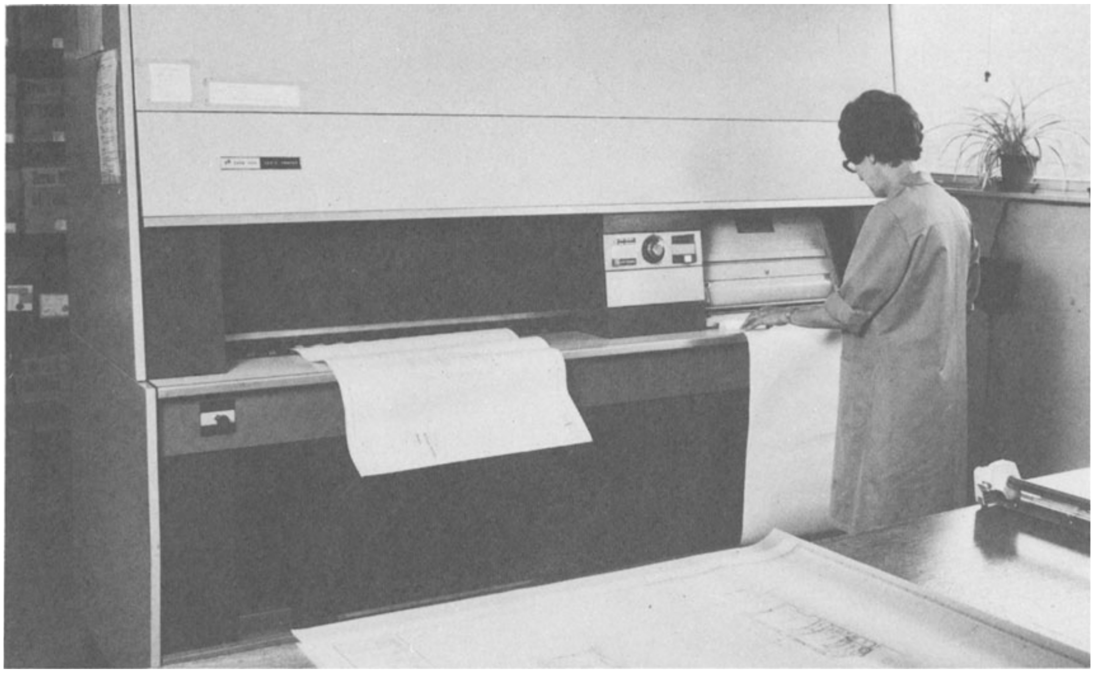


Figure 2.9 High-speed printer with automatic document feed and collation (courtesy of the London Borough of Ealing)

the microfilm at the rate of 5 per minute on to translucent polyester or paper.

A combined electrostatic printer and sorter (figure 2.9) can sort prints into up to 50 bins each capable of holding 150 copies.

The microfilm equipment includes a 35 mm camera capable of filming at resolutions of 160 lines/mm from an A0 size drawing (figure 2.10). Several thousand images are filmed every year, giving a space saving of more than 95 per cent compared with hard copy.

Figure 2.7 Electrostatic printing unit for large plan reduction and copying (courtesy of the London Borough of Ealing)

Figure 2.8 Electrostatic printer for microfilm (courtesy of the London Borough of Ealing)

Figure 2.10 35 mm microfilm camera with electronic exposure metering and enlarging facilities (courtesy of the London Borough of Ealing)

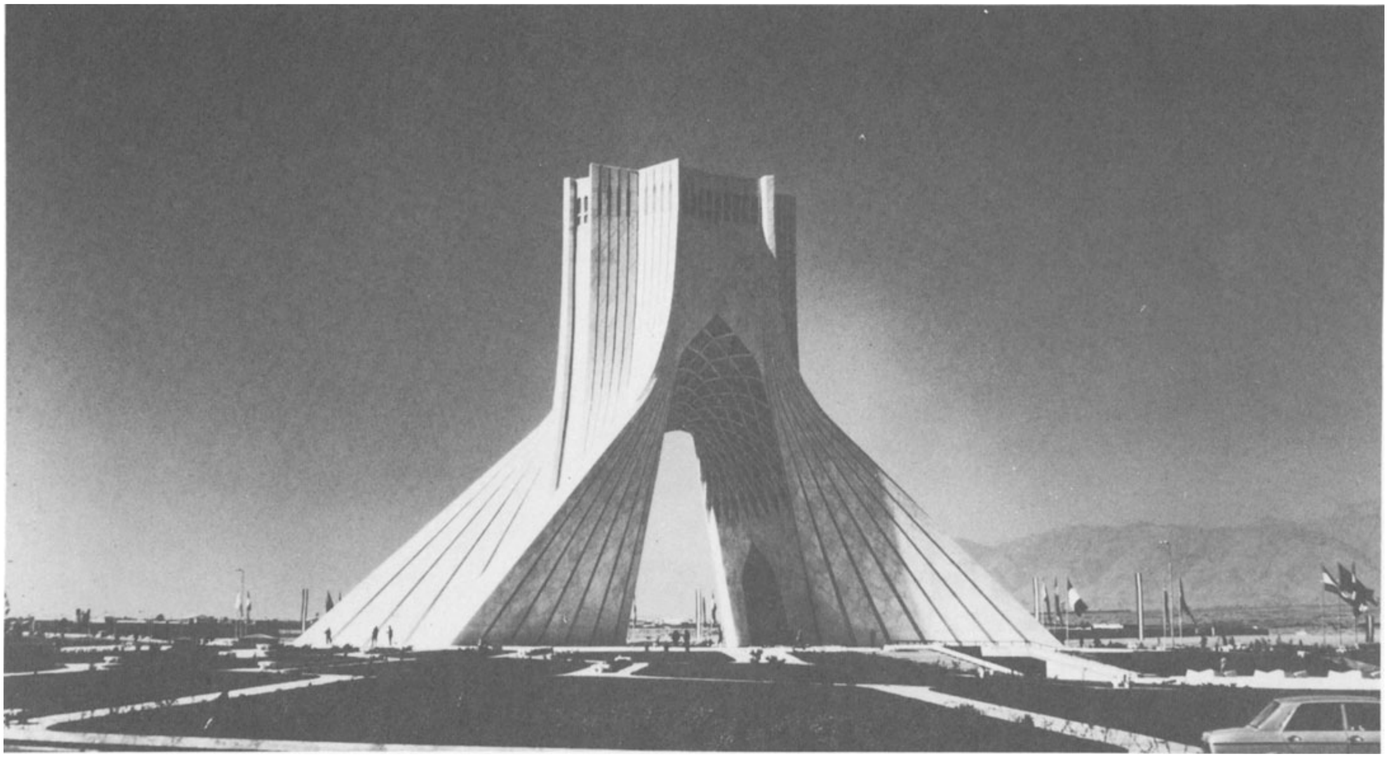


Figure 3.1 The Shahyad Ariamehr Monument, Tehran, Iran

As the basis for the geometry, four setting out points were established: three on the apexes of an equilateral triangle of side 80 m, and the fourth at the centroid of this triangle. Arcs of radius 36 m were swung from these points in defining the basic plan shape. The roof surface is entirely composed of triangular planes, the apexes of which were defined on plan as points of intersection of circular arcs and radial lines from the four original setting out points. The final structural analysis was carried out by computer using a three-dimensional plate bending and shell analysis finite element program. Geometry data checks were carried out using a computer perspective plot.

3. PROJECTIONS AND BASIC GEOMETRY

3.1 INTRODUCTION

Diagrams have always been one of people's most effective aids to communication. Anyone who has tried to describe the sequence of operations necessary to construct the simplest of objects will appreciate the truth of this statement. Most people will at some time in their lives benefit from an ability to interpret simple three-dimensional diagrams correctly. Diagrams are included with the assembly instructions for most household articles and the user will be annoyed and frustrated if illustrations are unclear or ambiguous.

As a means of conveying technical information, drawings are essential and must be prepared in accordance with strict rules and/or conventions to ensure that their meaning cannot be misinterpreted. Although three-dimensional drawings are an invaluable aid to visualisation they are not suitable for representing the information necessary for the construction of buildings and civil engineering structures. Two-dimensional related views called *plans*, *elevations* and *sections*, which are drawn to scale and dimensioned, are generally prepared for this purpose.

The plan is the view looking down on the object and the elevations are the side views. Sections are the shapes of imaginary cuts taken through the object and the position of the cut and the direction in which it is viewed must be identified on the plan and elevations. In order to appreciate how these views are prepared and arranged, a basic understanding of planes and projections is necessary. (see figures 3.2 to 3.7).

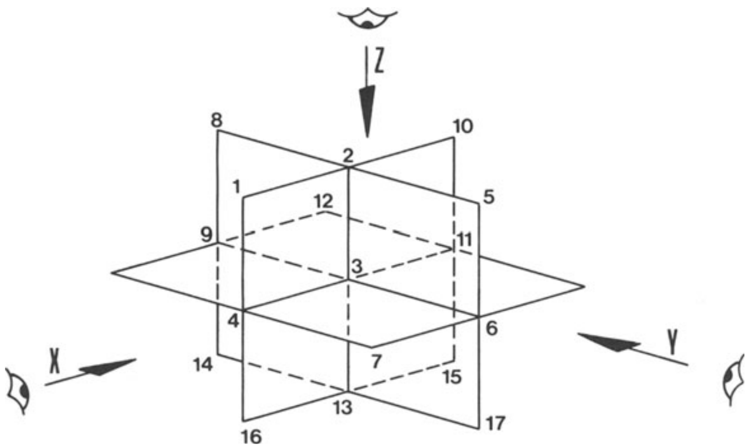
3.2 ORTHOGRAPHIC PROJECTION

The arrangement of the various two-dimensional views of an object is usually defined by the manner in which they are projected on to three interconnected planes which are at right angles to each other. The object is imagined to be placed in one of four possible quadrants as shown in figure 3.2. In each case the projection lines must be at right angles to the planes. The term 'orthographic' is derived from the word 'orthogonal' meaning 'at right angles to'. The sides of the object are then viewed in the three directions indicated. When the object is placed in the first quadrant the faces A, B and C are those directly in front of the view points and must be projected through and beyond the object in order to appear on the planes. This is termed *first-angle orthographic projection* (see figures 3.2 and 3.3).

When the object is placed in the third quadrant the faces A, B and C must be viewed 'through the planes' and projected backwards on to the planes. This is termed *third-angle orthographic projection* (see figures 3.2 and 3.3).

The planes are finally imagined to be opened out (this is called rebatement) to give the required arrangement for practical representation on a flat sheet of paper. It should be noted that orthographic projection only requires that the planes be at right angles to each other and that projection lines be at right angles to the planes; the object can be orientated in any way within the quadrants. From figure 3.4 it can be seen that only lines parallel to the planes on to which they are projected will be true lengths. Other lines will appear foreshortened on the views. Only true lengths will be dimensioned on the views. The object is usually orientated so that its principal side is parallel to the plane on to which it is projected, as in figure 3.5. If, as an exercise, the reader places the object in either the second or fourth quadrants he will find that the views cannot be arranged without a detachment of one of the planes. The resulting arrangement can at best only be interpreted as an improper mixture of first- and third-angle projection systems.

First-angle projection is recommended in both BS 1192 and BS 308. This may be quite suitable for buildings and mechanical objects but, in the author's opinion, a strict adherence to either system of projection is rarely appropriate to civil engineering drawings. For example in figure 7.23 (p. 116) the views have been arranged in the way that a tradesman would expect to see them. If a steelfixer or carpenter were working on the column shown on the left-



Planes used for the projections:

PROJECTION	X	Y	Z
FIRST ANGLE	3-2-5-6	1-2-3-4	3-6-7-4
THIRD ANGLE	13-14-9-3	13-3-11-15	3-9-12-11

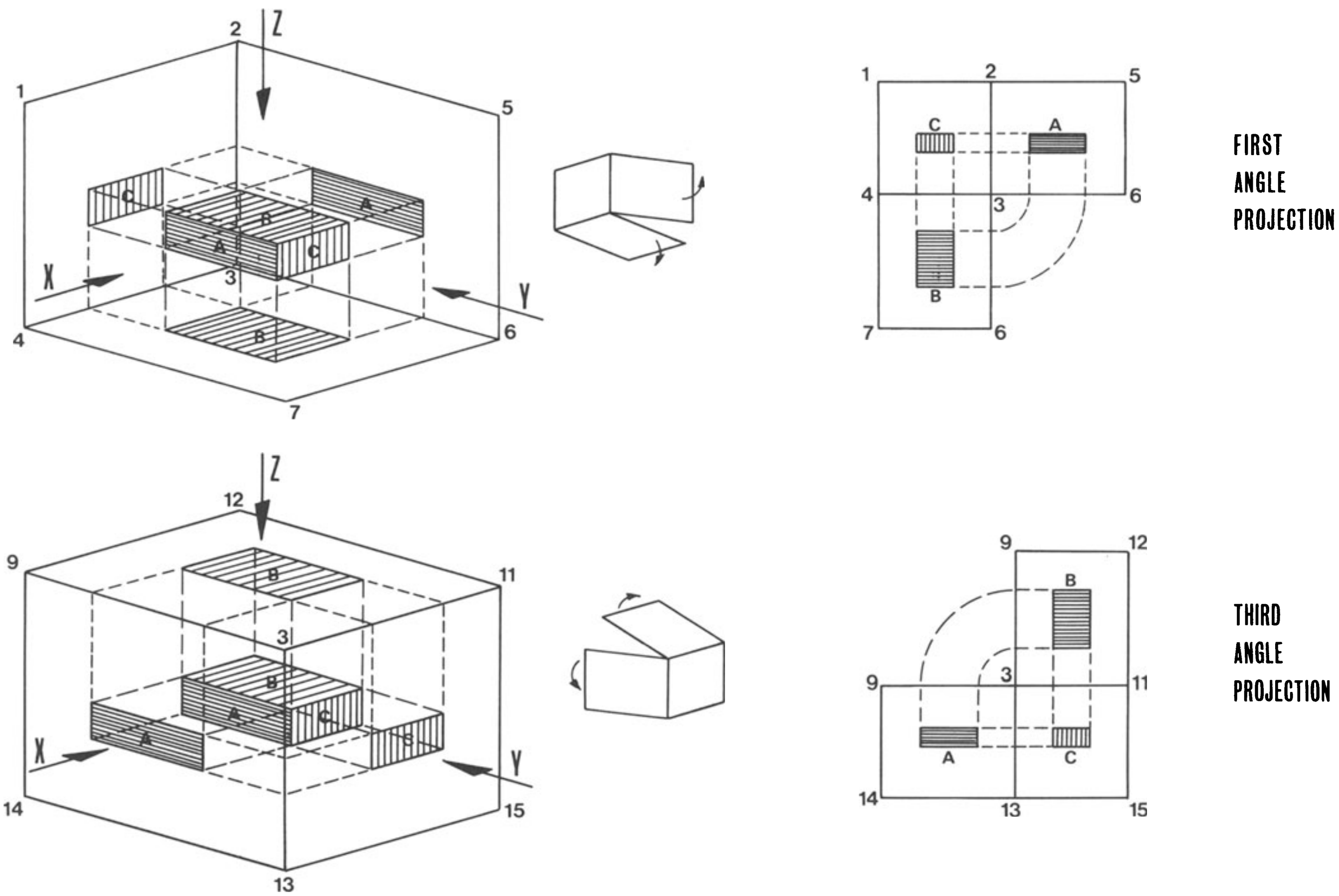


Figure 3.2 Orthographic projection

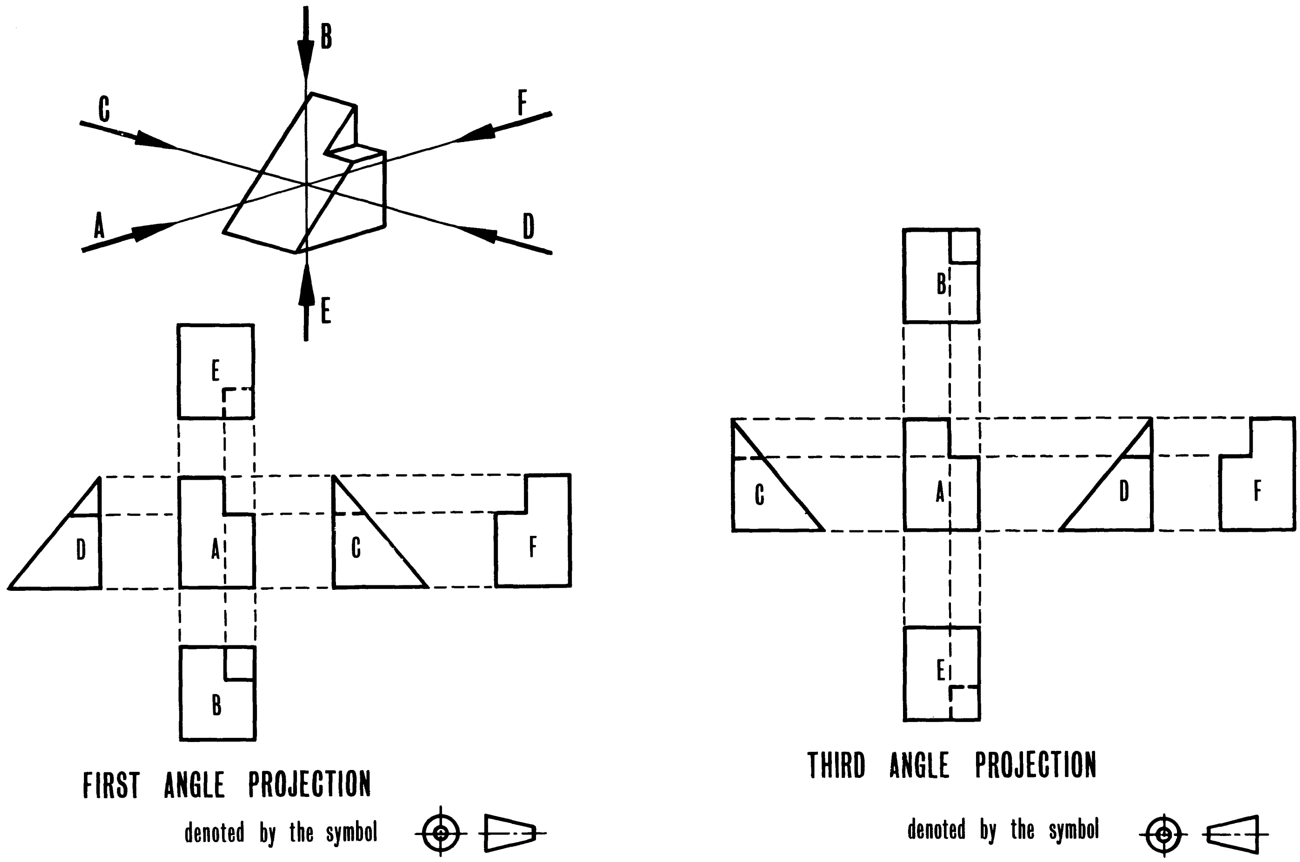


Figure 3.3 First and third-angle orthographic projection

hand side of the front elevation, then he would also expect to see other views of that column on the left-hand side of the drawing. The elevations and deck plan have therefore been represented in third-angle projection. It would not be logical to show the base plan strictly in accordance with this projection system because the base would never be viewed in this way (that is, upwards). The base has been viewed looking downwards as would be expected. This also conforms with the reinforcement detail drawing, where the base must be viewed from above in accordance with the *Standard Method of Detailing Reinforced Concrete*.

No matter which arrangement is adopted, however, all directions of viewing must be shown, and both arrows and views must be clearly referenced on the drawing.

In order to present fully dimensioned views of the sides of the object which are not parallel to the three orthogonal planes, additional planes called auxiliary planes are required and the method of projection is called *auxiliary projection*.

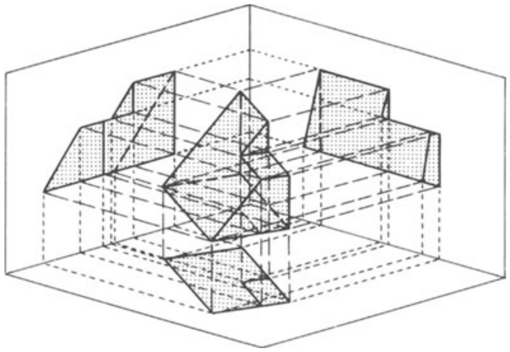


Figure 3.4 Orthographic projection

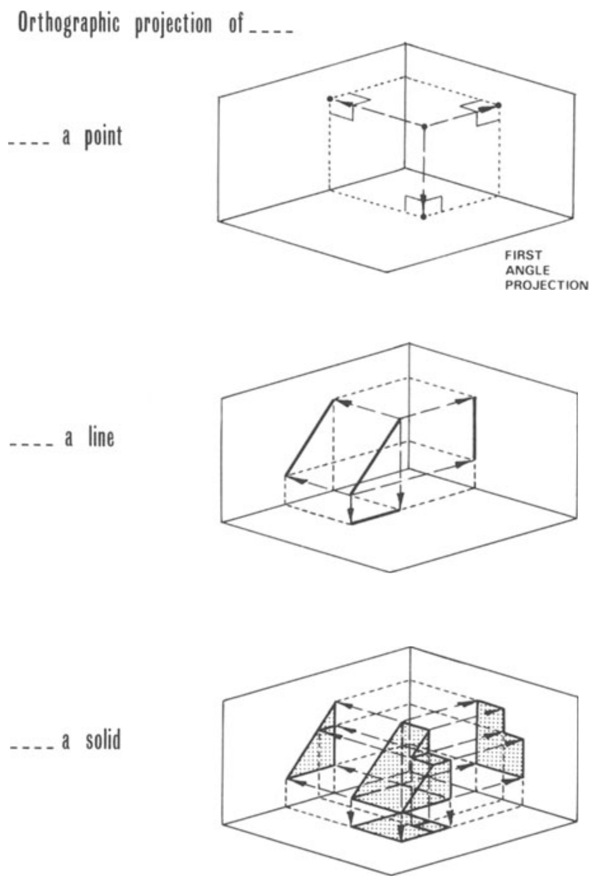


Figure 3.5 Projection of points, lines and surfaces

3.3 AUXILIARY PROJECTION

Auxiliary projection is a projection on to a plane which is not parallel to any of the three orthographic planes.

An auxiliary plane is usually made parallel to a number of principal lines on a view so that those lines can then be drawn to their true length and dimensioned (see figure 3.6).

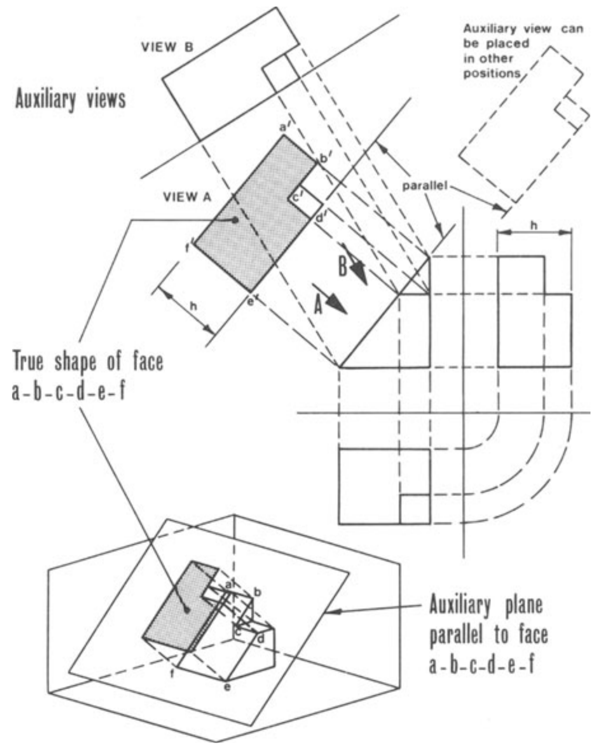
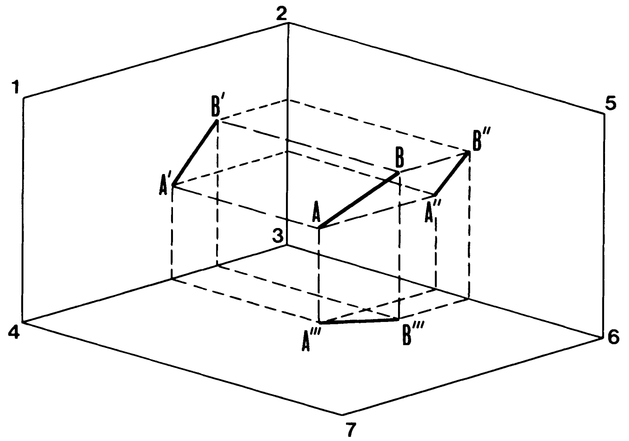
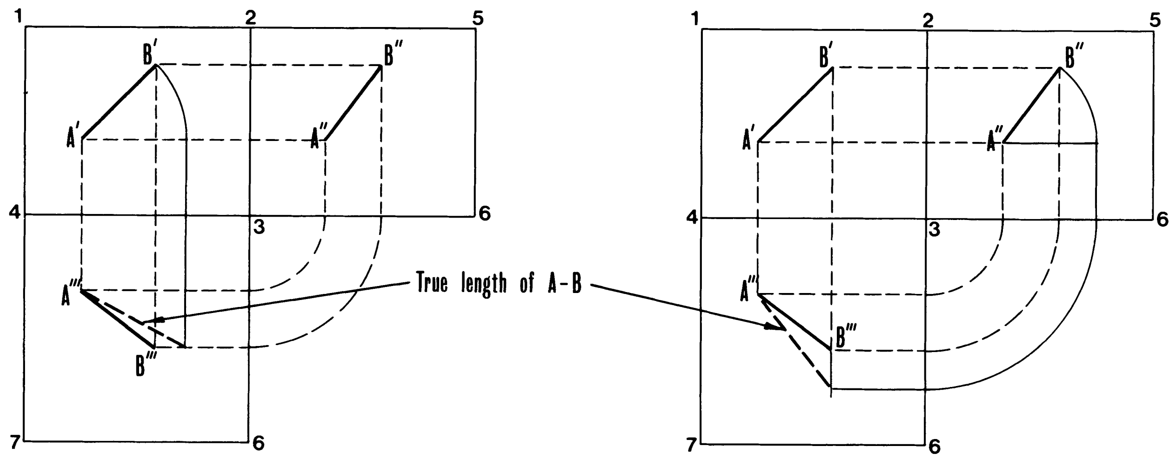


Figure 3.6 Auxiliary projection

3.4 TRUE LENGTHS

A line can only be represented as a true length if it is parallel to the plane on to which it is projected. The true length of any straight line can be obtained from orthographic views by a process called rebatement. See figure 3.7. The determination of the true shapes of surfaces is dealt with later in this chapter. Anyone making a model or following a dress pattern is using true shape views, called developments. In the case of the dress the complex shapes can be measured directly from the model. The true shapes of surfaces on simple objects may be determined graphically as shown later in this chapter, but mathematical calculations will be required for complex civil engineering structures (see figure 3.1).





Alternative methods of determining the true length of a line

Figure 3.7 True lengths of a line by rebatement

3.5 PLANS, ELEVATIONS AND SECTIONS

Buildings will usually be illustrated by means of plans and elevations arranged in accordance with one of the three projections mentioned above, plus vertical and horizontal sections to show the interior layout and construction details (see figure 3.8).

Most civil engineering drawings illustrate construction details on carefully chosen sections. The nature and scale of plans and sections will depend on the project to be illustrated. Major roadworks drawings will include large and small-scale plans, typical detail sections, cross-sections and longitudinal sections. Sewerage schemes require longitudinal sections, plans and detail sections. For structures above ground, where the exterior appearance is important, elevations, photo-montages and perspective drawings may also be prepared in addition to plans and sections.

For all civil engineering schemes there will be the need to show existing features and proposed layouts on plan views (see figure 3.9).

Ordnance Survey plans are frequently used for preliminary design purposes, for showing the routes of sewers, roads and similar projects which extend over long distances, and for indicating the location of more confined sites in relation to the surrounding area. The positions of borrow pits, tips, access points and similar information may also be shown on small-scale plans. Large-scale survey plans, frequently prepared from aerial photogaphs, will show such features as fences, manholes, telegraph and electricity poles, street lighting columns and trees (see figure 7.13). Geological maps, Statutory Undertaking records and other reference sources will supplement this detail by providing information on pipes, cables, nature of the soil, tunnels, coal workings, underground streams and similar hidden features. Grid levels, spot levels and contours will generally also be incorporated on these large-scale plans to define the ground topography.

It should be borne in mind that, although most of the required information on existing features can generally be obtained from records and surveys, no civil engineering project should ever be undertaken without first carrying out a thorough site investigation.

General arrangement plans for large structures are usually

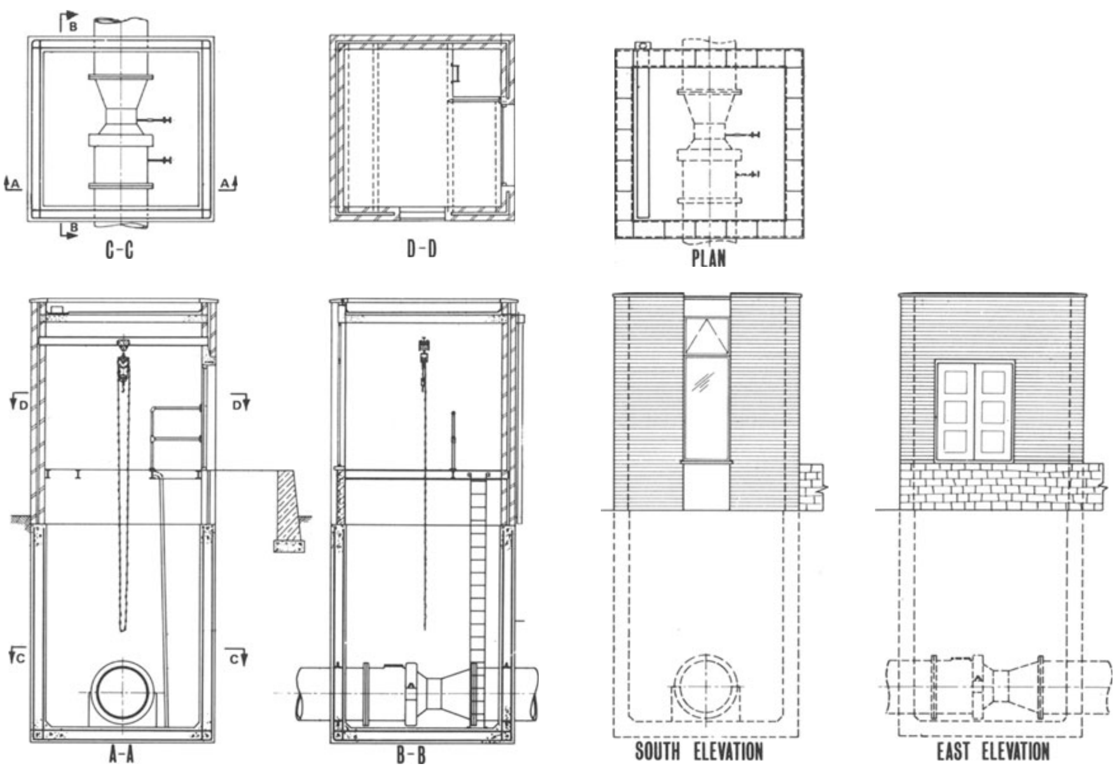


Figure 3.8 Flow-recording chamber: elevation and sections

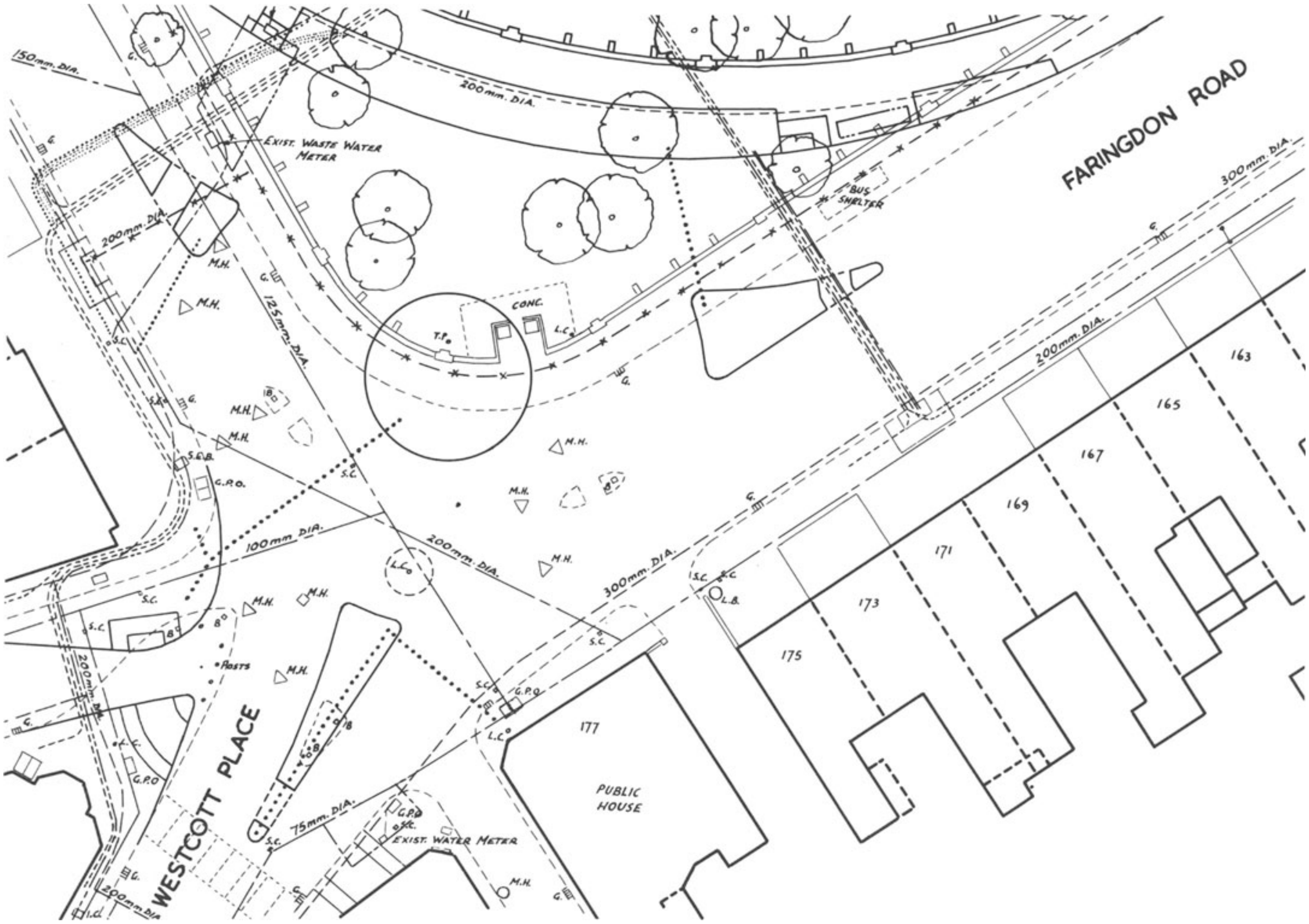


Figure 3.9

A proposed junction layout is shown superimposed on a survey plan of the existing features. Generally, thin lines represent existing features, while Public Utilities mains are shown thicker. Thick lines have been used to show building outlines, in order to avoid the need for hatching or shading transfers which would take longer to apply. Thick lines have been used to emphasise the proposals and distinguish them from the existing layout. It will be necessary to colour prints taken from the original, in order to indicate the proposals clearly. Note that for most types of drawing, colouring will be quite unnecessary. It is worth noting that the proposals involve excavation and the construction of carriageways over areas previously occupied by footways and open space. This is likely to affect Public Utility apparatus and the survey of existing features should also include mains below ground, which are then represented on sections. For greater clarity, setting out levels and dimensions, proposed road surface contours and road markings are better represented on separate large-scale plans. Each drawing should make reference to other related drawings for the scheme. All the plans should preferably have the same orientation and a north point should always be shown. A suggested method of representing Public Utilities mains is described in chapter 1 – see also appendix III.

isolated from the elevations and sections in order to show as much as possible, if not the complete area of the structure, on the same drawing. For relatively small structures, plans and the main sections can probably be incorporated on the same drawing (see figure 7.57).

Although preliminary layouts will usually be drawn up on contoured survey plans, it is by means of sections that (1) any problems likely to arise from the proposals are highlighted, and (2) most of the constructional details are illustrated. The ability to take sections through existing features and the proposed structure, so as to show all the information required in the most effective manner, is probably one of the most important skills associated with civil engineering drawing. In the early stages of a scheme the feasibility of various alternative proposals can often be assessed quickly from a study of small-scale contoured plans and a few well-chosen sections.

There are recognised methods of taking sections, depending on the type of structure. Also, standard conventions apply for the representation of materials, soils and geological strata. The use of typical sections will avoid a considerable amount of detailing, but there are problems associated with using typical details that should be borne in mind. For example, although the section shown in figure 1.12 may be a true representation of the position of the mains in 90 per cent of cases, complications will arise where there is a sharp bend in the road or the mains are a lot larger than those shown. In this situation the gas and water mains, for example, cannot always be laid parallel to the kerb without using very expensive special pipe bends and the size of the mains may be such that they cannot be accommodated in the space available. Some typical details will require a large column of notes to supplement the drawing details and these must be kept under constant review. It is always advisable to produce quick sketches whenever typical details are used, to establish whether drawings showing variations from the typical details are required.

Most of the information necessary for road and pipeline construction will be shown on longitudinal sections. Cross-sections at fixed distances (called chainages) along the route will usually be included for town centre and major roadworks schemes (see figure 7.52). It is debatable whether cross-sections at regular intervals are required for minor roads constructed through virgin land, and most of the setting out information can often be adequately represented on the longitudinal sections (see figure 7.48b). Draft cross-sections drawn on graph paper will, however, usually be necessary for the purposes of computing excavation and fill quantities, even if they are not incorporated in the final contract drawings.

Drawing applications are dealt with in greater detail in chapter 7.

3.6 BASIC GEOMETRY

Geometry is the science of the properties and relationships of lines, surfaces and solids in space. A knowledge of geometrical principles will be required both for the draughting process and for the graphical solution of many design problems. Graphical solutions can be far simpler than mathematical ones and are easier to visualise. The scale and accuracy of the drawings, however, must be suited to the design requirements for the completed structure.

Most of the curves likely to be used in civil engineering are derived from the properties of a simple right circular cone. Horizontal curves in roads are usually either circular or spiral. Vertical road curves, and the shape of bending moment diagrams for simply supported uniformly loaded beams, are parabolic. Angled sections through cylindrical objects are elliptical.

The geometrical development of surfaces is often necessary for determining the areas and shapes of shuttering and moulds used in concrete construction. The complex curved roofs of prestige buildings are frequently based on a network of interconnected straight steel or timber members.

3.6.1 Lines

To draw a line parallel to a given line (figure 3.10)

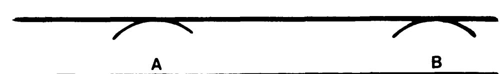


Figure 3.10

With two widely spaced points A and B (on the first line) as centres, draw arcs with a radius equal to the required spacing between the lines. Draw the second line to touch the curves as shown.

To divide a line into a given number of equal parts (figure 3.11)

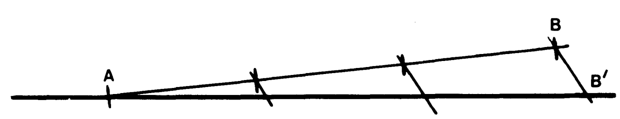


Figure 3.11 To divide a line into a number of equal parts

It is required to divide line AB into three equal parts. Draw line AB at a convenient angle and set off three equal divisions along it. From the third division B draw a line to B′. Draw lines parallel to BB′ as shown. (Greater accuracy will be achieved if these parallels are nearly perpendicular to AB.)

To draw a line at right angles to a given line (figure 3.12)

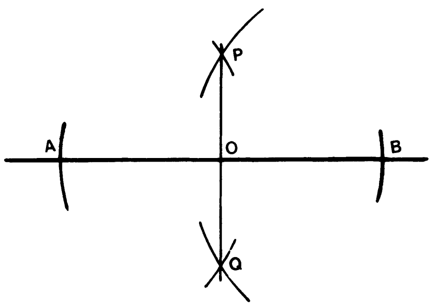


Figure 3.12 To draw a line at right angles to a given line

With a point O (near the middle of the line) as centre, draw an arc to cut the line at A and B. With points A and B as centres, draw equal arcs to intersect at P and Q. The line joining P, Q and O is perpendicular to line AB. Greater accuracy is achieved if the arcs at P and Q cross nearly at right angles to each other.

To find the centre of a given arc (figure 3.13)

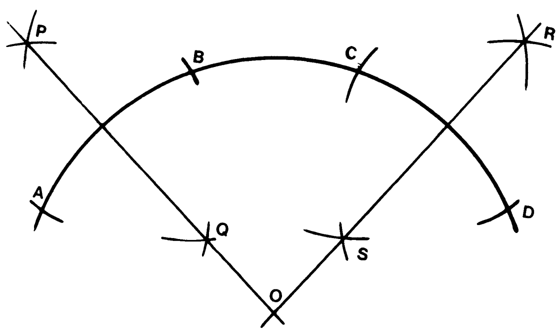


Figure 3.13 To find the centre of a given arc

From two points on the curve draw arcs to cut the curve at A, B, C and D. With points A, B, C and D as centres, draw equal arcs to intersect at P, Q, R and S. Lines drawn through P and Q and through R and S will intersect at O, the centre of the arc.

To bisect an angle (figure 3.14)

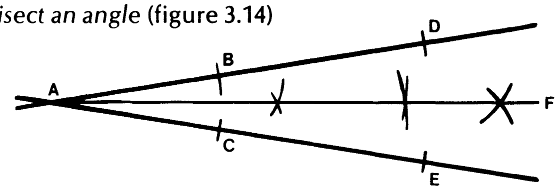


Figure 3.14 To bisect an angle

With the intersection of lines at A as centre, draw an arc to intersect the lines at B and C. With B and C as centres, draw equal arcs to intersect as shown. This process can be repeated at other points (D and E). Note that it is far easier to locate the intersection point when the arcs cross at right angles. The line AF through the intersections bisects the angle between the two lines AD and AE.

To find the junction of a straight line and a tangential arc (figure 3.15)

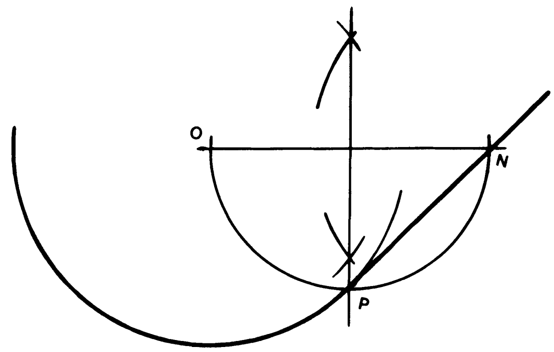


Figure 3.15 To find the junction of a straight line and a tangential arc

Draw a line between the centre of the circle, O, and any point N on the straight line. Bisect line ON and draw an arc to pass through O and N. Where this arc crosses the original curve is the point of tangency, P.

To find the junction of two tangential arcs (figure 3.16)

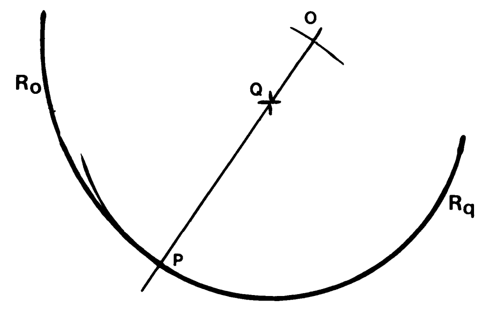


Figure 3.16 To find the junction of two tangential arcs

The centres, O and Q, of curves Ro and Rq and the tangent point P will lie on the same straight line.

3.6.2 Construction of Ellipses

To draw an ellipse (figure 3.17)

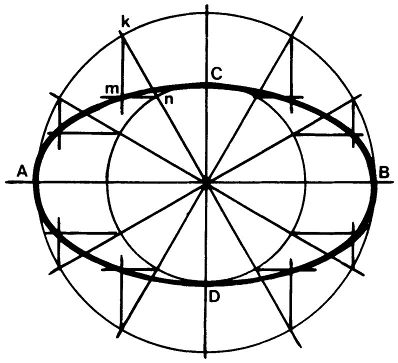


Figure 3.17 To draw an ellipse

Draw two perpendicular lines, and with their point of intersection as centre, draw two circles with diameters equal to the major axis AB and minor axis CD of the ellipse. Draw radials from the centre using a 30° set square or protractor. From the points of intersection, n, between the radials and the small circle draw horizontal lines. From the points of intersection, k, between the radials and the large circle draw vertical lines. The points, m, at which the horizontal and vertical lines cross, lie on the ellipse.

There are several other methods of drawing ellipses.

3.6.3 Construction of Polygons

To draw any regular polygon when one side is given (figure 3.18)

Draw a semi-circle of radius equal to one side AB of the polygon as shown. Divide the semi-circle into the same number of equal parts as there are sides to the polygon. Join B to the second division, C, of the semi-circle. Bisect, and draw lines at right angles to, sides AB and BC and extend these lines to intersect at O. With O as centre, draw a circle to pass through points A, B and C. Complete the polygon as shown with the aid of compasses or dividers.

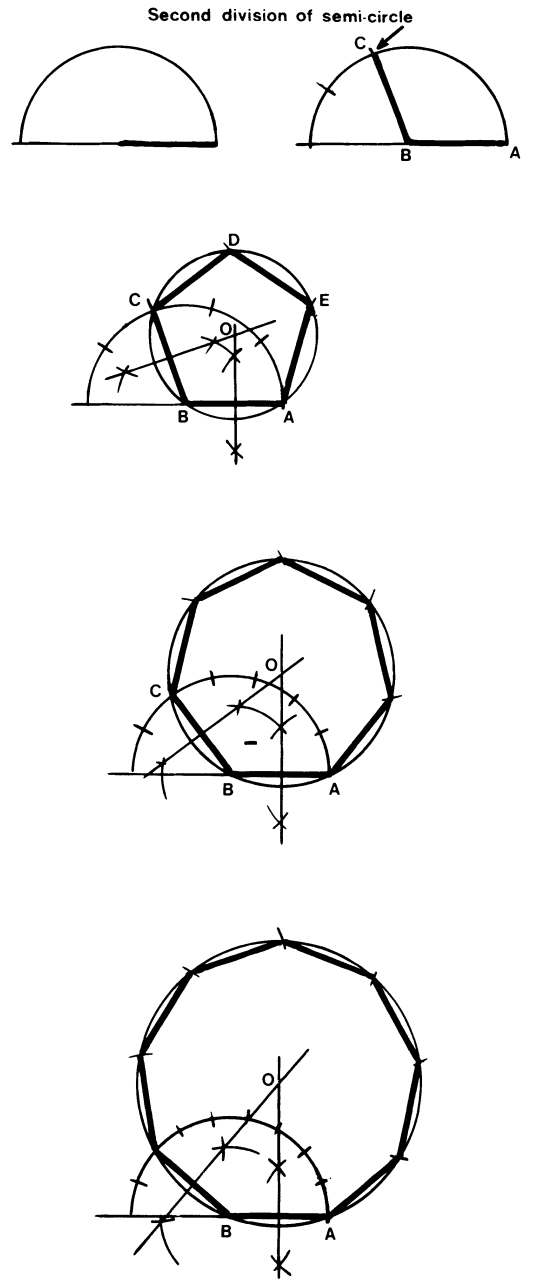


Figure 3.18 To draw a regular polygon given one side

To draw any regular polygon within a given circle (figure 3.19)

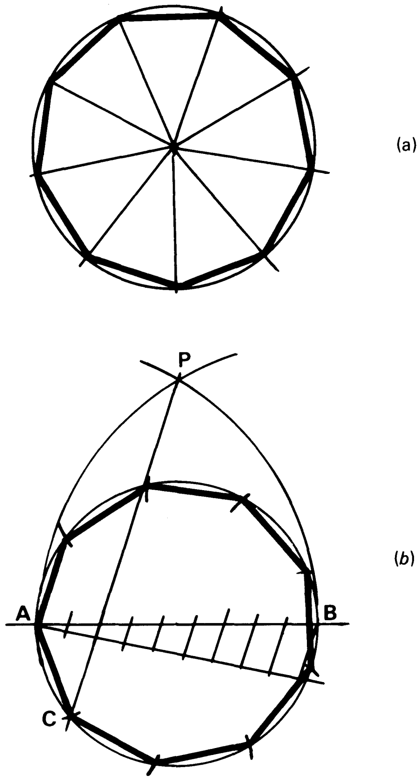


Figure 3.19 To draw a regular polygon within a given circle

Draw radials from the centre of the circle using a protractor to divide the circumference into the same number of equal parts as there are sides to the polygon (figure 3.19a).

Divide the diameter of the circle, AB, into the same number of equal parts as there are sides to the polygon, (figure 3.19b). With A and B as centres, draw arcs equal to the diameter of the circle. From the point of intersection, P, of the arcs draw a line through the second division of AB to intersect the circumference at C. Join A to C which is then one side of the polygon. Mark off equal divisions around the circumference and complete the figure as shown.

To draw any regular polygon around a given circle (figure 3.20)

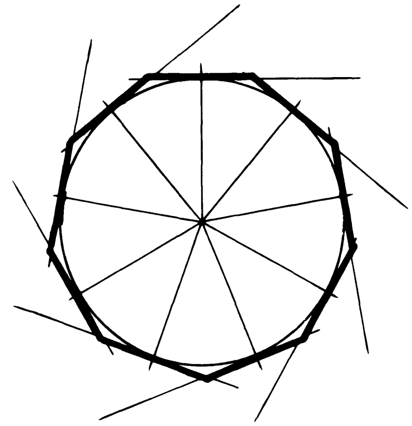


Figure 3.20 To draw a regular polygon around a given circle

Proceed as for figure 3.19 but draw tangents at the points of intersection between the radials and the circumference as shown.

To draw an octagon within a given square (figure 3.21)

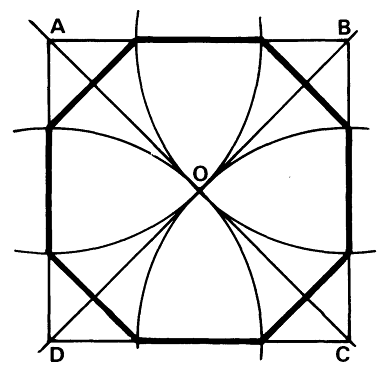


Figure 3.21 To draw an octagon within a given square

Draw diagonals to locate the centre, O, of the square. With the corners A, B, C and D as centres, draw arcs through O to intersect the sides of the square. Join the intersections as shown to complete the octagon.

3.6.4 Conics

The circle, ellipse, parabola, hyperbola and spiral are obtained from the properties of a cone.

Spirals give a smooth transition between two circular curves of different radius, or between a straight line and a circular curve; for this reason spirals are commonly used on high-speed roads to join a straight balanced section of carriageway to a fully super-elevated circular bend.

Parabolas and hyperbolas are the vertical curves used to join road gradients.

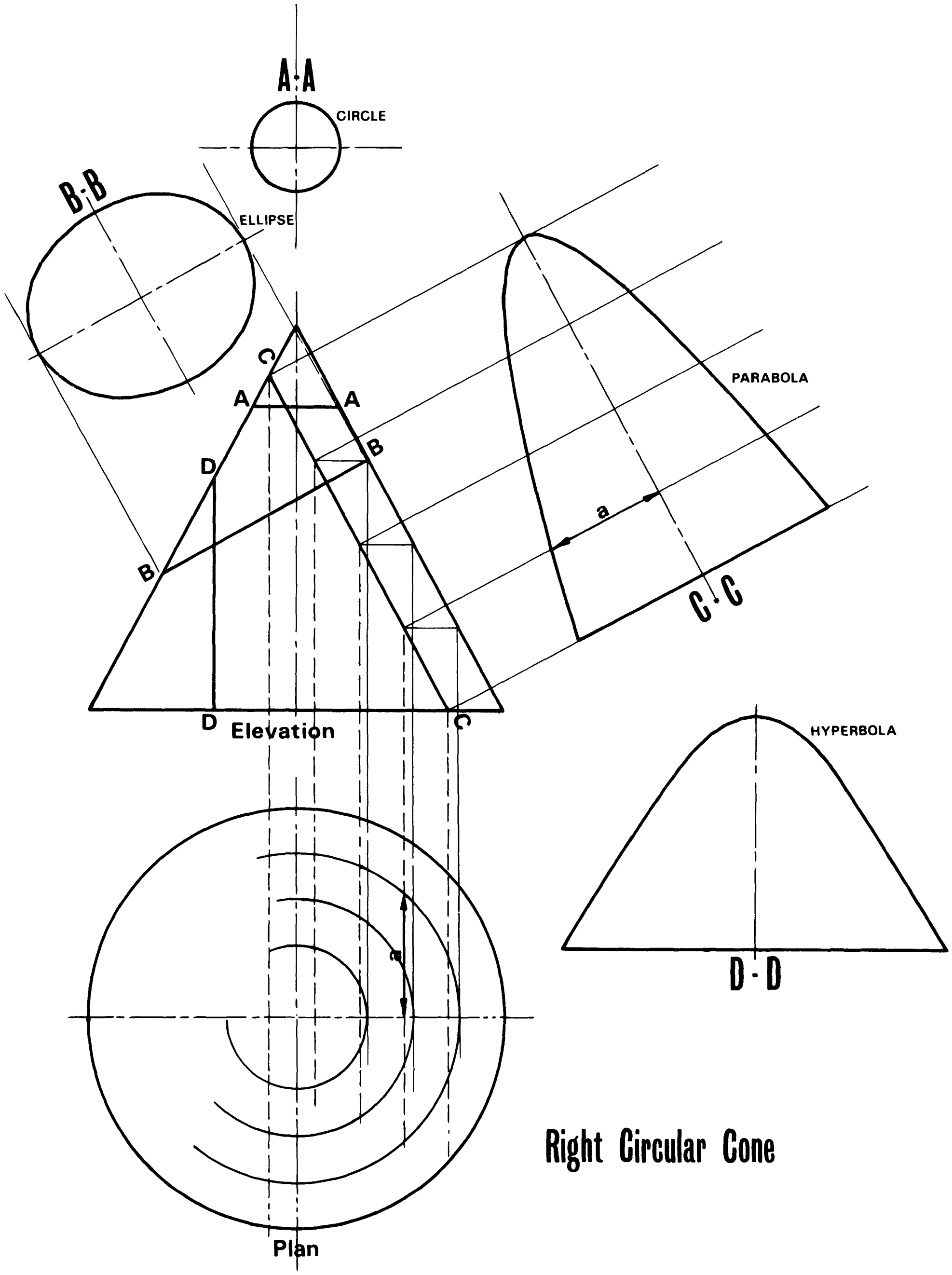


Figure 3.22 Conic sections

Conic sections (figure 3.22)

A circle is obtained by taking a section AA through the cone at right angles to the axis.

When a complete section BB through the cone is taken at an angle other than at right angles to the axis, the resulting curve is an ellipse.

A section CC parallel to the side of the cone produces a parabola.

A section DD parallel to the axis of the cone produces a hyperbola.

To construct a spiral (figure 3.23)

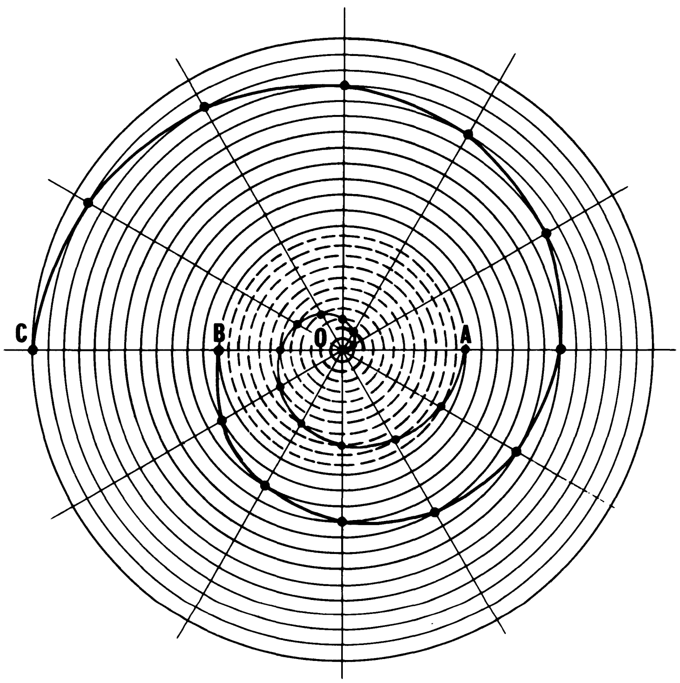


Figure 3.23 To construct a spiral

Draw radials from the centre of the circle using a 30° set square. Divide the radius into 12 equal parts and with O as centre draw circles to pass through these points. The line drawn through the points of intersection of the radials and circular arcs is a true spiral (curves OA and BC).

To construct a hyperbola given the asymptotes and a point on the curve (figure 3.24)

Draw a line through the given point p. The distances along this line between the asymptotes OA and OB and points on the curve, will be the same. At points C and D the curve is

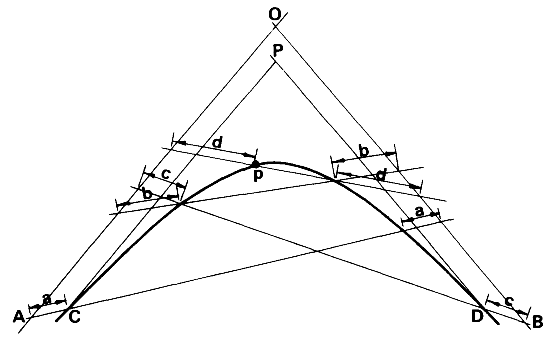


Figure 3.24 To construct a hyperbola

nearly tangential to lines parallel to the asymptotes. Distances PC and PD are equal. Determine further points p on the curve by marking off equal distances from the asymptotes, as shown.

To construct a parabola given the width and vertex (figure 3.25)

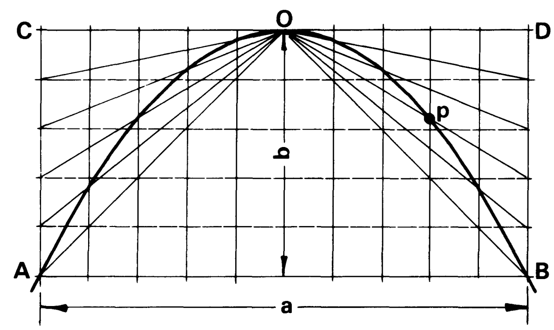


Figure 3.25 To construct a parabola given the width and vertex

Draw a rectangle ABCD with AB equal to the width, a, and sides AC and BD equal to the height, b. The apex, O, is located at the mid point of CD. Divide OC, OD, AC and BD into the same number of equal parts. Draw radials from O to the divisions on AC and BD. The curve drawn through the intersections p of the radials with the vertical lines as shown is a parabola.

To construct a parabola between two given equal tangents (figure 3.26)

Let OC and OD be the equal tangents. Divide OC and OD into the same number of equal parts. Draw lines between the divisions on the tangents as shown. The smooth curve drawn just to touch these lines is a parabola. The curve will meet the

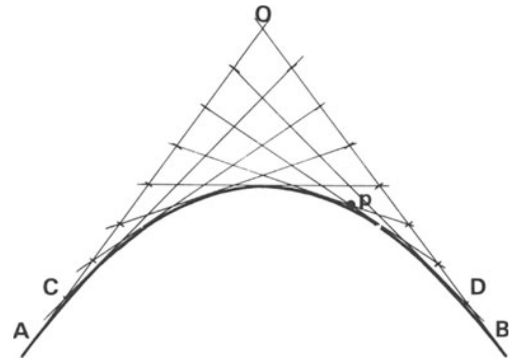


Figure 3.26 To construct a parabola between two given equal tangents

tangents at A and B beyond points C and D. A curve drawn through the intersections of the lines p will touch the tangents at C and D.

To construct a parabola between two given unequal tangents (figure 3.27)
The construction is similar to that described for figure 3.26.

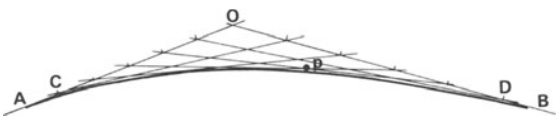


Figure 3.27 To construct a parabola between two given unequal tangents

3.6.5 Construction of a Helix

To construct a helix (figure 3.28)

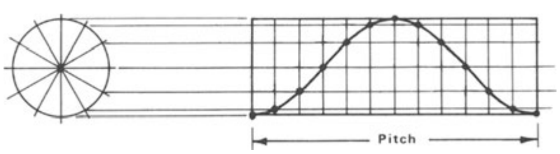


Figure 3.28 To construct a helix

Draw radials from the centre of the circular plan of the cylinder using a 30° set square as shown to divide the circumference into 12 equal parts. On the elevation divide the pitch into 12 equal parts. Project horizontal lines from the divisions on the plan to the vertical divisions on the elevation. Draw a curve to pass through the points of intersection as shown.

3.6.6 Developments, Interpenetrations and Sections

Developments are the true shapes of surfaces when laid out flat.

Development of a hexagonal prism (figure 3.29)

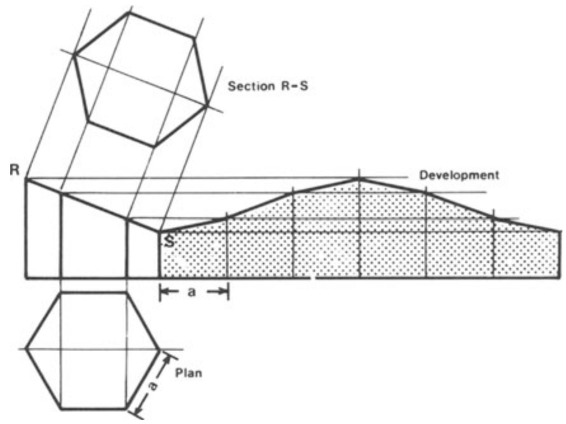


Figure 3.29 Development of a hexagonal prism

Each of the sides is vertical and at right angles to the base. Hence horizontal lines can be projected directly from the elevation to enable the completion of the development as shown. The true shape of the section RS is obtained by projecting an auxiliary view as shown.

Development of a cylinder (figure 3.30)

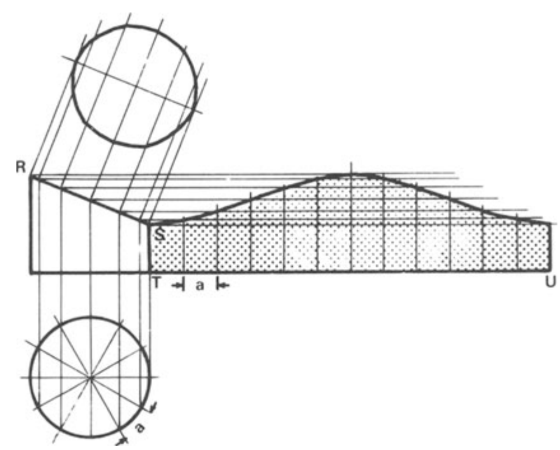


Figure 3.30 Development of a cylinder

Divide the circumference of the plan view into equal parts as shown and draw vertical projections to intercept the cut line RS. Draw horizontal projectors from the intersections and complete the development as shown. Note that TU is equal to the circumference of the plan view and that a is measured along the curve.

Development of a cone (figure 3.31)

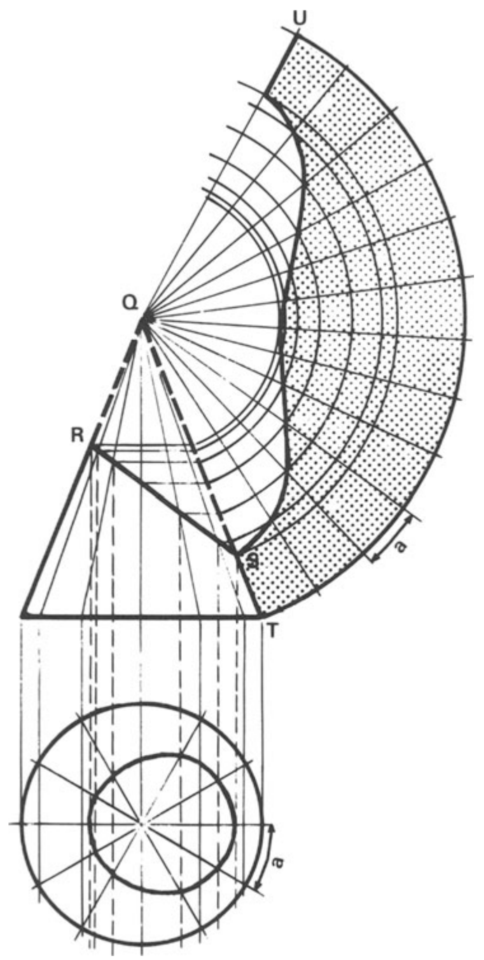


Figure 3.31 Development of a cone

Draw radials to divide the plan view into equal parts as shown. Project vertical lines, from the divisions on the circumference, to the base line on the elevation. Continue the projectors towards the apex, Q, of the cone to intersect the section line RS.

Draw horizontal lines from the intersections on RS to the sloping side QT. With Q as centre, draw arcs to pass through the points of intersection as shown. With Q as centre, draw an arc to pass through T and then mark off equal divisions, a, as shown.

Draw a curve through the intersection of the radials projected towards Q and the arcs scribed from the points on the sloping side QT as shown. The developed shape of the complete cone will be the segment of a circle which has a radius equal to the sloping side of the cone QT and a base length, UT, equal to the circumference of the base of the cone.

The plan outline of section RS is obtained by projecting vertical lines, shown broken, to intersect the radials on the plan view. The true shape of section RS can be obtained by projecting an auxiliary view in a manner similar to that shown in figure 3.30.

Interpenetration of cylinders

Figure 3.32 shows the development of a small cylinder which is connected obliquely to a larger cylinder.

Draw the front and side elevations of the oblique connection. Draw a semi-circle below the front elevation with a diameter equal to that of the small cylinder. Draw radials dividing the semi-circle into equal parts. Project a vertical line from a to intersect the circumference of the large cylinder at b.

Draw a semi-circle beyond the end of the small cylinder in the side elevation as shown. Divide the semi-circle into the same number of equal parts used in the front view. Project a line from c parallel to the side of the cylinder to intersect the horizontal projector from the front view at point d. From d draw a projector at right angles to the side of the small cylinder. Locate point g and complete the development in a manner similar to that shown in figure 3.30.

Vertical lines are projected from the side elevation as shown to determine the development of the hole in the large cylinder. Note that the distances between r, s, t and u are measured along the circumference of the large cylinder in the front elevation.

Development of a sphere (figure 3.33)

Divide the plan into twelve equal segments. Project vertical lines from the divisions on the circumference to intersect line OB. With O as centre draw arcs to pass through these intersections. Draw a projector through O and bisecting angle AOB. Draw projectors parallel to this line from the intersections of the circles with the two radials OA and OB as shown.

Develop the shape of one gore of the sphere as shown. The length of each gore is equal to the circumference of the sphere. The development shown is an approximation. If measurements are taken along the arcs in the plan view to

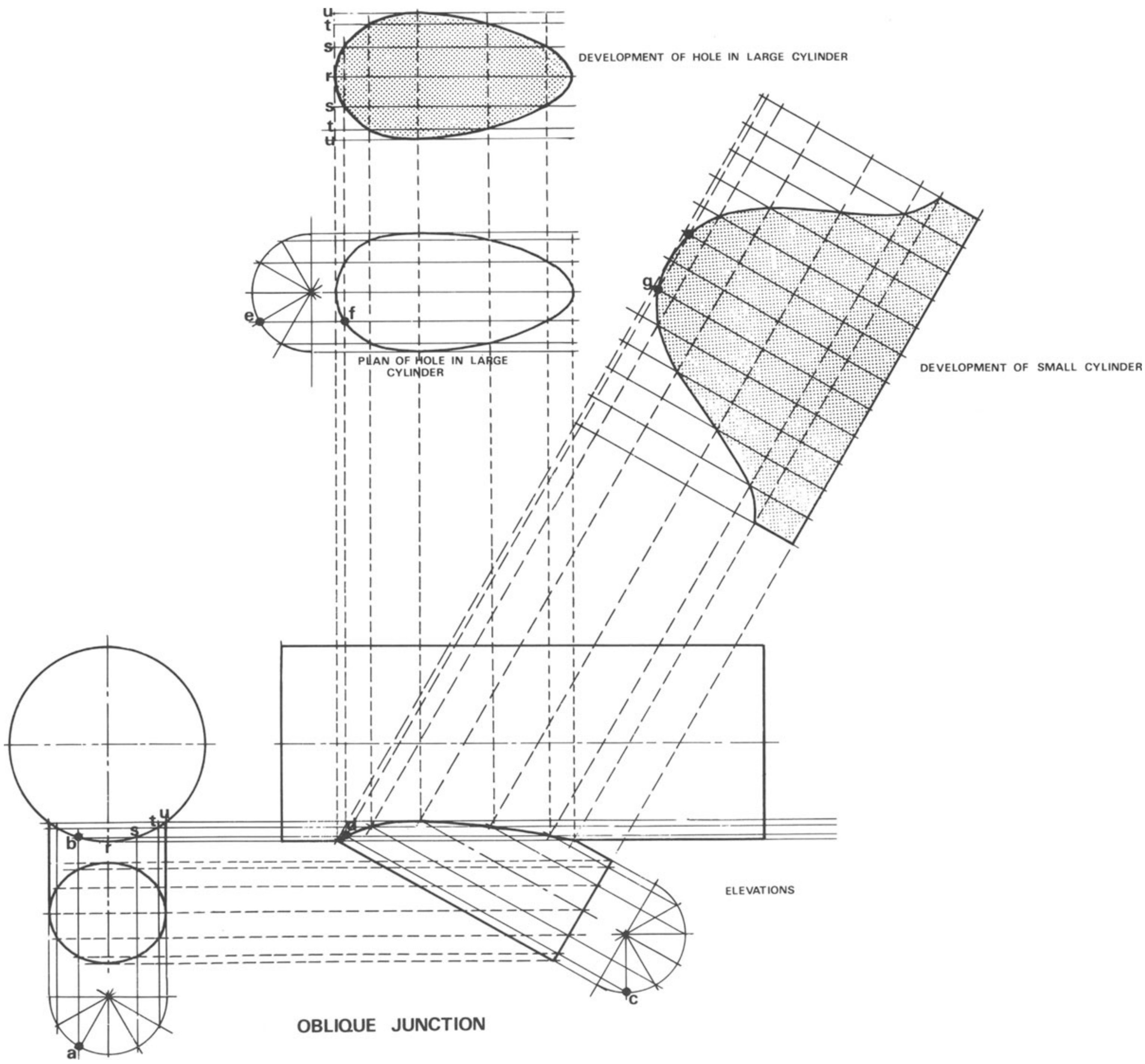


Figure 3.32 Interpenetration of cylinders

obtain the width at each division of the gore, this will give a more accurate result.

Project vertical lines from the elevation to the plan as shown. At the points of intersection with the circumference on the plan view, draw horizontal lines to divide the circle into six parts. Consider one zone ABCD. Draw a line through points C and D to intersect the extension of the vertical line through the centre of the circle at E. With E as centre, draw arcs to pass through C and D. Measure along these arcs distances equal to the circumferences of the sections at BC and AD (C′C″ and D′D″). Repeat this procedure to determine the developments of the remaining zones.

3.6.7 Conicoids

Conicoids are the twisted surfaces derived from a triangle, circle, ellipse, parabola or hyperbola.

Surfaces which have the hyperbola as the main contour are known as hyperboloids. Other sections through the surface will define the type of hyperboloid. Hyperboloids have properties which enable the use of straight elements in their formation.

Parabolic hyperboloids, commonly used in shell roof construction, can be visualised by placing a thin rectangular sheet of plastics on a level surface and then raising two opposite corners. The corners can also be bent down, or two corners can be bent downwards while the other two are raised. Lines on the surface parallel with the edges will be straight, and those parallel to the diagonals will be parabolic.

The distinctive shapes of power station cooling towers are circular hyperboloids.

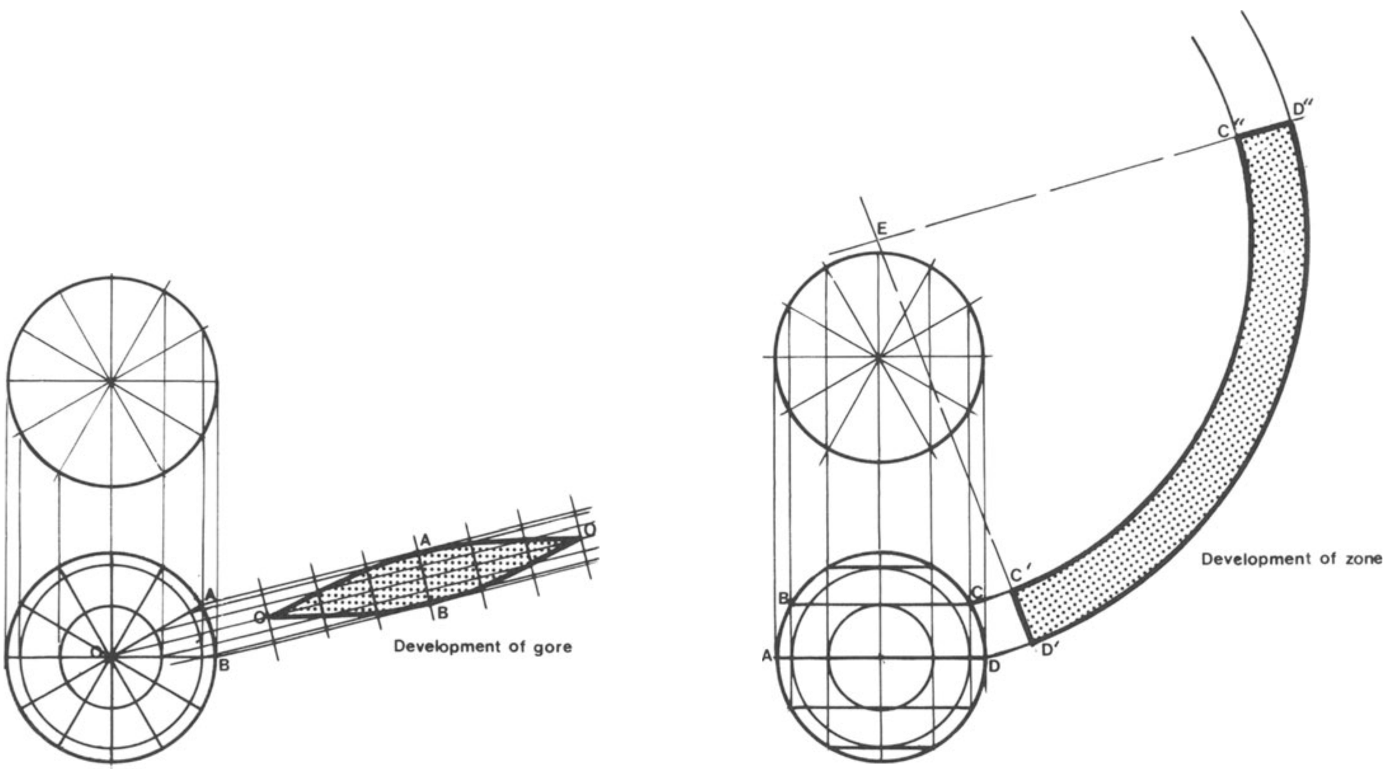


Figure 3.33 Development of a sphere

4. THREE-DIMENSIONAL DRAWING AND SKETCHING

4.1 INTRODUCTION

This chapter deals with the basic principles of three-dimensional drawing and sketching. Although the student of civil engineering may seldom be called upon to be an artist, he must nevertheless attain some proficiency in freehand sketching.

4.2 SKETCHING

Sketching is generally used to illustrate a proposed idea rather than an existing view or object. The reason why so many people find it difficult to sketch their ideas is that they have not developed a conscious awareness of the factors that dictate the shape and form of many everyday objects; the mind does not always appreciate what the eye sees. These factors include perspective, proportion, symmetry, shading, shadows, light and colour – of these the first two are the most important.

4.2.1 Proportion and Symmetry

The essential features of an object should be drawn approximately in their correct proportions. For example, is the over-all length one-and-a-half times or twice the width? Is a particular part of the object one-quarter or one-third of the size of the whole?

Coordinate papers (see figure 1.27) will be found particularly helpful for both two and three-dimensional sketches. Figure 4.1a shows several common large objects drawn in their correct proportions. One method of gauging proportions is to hold a pencil at arm's length and mark off the observed dimensions of the object with the top of the thumb as shown.

It has long been considered that a rectangle, known as the golden rectangle, has aesthetically pleasing proportions. The construction of this rectangle is shown in figure 4.1b.

Figure 4.1c shows a method of drawing a circle through the intersections of straight line divisions of a square. (Figure 4.1f shows how to construct an ellipse in a similar manner.)

Two squares with sides in the proportion 1:1.414 can be obtained by means of the construction shown in figure 4.1d. Alternatively the circle can be drawn within the given squares as shown.

Figure 4.1e shows how to divide a square into smaller squares by means of diagonals, and figure 4.1i shows how a square grid can be extended in a similar way.

Each of the rectangles shown in figure 4.1g has an area equal to half that of the next largest size. Standard metric drawing sheet sizes have these proportions (see table 1.1).

Figure 4.1h shows how to divide a rectangle into two different sized rectangles having the same length to width ratio.

Figure 4.1j shows how to divide the sides of a rectangle into halves, thirds, quarters and fifths.

Some of these constructions will be found particularly useful in three-dimensional drawings and sketches.

4.2.2 Perspective

From everyday observation the reader is of course aware that an object will appear smaller the further it is placed away from the eye. Probably it will also have been noticed that the eaves of buildings along a long straight road appear to converge towards a single point. If the sea were to be visible beyond the end of the road this point would appear to lie on the line dividing the sea and the sky, that is, the horizon.

Other rules governing what the eye sees (summarised below) are not so readily apparent.

(1) All parallel lines will appear to converge towards a single point known as the vanishing point, except when they run directly across the view, that is, where the lines are at right angles to the line of sight. They are then drawn just as they would appear in an orthographic elevation, that is, the vanishing points are an infinite distance away from the object.

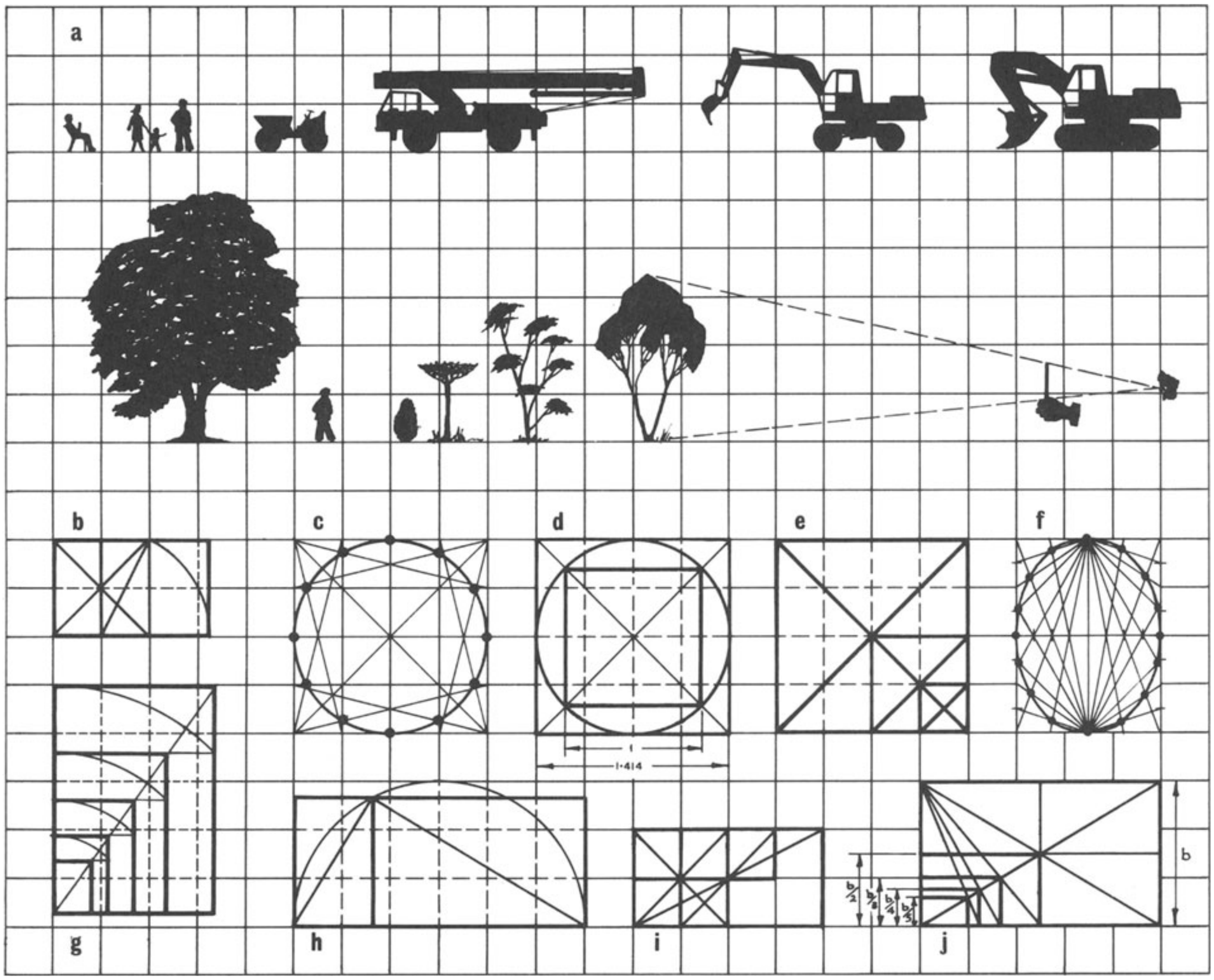


Figure 4.1 Proportions

(2) Lines that are both parallel and horizontal will appear to converge to a single point on the horizon.
(3) The horizon always appears at the same level as the eye.
(4) Sets of parallel lines having different directions in plan will each have their own vanishing points.
(5) If parallel lines are inclined upwards, their vanishing point will be above the horizon, and if inclined downwards, the vanishing point will be below the horizon.
(6) If the line of sight is horizontal, all vertical lines will also be drawn vertical in the perspective view.
(7) If the line of sight is inclined, vertical parallel lines will appear to converge towards a single point.
(8) If the line of sight is inclined upwards, vertical parallel lines will appear to converge to a point above the horizon, and if inclined downwards, the vanishing point will be below the horizon.

Figures 4.2 to 4.6 serve to illustrate some of these basic principles of perspective. Figures 4.2, 4.3 and 4.4 are rough freehand sketches of the building shown in isometric view in figure 4.12. The basic outlines only of the building are shown,

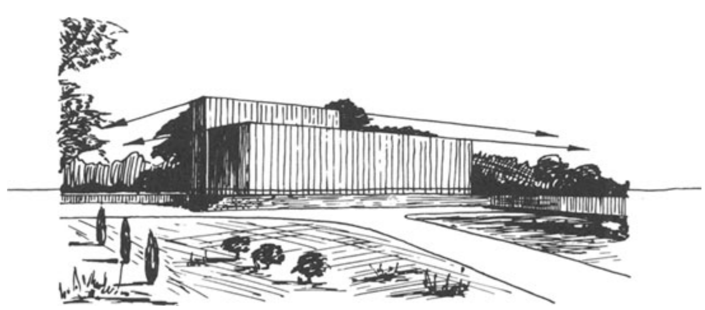


Figure 4.2 Line of sight horizontal, natural view

with greater attention being paid to the rendering of the surrounding detail which serves mainly to complement the view of the building.

Assuming that the observer is standing on ground which is at the same level as that directly in front of the building, the eye level or horizon line in figure 4.2 is situated just above the wall which is approximately 1.3 m high. This would be the height of the observer's eye were he to stand next to the wall. The line of sight is horizontal and the main horizontal outlines converge to two vanishing points on the eye level to the right and to the left of the picture. The parallel lines of the approach road, also assumed to be level, will converge to a point on the eye level. Note the attention to the foreground, the trees around the building, and the cloudless sky.

In figure 4.3 it is assumed that the ground level immediately in front of the building is higher than the ground where the observer is standing, and that the approach road is inclined upwards. It is also assumed that the observer maintains a horizontal line of sight. Hence the vanishing points for the horizontal lines of the building will still converge to points on the eye level, but both the wall and the vanishing point for the approach road will lie above the eye level. Note the lack of detail in the foreground, the trees to the side of, rather than around, the building, and the clouds in the sky. The best composition is achieved if (1) the centre of the focal area, in this case the building, is situated approximately within the middle third of the picture, (2) the centre of the picture does not coincide with a vertical corner of the building, and

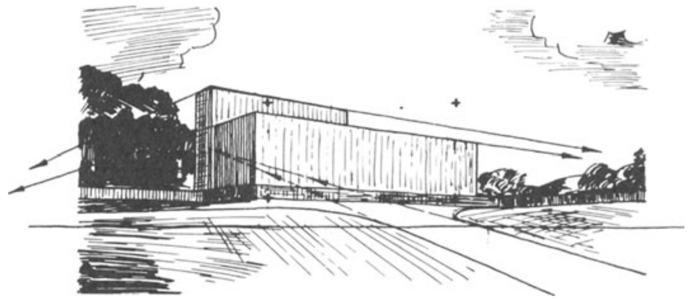


Figure 4.3 Line of sight inclined upwards

(3) the most important elevation of the building is given prominence.

Figure 4.4 shows a view of the building as seen from above with an inclined line of sight. Note that vertical lines converge towards a point below the picture. Particular attention is given to the surrounding detail and shadows.

The apparent dimensions of the lines in these views have only been guessed. The following text describes how a more accurate assessment can be made.

Figure 4.5 shows how the lines of a tall building appear to converge towards three vanishing points when looking up at the building as in figure 4.5a, and looking down as in figure 4.5b.

With any form of sketching, the basic outlines only of the objects should be drawn before filling in the detail (see figure 4.6). Shadows can be roughly drawn by first

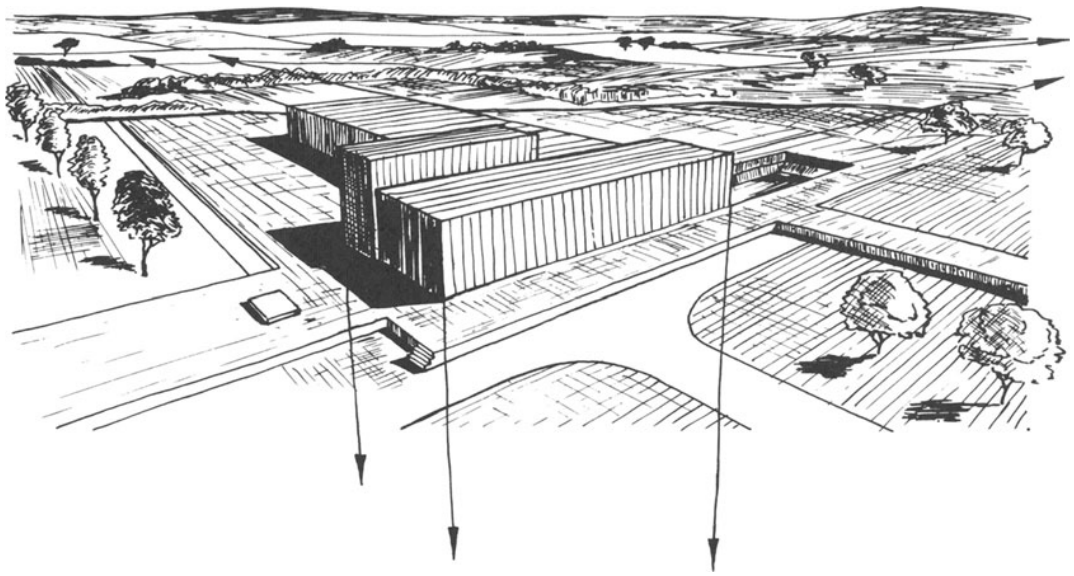


Figure 4.4 Bird's eye view

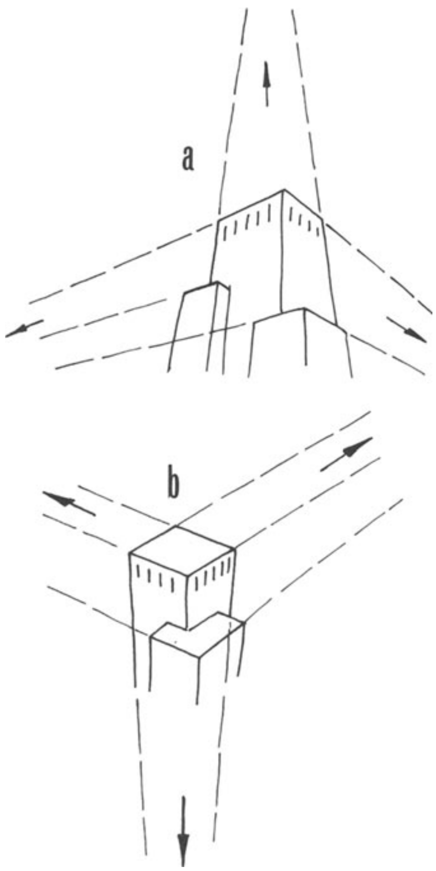


Figure 4.5 Perspective sketches with three vanishing points

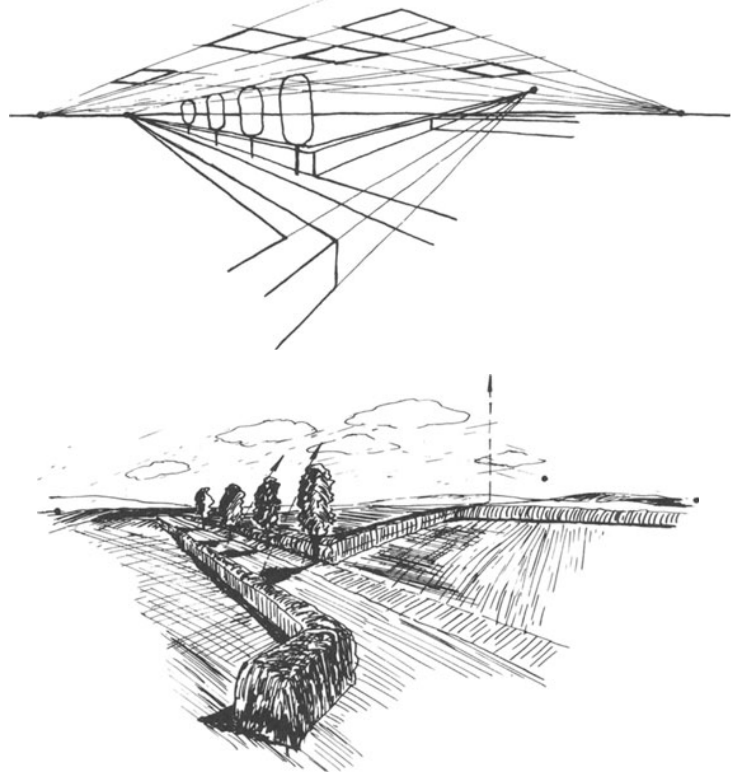


Figure 4.6 Perspective sketching with the aid of construction lines

establishing the position of the sun. Then, taking the tree shown in figure 4.6 as an example, draw a line from the position of the sun to touch the top of the tree. Extend this line to intersect a line through the base of the tree to a point on the horizon directly below the sun, and sketch in the shadow of the tree as shown. Note that this is only an approximation which assumes that the ground on which the shadow is cast is level.

A method of illustrating interior views, frequently used by technical illustrators, architects and planners, involves placing one elevation at right angles to the horizontal line of sight. All horizontal lines of the view that are at right angles to this elevation will then appear to converge towards a single vanishing point. This is termed 'one-point' or parallel perspective. Certain civil engineering structures can also be appropriately represented in parallel perspective. An obvious example is a footbridge, which will be seen in elevation from a car driver's viewpoint (see appendix I).

The usual method of illustrating exterior views of buildings is by means of 'two-point' or angular perspective. In this case the elevations are set at an angle, other than a right angle, to the horizontal line of sight. The horizontal lines of one elevation will appear to converge to a point on the eye level to the left of the picture, while the horizontal lines of the other elevation, at right angles to the first, will converge to a point on the eye level to the right of the picture.

Figure 4.7 shows how the constructions in figures 4.1c, e, f and i are used to sketch a cubic grid and to draw a circle and an ellipse, in both parallel and angular perspective.

No attempt has yet been made to describe how dimensions are accurately determined along the lines converging towards the vanishing points; this is discussed in section 4.3.

4.2.3 Rendering and Shading

Recent changes in the course syllabus for civil engineering students are clearly intended to encourage the civil engineer to consider very carefully the influence that his work may

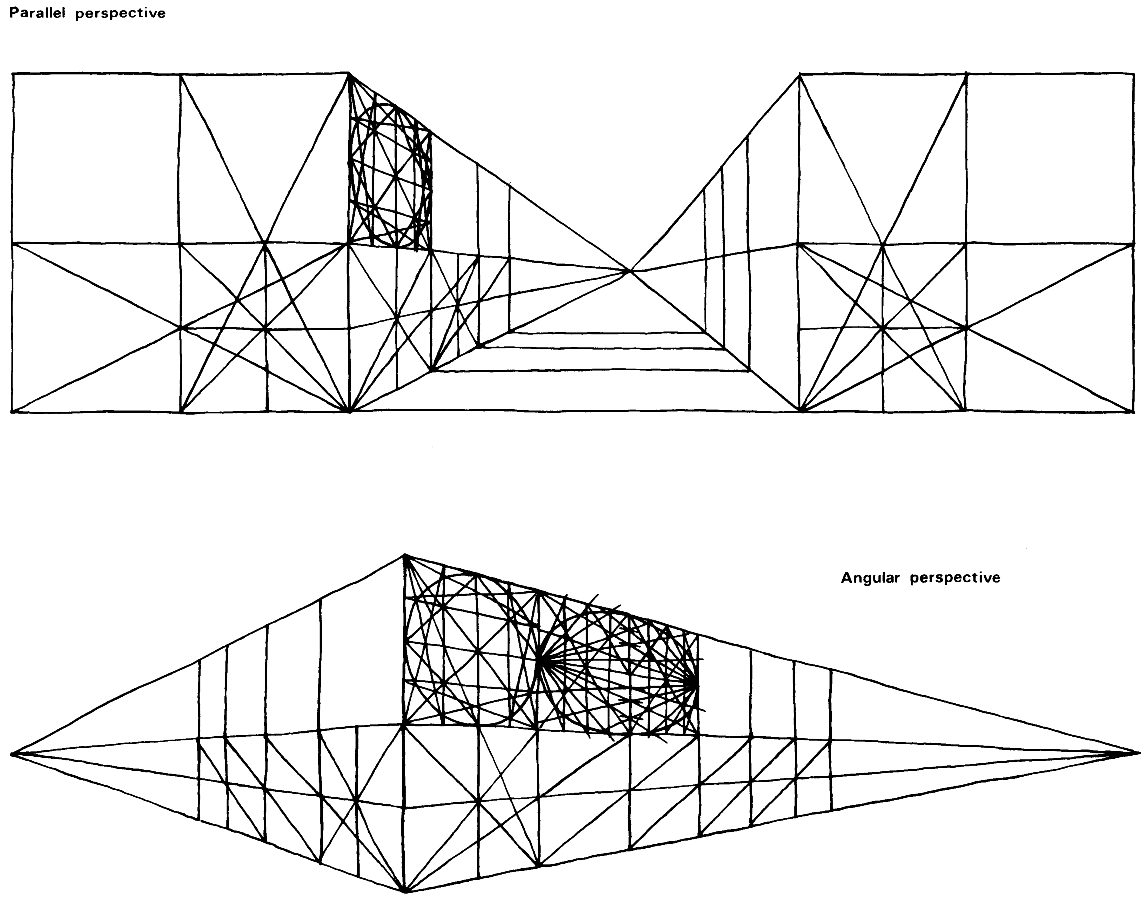


Figure 4.7 Construction lines: parallel and angular perspective sketches

have on society as a whole; in addition to his technical and economic judgements, today's civil engineer is being asked to make social, moral and aesthetic judgements as well.

Perspective drawings, properly rendered and shaded, can be a very effective means of assessing the appearance of a proposed structure and the likely impact that it will have on its environment. The revised BS 1192 is likely to place a greater emphasis on three-dimensional projections.

In order to convey a sense of realism, some attention should be paid to the features surrounding a large structure drawn in perspective. The structure itself may be drawn in constructed linework, but it will usually be sufficient merely to sketch in background and foreground features – a few narrow lines suggesting the basic outlines of buildings with light shading between, or a blurred mass of distant trees. Pencils and colour wash are very suitable materials for rendering and shading.

The method described below, and illustrated in figure 4.8, is an example of how a variety of drawing materials and media can be used to good effect in quickly producing simple drawings that show a variety of alternatives for a scheme, at a fixed location.

(1) Mark two points at the proposed bridge location with ranging rods, and then take a photograph from the required viewpoint.
(2) Sketch the basic outlines of existing features on to detail paper by scaling up from the photograph.
(3) Place a sheet of tracing paper over the sketch and quickly shade in the clouds, trees and grass areas with a wash of black ink and water diluted as required. This will be quicker than hatching.
(4) Obtain a copy polyester negative (intermediate) of the colour washed tracing, ensuring that the printing is on the gloss side.
(5) Mark in the kerb lines, handrailing, tree trunks and

(a)

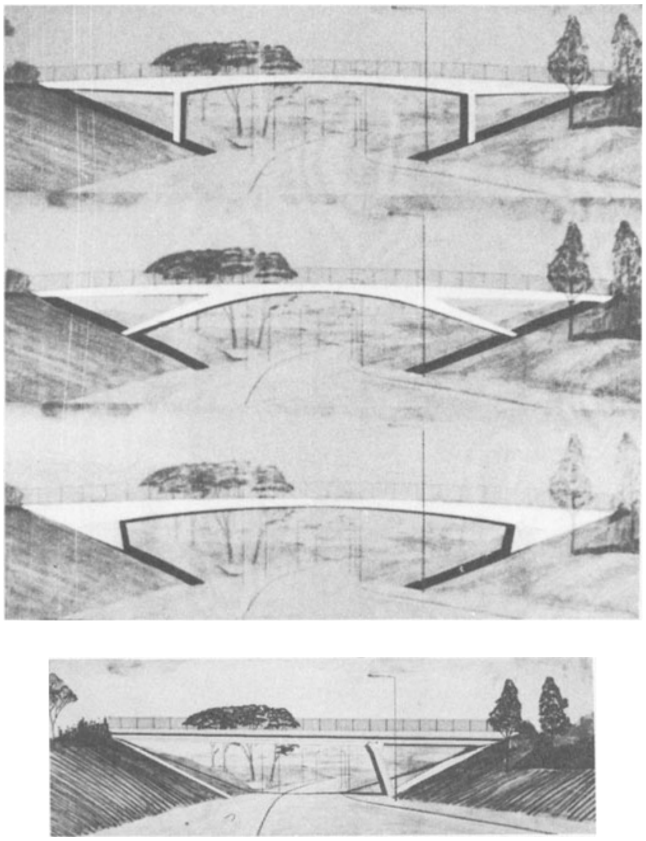


Figure 4.8 Sketches of alternative bridge schemes

branches, lamp columns and additional shading, using an H pencil.

(6) Overlay the negative with one of the alternative bridge shapes, cut from card or cartridge paper, and pass through the developing section of the dyeline printing machine. This shape will come out black when the print is passed through the printing section of the machine. Cut out the shape of the bridge elevation alone and fix it to the print. Repeat this procedure with the other shapes (figure 4.8a).

(7) Draw the chosen design in greater detail on the matt side of the copy negative and remove any encroaching background detail, with water and a hard rubber, from the gloss side (figure 4.8b).

A more formal style of rendering, using transfers and straight hatching lines, may be more appropriate for a two-dimensional elevation and the front elevation of a structure drawn in parallel perspective. Transfers should also be used for representing people, vehicles and similar features which are difficult to draw realistically.

Important detailed presentation drawings for public display should, however, be left to those who specialise in this type of work.

4.2.4 The Mechanics of Sketching

Sketching is used in civil engineering chiefly by designers to illustrate their preliminary ideas or convey their requirements to draughtsmen or detailers, who then prepare the working drawings.

Sketching therefore requires the ability to draw regular geometric shapes rather than a knowledge of perspective and rendering. Straight lines, circles, ellipses and lettering should be formed quickly with a reasonable degree of neatness and accuracy, and there is no substitute for practice in achieving this. Square and isometric coordinate paper will be found very useful for accurate proportioning, and for drawing parallel lines.

The reader should be able to achieve proficiency in freehand sketching by practising the following operations, mastering each one in turn.

(1) Mark two arbitrary points on the paper and try drawing a straight line between them with a continuous movement. Repeat, increasing the distance between the points.

(2) Quickly draw parallel lines at even spacings. Alter the spacing and angle of the lines. Draw the lines at gradually diminishing spacings, as would be required for hatching perspective drawings or indicating curvature of a surface.

(3) Draw a square, divide it as shown in figure 4.1c, and develop a grid as shown in figure 4.1i.

(4) Draw lines at approximately 30° to the horizontal, as would be required for isometric sketches.

(5) Draw a series of straight lines of equal length and with equal spacings between them. Alter the length of the lines and the space between them.

(6) Draw a circle within a divided square, and an ellipse within a divided rectangle, keeping in mind that the curve will be tangential to the straight construction lines where it touches them.

(7) Draw a circle and an ellipse without the aid of a square or rectangle. This will usually involve sketching a number of feint lines close together and estimating the best line through them, which is then drawn firmly.

All the above movements should be practised without the pencil actually touching the paper, in order to establish the most suitable position of the hand for each stroke.

4.3 CONSTRUCTED THREE-DIMENSIONAL DRAWINGS

Three-dimensional drawings are derived from different methods of projection from orthographic views.

There are three broad groups, shown pictorially in figure 4.9.

(1) Oblique projections in which the projection lines are parallel and oblique to the plane of projection.
(2) Axonometric projections in which the projection lines are at right angles to the planes of projection.
(3) Perspective projections.

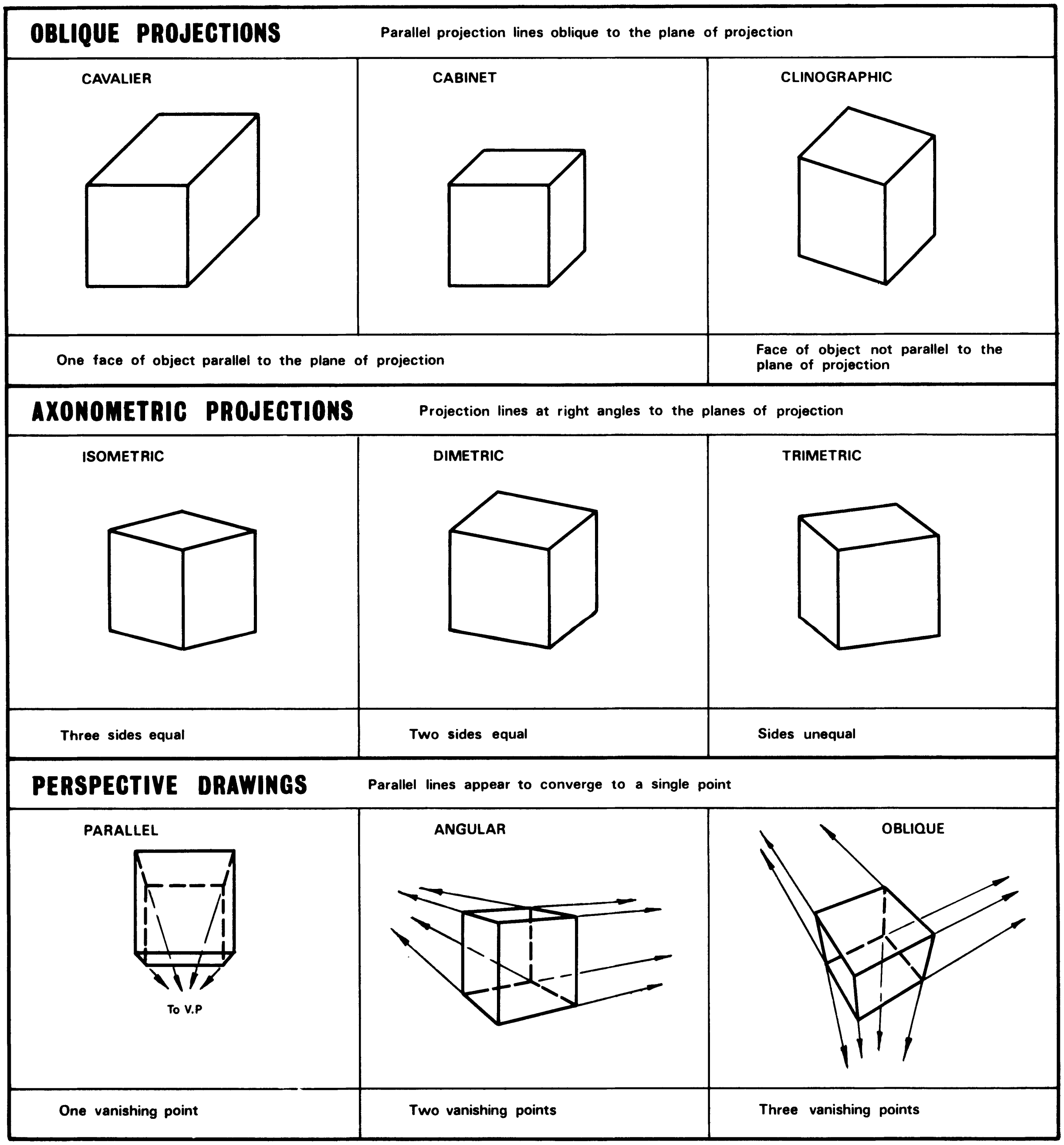


Figure 4.9 Three-dimensional drawings

4.3.1 Oblique Projections and Drawings

The projection lines used to derive oblique projections are parallel and oblique to the plane of projection.

The object itself can be situated in any position, but it is usual to arrange one elevation parallel to the plane of projection. All lines on this elevation, and planes parallel to it, will then be the same as they would appear in an orthographic view. Measurements in the direction of the receding axis are related to the angle of the projection lines but not to the angle of the axis itself.

Although oblique drawings are simpler to construct than other three-dimensional drawings, they tend to give a more distorted appearance and are generally unsuitable for illustrating civil engineering structures. The amount of distortion can be reduced by the careful choice of (1) the angle of the receding axis, (2) the foreshortening of the views in the direction of the receding axis, and (3) the front elevation. The usual choices for the angle that the receding axis makes with the horizontal are 45°, 30° and 15°. The most commonly used oblique drawings are

(1) cavalier drawings, in which dimensions on the receding views are to the same scale as those on the front elevation;
(2) cabinet drawings, in which dimensions on the receding views are one-half the scale of those on the front elevation.

Figure 4.10 shows an oblique view of a footbridge.

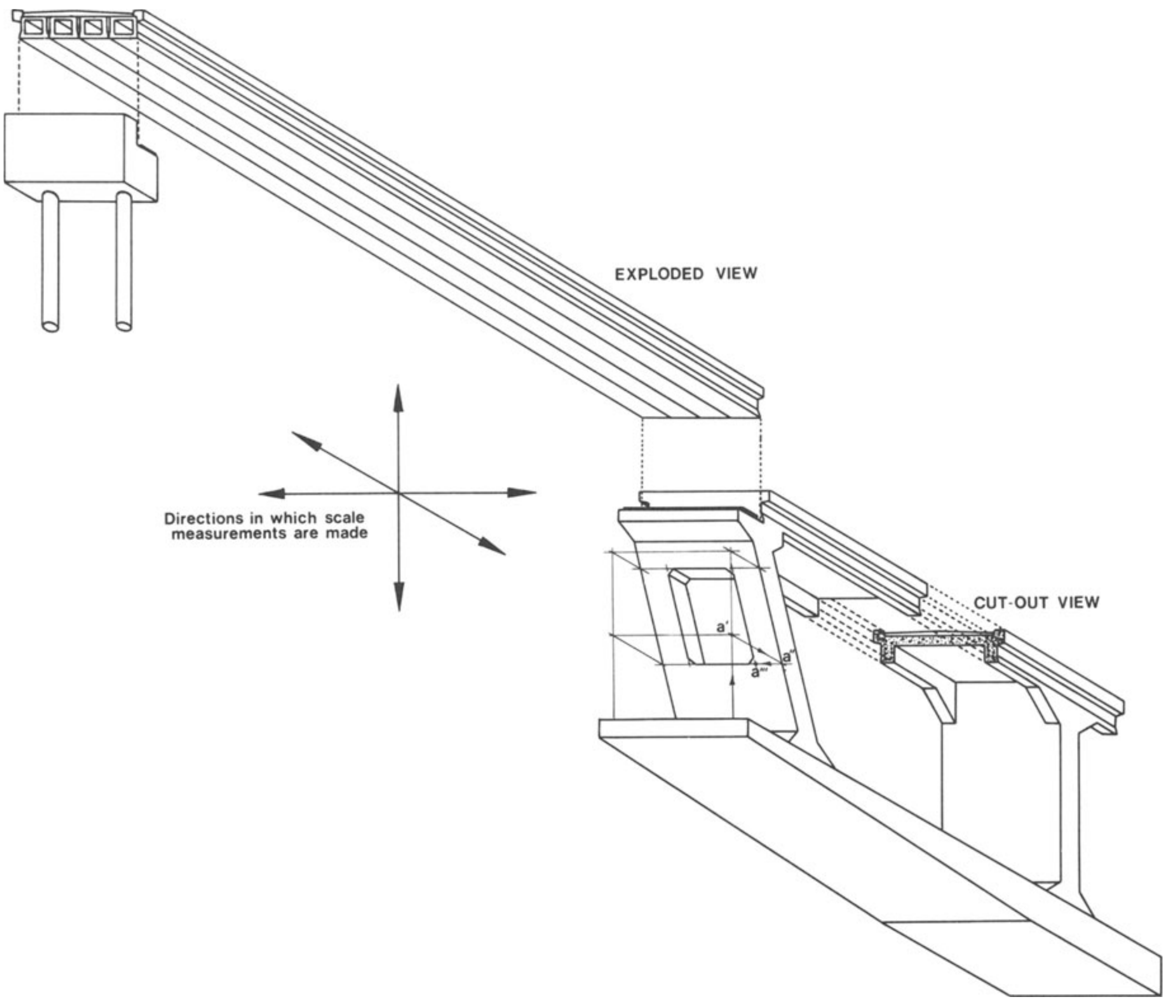


Figure 4.10 Cavalier drawing of a footbridge

4.3.2 Axonometric Projections and Drawings

The method of constructing an axonometric projection is shown in figures 4.11a and b.

(a) (1) Draw the three principal axes of the object.
(2) Project the line of one axis from O to F and draw a line in a convenient position at right angles to this projection line to intersect the other two axes at A and C.
(3) Draw a line from C at right angles to OA to intersect the first axis at B.
(4) Draw DE parallel to AC, and GH parallel to BC.
(5) Draw semi-circles on DE and GH. Extend OB to intersect the semi-circle at F. Extend OA to intersect the semi-circle at I.
(b) (6) Draw the side JK of one elevation of the object parallel to DF, KL parallel to FE, NM parallel to IG, and NP parallel to IH.
(7) Project the axonometric view of the object from the two elevations as shown.

The foreshortening of the sides of the axonometric view are related to the orientation of the axes. When the scale of the measurements along all three axes is the same this is termed isometric projection. This occurs when the angles between adjoining axes are the same, that is, 120°. Dimetric projections are those in which two scales are the same; in trimetric projections all three scales are different. Note that with all true axonometric projections the lines on the three-dimensional view will be shorter than the corresponding lines on the orthographic elevations. For example, the ratio of an isometric scale to the orthographic scale is 1:1.224.

Axonometric drawings, which are rarely projected directly from orthographic views, are similar to, but rarely the same as, true projections. For example, the scale for measurements on an isometric view is usually the same as the scale used for the orthographic elevations. However, when elevations or sections and the isometric view are incorporated on the same drawing, which is often the case in mechanical engineering, the reduced scale is used for the isometric view so that it does not appear unnaturally large in relation to the other views.

Isometric drawings are used in civil engineering more frequently than other three-dimensional drawings because they are easier and quicker to construct, particularly for cut-out views. Figure 4.12 shows cut-out isometric views of a sand filtration plant at a sewage works. Each cut-out has been carefully chosen to convey a clear understanding of the overall working of the plant. Feint construction lines were taken right across the views before the outlines and boundaries of each cut-out were drawn. The isometric drawing shown in figure 4.12 bears some similarity to a bird's eye view. Because this is an uncommon viewpoint, the fact that the sides of the building do not appear to converge towards vanishing points was not considered to be of significant importance. A perspective would, of course, have taken much longer to produce.

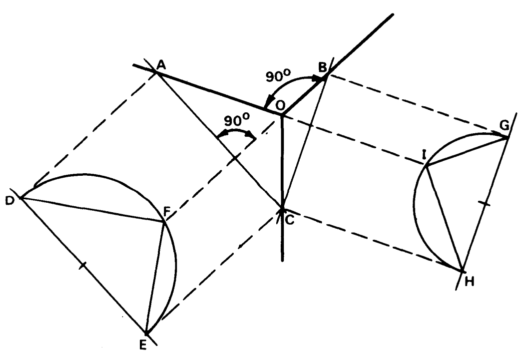
Presentation drawings of large structures, particularly those which do not involve cut-out views, should be drawn in perspective (see inset view of plant in figure 4.12).

In axonometric drawings, scale dimensions can only be made along lines parallel to the three principal axes. Curves are usually drawn through points which have been determined by means of coordinates parallel to these axes. Hidden lines are not usually drawn on three-dimensional drawings.

In the isometric drawing of part of a footbridge shown in figure 4.13, it was found to be clearer to show the cut-out views beyond the limits of the main views.

Figure 4.14 shows an example of dimensioning isometric views.

(a)



(b)

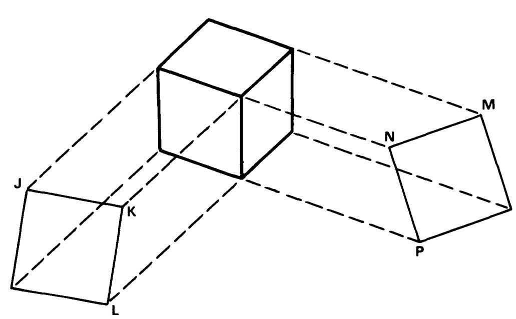


Figure 4.11 Axonometric projection

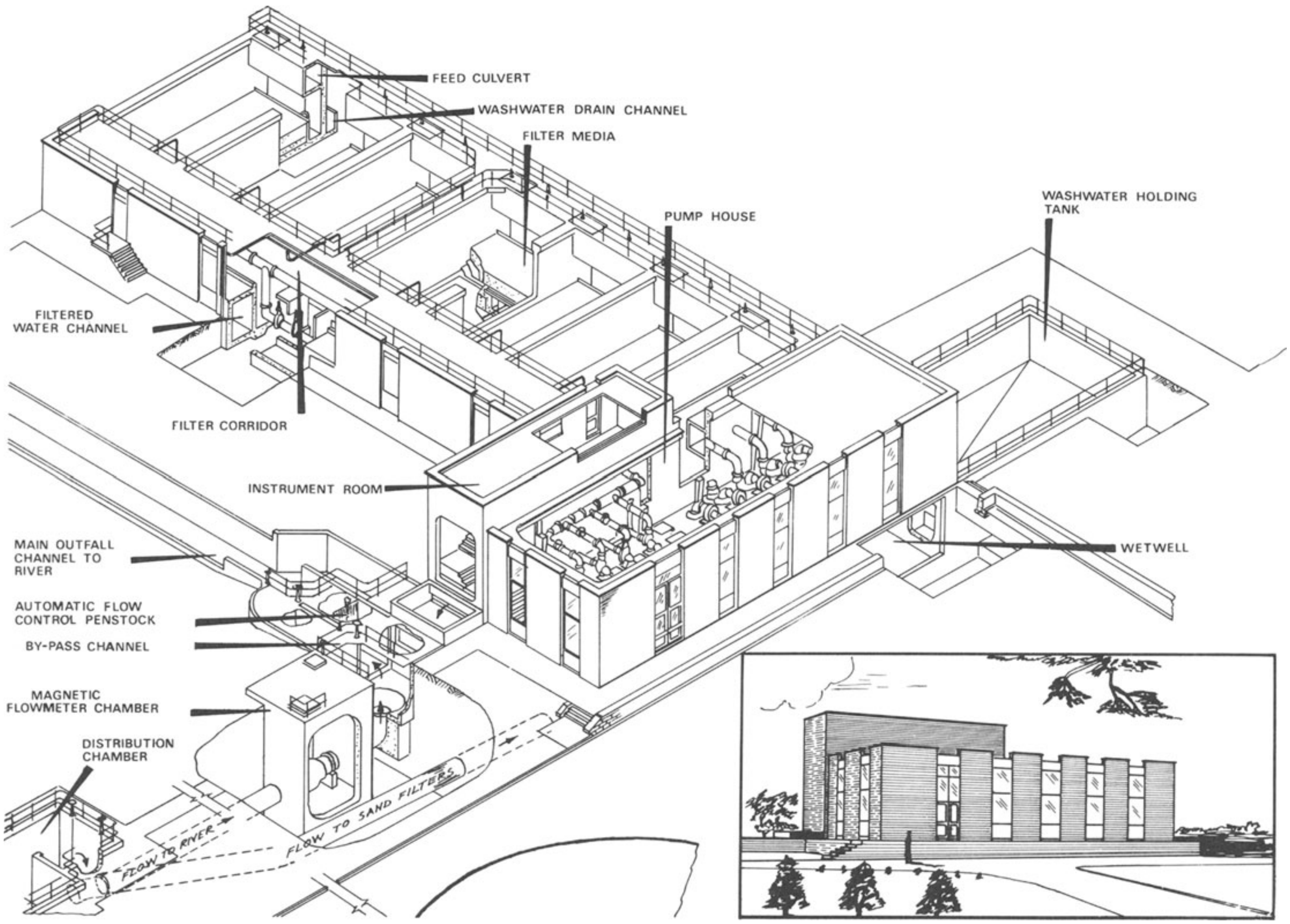


Figure 4.12 Isometric cut-out views of a sand filtration plant

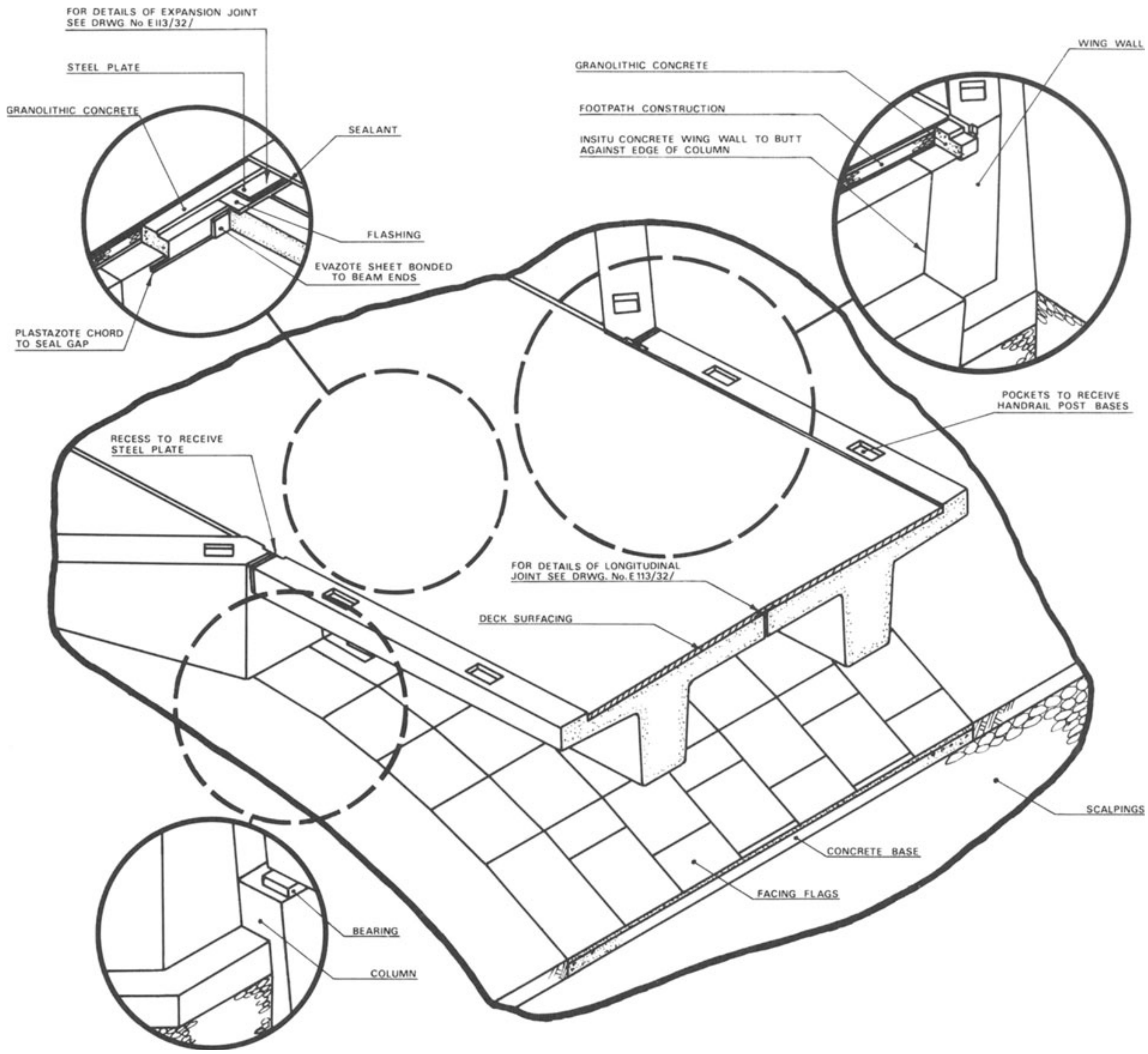


Figure 4.13 Isometric cut-out views of a footbridge deck

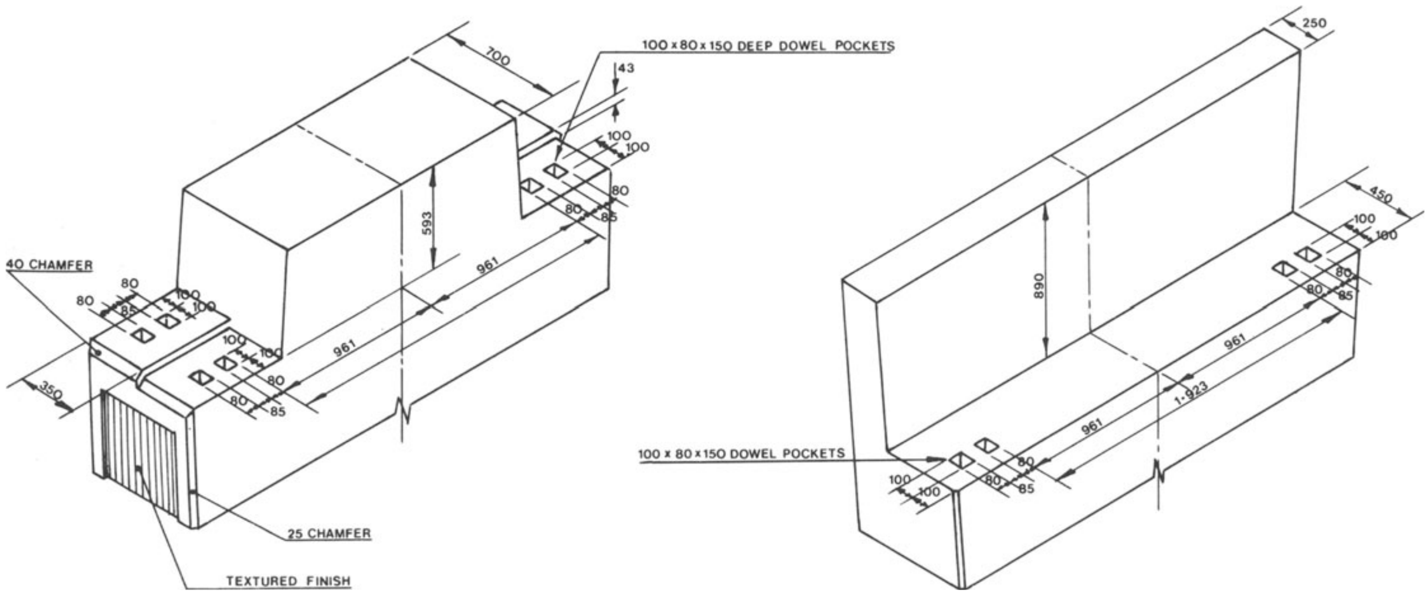


Figure 4.14 Dimensioning on isometric views

4.3.3 Perspective Drawings

Perspective drawings are principally used either to illustrate a proposed structure realistically, or to show how it would appear in an existing environment. They are not generally used to illustrate an existing building unless cut-out views are involved – photographs are more effective and cheaper for this purpose.

There are several principles and terms used in constructed perspective drawings that need to be understood. These can perhaps be more easily visualised by following the simple procedure described below and referring also to figure 4.15.

(1) Fix a piece of transparent paper on a window, and with the arm outstretched draw the view that can be seen. The eye, or point of observation, is termed the 'station point' and the window the 'picture plane'. The view that is registered comfortably by the eye, without altering the line of sight, is called the 'cone of vision'. The line of sight is assumed to be horizontal.
(2) If the paper is then removed, and the horizontal lines of any buildings on the drawing are extended, they will be found to converge to points on a straight line which is in fact the 'horizon line'. Parallel lines that are not horizontal will converge to points either above or below the horizon line. All these points are known as 'vanishing points'.
(3) If the view were drawn while maintaining a horizontal line of sight, vertical lines would remain vertical on the drawing. If the line of sight were inclined, all vertical lines would converge to a single point located either above or below the horizon line.

Most perspective views are drawn on the basic assumption that the line of sight is horizontal, because this greatly simplifies the construction, as will be shown later in this chapter. The eye level line then coincides with the horizon line, as shown in figure 4.15, and all horizontal sets of parallel lines therefore also converge at vanishing points on the 'eye level'. The vertical line on the picture plane, through the centre of the cone of vision, is called the 'centre of vision'. In order to obtain an undistorted view, the station point must be so situated in relation to the picture plane as to allow all the features required on the drawing to be encompassed within the cone of vision.

A further simplification arises in the case of building illustrations in that most of the lines are parallel in two directions, and either horizontal or vertical. Drawings of this type will be either (1) parallel perspective drawings, in which there is one principal vanishing point, or (2) angular perspective drawings, in which there are two principal vanishing points. The directions of lines which are not parallel to the other lines can be determined by means of coordinates.

Other terms and abbreviations, and the method of constructing parallel and angular perspective drawings, are described in appendix I by means of two practical examples.

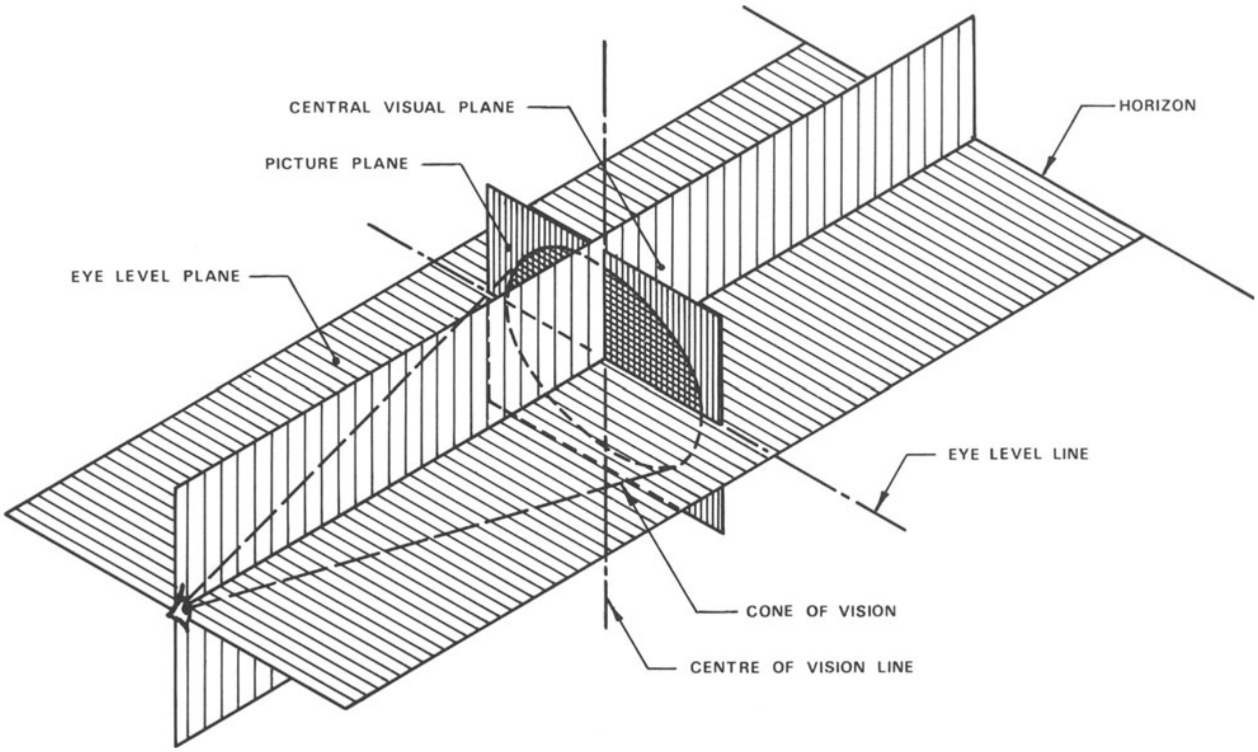


Figure 4.15 Constructed perspective

Perspective drawings of buildings in particular, however, are far easier to produce with the aid of pre-printed perspective coordinate paper.

If pre-printed paper imposes unsatisfactory limitations, then a cubic perspective grid can be easily constructed, as shown in figure 4.16. The angles between the construction lines will be less acute if a plan of the grid is drawn below the perspective view. The horizontal reference line for the plan can be any convenient distance below GL. The plan of the structure will be drawn on the perspective plan grid, and points on the plan will then be projected vertically to intersect construction lines in the three-dimensional grid, as shown in figure 4.17. This method should simplify the task of drawing cut-out views in particular.

Figure 4.18 shows the method of constructing a single cube in both parallel and angular perspective. The cubes can be divided or repeated to form a grid, as shown in figure 4.7. Figure 4.18 also illustrates how reflections are developed by means of vertical ordinates measured above and below the reflective surface.

4.3.4 Shadows

Light rays from the sun are assumed to be parallel. The usual convention adopted on most three-dimensional drawings for developing shadows assumes that light rays are

(1) from the top left-hand side and at 45° to the horizontal, on the orthographic front elevation, and
(2) from the bottom left-hand side, and at 45° to the horizontal, on the plan.

The shadows are projected on to these views and then transferred to the perspective view, as shown in figure 4.19.

The method of developing shadows cast beneath artificial light on to a level surface, is illustrated in figure 4.20.

(1) The positions of the light source, and of a point vertically below it on the horizontal ground plane, are established, and then transferred to the perspective view.
(2) The boundaries of the shadows are defined by the intersection of lines radiating from the light source and the point directly below it.

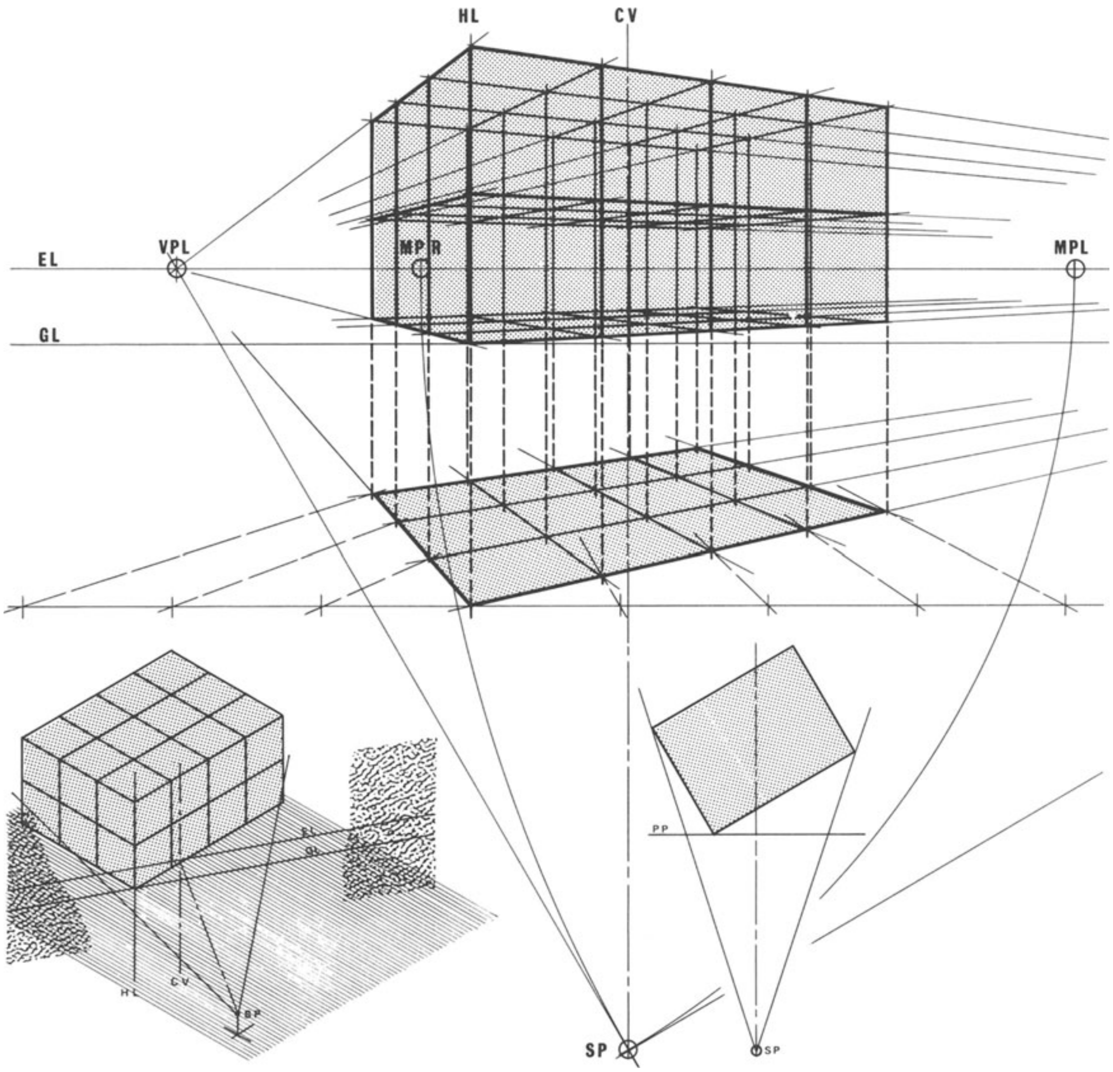


Figure 4.16 Perspective cubic grid

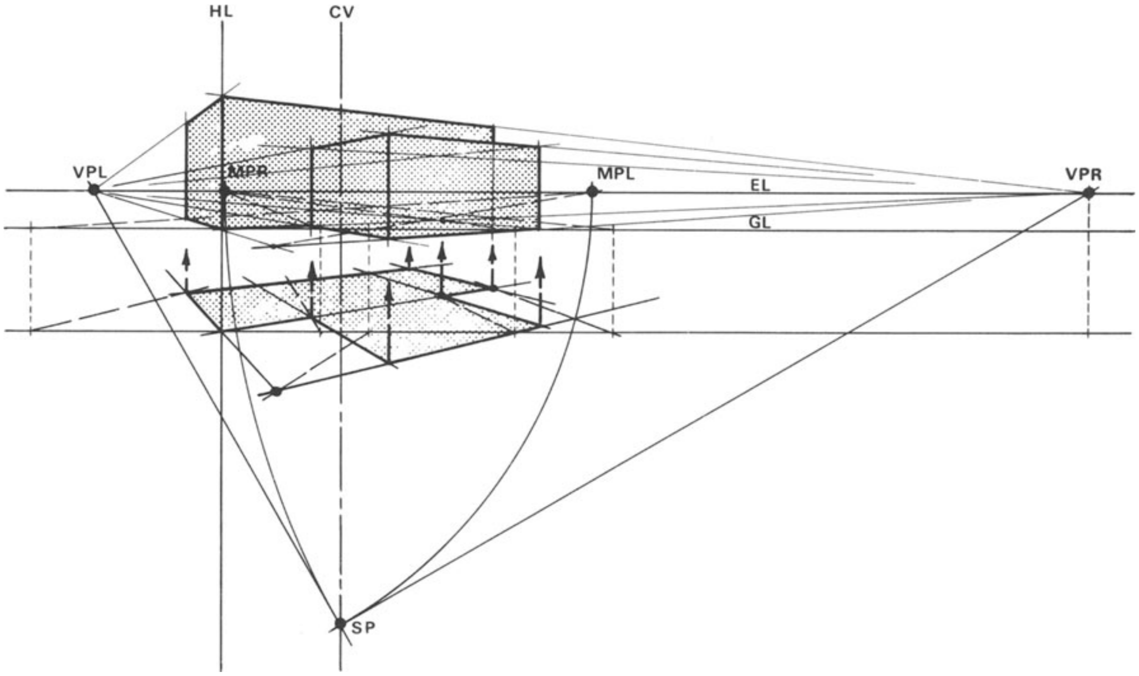


Figure 4.17 Angular perspective: projection from a perspective plan

The method of developing shadows in natural light is also shown in figure 4.20. The position of the sun, and a point on the horizon (which coincides with the eye level) vertically below it, are established. The boundaries of the shadows are then defined by the intersection of lines radiating from these two points, as shown.

4.3.5 Oblique Perspective

The previous examples have all involved a horizontal line of sight and objects whose principal sides have been either horizontal or vertical. If the object had been tilted, or if the line of sight were inclined, then vertical lines would also appear to converge to a vanishing point in the perspective view. A drawing requiring three principal vanishing points is called an 'oblique perspective'. A method of construction in which the vanishing points have been fixed, is shown in figures 4.21a and b.

(a) (1) Draw straight lines joining the three vanishing points to form a triangle. Draw three lines, perpendicular to the sides of the triangle and passing through the vanishing points, to intersect at S.
(2) Draw semi-circles on two of the sides as shown, to intersect the lines through S at S1 and S2.
(3) With VP Vert. as centre, draw an arc through S1 to intersect the side VP Vert. to VP Right at MP Vert. With VP Right as centre, draw an arc through S2 to intersect the side VP Left to VP Right at MP Right. With VP Left as centre, draw an arc through S2 to intersect the side VP Left to VP Right at MP Left.

(b) (1) Establish approximately the point D so that S will be situated near the centre of the perspective view of the object.
(2) From D draw lines parallel to the sides VPL to VPR and VPV to VPR. These are the reference lines along which measurements are made to scale. Set off the dimensions of the object ED, DF and DG to scale.
(3) Draw lines from E, F and G towards the measuring points, to intersect lines from D towards the vanishing points, at H, J and L. Draw lines from H, J and L, towards the vanishing points, to intersect at I and M.

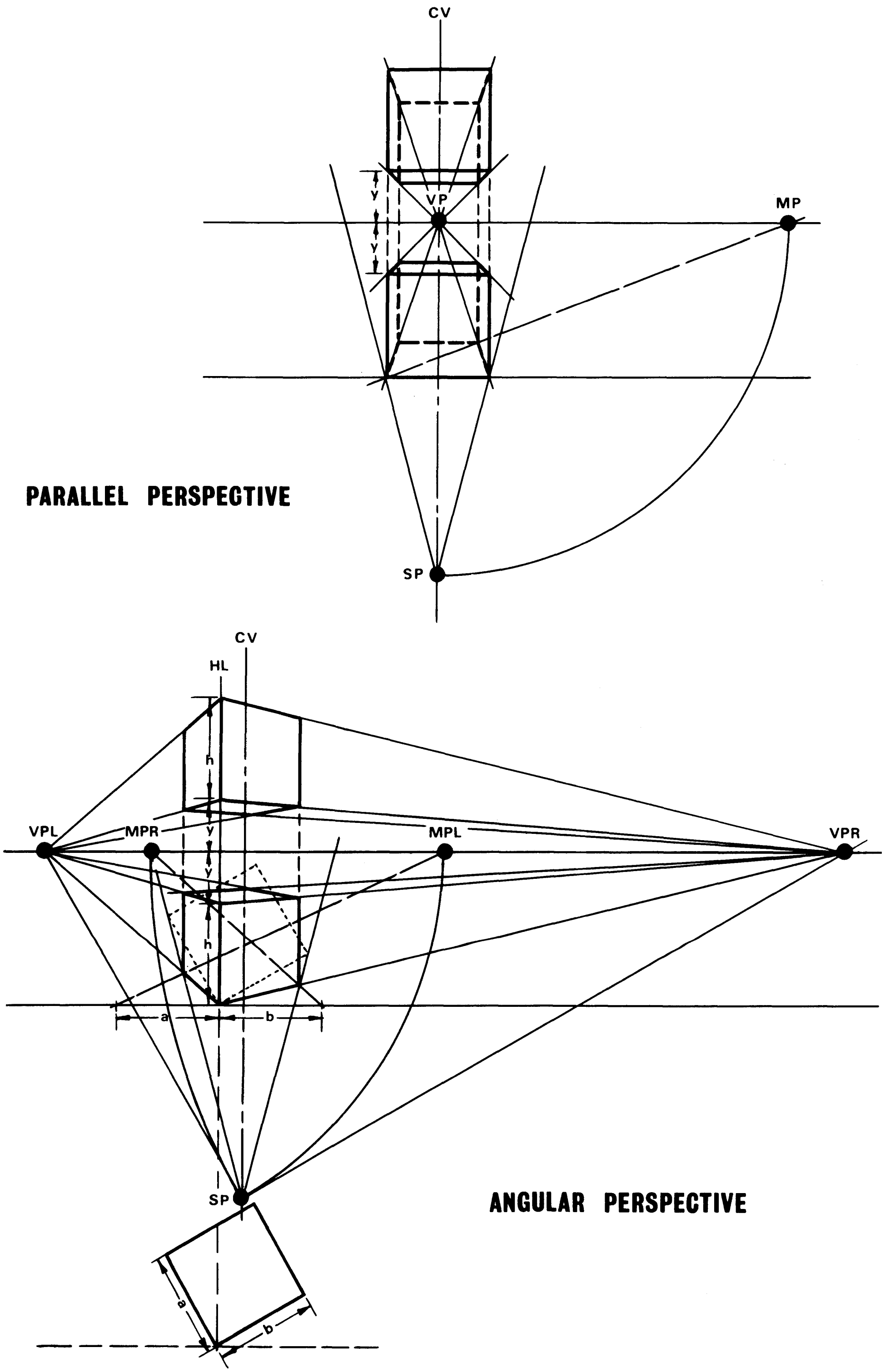


Figure 4.18 Reflections: parallel and angular perspective

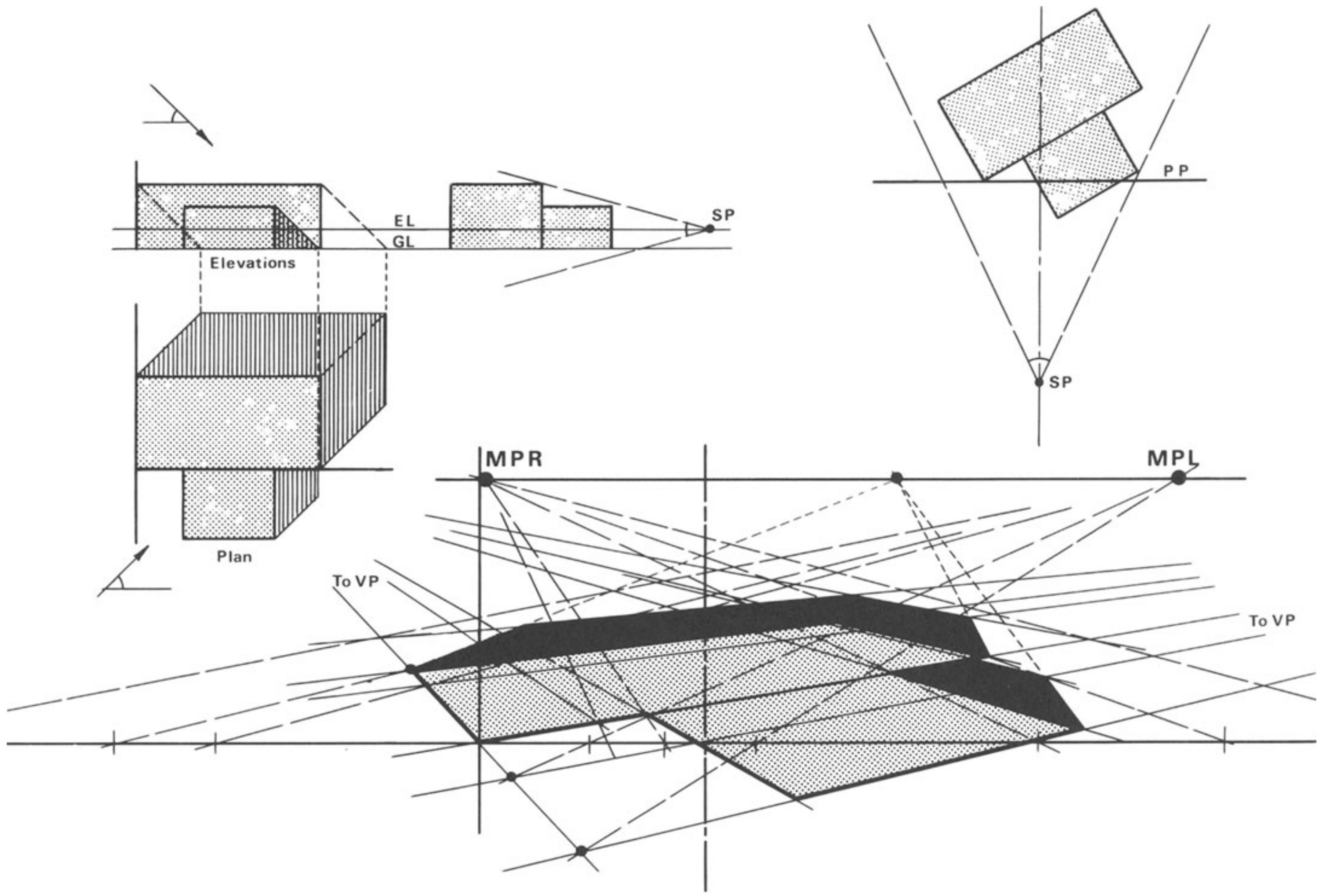


Figure 4.19 Shadow projection from orthographic views

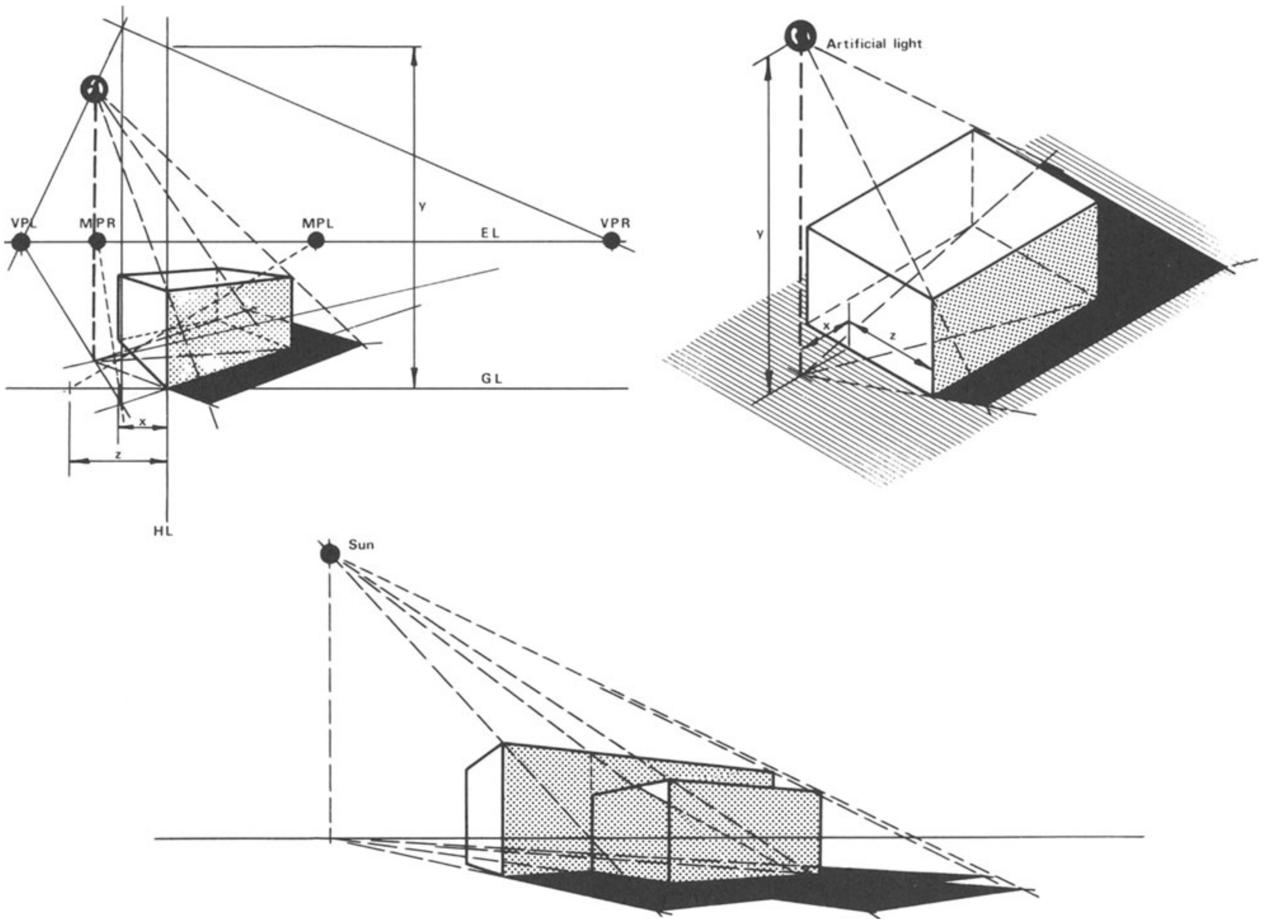


Figure 4.20 Shadows cast on to a level surface

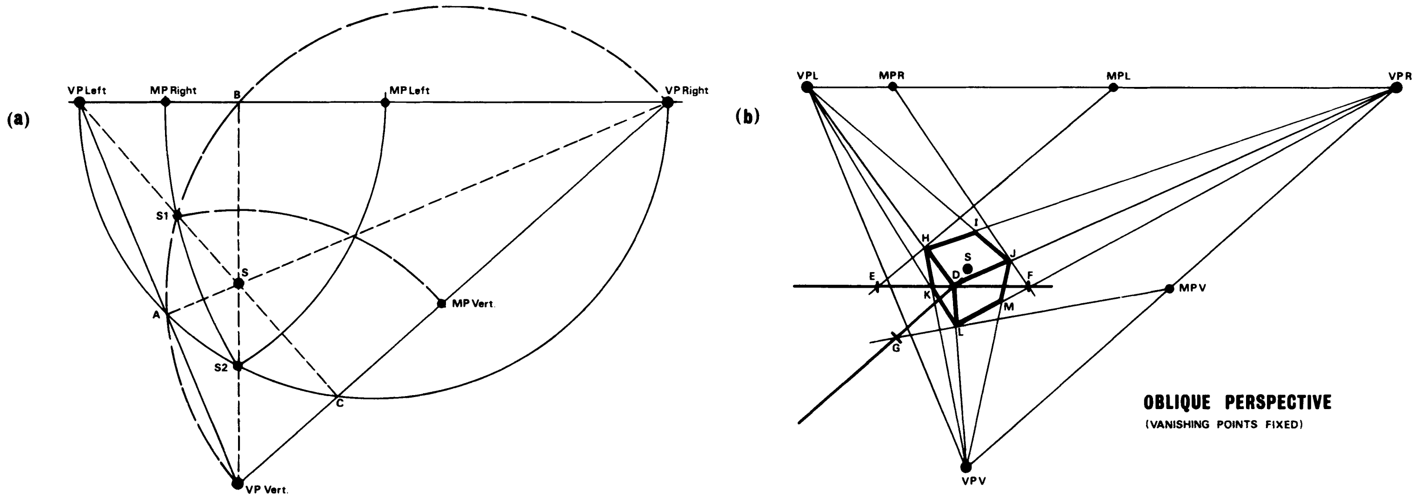


Figure 4.21 Oblique perspective

5. GRAPHICAL AND PICTORIAL METHODS OF DESIGN AND PRESENTATION

5.1 INTRODUCTION

As a general rule, technical data are more readily understood when presented in a pictorial form. In addition to the usual projection drawings described in the previous chapters, models, photographs, graphs, charts and diagrams are frequently used in civil engineering to

(1) plan and visualise projects,
(2) solve and simplify design problems,
(3) present management and technical data.

In addition, mathematical equations can often be solved or derived graphically.

Good technical reports will incorporate many diagrams, simply presented and devoid of irrelevant information. Supporting graphs and tabular data will usually be placed in appendixes.

Models are frequently used for presentation or testing. Photographs are often the best means of illustrating existing features; they should be regarded as an essential supplement to the recording of the continuously changing activities on the sites of construction works.

Although this chapter is not intended to give guidance on structural analysis, mechanics or mathematics, it aims to introduce the reader to a few typical examples of the variety of ways in which technical problems can be solved and represented graphically. In all cases of graphical analysis the accuracy of the results must be considered.

5.2 CHARTS, GRAPHS AND DIAGRAMS

5.2.1 Logarithmic and Semi-logarithmic Charts

Mathematical equations of the general form $y = Cx^n$, where C and n are constants, will produce a straight line when plotted on logarithmic graph paper. Equations of the form $y = C^{nx}$ will produce a straight line on semi-logarithmic paper – see figure 5.1.

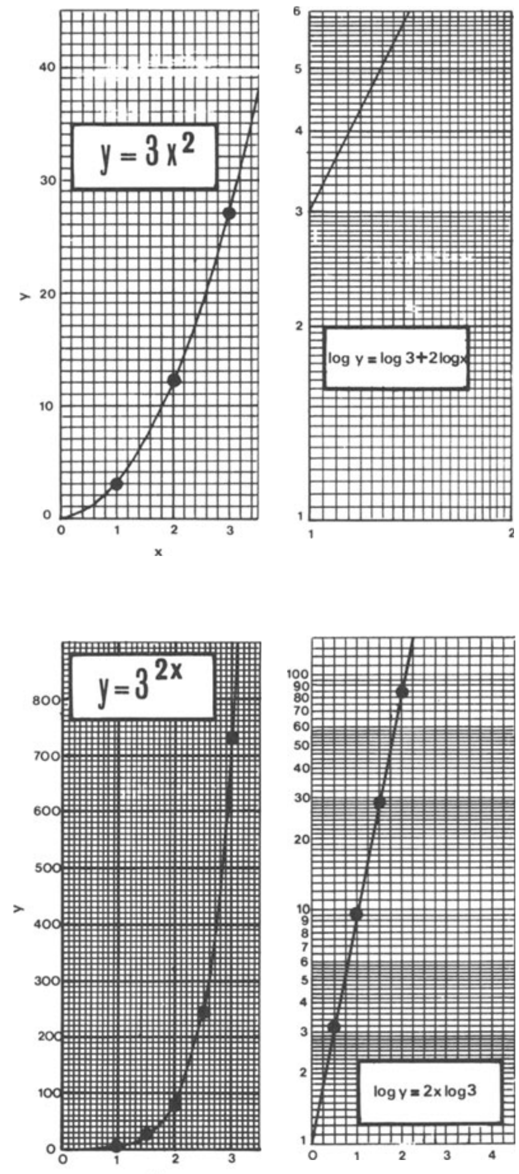


Figure 5.1 Logarithmic and semi-logarithmic graphs

Graph paper of this type is often used to derive the equation of the curves through points plotted from test data. Logarithmic paper has a logarithmic scale in both directions, while semi-logarithmic paper has a logarithmic scale vertically and an arithmetic scale horizontally.

Semi-logarithmic charts are particularly useful when it is important to show the rate of change of one variable with respect to the other.

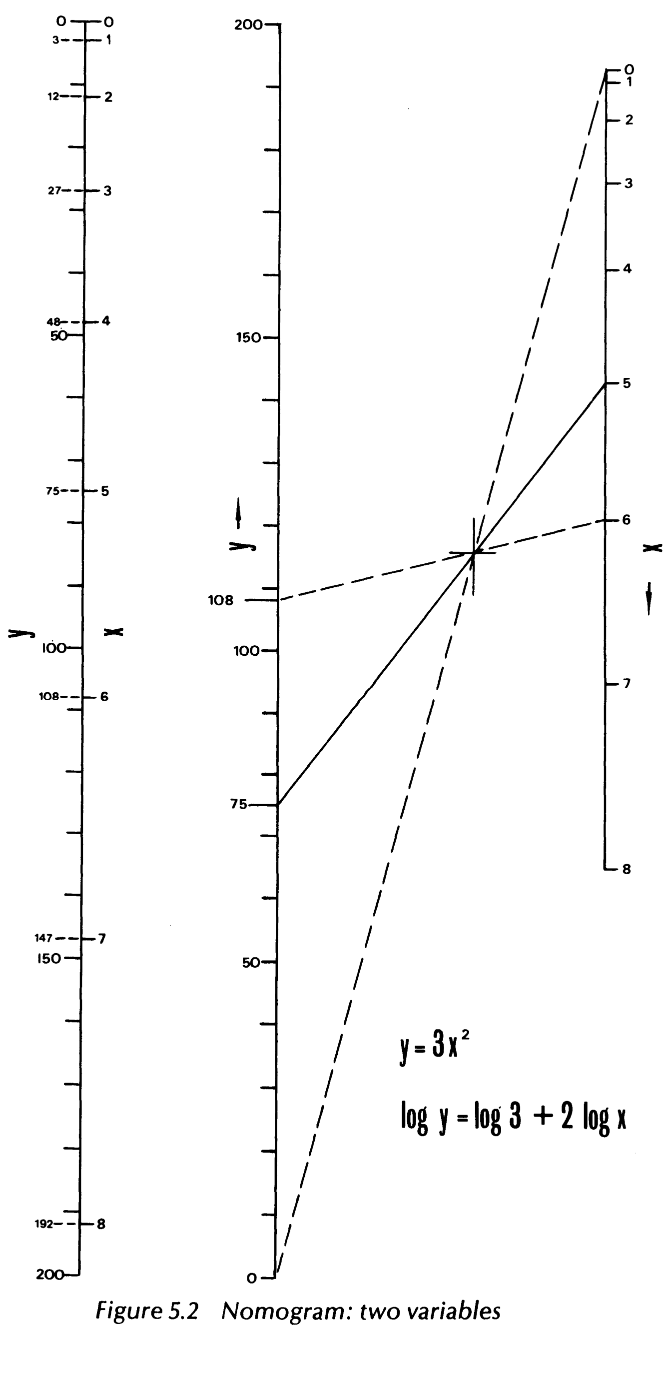


Figure 5.2 Nomogram: two variables

5.2.2 Nomograms

Nomograms are two-dimensional charts which enable problems involving two or more variables to be solved. Figure 5.2 shows two alternative methods of drawing a nomogram for the equation $y = 3x^2$. The data required for the chart are as follows.

x	0	1	2	3	4	5	6	7	8
$3x^2$	0	3	12	27	48	75	108	147	192

The solutions to the equation are found by (1) plotting the corresponding values of x and y directly opposite each other, or (2) drawing the scales of x and y in opposite directions, and solving the equation by means of a straight line drawn through a single point which is determined as shown in figure 5.2.

Note that the divisions on the y-axis are evenly spaced and those on the x-axis have a logarithmic form. It can also be seen that the equation conforms to the general case $y = Cx^n$ and can therefore be solved from the straight line drawn on logarithmic paper $\log y = \log 3 + 2 \log x$.

Figure 5.3 shows a nomogram which provides the solutions to an equation with three variables: if $z = x^2y^3$ then $\log z = 2 \log x + 3 \log y$.

The data required for the chart are as follows.

x, y	1	2	3	4	5
$\log x$	0	0.301	0.477	0.602	0.699
$2 \log x$	0	0.602	0.954	1.204	1.398
$3 \log y$	0	0.903	1.431	1.806	2.097

The procedure for drawing the nomogram is as follows.

(1) Plot the values of $2 \log x$ to a suitable scale and opposite these mark on the corresponding values of x.

(2) Plot the values of $3 \log y$ to a suitable scale and opposite these mark on the corresponding values of y. For example, when y is 5 then $3 \log y = 2.097$. The scale is 1 cm to 0.2 units therefore the scale distance between $y = 1$ and $y = 5$ is $2.097/0.2 = 10.49$ cm. (Note: the scale for the x-axis is 1 cm to 0.1 units.)

(3) Arrange a convenient spacing between the three axes. Draw straight lines between the limits of the x and y-axes, then, by proportion, the scale distance between the limits

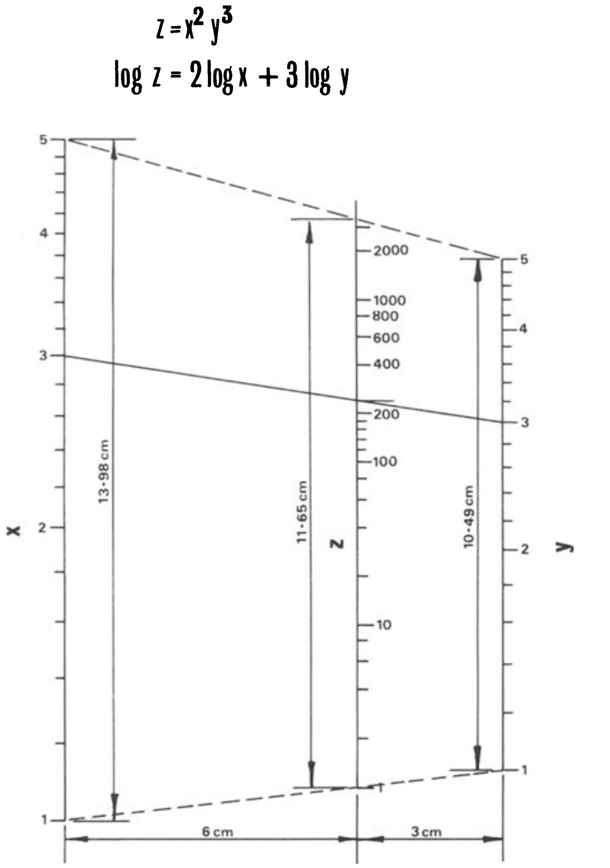


Figure 5.3 Nomogram: three variables

of the z-axis is 10.49 + (3/9)(13.98 − 10.49) = 11.65 cm. The corresponding logarithm for 2 log x + 3 log y = 1.398 + 2.097 = 3.495. Hence the scale for this axis is 1 cm to 0.3 units. The corresponding value of z (that is $\log^{-1}$ 3.495) = 3125.

(4) Draw up a table as follows and plot the log z values to the scale 1 cm to 0.3 units and opposite these mark on the corresponding values of z.

z	1	10	100	200	400	600	800	1000	2000
log z	0	1.00	2.00	2.30	2.60	2.78	2.90	3.00	3.30
scale dimension (cm)	0	3.33	6.67	7.67	8.67	9.27	9.67	10.00	11.00

5.2.3 Pie (or Sector) Charts

The clearest method of showing the component parts of a whole is by means of a pie chart. Each part, hatched in a

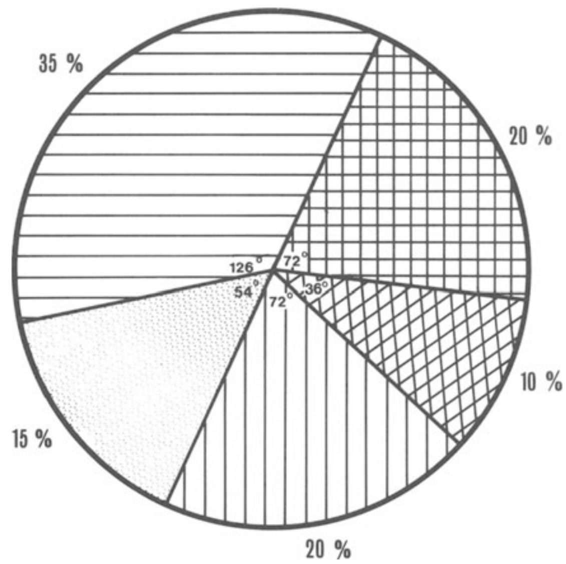


Figure 5.4 Pie diagram

different manner, is represented by a sector of a circle. Taking figure 5.4 as an example, the part which is 10 per cent of the whole is represented by a sector subtending an angle of 360 × 10/100 = 36° at the centre of the circle. Where a number of pie charts form part of a greater whole, the diameters of the circles can be varied to reflect the relative proportions of the whole represented by each chart.

5.2.4 Force Diagrams

The magnitude, direction and sense of the primary forces in a statically determinate frame can be derived graphically if it is assumed that the joints between the members are pinned and that external forces are applied at the joints. Figure 5.5 illustrates the method of analysing a typical roof frame.

(1) Draw a scale diagram of the frame and the direction of the forces applied to it. In this example the frame is symmetrical and therefore only half the frame need be considered.
(2) Letter the spaces between the external forces in a clockwise sequence (A to E).
(3) Letter, or in the case of a large frame, number the spaces between the frame members (F to L).
(4) Draw the magnitude and direction of the external forces to scale on the force diagram. For example, the force, W, between the spaces A and B on the frame diagram, is represented to scale by ab on the force diagram. This force acts downwards and hence b is below a.

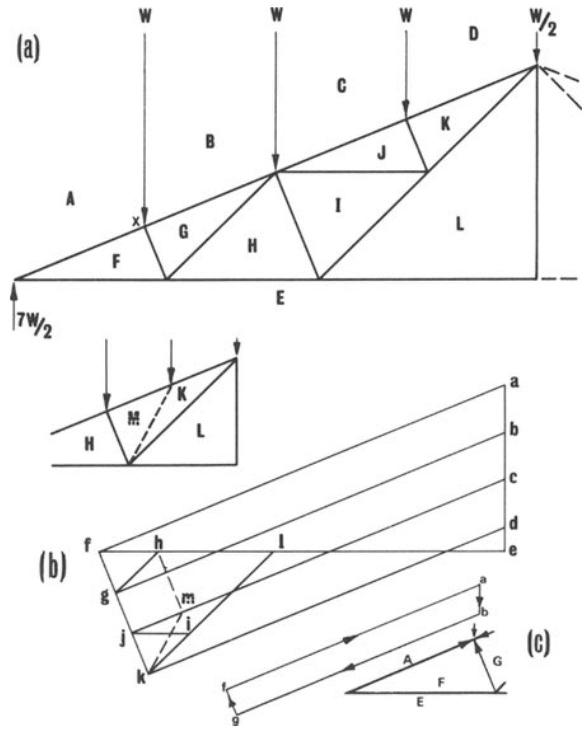


Figure 5.5 Force diagram: Bow's notation

(5) Complete the force diagram in the following manner. From a draw a line parallel to the member AF and a line from e parallel to FE. The lines intersect at f. Follow this procedure to locate the other points on the force diagram. In order to complete the diagram, it will first be necessary temporarily to replace the members IJ and JK with a single dummy member MK, as shown.

(6) Determine the magnitude of the forces in the members by scaling from the corresponding lines of the force diagram.

(7) Determine the direction of the forces in the members by considering each joint in turn. Consider joint X: in order to maintain equilibrium the arrows in the polygon abgf must follow around the link in the same direction.

(8) Taking the member AF as an example: by scaling from the force diagram, the magnitude of the force in the member is found to be 9.2*W*. The external forces, equal and opposite in direction to the internal forces, place the member in compression.

(9) Determine the magnitude and direction of the other forces in the members in a similar way. Members in compression are called 'struts' and members in tension are 'ties'.

5.2.5 Bending Moment Diagrams

The theoretical bending moments and shear forces in a structural frame are usually represented on a line diagram of the structure drawn to scale. The magnitudes of the moments are superimposed to scale on the line diagram at right angles to the members. The moments for a reinforced concrete structure are drawn on those sides of the frame which are in tension. The moment diagram thus indicates at a glance where the main reinforcement is required. Figure 5.6 shows

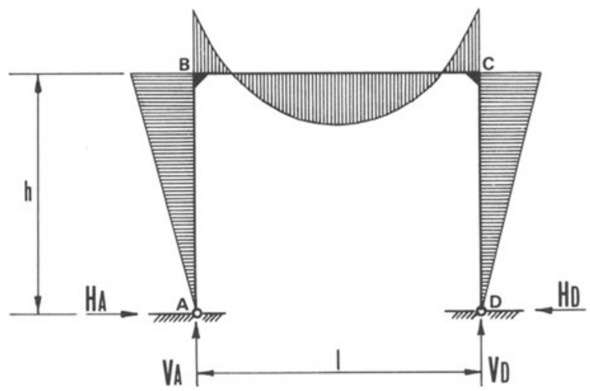


Figure 5.6 Bending moment diagram of a portal frame

the shape of the bending moment diagram for a pin-jointed portal frame subjected to a uniformly distributed load on the horizontal member BC.

Most structures must be analysed for a variety of loading conditions and adequate reinforcement provided to withstand the maximum design stresses in all parts of the structure. The diagram for the maximum moments is termed a 'maximum bending moment envelope'. In order to simplify the analysis, clear scale diagrams of each loading condition should be drawn. Separate bending moment diagrams can then be drawn for each load and the moments algebraically summed for each loading condition. All the complete moment diagrams for each loading condition are then algebraically summed to produce the maximum bending moment envelope.

5.2.6 Programme and Progress Charts

Careful thought must be given to the planning of any scheme. The project may involve a large number of professional disciplines at both the design and construction stages, in which case an independent group may be established to plan and coordinate the various activities, and ensure that target dates are met. The resources for, and the duration of the activities necessary for completion will usually be considered in relation to economic factors. However, there will be instances when the completion date will be fixed by the promoter, who may stipulate heavy penalties in the contract should the work not be finished on time. In this instance planning will be approached from a different standpoint, and may necessitate the adoption of measures more costly than might otherwise have been used.

Figure 5.7 illustrates in a clear and simple manner some of the basic stages which were involved in the planning and construction of a large exhibition hall at Mannheim in the Federal Republic of Germany. A considerable amount of consultation with all the parties involved would be required before a chart of this type could be produced, and each specialist group would need to undertake a certain amount of detailed planning to provide the coordinator with realistic information about his own contribution to the over-all scheme. It can be seen from the example in figure 5.7 that architects, structural engineers, civil engineers, scientific researchers, model makers and many other trades were involved in this project. The top diagram shows the dates when major decisions affecting the programme should be made. The lower chart has combined a basic programme and activity network. The network shows the interdependency of the various activities and how delays in the completion of any one of them could affect the others and even the over-all completion date. Some interrelated activities cannot be started ahead of programme, nor can their completion be delayed, without delaying the over-all completion date. These activities are said to be 'critical' and must accordingly be given particular consideration at the planning stage. Some examples of charts used for detailed planning and control are described below.

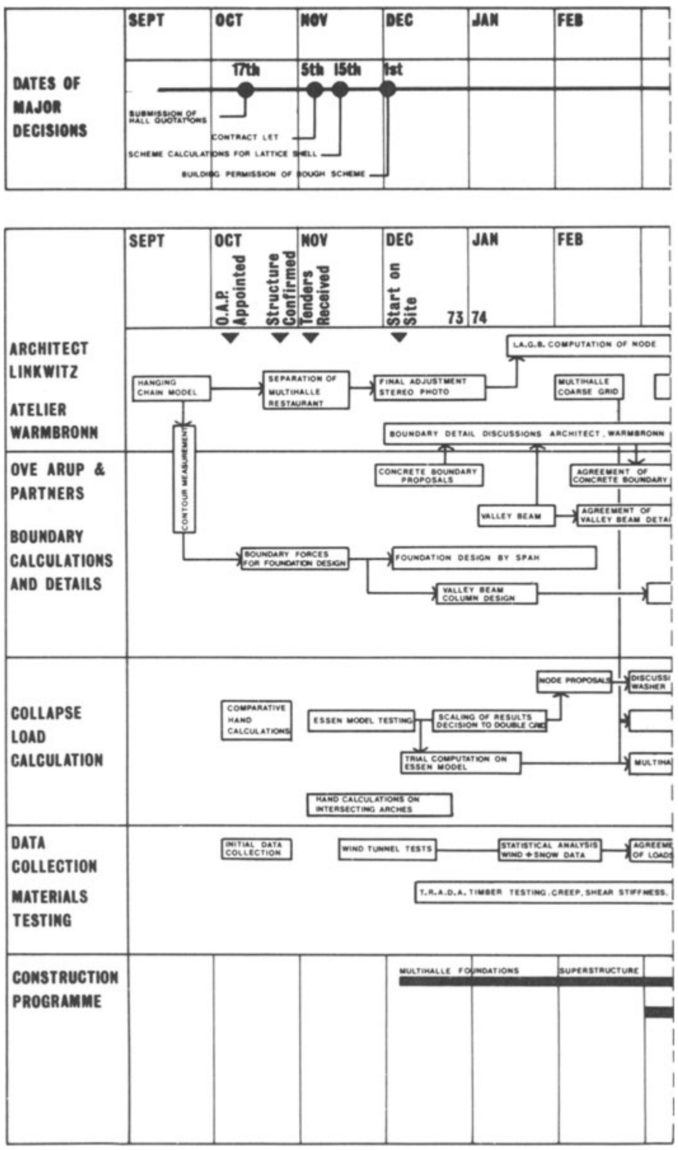


Figure 5.7 Simplified combined programme and network diagram

In order to establish accurately the resources and time required to complete any activity it should first be broken down into all its component parts. Manpower is the main resource required at the design stage and it can be surprising to learn how much time must be allocated to take account of holidays and sickness, and for ancillary administrative duties. Some assessment must also be made of the likely resources (plant, labour and materials) needed for the construction, in order to determine a reasonable contract period. The detailed construction programme will be prepared by the contractor. A typical combined programme and progress chart is shown in figure 5.8. The most effective means of comparing the programme with actual performance is by applying standards of physical measurement to each activity. For example, lineal metres for pipelines and kerblines, cubic metres for excavation and in situ concrete work.

5.2.7 Network and Critical Path Diagrams

Anyone involved in planning, whether they be a top executive or a foreman on a construction site, will need to consider logically the sequence of operations necessary to complete the work for which they are responsible. Both will draw on their wide experience to make the right decisions. Network analysis, which involves listing and then connecting

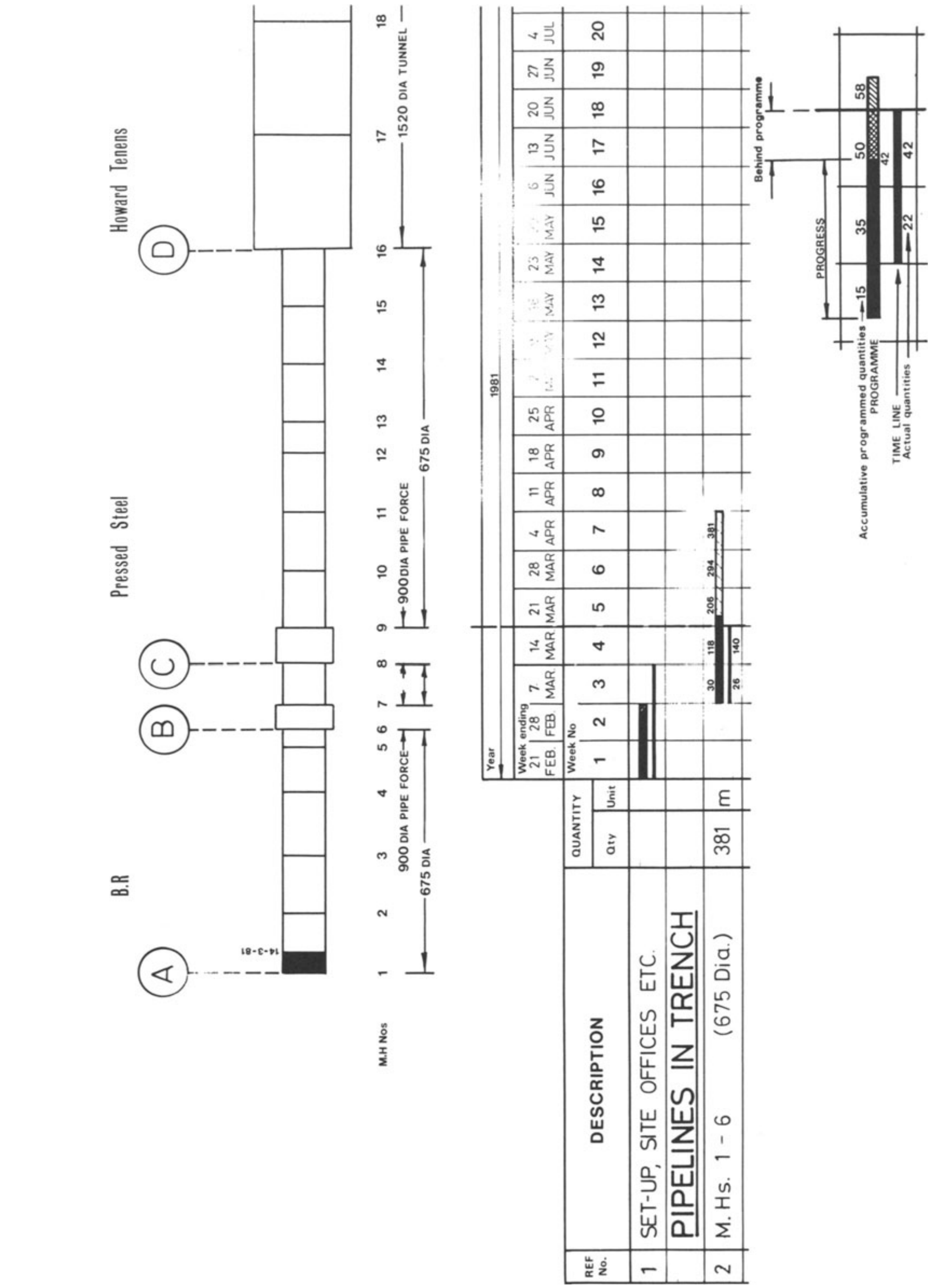


Figure 5.8 Programme and progress bar chart

interrelated activities, ensures a more disciplined approach to the problem of planning.

All the activities are first listed roughly in their correct sequence and the duration for each one is estimated. A network diagram of interrelated activities is then drawn for the whole project. Each activity is represented by an arrow and its start and finish events are given a reference number. The letter 'i' is the usual abbreviation for denoting the start events for each activity and 'j' for the finish events. The data in table 5.1 form the basis of the network diagram shown in figure 5.9.

It is important to draw the network so that all the activity descriptions and event times are clearly and neatly represented. A complicated network will probably have to be redrawn several times before a suitable layout is achieved. Note that the arrows are not drawn to scale.

There are certain interconnected activities which cannot be started early, nor can they be finished late, without increasing the over-all time for completion. In other words, the latest completion date for each activity is the same as the earliest start date for the activity which follows it. The summation of the durations in this chain of arrows, called the 'critical path', is greater than that of any other chain, and is the shortest possible time in which the project can be completed. This being the case, it is clear that the activities which are not in

Table 5.1

Activity i/j	Duration (weeks)
1/2	2
2/3	3
2/4	2
2/5	4
3/6	4
4/6	0
4/9	5
5/7	3
5/8	4
6/9	2
7/9	2
8/9	5
9/10	2

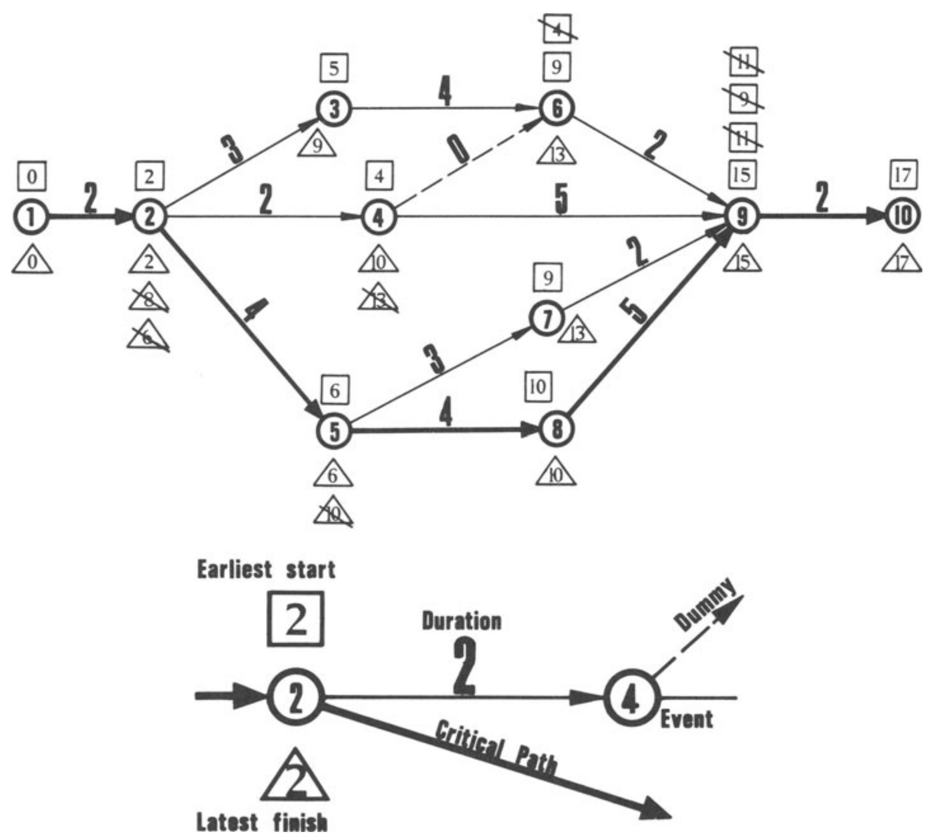


Figure 5.9 Critical path diagrams

the critical path can be delayed to varying degrees without affecting the over-all completion time. Once the critical path has been added, the network is called a critical path diagram.

Taking figure 5.9 as an example, the procedure for drawing the critical path diagram is as follows.

(1) Draw the basic network showing the arrows, event numbers and activity durations. Draw the first activity arrow 1/2. Activities 2/3, 2/4 and 2/5 can be started concurrently as soon as 1/2 has been completed. Activities in each of the chains 1–2–3–6–9–10, 1–2–4–9–10, 1–2–5–7–9–10 and 1–2–5–8–9–10 are in series. Activity 6/9, in addition to activity 4/9, cannot be started until 2/4 has been completed. There is no intervening activity 4/6 and the relationship between events 4 and 6 is indicated by a broken line 'dummy' arrow.

(2) Determine the earliest start date for each activity, taking the first event as at week 0. Different earliest start date figures will be obtained for each event, depending on the route taken through the network. The largest figures obtained at each event are the correct ones. To illustrate the procedure, consider the alternative routes to event 6. Taking first the route 1–2–3–6, the earliest start at event 6 is week 9. Taking the route 1–2–4–6, the earliest start is week 4. Hence week 9 is the correct figure. Do not proceed beyond an event until the correct earliest start for that event has been established.

(3) Determine the latest finish for each activity, working back from the last event which has been established as week 17. The smallest figures obtained at each event are the correct ones. Consider the alternative routes back to event 5. Taking first the route 10–9–7–5, the latest finish at event 5 is week 10. Taking the route 10–9–8–5, the latest finish is week 6. Hence week 6 is the correct figure. Do not proceed beyond an event until the correct latest finish for that event has been established.

(4) The chain of arrows with the same earliest starts and latest finishes at each event is 1–2–5–8–9–10 and is hence the critical path.

The spare time available for completing each of the activities not in the critical path, without increasing the over-all time for completion, is termed the 'float'. This can be defined in the following ways.

(1) The 'total float' for an activity is the maximum amount of time that can be taken up without increasing the over-all completion time.

(2) The independent 'float' is the amount of spare time available when an activity begins at the latest start time and the start of any subsequent activity is not delayed.

(3) The 'free float' is the amount of spare time available when an activity begins at the earliest start time and the start of any subsequent activity is not delayed.

Figure 5.10a shows the network diagram represented in bar chart form. Figure 5.10b shows the total float taken up (broken lines) for each event. Figure 5.10c shows the free float available for each event.

Network diagrams are useful in the early planning stages of a project, chiefly because their preparation ensures that all the activities are listed and considered in a logical manner. Once the initial plan is implemented, however, its continued value is related to control procedures, and the extent to which the network is updated in the light of changing circumstances. This procedure could involve a considerable amount of technical time. It should be borne in mind that the network will be continuously changing and so also may the route of the critical path.

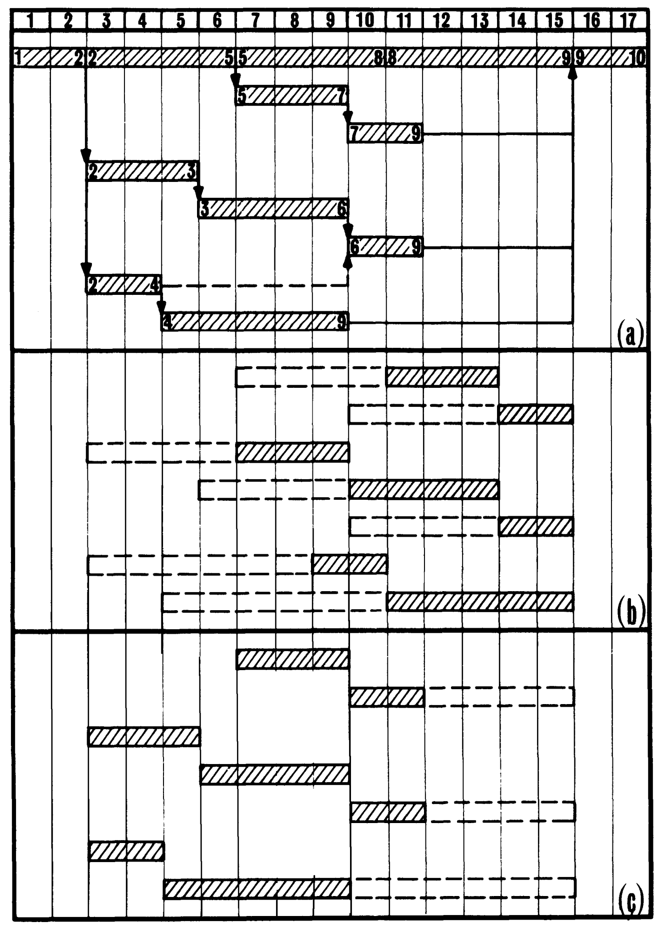


Figure 5.10 Float

Taking into account any constraints in the programme, the planner will try to arrange the activities in a way that will provide the most effective use of the resources required. For example, a contractor may wish to keep an expensive item of plant continuously working on one project, or to determine which activities should be carried out by his own employees to ensure their continuous employment, and which activities should be sub-contracted. There are many different techniques involved in this type of planning but their description is beyond the scope of this book.

Examples of the diagrams used in these techniques include histograms for statistical analysis and resource levelling, frequency charts, quality control charts, Z charts, flow process charts and mass-haul diagrams for balancing cut and fill earthworks on major road schemes.

5.2.8 Flowcharts

Flowcharts can be used to show the various stages of a project, the relationship between people or events, or the sub-divisions of an organisation – a 'family tree' is an obvious example. Flowcharts are used widely and in many cases are the only satisfactory means of representing the information they contain (see figure 5.11).

5.2.9 Traffic Flow Band Diagrams

Flow band diagrams are used to show the recorded volumes of traffic at various sections of a road network. The volumes are related to the widths of bands, drawn to scale, which are superimposed on a suitable plan of the area, as illustrated in figure 5.12.

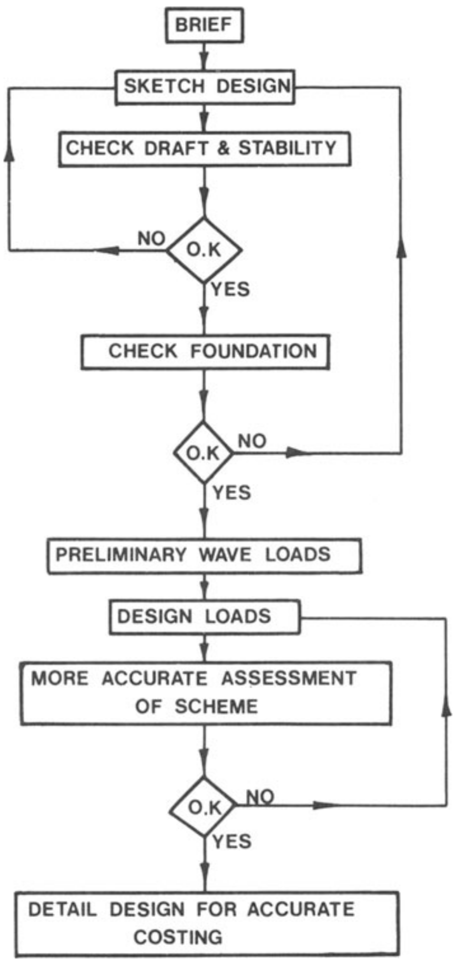


Figure 5.11 Flowchart

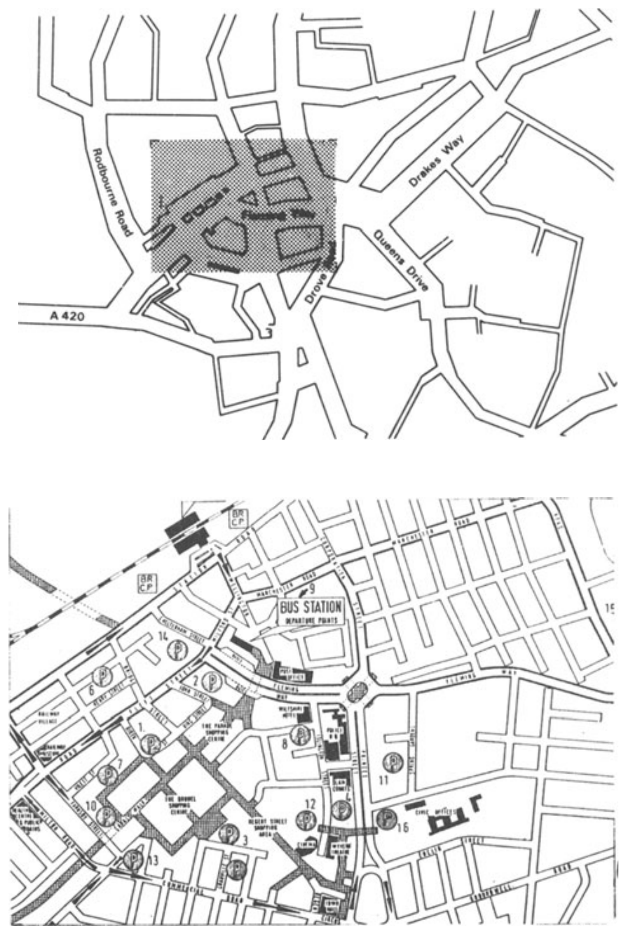


Figure 5.12 Traffic flow band diagram

5.3 MODELS

There are two basic types of model.

(1) A true-to-scale replica of the prototype used for planning, presentation, advertising and similar purposes.
(2) A technical model, usually designed in accordance with the principles of dimensional analysis, which is tested in such a way as to enable the behaviour of the prototype to be predicted in conditions that it is likely to experience during its design life.

The reader will probably have inspected models like those commonly used by architects and town planners to illustrate their proposals for their clients, employers or the general public. Figure 5.13 shows a typical example in which the designer is using a modelscope which simulates the view of an observer standing at the same relative position in the prototype (the actual completed project). A camera can be attached to the modelscope; figure 5.14 shows a photograph taken through a modelscope.

A video camera can be used to exploit the advantages of a presentation model to the full. The camera is moved through the model, which is erected vertically, and the recorded view can be transferred immediately to a TV screen or visual display unit.

A presentation model of a North Sea oil platform is shown in figure 5.15.

Figures 5.16 to 5.20 show both presentation and technical models and illustrate a part of the prototype structure for which they were prepared.

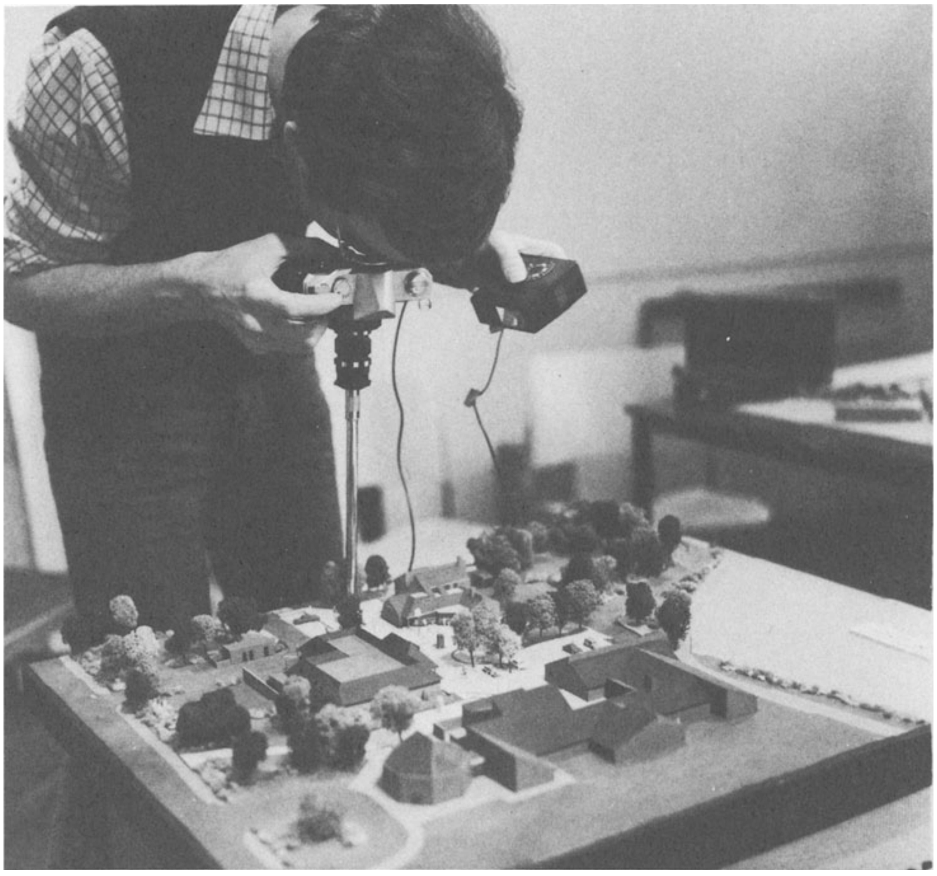


Figure 5.13 Use of modelscope

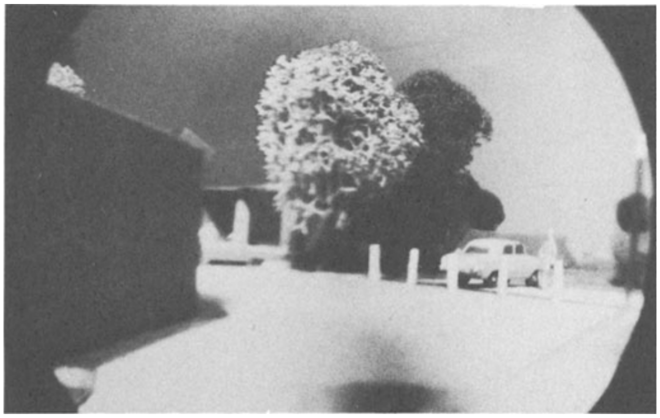


Figure 5.14 *Photograph taken through a modelscope*

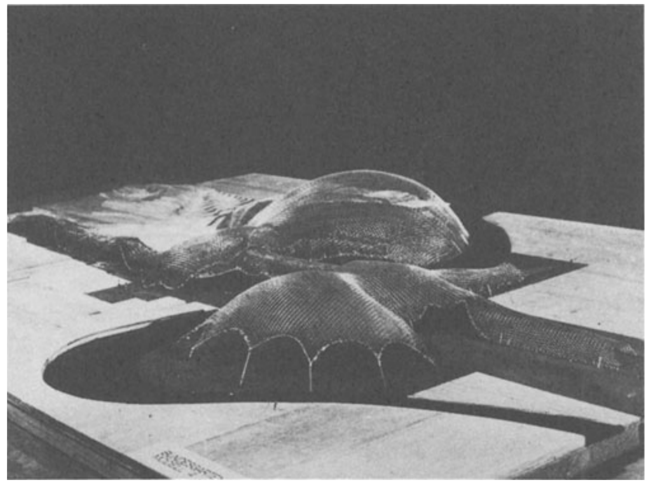


Figure 5.16 *Wire mesh model*

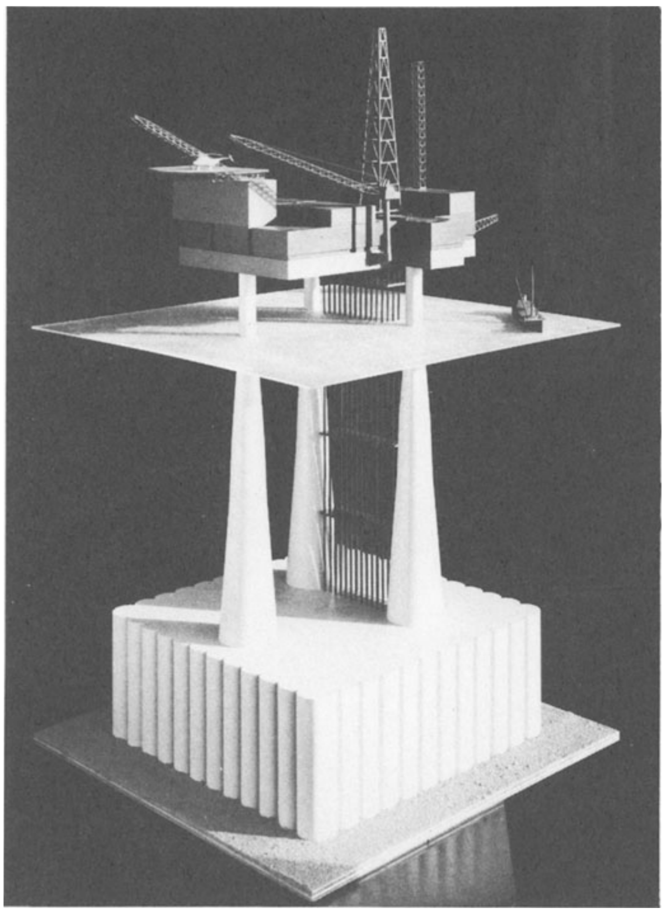


Figure 5.15 *Model of oil-drilling platform*

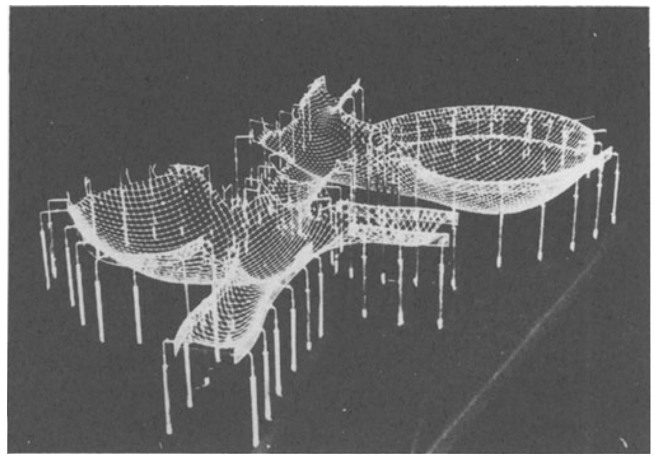


Figure 5.17 *Hanging chain model*

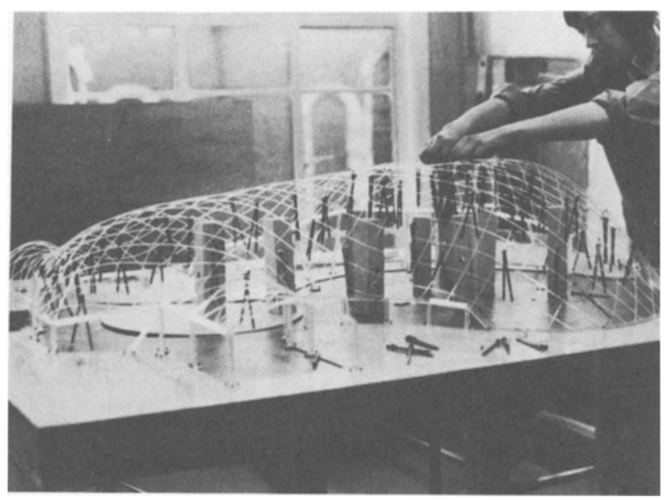
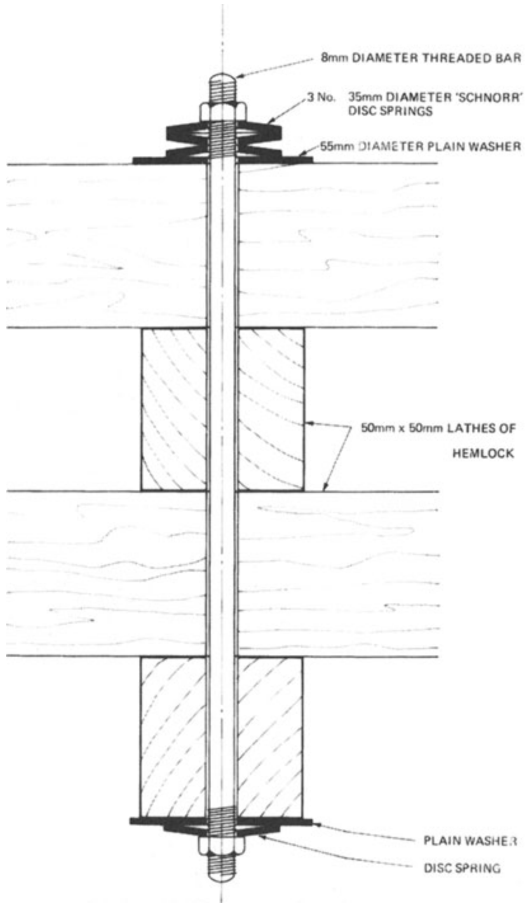


Figure 5.18 *Perspex model*



(a)

(b)

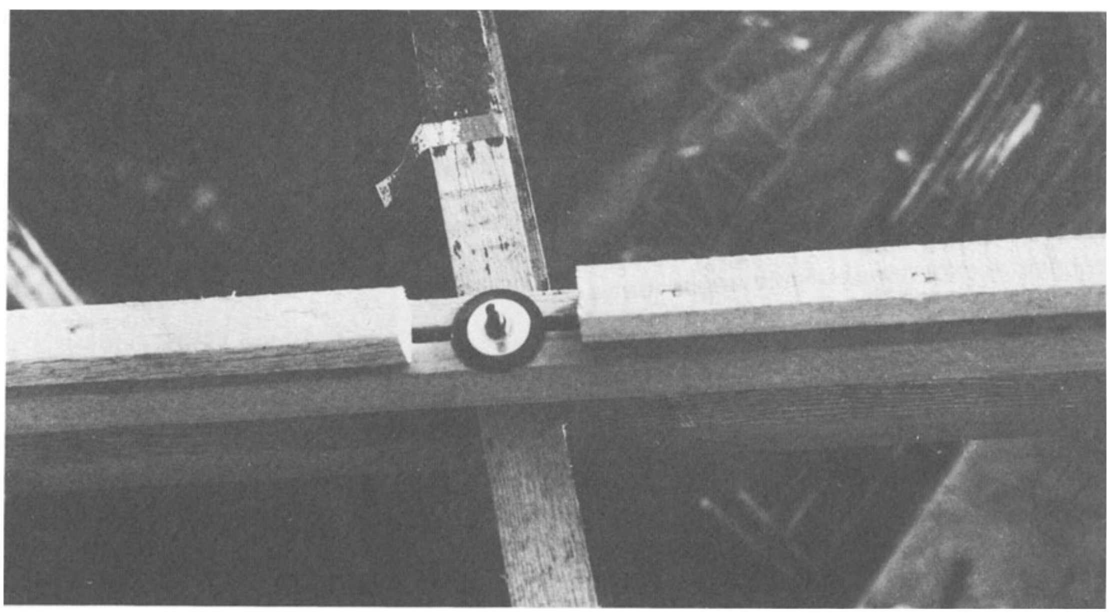


Figure 5.19 (a) Section of a typical node joint; (b) node joint

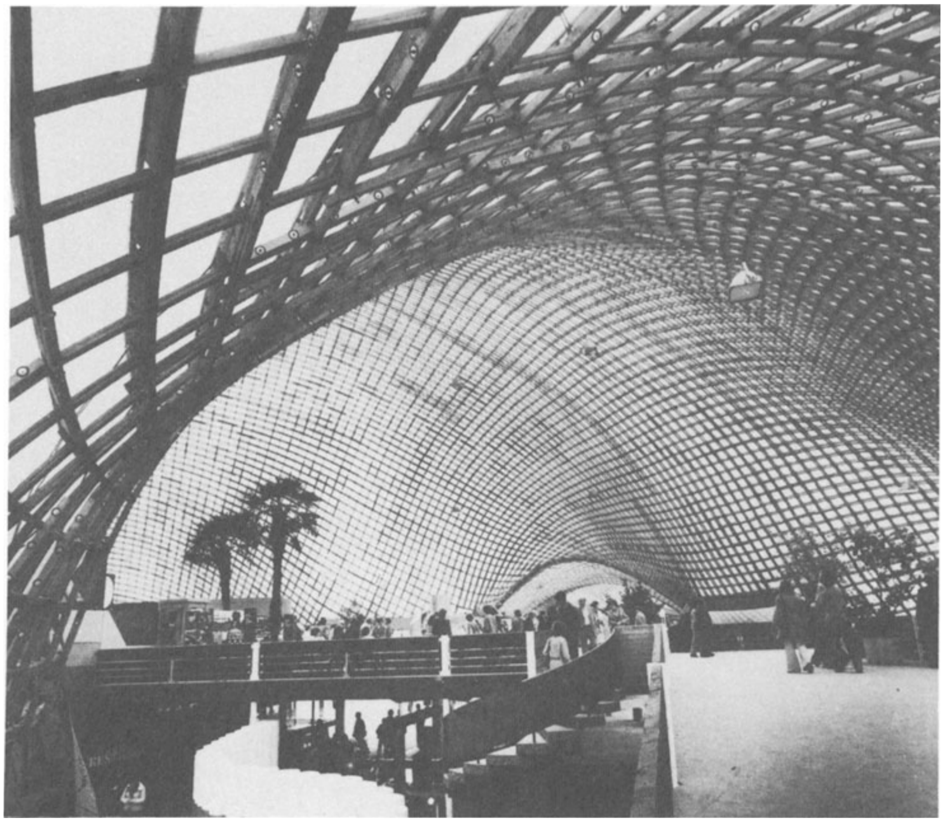


Figure 5.20 Inside view of the Mannheim Multihalle

6. COMPUTER GRAPHICS

6.1 INTRODUCTION

There can be no doubt that the computer revolution is having, and will continue to have, a profound influence on the lives of everyone. Computer technology is developing at such a rapid rate that a vast number of possibilities, which hitherto might have been thought absurd, are now quite feasible. Perhaps it would be prudent to assume that there are in fact no limits to what may be achieved, for good or evil, with the aid of computers, and that careful judgements will soon be needed on the direction of future developments. The three main features of a computer that make it such a powerful tool are (1) the speed at which it generates information, (2) its storage capacity, and (3) its versatility. The magnitude of all three capabilities can only be described in superlatives.

The use of computers, visual display units (VDUs) and automatic plotting equipment for producing or generating drawings has now progressed well beyond the research stage. In fact the production of drawings as a by-product of design is now established commercially. Taking into account the time taken to prepare the data, convert it to machine-readable form and produce two or three test drawings, it is still usually possible to produce a drawing in less time than it would take by hand. The time that the plotter takes to produce the drawing can be measured in seconds, while the time taken by the computer to process the information fed into it can be measured in milliseconds. It may not be long before the demands of cost effectiveness cease to be a constraint on the use of the computer purely as a 'draughtsman'.

Whether a picture is to be generated on a VDU or a drawing produced by an automatic plotter, the computer must receive a logical sequence of instructions. This may be achieved in several ways, depending on the type of equipment used.

(1) A program, or suite of programs, that involves a laborious determination of the *X* and *Y*-coordinates of points on the drawing, is first developed. This requires the skills of a systems analyst, who will take full advantage of the storage capabilities of the computer in relation to the number of similar or identical shapes on the drawing. The information is written on to prepared data sheets from which it is keyed on to punched cards or other machine-readable media. The cards are processed by the program and the drawing can then be plotted directly or automatically transferred to magnetic tape by the computer. The tape can be stored and used later in the tape unit of the automatic plotter as and when required.

(2) The difficulties involved with the above method concern the time taken to produce the input data, the inability to check the input and the delay in obtaining the finished drawing. The problem can be partly overcome by using a VDU coupled with a digitiser. Simple diagrams can either be generated directly using a keyboard of symbols on the display unit, or any of the symbols can be located anywhere on the screen by first positioning a sensitised cursor or digitising pen over the required point and then pressing the required key. The sequence of data describing the symbol is automatically generated and transmitted to the computer. The various shapes which can be built up from the keyboard can in turn be stored and recalled when required.

A computer system called CADRAW 2, which is being developed by the Research and Development Group of Ove Arup & Partners for use on their DEC System-10 computer, takes advantage of the fact that many drawings for buildings contain a large number of similar shapes. Also there are many shapes that will be standard for a range of drawings, for example, the border, grid and title block. There are several sub-programs within the system which have been devised to carry out the different types of process. The basic procedure is as follows.

(1) A large number of different shapes are built up on a VDU, are referenced and then stored within the computer in the system shapes library (see figures 6.1 and 6.2).

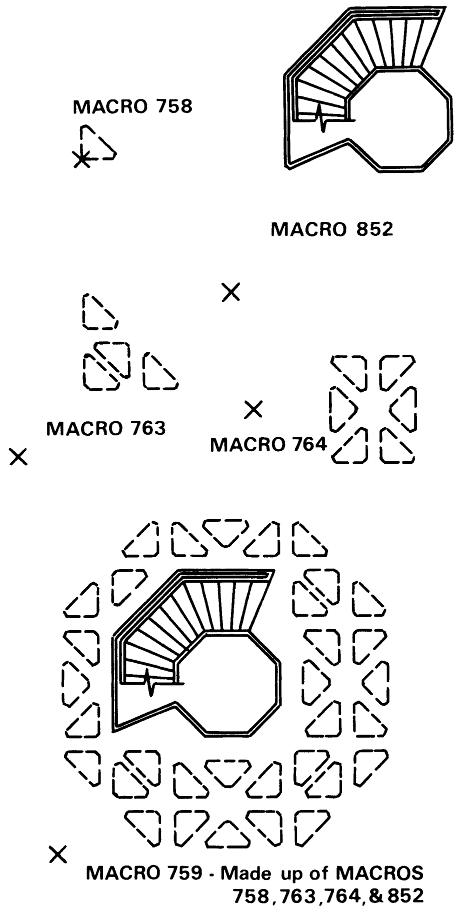


Figure 6.1 System shapes and macros (Courtesy of Ove Arup & Partners)

(2) When the data required for a particular drawing are being built up, the relevant basic shapes are recalled from the systems shape library, dimensioned, and related to the scale of the drawing. The resulting shape, which is called a macro, is referenced and stored in the job shape library. Note that macros can be used to build up further macros.

(3) Rather than build up the drawing in one operation, a system of overlays is used as shown in figure 6.3. These overlays are formed with macros which are situated and orientated by means of coordinates or by using a digitiser. For any new job, the scale, border and a grid system must first be defined. The details on the drawing are then built up with macros which are related to the grid. The data for the plotter will specify the pen thickness, type of ink and whether the drawing is to be produced on the front or back of the drawing sheets. Notes on the drawings, including titles, will also be defined and related to the grid. Because the complete drawing is built up with overlays and macros, the programs will need to be edited carefully to remove detail which should be hidden, and to replace full lines with broken lines where necessary.

The benefits of computer-aided design are now well established. Building Computer Services Ltd, who specialise in structural engineering applications, are one of several firms that produce drawings as a by-product of design. The nature of the projects designed by this firm has determined that programs for the design and drawings should be built up on the basis of completed details, not overlays as in the system described above. Hence, editing to take account of hidden detail is not required. Neither a VDU nor a digitiser is used.

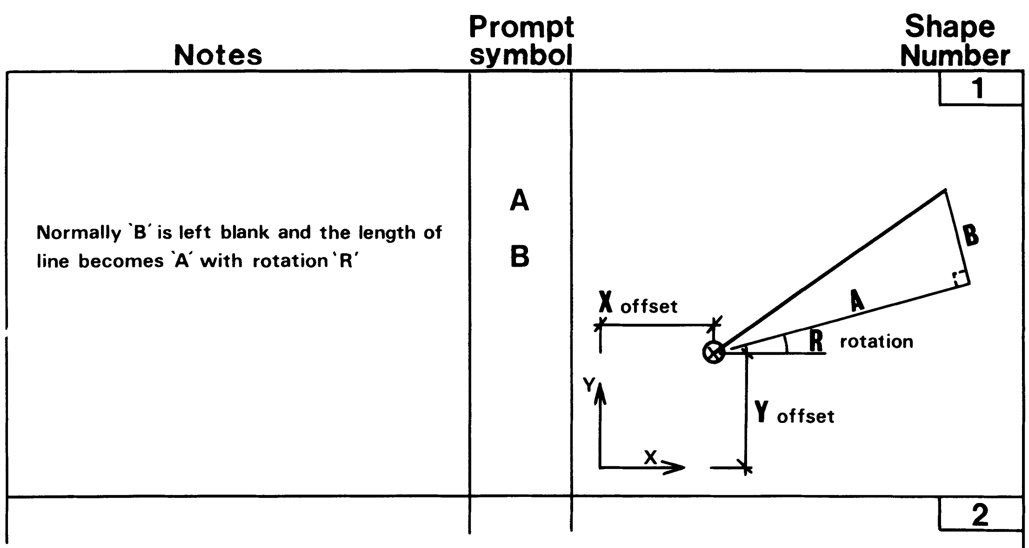


Figure 6.2 System shapes library (Courtesy of Ove Arup & Partners)

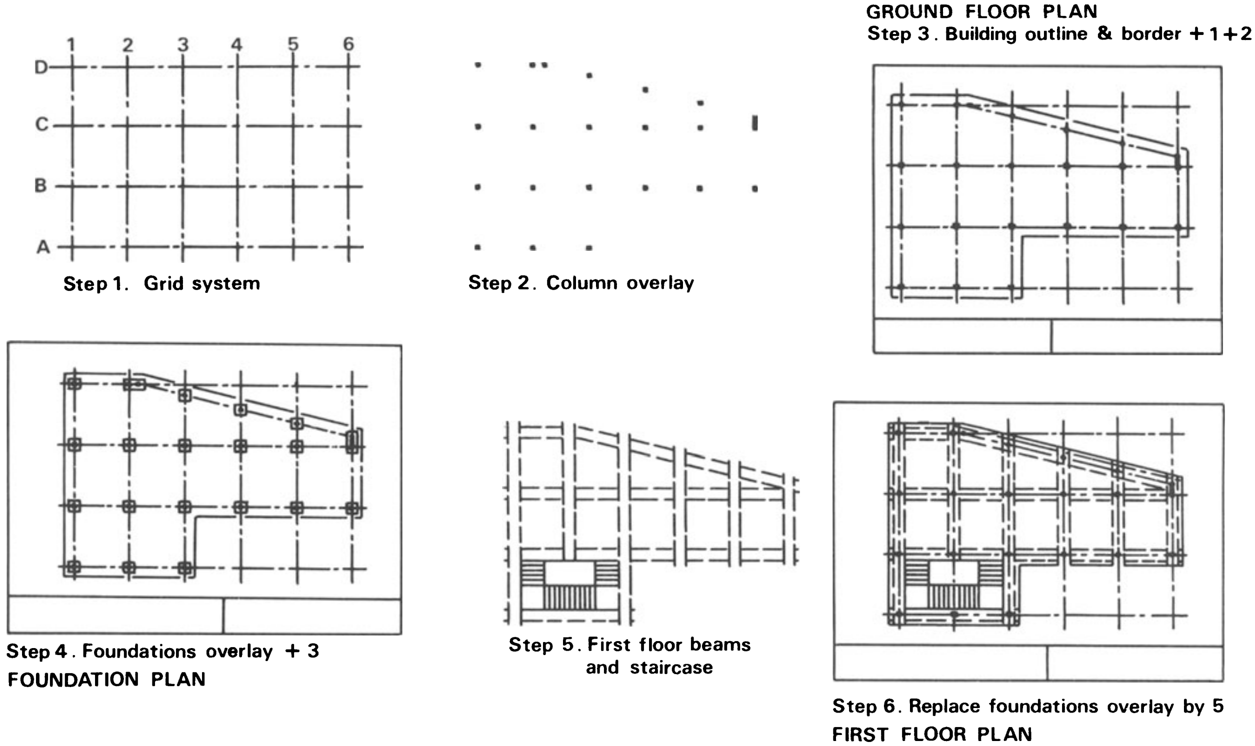


Figure 6.3 Overlays (Courtesy of Ove Arup & Partners)

Programs are developed and normally held in permanent storage on discs. Working from a rough sketch, the loads, geometry, constants, etc., are transferred to pre-prepared data sheets appropriate to the program used and then keyed into punched cards which are processed by the programs. The processed data are recorded on magnetic tape.

The Benson 1330 plotter used has its own tape unit, and operates three pens, each of which can be instructed to perform a different function. Hence lines of differing status on a drawing can be distinguished by three different colours or thicknesses. Conventional ink, fibre tip, and ball point pens are used for plotting on detail and tracing paper. Hardened steel tip pens are used for plotting on polyester film. Plotters can be driven 'on-line' (that is, permanently attached to the processor) or 'off-line' using magnetic tape as the data transfer medium.

Perhaps of even greater benefit than the speed and accuracy which can be achieved in the original analysis, is the ability afforded by the computer to assess design modifications quickly, particularly if they need to be made when siteworks are already in progress.

The Department of Industry recognised the potential of computer-aided design when, in 1969, it set up the Computer-aided Design Centre which now specialises in managing and executing design projects in collaboration with companies in the United Kingdom, Europe and the United States. Advanced equipment has been designed and produced by the Centre for colour graphics display processing, and specialised data switching equipment has been developed for applications in computer-aided design and plotting. Projects have been carried out in the construction, chemical, mechanical and electrical engineering industries.

Several programs have been developed for visualising any form of three-dimensional view: (1) in colour on a display unit, or (2) in a drawing produced by a digital plotter. Once the data have been input into the computer, different pictures of the object can be generated from any assumed viewpoint.

Figures 6.4 to 6.7 show examples of computer visualisations and drawings. In figure 6.7, the computer wire line visualisations were produced by a program called GINO. A combination of software and hardware enables a mathematical model to be constructed in the computer and various views (figures 6.7a, b and c, for example) can be displayed from chosen viewpoints. Figure 6.7d shows a line diagram of an existing carriageway; line diagrams of proposed structures are shown

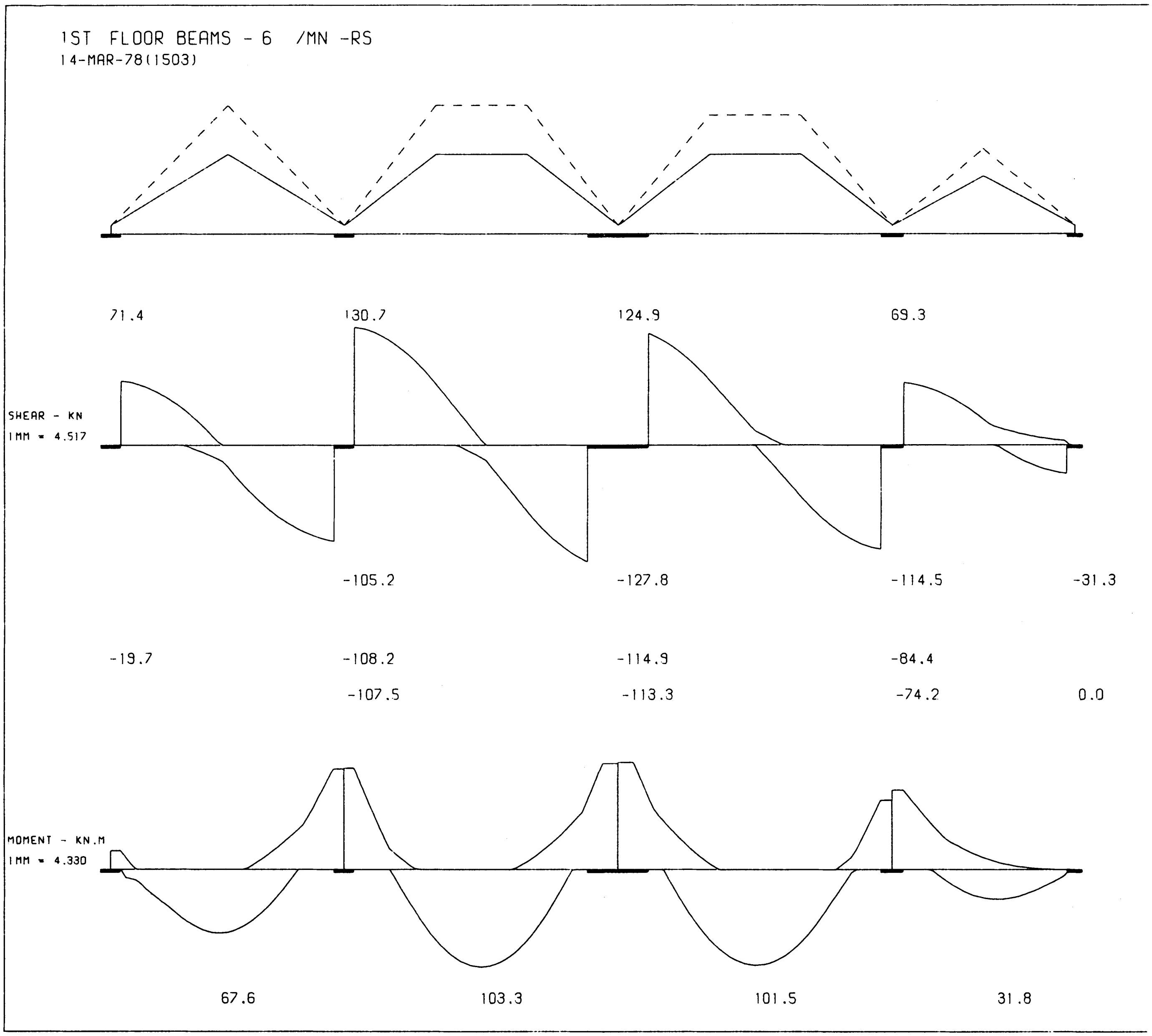


Figure 6.4 Computer-aided design: shear and moment diagrams for floor beams (courtesy of Building Computer Services Ltd, Bristol)

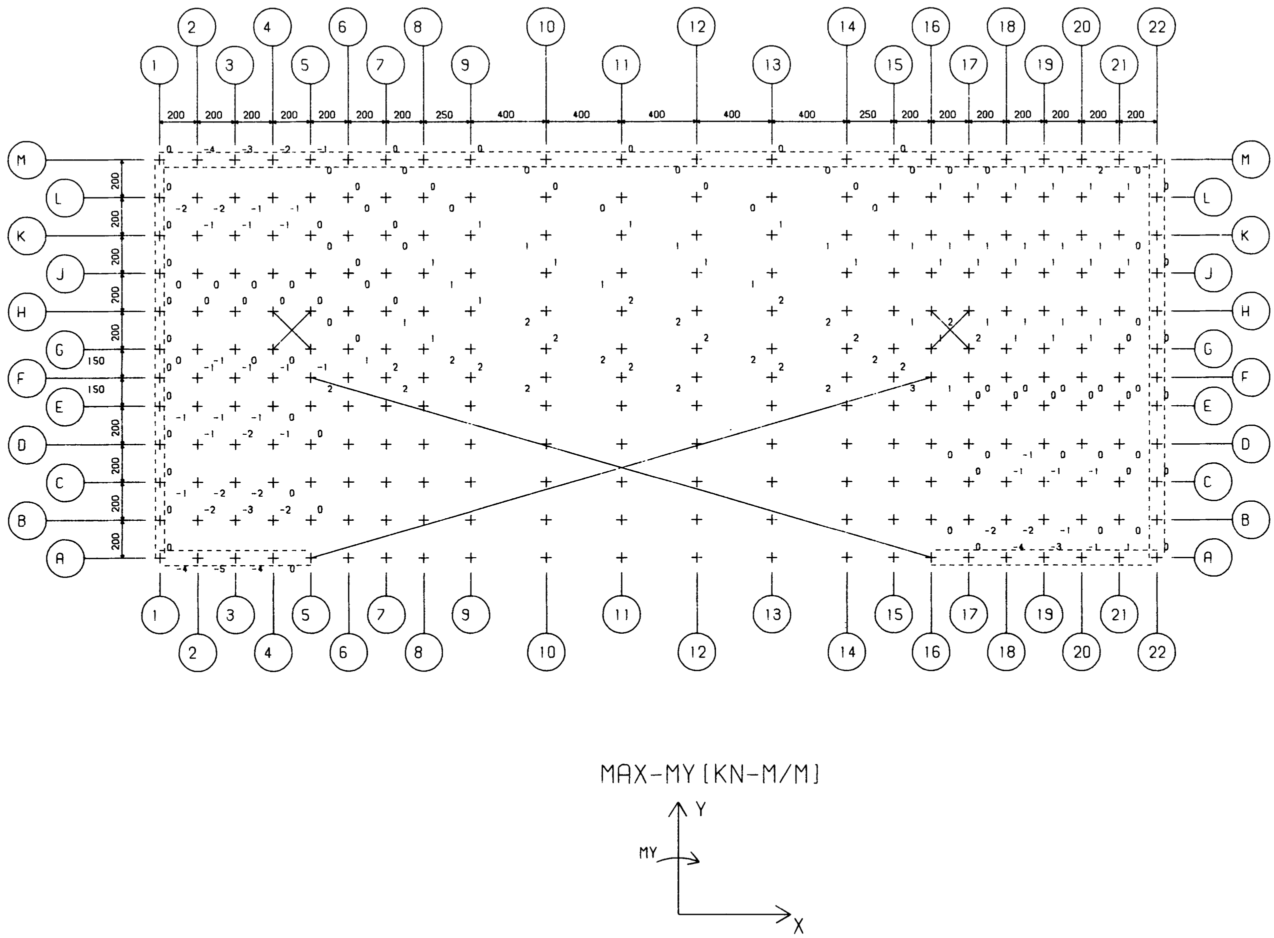


Figure 6.5 Computer-aided design: Example of safe finite element plot (courtesy of Building Computer Services Ltd, Bristol)

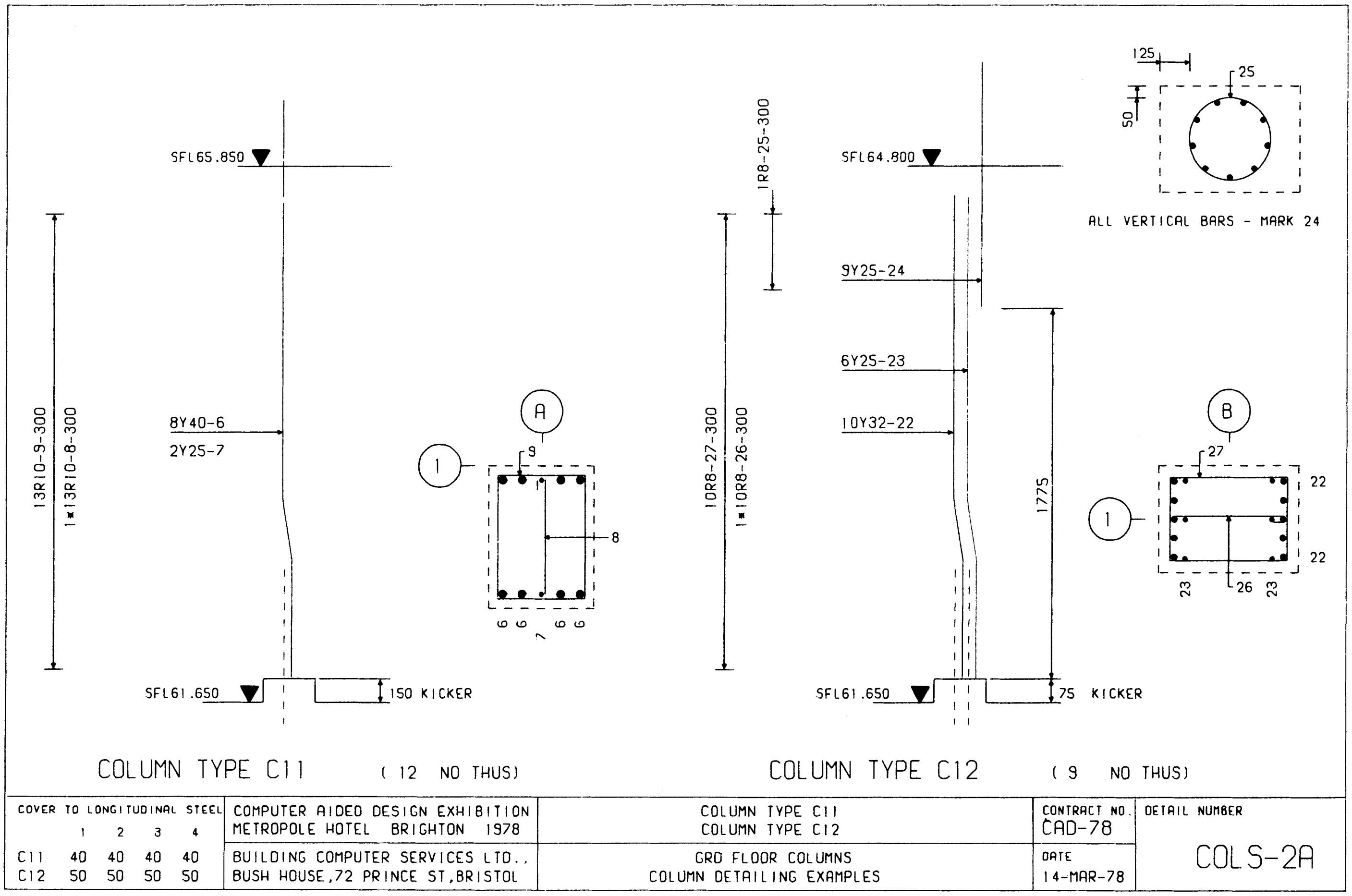


Figure 6.6 Computer-aided design: examples of column detailing (courtesy of Building Computer Services Ltd, Bristol)

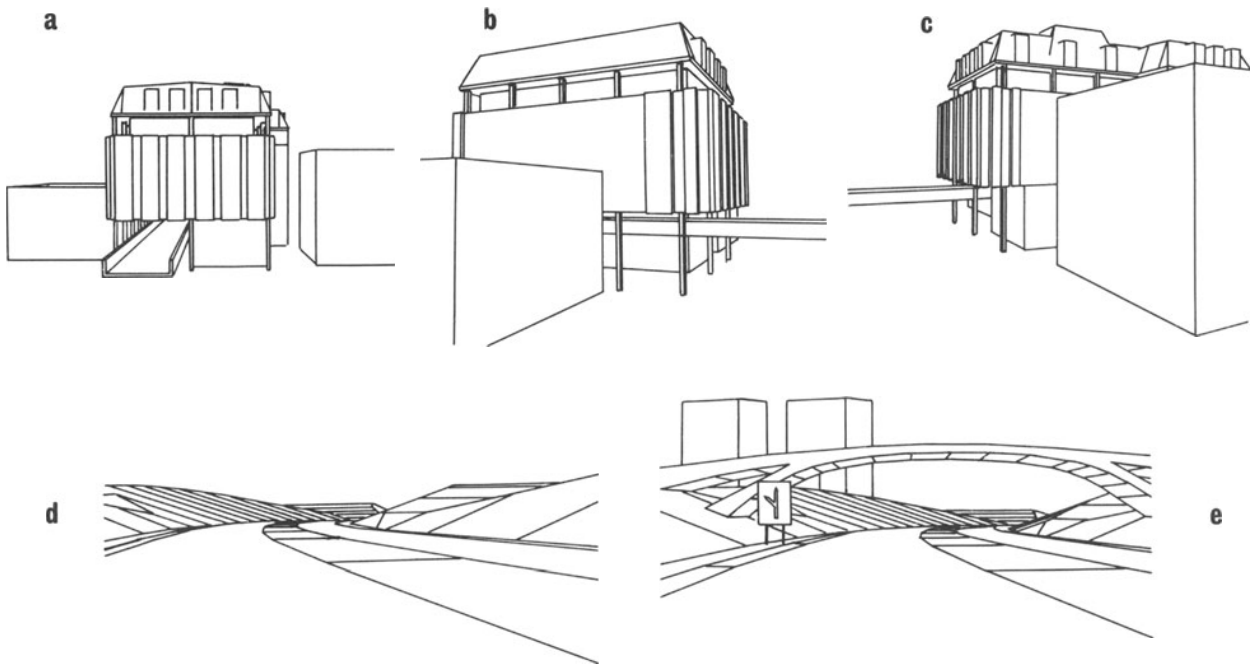
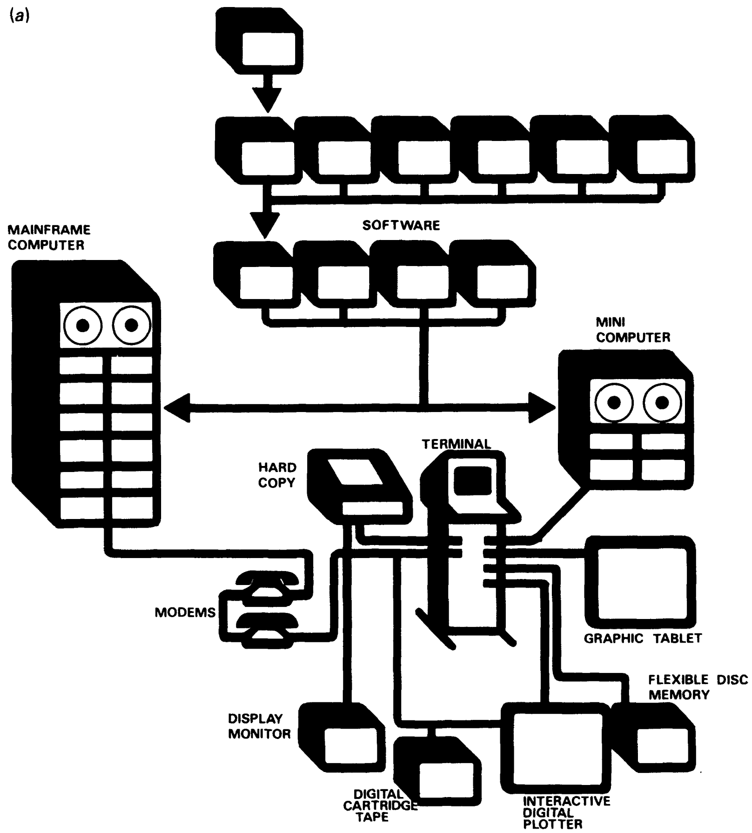


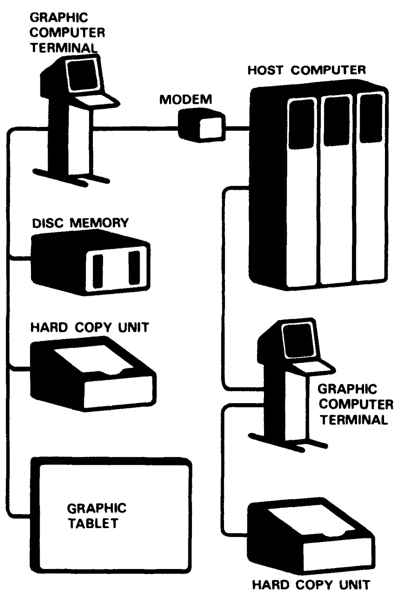
Figure 6.7 Perspective visualisations (courtesy of the Computer-aided Design Centre)

Figure 6.8 Block diagrams of computer graphics equipment (courtesy of Tektronix U.K. Ltd). Parts a and b show two ways in which computer graphics equipment can be linked to give varying degrees of flexibility in the generation of information. Arrangement (a) provides many options: for example a plan, graph or photograph could be placed on the graphic tablet shown connected to a terminal. The image could then be digitised for magnetic storage and/or display on a screen. The generation of any computer graphics output requires the communication of data in two stages: between human and machine, and from machine to machine. The first stage requires an elaborate system of coding and numerical transformations before the machine can make sense of the human information. The second stage – which usually requires the conversion of digital data (1s and 0s) to some sort of analog signal waveform, and the reconversion of that signal at the other end to digital data – involves a complicated exchange of preliminary messages (protocols). Devices (shown in c) that convert digital signals (two-state signals) coming from the computer into analog signals (suitable for transmission over a telephone line) and vice versa are called MODEMs (MOdulator–DEModulator).

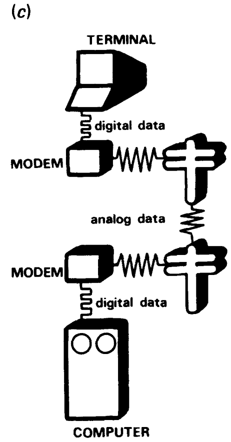
(*a*)



(*b*) **EQUIPMENT USED IN STRESS ANALYSIS**



(*c*)



superimposed in figure 6.7e. A photograph could have been used in place of figure 6.7d and the view with the superimposed structures would then have been a photomontage. Visualisations can also be generated in photograph-like effects in colour.

Figures 6.8 to 6.13 illustrate and describe a range of equipment used in computer graphics.

The use of technical terms peculiar to computer technology has deliberately been avoided in this chapter. In order to gain a better understanding of the technicalities of the subject, the reader will need to obtain some knowledge of computer programming and a few of the more commonly used computer languages such as BIPS and FORTRAN. The development of programs on a programmable calculator is a good way to start – see appendix II.

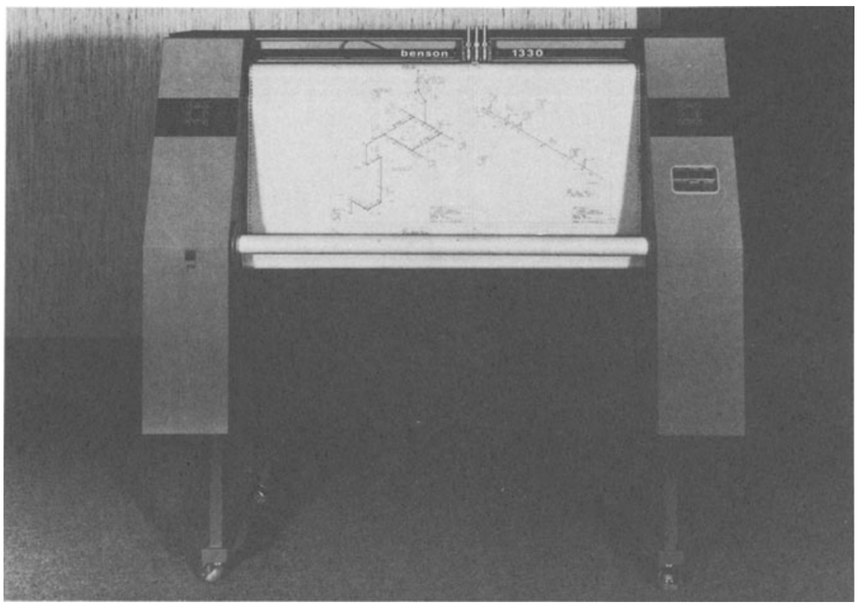
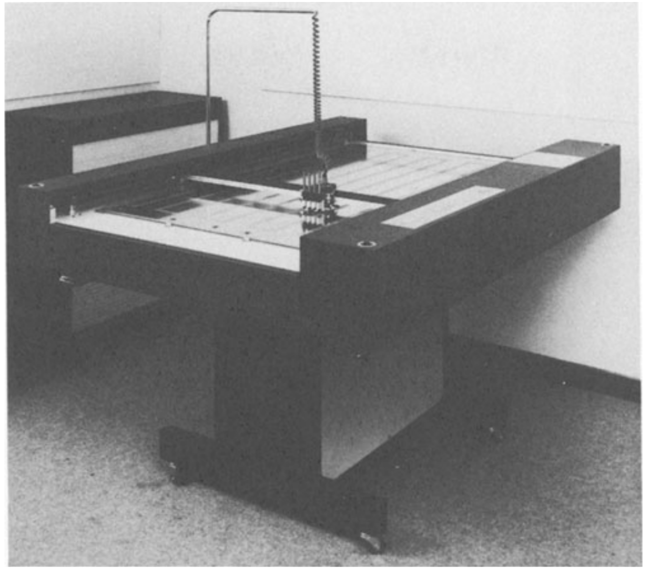
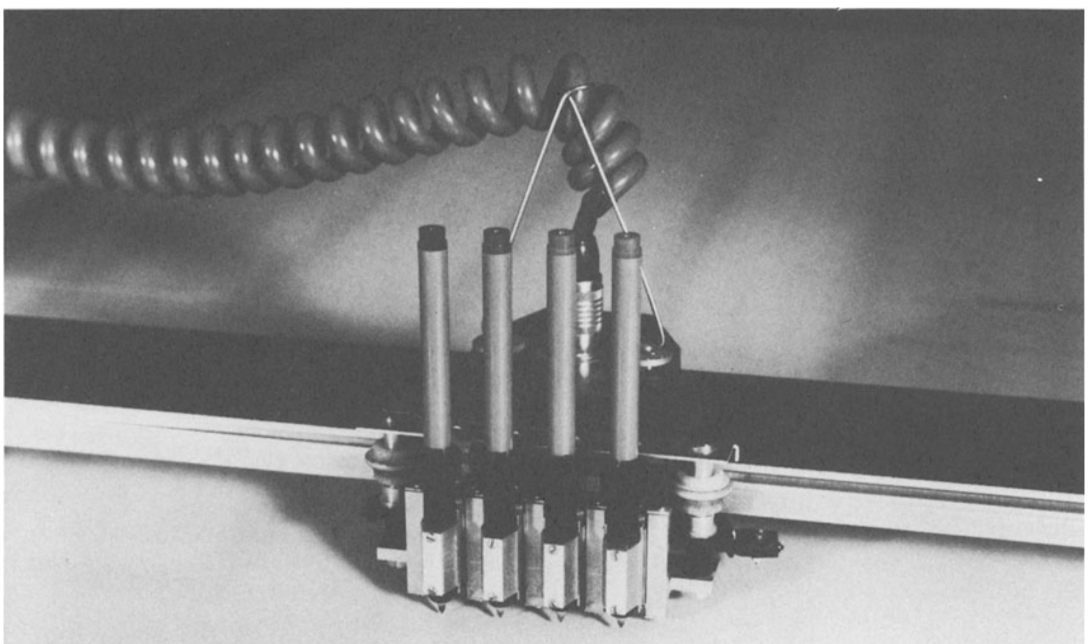


Figure 6.9 This high-speed drum plotter has a maximum plotting speed of 250 mm/s along axes and 350 mm/s on diagonals, when moving with the pen down and using ink. The plotting media normally used are either 55 g plain paper, 90 g tracing paper, double matt polyester film or translucent paper in roll widths up to 930 mm. The pen carriage consists of three pen heads. Liquid ink pens using various nib sizes, ballpoint or fibre-tip pens may be used. Pen sizes from 0.2 mm to 0.8 mm with stainless steel or tungsten tips can be used. (Courtesy of Benson Electronics Ltd)



(a)



(b)

Figure 6.10 The flat bed plotter shown in (a) provides a plotting area of 840 mm × 1200 mm; another model has an area of 840 mm × 1500 mm. The maximum plot speed along axes is 75 mm/s and 100 mm/s on diagonals. A scaling switch can be incorporated to reduce the drawing size by factors of 2 and 4. The pen carriage shown in (b) consists of a cartridge of four pen holders. (Courtesy of Benson Electronics Ltd)

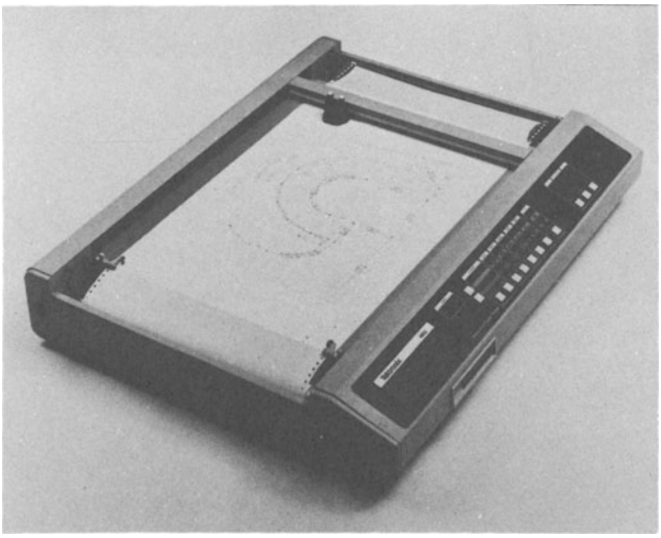


Figure 6.11 Interactive digital desktop plotter (courtesy of Tektronix U.K. Ltd). A digitiser enables a diagram to be either generated or copied directly on to a display screen. Each required point is probed by aligning the 'pencil' or cursor graticule over the point and pressing one of the digitising buttons. A sequence of data describing the point is then automatically generated and output to a recording device. Information about the drawing can also be transferred to magnetic tape which can be used later to instruct an automatic plotter to reproduce the drawing. The plotter shown also has a facility which enables the user to digitise and immediately plot back a portion of the drawing, either directly over the original or to one side, in order to verify that the digitising has been done correctly

Figure 6.12 Desktop graphic computing system (courtesy of Tektronix U.K. Ltd)

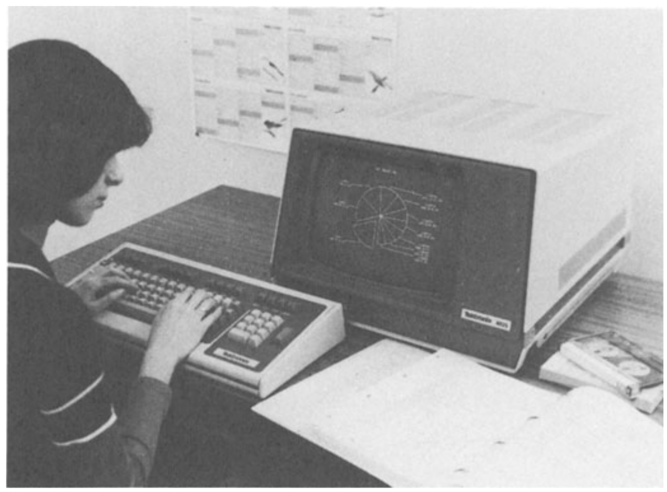


Figure 6.13 Graphics display terminal (courtesy of Tektronix U.K. Ltd). This terminal can display 34 lines of 80 characters on the screen and has a 4K memory that can be expanded to 32K to create forms beyond the limits of the screen. To facilitate data entry and editing, the screen can be divided into two areas: one to create the form (such as bar charts with multiple shadings, histograms, log plots and pie charts), and the other for communication with the host computer. Hard copy can be obtained in the size 216 mm x 279 mm. The different line types are solid, several styles of dashed line, single points and dark vectors which erase lines previously drawn.

7. DRAWING APPLICATIONS

7.1 INTRODUCTION

At the very outset of his career the student engineer will be expected to acquire quickly some proficiency in drawing and detailing before he has the opportunity of applying the essentially scientifically based knowledge gained during his academic training. He may find that he cannot strictly apply the drawing principles he has learned, possibly biased towards mechanical engineering, to the practical detailing problems that he will be faced with in a civil or structural engineering drawing office.

Because the student engineer is therefore likely first of all to seek some guidance in detailing, it is appropriate at this stage to introduce the reader to some of the broader aspects of civil engineering as a whole. This final chapter includes drawing examples typical of those prepared in some of the many specialised branches of civil engineering – highways, bridges, dams, railways, docks, sea defences, oil rigs, building foundations and structural frames, sewerage and sewage disposal, water supply, pumping stations, car parks and airports.

Each diagram in this chapter serves to emphasise particular drawing and detailing principles, although for practical reasons the figures are not copies of complete full-size drawings. Actual dimensions have been omitted on most of the figures but dimension and projection lines are generally shown.

There are certain works that could be regarded as purely of a civil engineering nature, but more often than not in these days of increasing specialisation, the engineer will be a member of a team. If the project is basically civil engineering in scope, he may be called upon to assume a leading or coordinating role within the group, if only on technical matters. An independent management department may be established to plan and coordinate the activities of a team involved in the design and construction of a large complex structure, where the work involved in the various trades may be more evenly distributed. In this case, it is essential to the success of the whole project that all members of the team cooperate fully with each other and consult frequently on day-to-day technical matters. This should not be regarded as the coordinator's responsibility.

The author would like to impress on the reader at this point the need to strive for an appreciation of the problems of those in other professions with whom he comes in contact. One of the main disadvantages of specialisation and departmentalisation is the natural human tendency of those in a closed group to criticise those outside it. Criticism can be constructive, but if born of ignorance and carried to extremes it could be a recipe for disaster.

It may be helpful to the understanding of the various techniques used in graphical presentation to consider the broad classifications of civil engineering works and the basic resources used in their construction. The broad classifications of work are as follows.

(1) Surveying and site investigations to fix the location and levels of existing topographical features and the nature of ground conditions. These investigations require a knowledge of geology, soil mechanics and a variety of surveying techniques.
(2) Structures below ground, for example, building and other structural foundations, humus and sedimentation tanks at sewage works, retaining walls and pipelines. These structures must be designed to withstand both earth and water pressures in addition to other dead and imposed loads, and the effects of flotation must always be considered. Certain chemicals in soils, and the liquids which may be present in liquid-retaining structures, can have an adverse effect on the materials of construction. The ground itself should be considered as part of the structure. The shear strength of the soil and the effect of groundwater movements on the structure itself, and existing buildings in the vicinity, must be taken into account. The importance of sections, including those derived from geological maps, cannot be over-emphasised – one cannot draw too many of them.

(3) Structures above ground can be subdivided into four broad groups.
(a) General land-based structures, such as buildings, roads, bridges and land drainage structures.
(b) Reservoirs – geological considerations are particularly important in the design of dams.
(c) Dock and sea defence structures must be designed to withstand highly abrasive wave forces and the corrosive salt water environment; tidal effects must also be taken into account.
(d) Sea-based structures – the exceptional forces imposed by the natural elements pose special problems for the designers of the North Sea Oil installations.

The resources available to the civil engineer can be summarised under the broad headings of plant, labour and materials. The organisations that have been established to promote and provide research information on the civil engineers' chief materials, namely concrete, steel and timber, are

(1) The Cement and Concrete Association and the Concrete Society
(2) The British Constructional Steelwork Association and the Constructional Steel Research and Development Organisation
(3) The Timber Research and Development Association.

The Cement and Concrete Association have a highly organised training division producing technical data and running residential courses on all aspects of concrete design and detailing. All three organisations provide a wealth of design and research literature and advice.

The author believes that the reader might appreciate an insight into the preparation of all the documents, not just the drawings, for a civil engineering contract. This would present an enormous problem for a large and complex structure, therefore a small subway has been chosen for this purpose. The preparation of the documents, and the construction, are discussed briefly to serve as an introduction only to a much broader and more complex subject. (See section 7.5.)

The quality of a finished structure and the safety of the works during construction will depend to a great extent on the adequacy of the temporary works, and their importance should never be underestimated. The reader is advised to study books dealing comprehensively with this subject. Many engineers will have had little involvement with the design of temporary works, but may nevertheless have supervised contracts in which they were continuously used.

It is the author's opinion that all engineers should have as much experience as possible on the site of construction works early in their careers. Technicians, draughtsmen and detailers would also benefit from site experience at periodic intervals, even if they are basically employed in a drawing office. Undoubtedly more will be learnt during a period on site than during an equivalent period in an office. The reader will probably find that he will start to prepare drawings with an added confidence following early site experience and will have a much better understanding and appreciation of his work. Having prepared drawings for use on site it will prove to be well worth while obtaining the reactions of the resident engineer, the contractor's agent and the workmen doing the job, as to the clarity and practicability of the details shown.

The young draughtsman should appreciate that he is not required to be an artist. He should perhaps consider that the end product of his efforts is not only the drawing itself, but the successful completion of the structure he is seeking to illustrate.

7.2 SURVEYING

The purpose of a survey is to represent in plan the nature and topography of the ground and the position of all visible features. This can be achieved using precision instruments to determine levels and angular and lineal measurements, or by aerial photography.

The first step in carrying out a survey on the ground is to establish a base of interconnected straight lines, called a traverse, from which measurements can be taken to existing features with the greatest degree of accuracy and convenience. The points or stations at which there is a change of direction in the traverse are established, using steel nails driven into existing hard ground or by means of steel tubes or rods which are embedded in concrete. The traverse may be open ended or closed. A closed traverse, in which the base lines form a closed loop, should be used whenever possible, unless both ends of the traverse can be accurately related to existing reference points on the National Grid (see figure 7.12). The angles between the lines, and the distances between the stations are then accurately measured. Electronic measuring devices are required for large distances. It should be noted that tape measurements must be corrected to take account of the sag and shrinkage or contraction of the tape, the slope of the ground and the curvature of the Earth. (Figure 7.5 shows an electronic distomat being used for both distance and angular measurements.)

Figure 7.1 Bridge segment: reinforced concrete bridge unit being loaded for transport (courtesy of Dow–Mac Concrete Ltd)

Figure 7.2 Bridge unit being positioned (Berry Lane Viaduct)

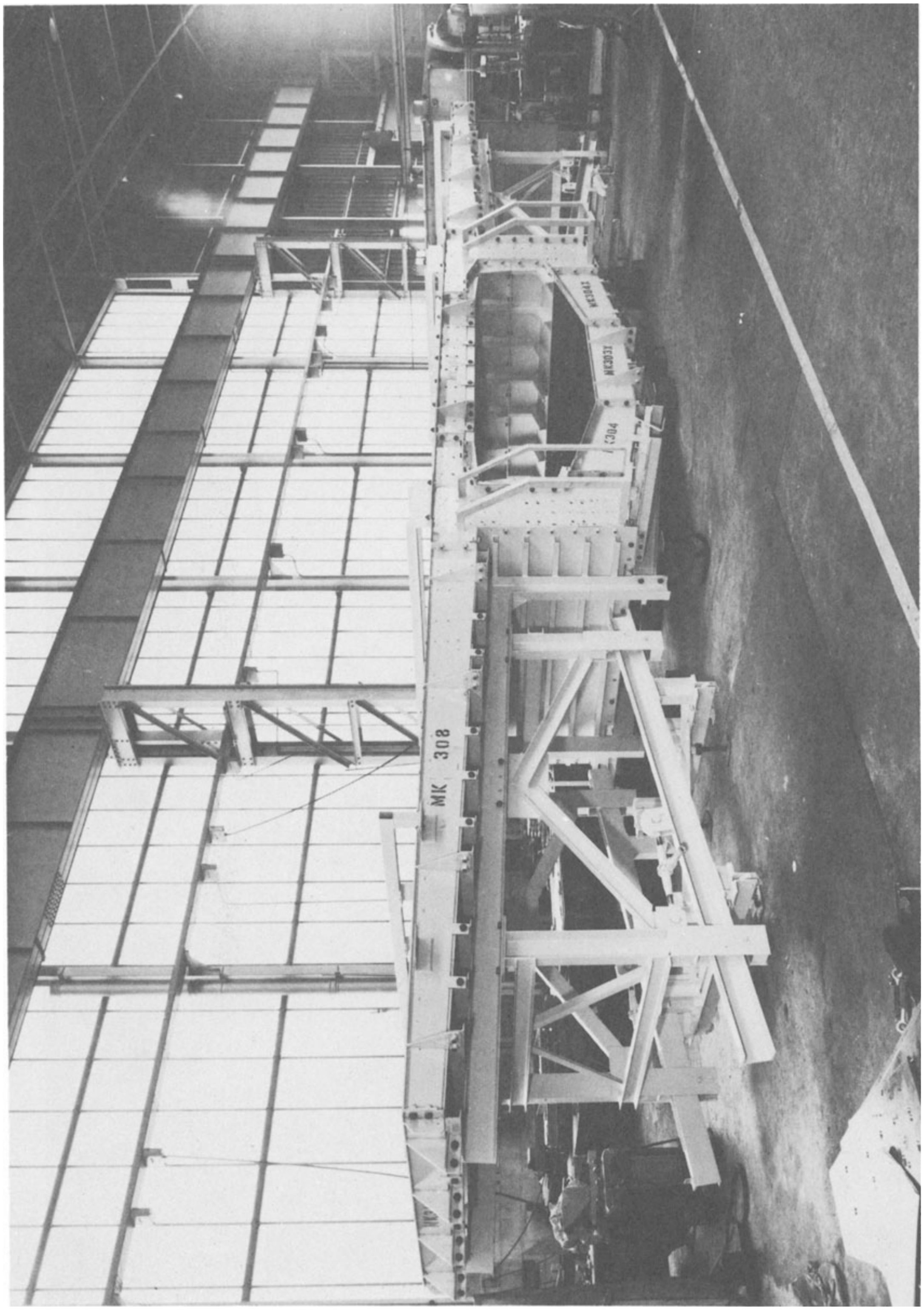


Figure 7.3 Mould for bridge unit

Figure 7.4 Timber bridge (courtesy of Lamwood Ltd)

Figure 7.5 Distomat

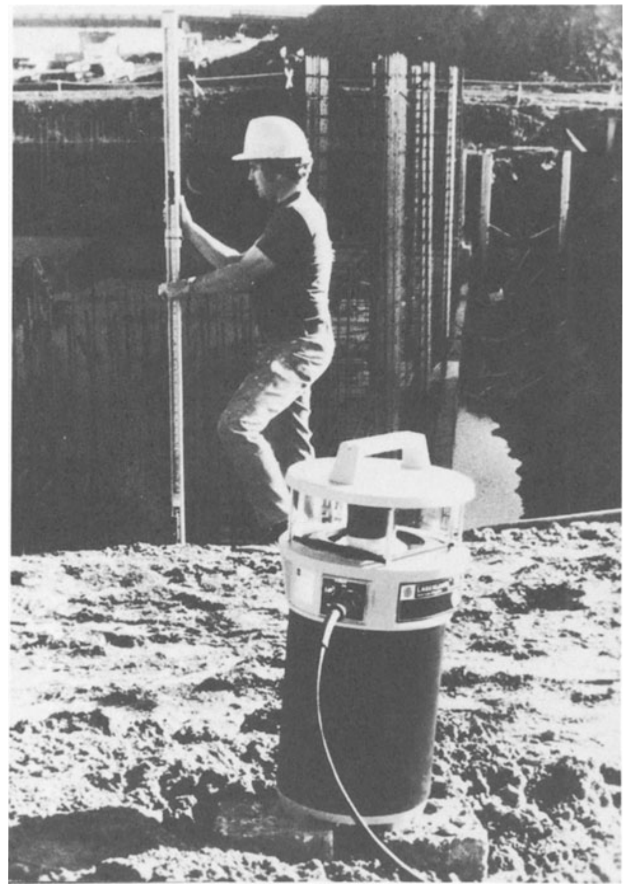


Figure 7.6 Laser (courtesy of Spectra Alignment Ltd)

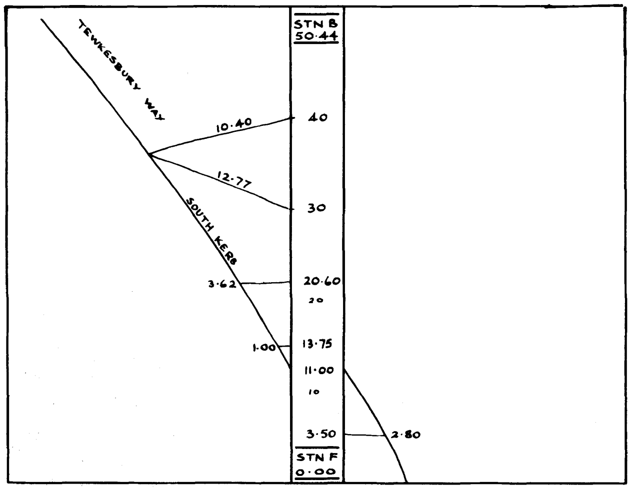


Figure 7.7 Chain survey

Figure 7.7 gives an example of measuring and booking a portion of the survey detail between the stations F and B shown in figure 7.9. Note that points less than 5 m from the chain have been recorded by means of right-angled offsets. Where the distance is greater than about 5 m, it is better to record points by means of ties from two positions on the chain. The ties should be taken in such a way that the arcs ascribed to fix the point on the survey plot intersect approximately at right angles to each other.

There are two methods of measuring, recording and plotting topographical detail from the traverse: chain surveys, and polar coordinate surveys.

7.2.1 Chain Surveys

The traditional chain survey makes use of a steel chain 30 m long which is divided into 100 links. Existing features are measured by means of ties or offsets from the chain and recorded in a field book, as shown in figure 7.7. The over-all distances between the stations are usually measured with a steel band or steel tape.

7.2.2 Polar Coordinate Surveys

The topographical detail is measured by means of polar coordinates, using a theodolite and tape, tacheometer or electronic distomat, and recorded as shown in figure 7.8.

STN F

R.O. STN B 00°00'00"

Detail No	Horiz. angle	Horiz. dist.	Remarks
1	344.57	39.17	
2	349.58	20.98	SKETCH SHOWING
3	355.35	13.84	DETAIL PLUS DESCRIPTION
4	38.52	4.47	

Figure 7.8 Polar coordinate survey

Where there is a large amount of detail to be recorded within a relatively small area, a polar coordinate method can be used to advantage. Detail can be recorded very quickly with the aid of a distomat or similar instrument, which measures angle and distance. This facility is clearly a particular advantage in areas where traffic is heavy.

It would be confusing to show the radial lines and angles in diagrammatic form in the field book and a sketch is drawn showing each point of detail referenced with a number. Angles and distances pertaining to each point are then recorded in a tabular form.

In the example, the instrument has been set up at station F, and the angle set to zero with a sighting on to station B (R.O. STN B 00° 00′ 00″). Angles have then been measured clockwise to each point of the detail.

Even if distance measurements must be taken with a tape, there may be advantages over the chain method in that a large number of long measurements can be taken at one time. However, if most of the detail is close to the traverse lines (for example, the boundary fence of a large field) the chain method is likely to be the most convenient. If a distomat is available, then the polar coordinate method is likely to be used for all the survey work.

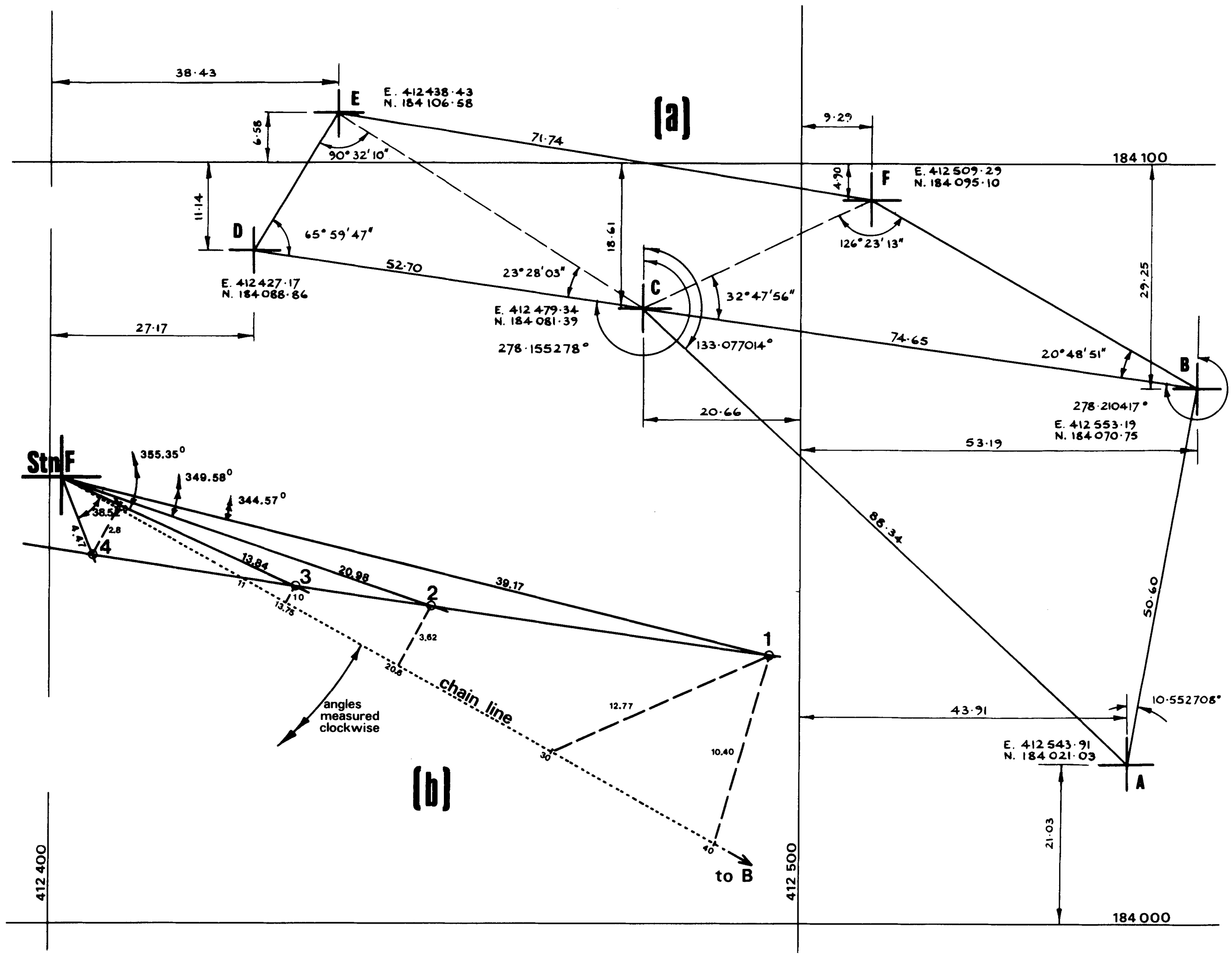


Figure 7.9 Plotting the survey traverse and detail

a Shows the basic field and plotting data for the traverse which forms the framework for the survey detail. Note: because of the steep bank interposed between the base lines EF and DCB and the resulting difficulty in measuring lines DE and FB accurately, the stations E and F have been established by means of the base lines DC and CB and the internal angles of the triangles CDE and BCF. Angular measurements are usually converted to whole circle bearings (that is, measured clockwise from due north). Angles have been shown to 6 decimal places where it has been necessary to convert degrees, minutes and seconds to degrees.

b Shows the two alternative methods of plotting the survey detail from the field books (see figures 7.7 and 7.8).

7.2.3 Plotting the Survey

Before plotting the detail, a square grid is accurately drawn on heavy-duty cartridge paper or polyester film, using the methods described in chapter 1. The rectangular coordinates of the stations, called eastings and northings, are usually related to the National Grid, and transferred to the survey grid, as shown in figures 7.9 and 7.10. (Figure 1.25 illustrates the use of a polar coordinatograph for plotting detail.)

The recognised conventions for representing survey detail are shown in figure 1.19.

Figure 7.9b illustrates the way in which detail is plotted from the field books using the alternative offset and polar coordinate methods.

7.2.4 Levels

Existing ground levels are usually related to Ordnance datum, and are represented on a plan by means of contours or spot levels. Points on contours can be established directly on the ground by means of polar coordinates measured with a tacheometer, or by interpolation from a square grid of spot

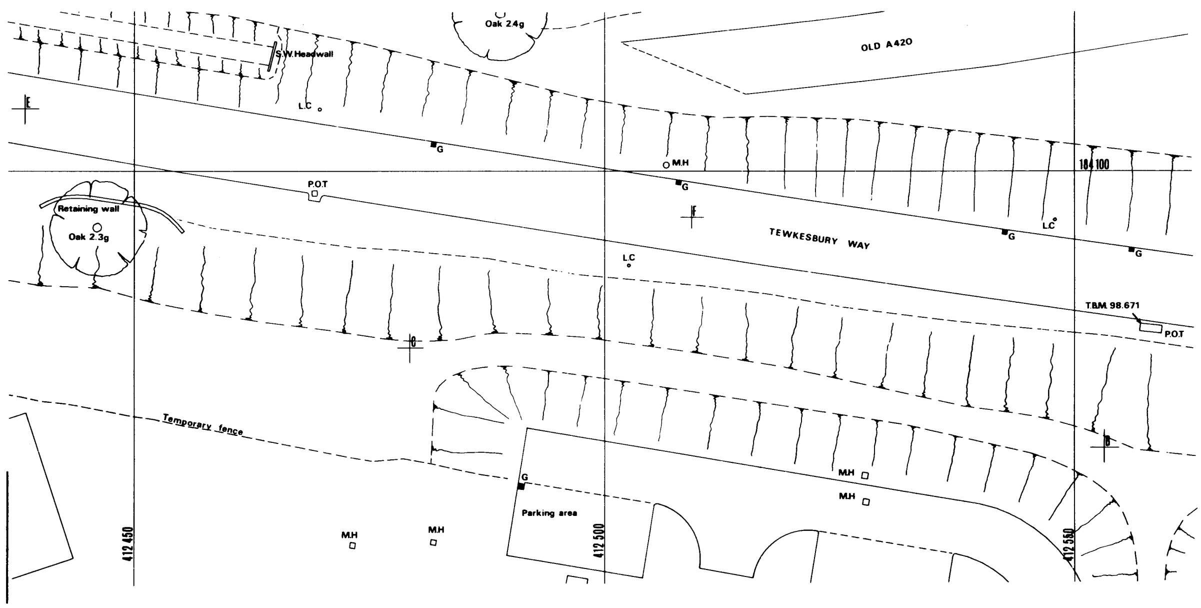


Figure 7.10 The completed survey

levels. There are two methods of booking levels, called the 'collimation' method and the 'rise and fall' method. The latter provides more arithmetic checks when computing the levels in the field book.

7.2.5 Aerial Surveys

There are occasions when aerial surveys can be justified, when compared with the time and costs involved in the alternative ground survey methods; this is often the case when surveys and contours are required for large areas proposed for future development. This method has the added advantage that the survey does not involve entry on to private land.

Aerial survey maps are obtained by applying the principles of photogrammetry to photographs taken vertically from an aircraft flying over the survey area approximately horizontally at a near constant height.

Figure 7.13 shows part of an aerial photograph and the corresponding plan.

7.3 SITE INVESTIGATIONS

No civil engineering project should ever be undertaken without first carrying out a thorough site investigation. A study of civil engineering failures will show that many have been due to an inadequate appreciation of the existing ground conditions.

Usually site investigations will include a study of old records and plans of the area, geological maps and topographical survey plans. It will also prove worth while talking to those who have a special knowledge of the area and its history. Has any part of the area ever been used as a refuse tip? Have there ever been any springs or mine workings in the area? Surveyors and setting out engineers can often gain unsolicited information while on site which may be helpful to the designer.

Having obtained as much information as possible from existing records, a geotechnical firm is usually employed to carry out boreholes, take and test samples of the soil, and submit a technical report. The report for the footbridge in appendix I was submitted in two parts. The first included a statement of the contract brief, a factual report of the site works and observations, the geology of the area and the recommendation as to the type of foundations required. The second part included a site and borehole location plan, borehole logs and the test results. Part of the borehole log is shown in figure 7.14. Tests were carried out to record the strata and groundwater conditions, determine the possible short and long-term ground settlements at various depths under the estimated imposed loading, and measure the sul-

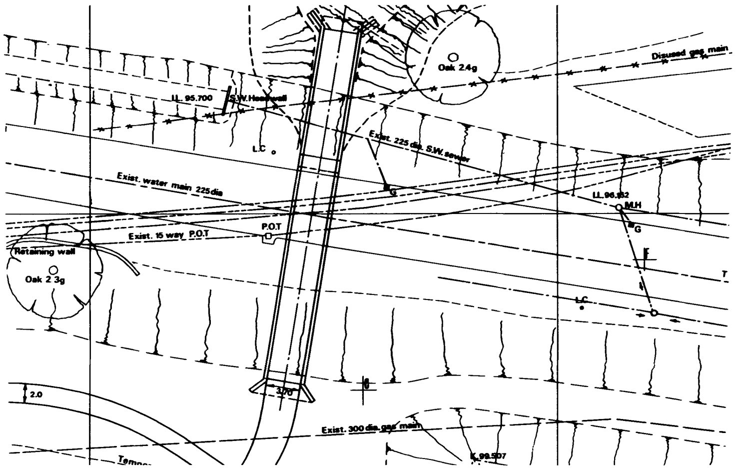


Figure 7.11 Part of survey plan with underground features and proposals added

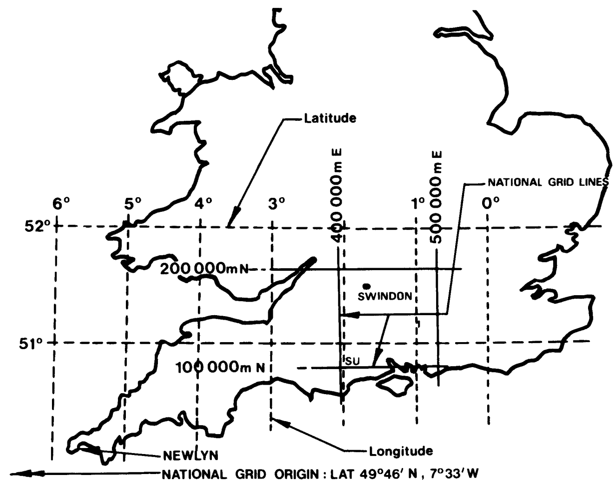


Figure 7.12 National Grid system

The grid lines and station coordinates shown in figure 7.9 are related to the National Grid. The 100 km square portion of the Grid within which these lines are situated has the reference SU in this system as shown above. The National Grid (false) origin has been so situated that all 'northing' and 'easting' coordinates in the United Kingdom are positive.

phate contents and shear strengths of the soil. The estimation of the depths for the boreholes was based on the assumption that piled foundations would be required.

7.4 DETAILING

There are established conventions for representing concrete reinforcement and structural steelwork details which should be strictly followed wherever possible. Detail design and drawing is a very time-consuming and highly skilled procedure if carried out properly. Insufficient or blurred detailing will present construction site staff with a lot of headaches and more often than not will lead to errors. On the other hand, fussy detailing that shows every brick in a wall or the complete hatching of a large area is a waste of time and can be equally aggravating. Poor details can be the result of many factors but are mainly due to inadequate research or insufficient time.

7.4.1 Reinforced Concrete Detailing

Reinforced concrete is one of the most important materials used in civil engineering. Concrete and steel can be combined in such a way as to utilise to the full the inherent structural properties of both materials while almost nullifying their essential weaknesses.

Concrete is strong in compression and has a high resistance to corrosion and intense heat, but is weak in tension. Steel is strong in both tension and compression but expands quickly and can buckle when subjected to high temperatures; it also has a tendency to corrode. Hence, putting it simply, the steel is used to provide the resistance to tensile stresses while the concrete protects the steel. Also, the compressive strength of the concrete is often fully utilised in the production of slender beams by means of a process known as pre-stressing.

The terms used to define the principal forces imposed on structural members are tension, compression, bending and shear, all of which can induce tensile stresses in unreinforced and reinforced concrete. The basic theory of reinforced concrete design is that steel bars are introduced in such a way as to provide the whole resistance to the tensile stresses; the tensile strength of the concrete is ignored (see figure 7.15).

The reader will find that he is well along the road to an understanding of reinforced concrete detailing if he can appreciate (1) how fundamental stresses are set up within a structural member under the application of external loading, and (2) the types of steel bars needed to resist those stresses and the form of their arrangement in the member (see figures 7.15 and 7.16).

The recognised methods of detailing reinforced concrete are described in the *Standard Method of Detailing Reinforced Concrete*, produced by the Concrete Society and the Institution of Structural Engineers, which should be used in conjunction with BS 4466: 1969 Bending Dimensions and Scheduling of Bars for the Reinforcement of Concrete.

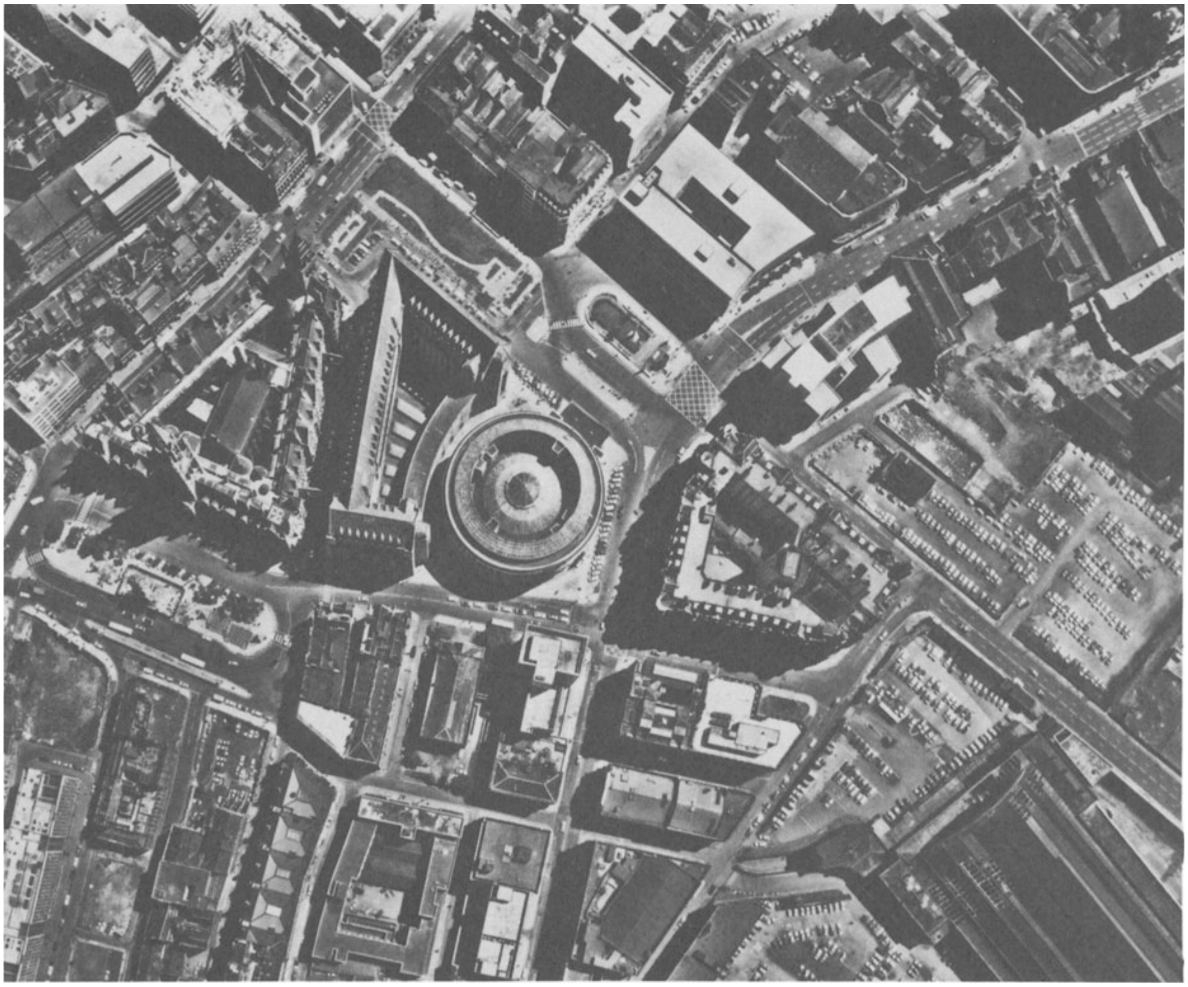


Figure 7.13 Aerial survey

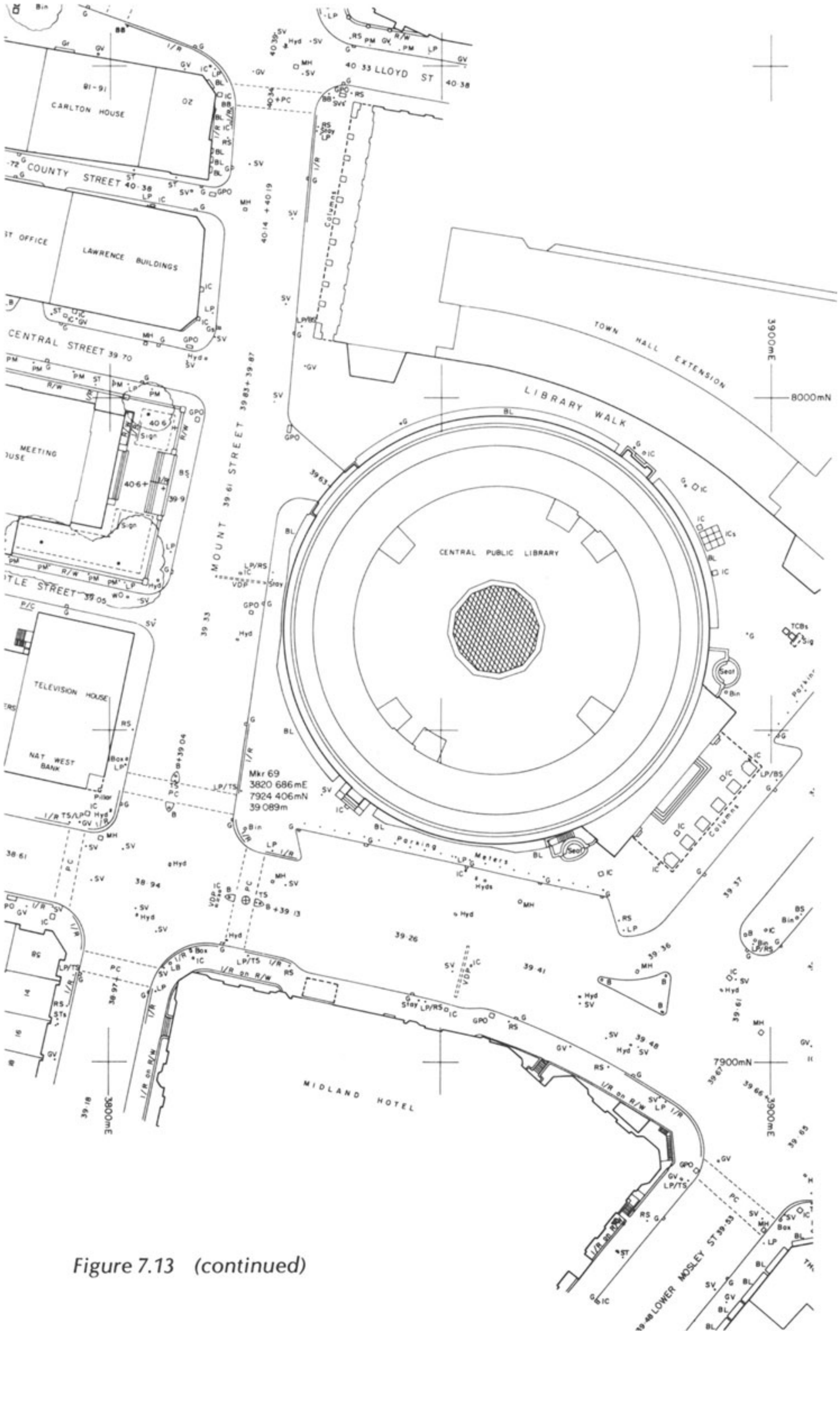


Figure 7.13 (continued)

Sampling		Properties			Strata			
Depth	Type	Strength kN/m²	w %	SPT N	Description	Depth	Level	Legend
					Turf and TOPSOIL.	GL	99.4	
0.2	D		25			0.2	99.2	
0.5-1.0	U(14)	40	24					
1.2	D		26		Soft to firm light brown-grey silty sandy CLAY with pockets of silt and occasional gravel.			
1.5-2.0	U(10)	20	24					
2.2	D		24					
2.5-3.0	U(25)	70	30			2.8	96.6	

Samples				Chemical		Classification					Strength				
Hole	Depth	Type	Description	pH	SO_3	I_P	w_L	w_P	w %	γ_b Mg/m³	Test	σ_3 kN/m²	$\sigma_1 - \sigma_3$ kN/m²	c kN/m²	$\phi°$
19	0.2	D	Stiff yellow brown mottled light grey silty CLAY with occasional roots.						25						
	0.5-1.0	U	Firm light brown mottled grey silty slightly sandy CLAY with occasional gravel, roots and pockets of silt.			100% 15	33	18	24 24 25	1.98 1.98 1.94	UT 38	100 200 400	94 83 68	40	–

Figure 7.14 Borehole log

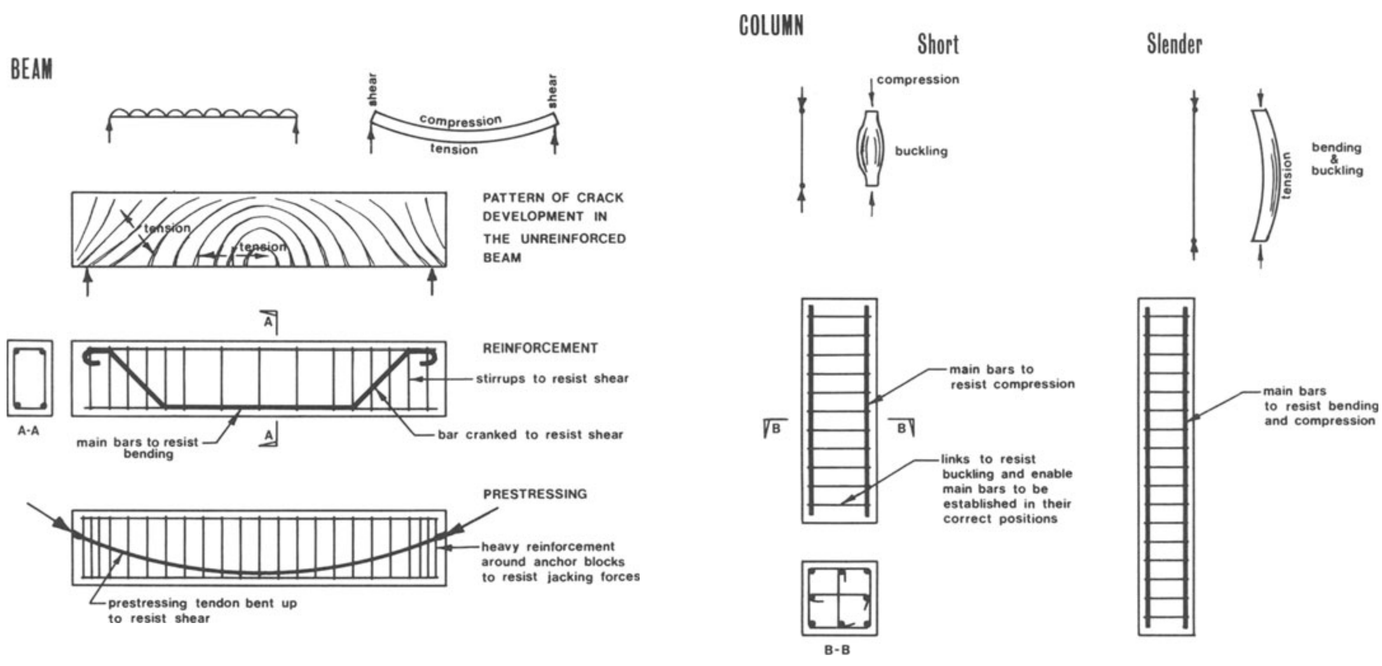


Figure 7.15 Tensile stresses in concrete

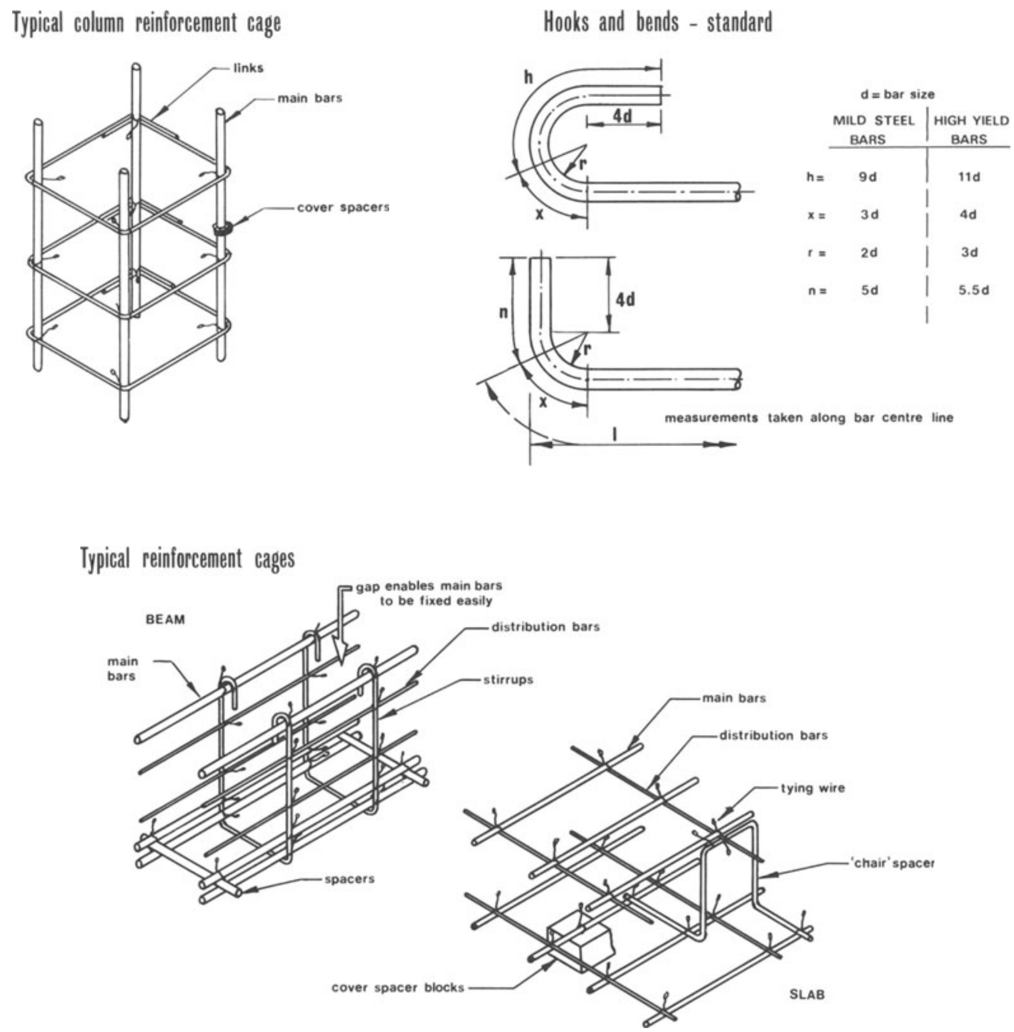


Figure 7.16 Links, stirrups, chairs and spacer bars. (The terms 'links' and 'stirrups' are now more commonly called 'column links' and 'beam links' respectively)

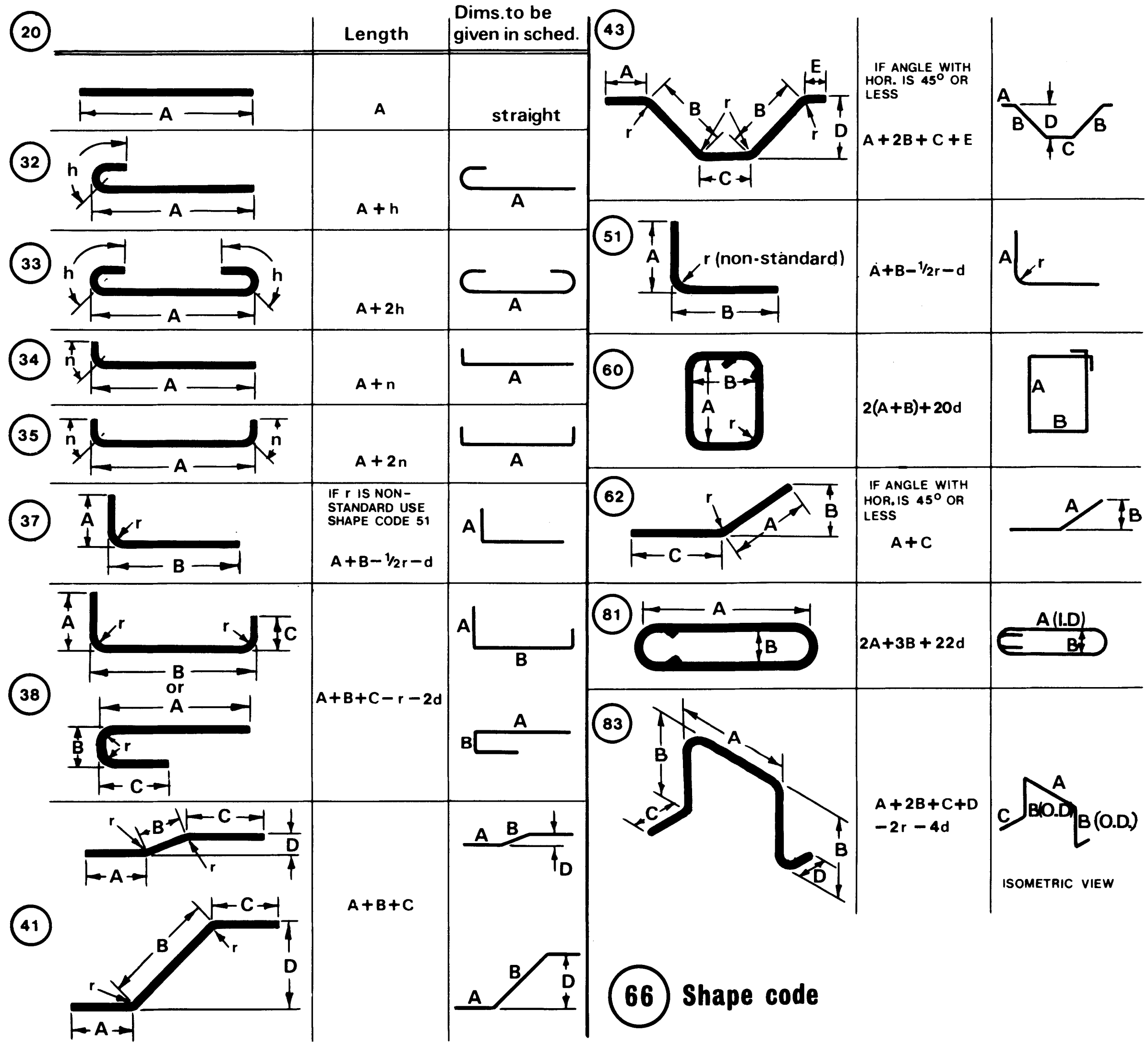


Figure 7.17 Preferred bar shapes

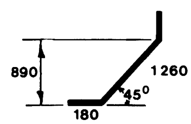
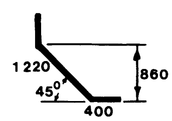
Taken from BS 4466:1969 Bending Dimensions and Scheduling of Bars for the Reinforcement of Concrete, reproduced by permission of the British Standards Institution, 2 Park Street, London W1A 2BS, from whom complete copies may be obtained. Other shapes are also given in BS 4466.

THAMESDOWN BOROUGH COUNCIL
TECHNICAL SERVICES GROUP

Metric Bar Schedule ref. 0 1 1 0 2 –

Site Ref. LIDEN DRIVE SUBWAY U9 – WING WALLS Date. 10/1/1978

Member	Bar mark	Type & size	No. of mbrs	No. in each	Total No.	Length of each bar. mm	Shape code	A mm	B mm	C mm	D mm	E/r mm
BASE	17	R25	4	31	124	3460	37	1560				
& STEM	18	R16	4	23	92	1740	48	180	1260		890	
	19	R16	4	23	92	2020	48	400	1220		860	

Member	Bar mark	Type & size	No. of mbrs	No. in each	Total No.	Length of each bar. mm	Shape
BASE & STEM	17	R25	4	31	124	3 460	
	18	R16	4	23	92	1 740	
	19	R16	4	23	92	2 020	

Location	Fabric mark	Type	No. of sheets	Length (main wires) mm	Width mm	Bend or cut

Figure 7.18 Bar and fabric schedules

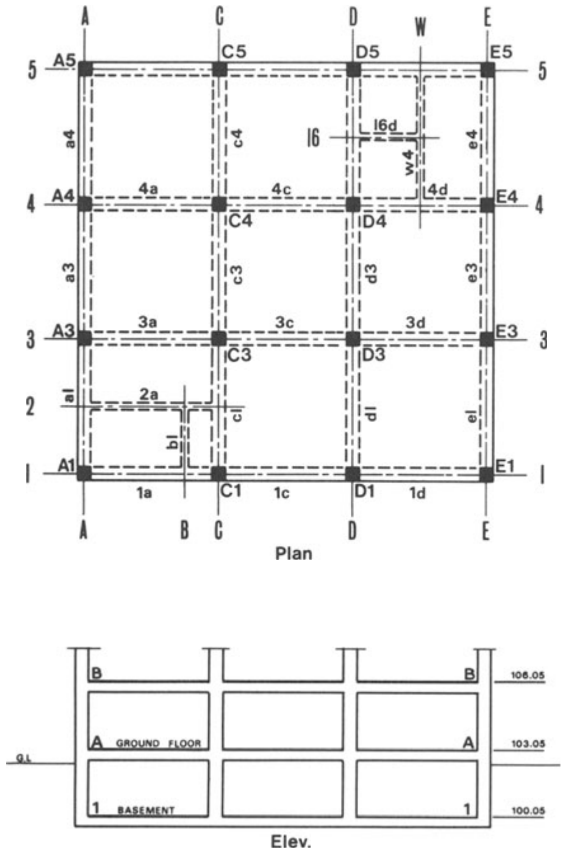


Figure 7.19 Grid referencing

Letter/number system: Columns are numbered by the intersection of lines, for example C2 at the intersection of lines C and 2. Beams are numbered in lines, for example 3a, 3b, 3c on line 3 and b1, b2, b3 on line a. Lower-case letters are not acceptable for use in computing systems and the Standard Method now recommends that only capital letters be used. BS 1192 recommends that the origin of the grid system be in the bottom left-hand corner as shown above and in figure 7.21. The origin has, in the past, usually been placed at the top left-hand corner, as shown in figure 7.20, and this system is probably still widely used.

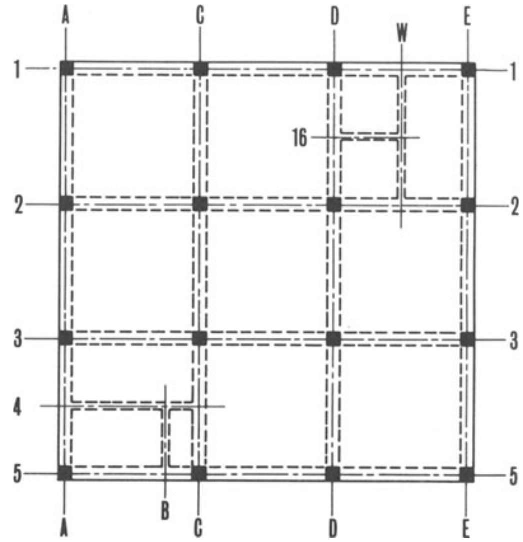


Figure 7.20 Grid referencing

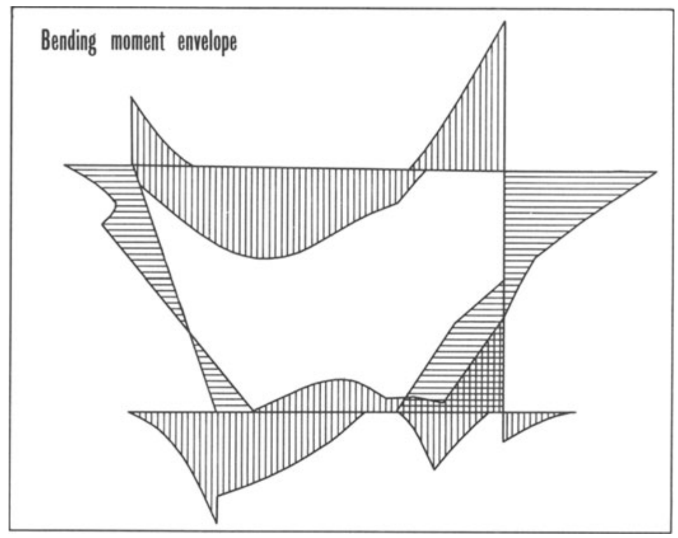


Figure 7.22 Maximum bending moment envelope

The maximum bending moment envelope is just one of several design diagrams that are used in determining the size and arrangement of the main reinforcing bars in a structure.

Plan at level Z 106.05

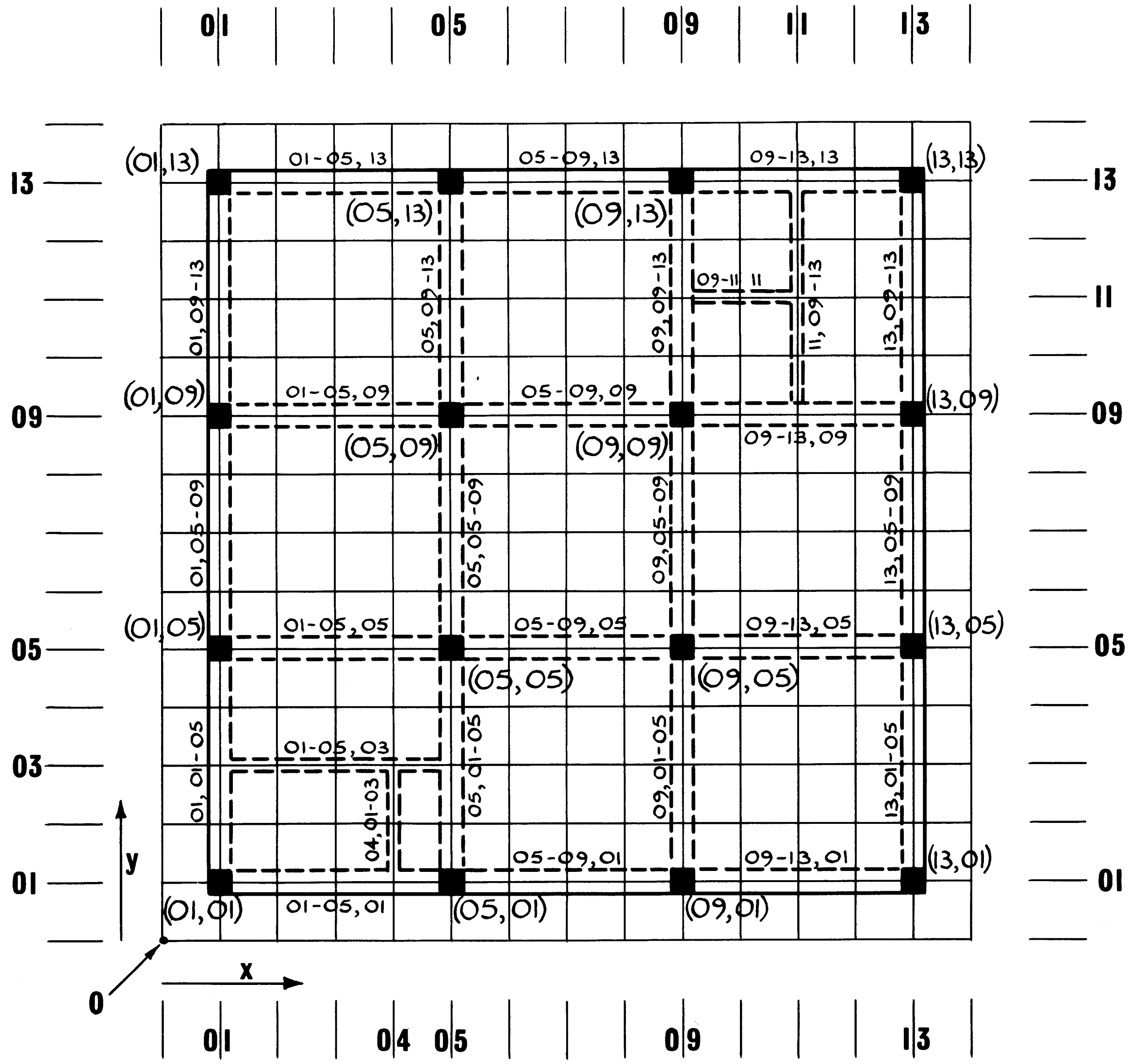
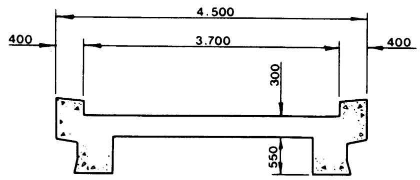
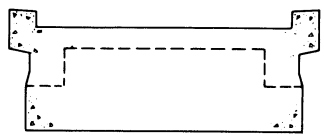


Figure 7.21 Grid referencing

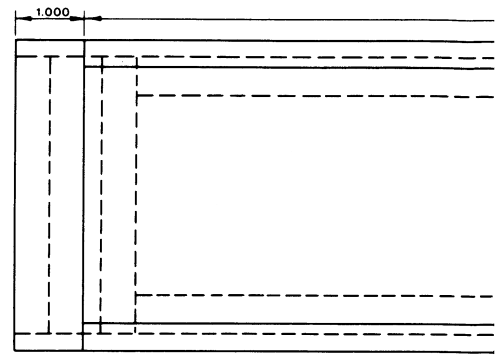
Three-dimensional coordinate system: The above grid referencing system is suggested in BS 1192. Any point on the plan, section or elevation can be identified and its position defined by its distance and appropriate coordinate x, y or z from the point of origin which is placed outside the area defined by the drawing.



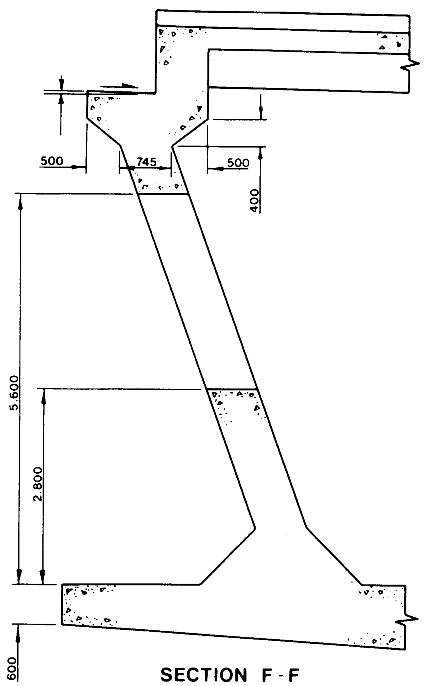
SECTION J-J



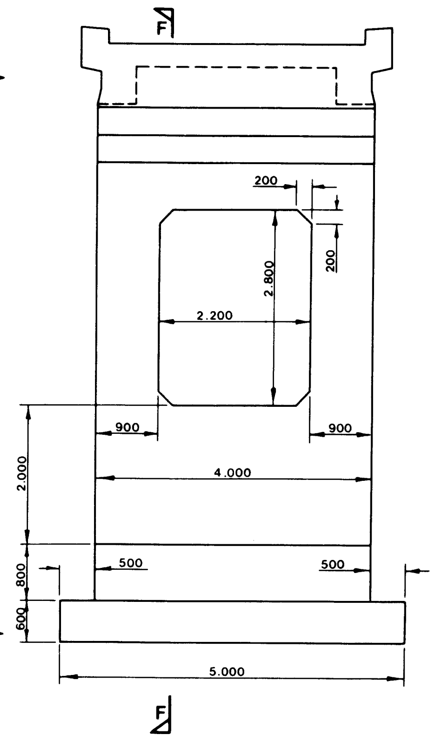
SECTION H-H



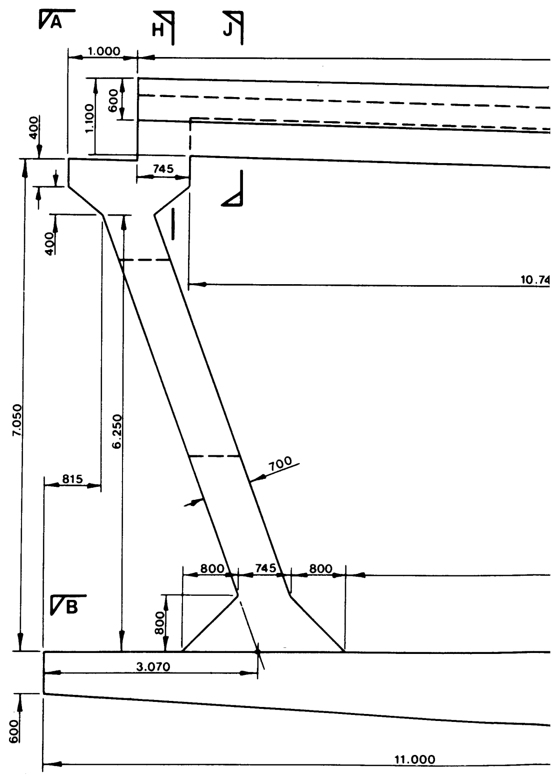
DECK



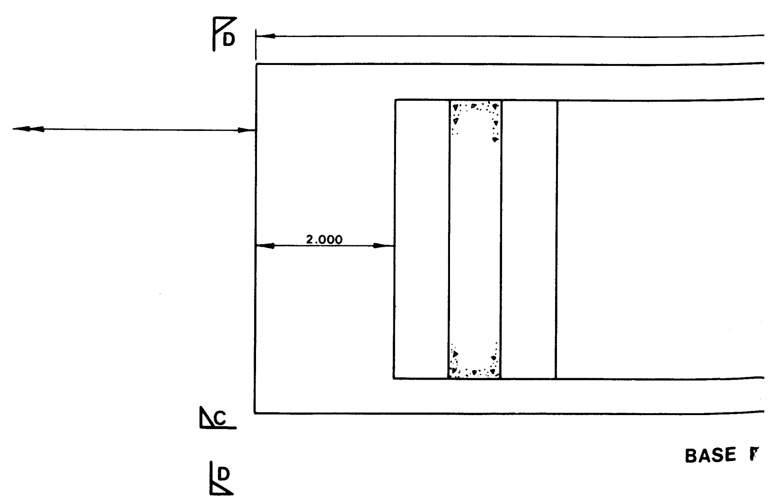
SECTION F-F



SOUTH COLUMN ELEVATION D-D



EAST E



BASE

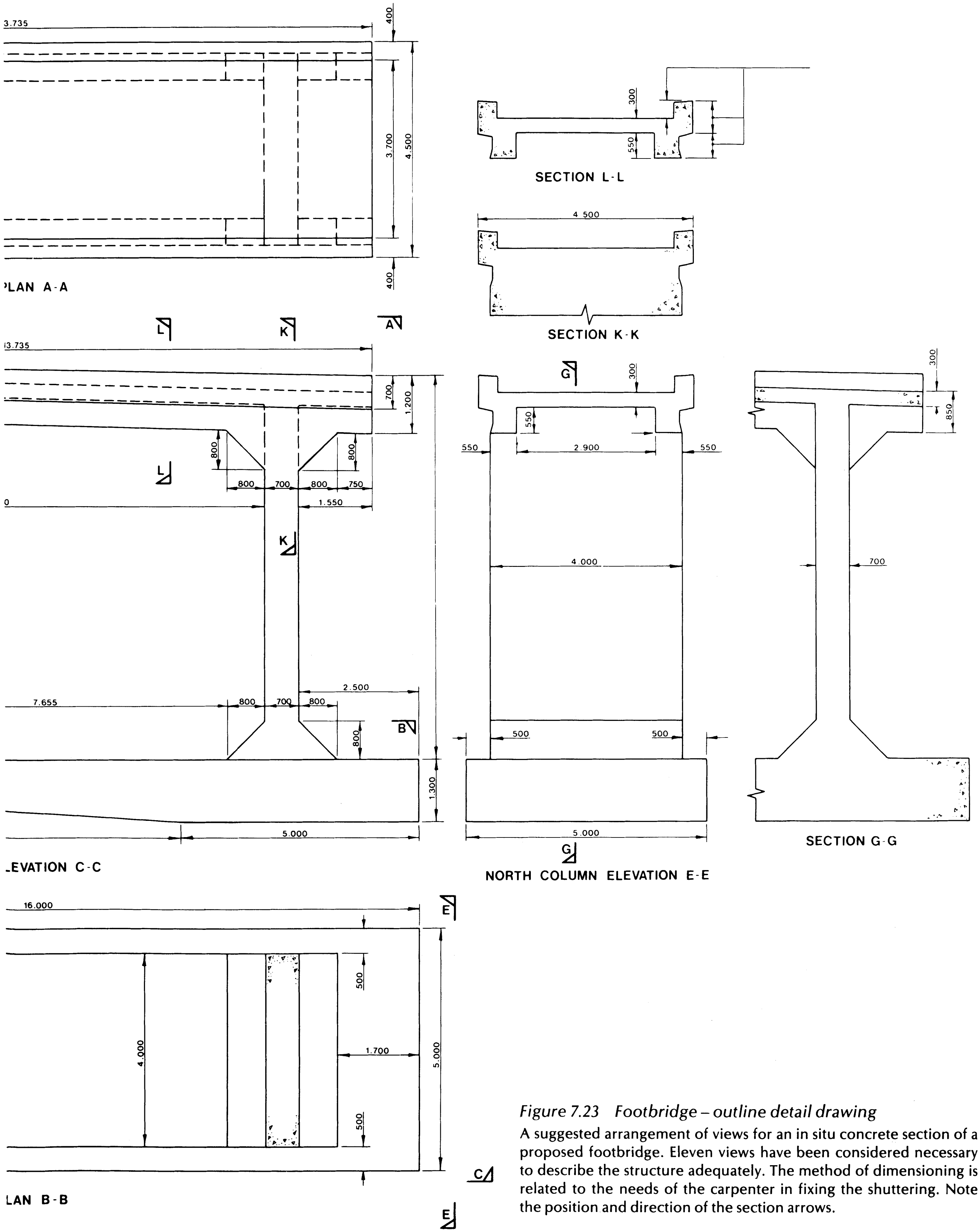


Figure 7.23 Footbridge – outline detail drawing

A suggested arrangement of views for an in situ concrete section of a proposed footbridge. Eleven views have been considered necessary to describe the structure adequately. The method of dimensioning is related to the needs of the carpenter in fixing the shuttering. Note the position and direction of the section arrows.

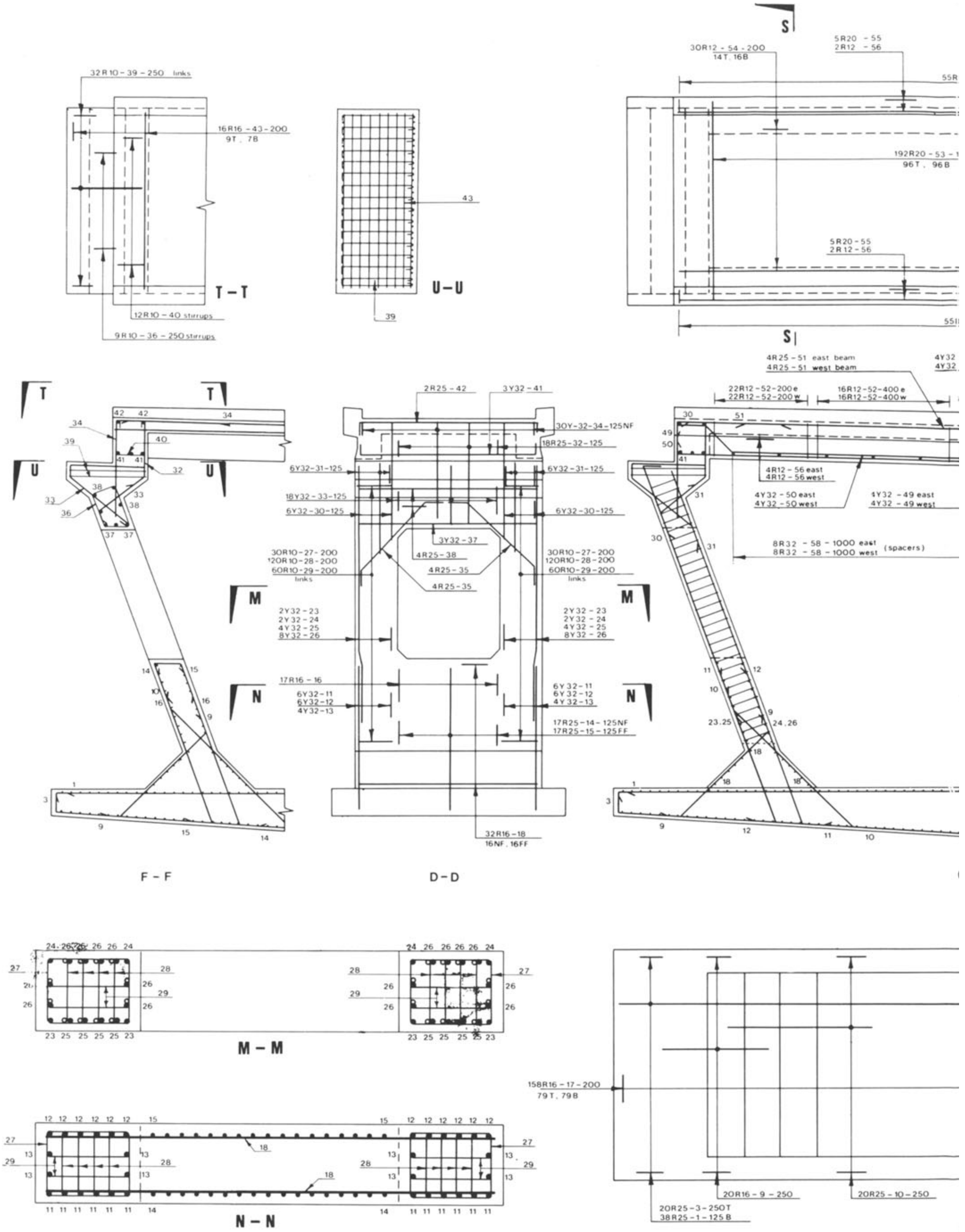


Figure 7.24 Footbridge – reinforcement detail drawing

Befo
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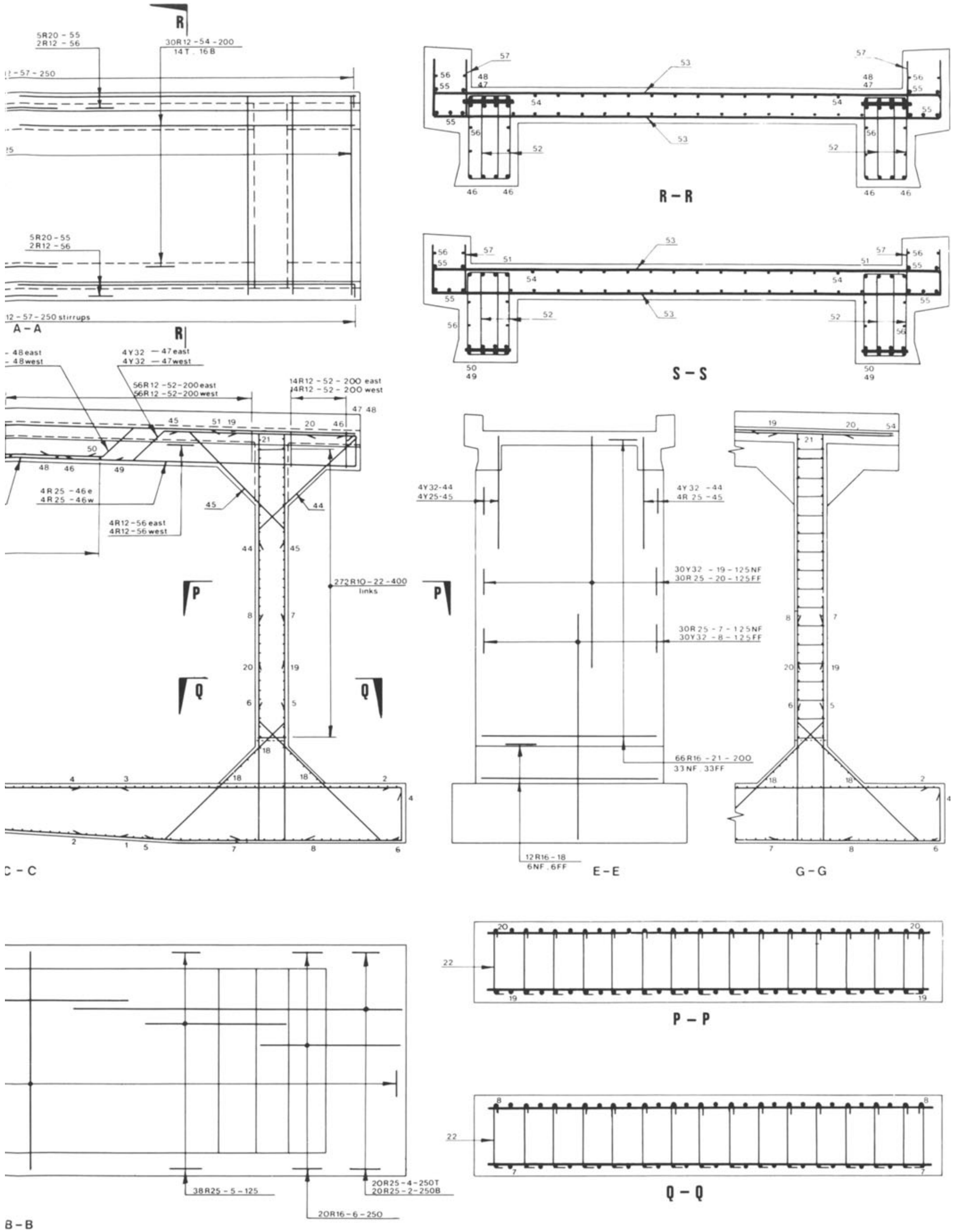
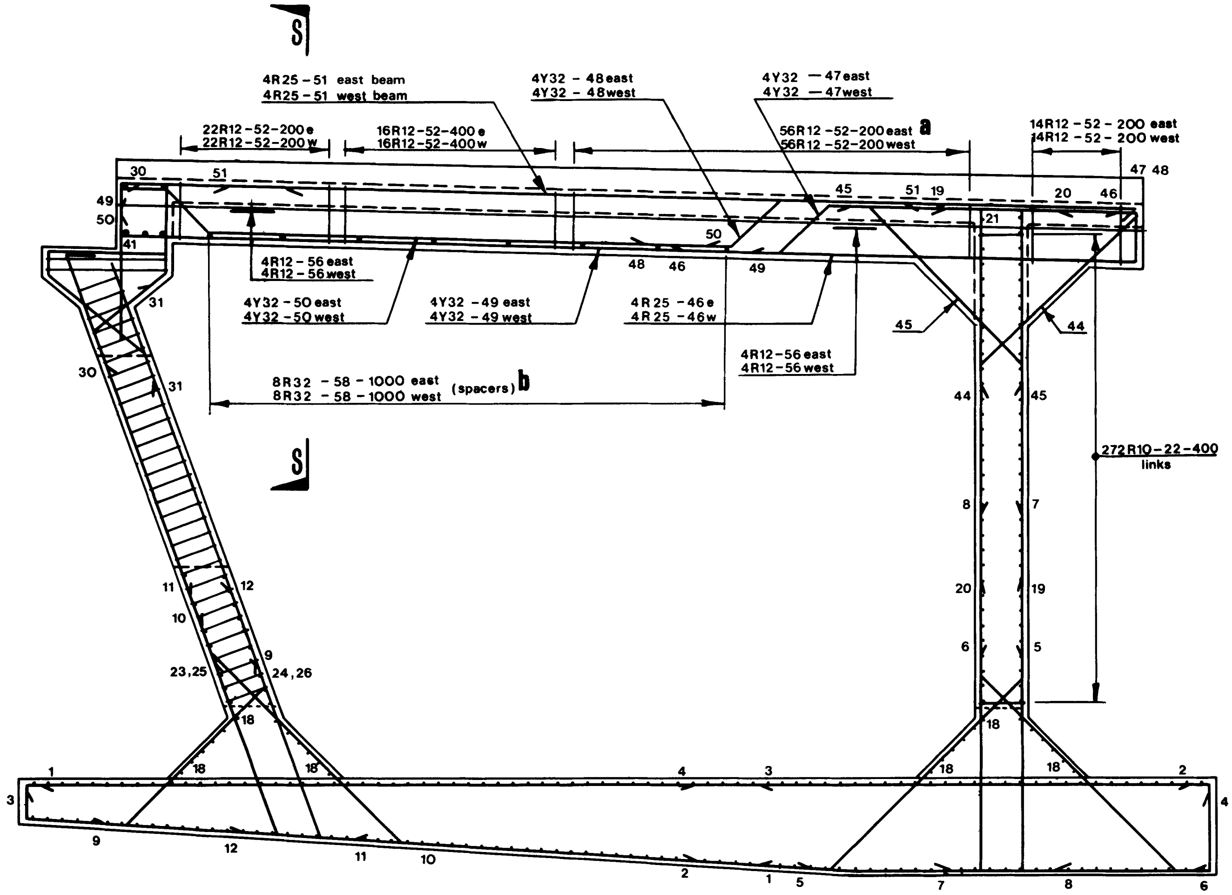


ıre the dimensions were added to the drawing shown in figure 7.23 a copy negative was obtained to form the basis of the reinforcement ıils. The views have been arranged close to each other to suit the book format. They would, of course, have to be spaced much wider apart on ull-sized drawing. Drawn to a scale of 1:50 they can be well arranged on an A0-sized sheet.



C - C

Figure 7.25 North foundation reinforcement detail – elevation

The dimensions shown on a reinforcement detail are related to the needs of the steelfixer, hence the cover to the main bars and other dimensions clearly showing how the bars are situated in relation to the shuttering must be indicated (omitted from this diagram for clarity).

Note that projection lines and arrowheads have not been used to mark the end of bars and the reader can perhaps decide for himself whether they are necessary. (Compare with figure 7.34.)

a In this drawing the bars have been completely called up for both beams. Usually the bars in identical beams are called up completely for one beam and the number of beams are stated. For example '8 beams thus:'. Also where more than one stirrup or link are grouped together at the same centres then the number of bars in the group should be stated. For example 56 R12–52–200 'in pairs'. See figure 7.29 for bars marked 52.

b See figure 7.16.

There are preferred basic shapes for reinforcing bars, each of which is given a shape code in BS 4466 to facilitate the use of computers for scheduling.

Before starting the details, it is important to bear in mind the following points.

(1) Consider the people whose interpretation of the drawings is most likely to influence the successful completion of the structure. A complicated and impressive-looking drawing is of little use if it cannot be understood by the steelfixer. The engineer cannot be on hand to supervise the placing of every bar.

(2) Remember that reinforcement drawings always receive rough handling on site.

(3) Appreciate that considerable time can be wasted if the required bars are difficult to find. Hence all like bars should be bundled together and uniquely referenced. If there are several structures on the same site then this should be indicated in the reference.

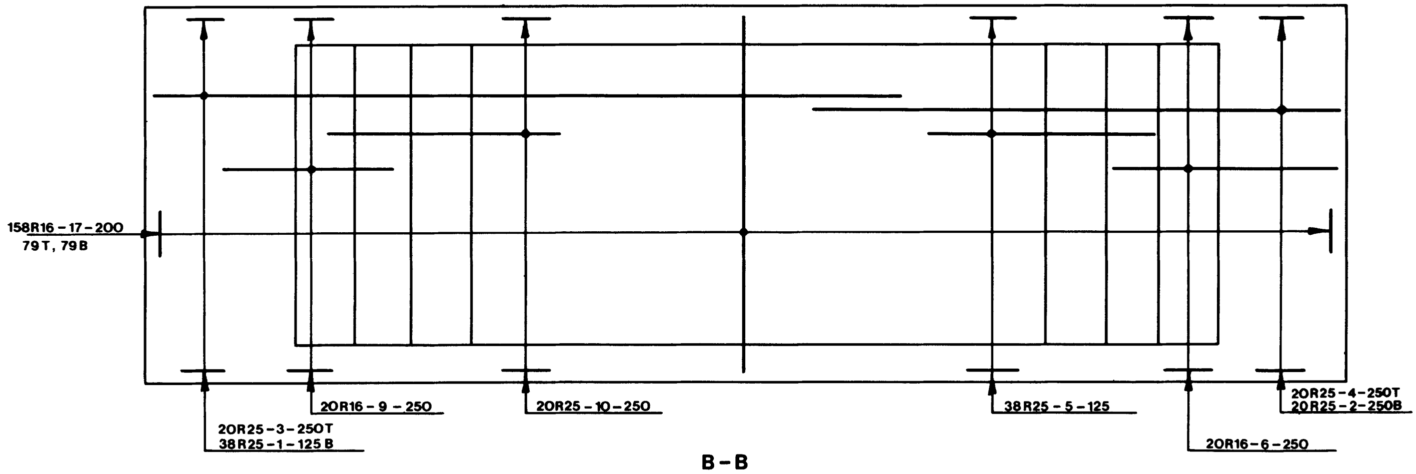
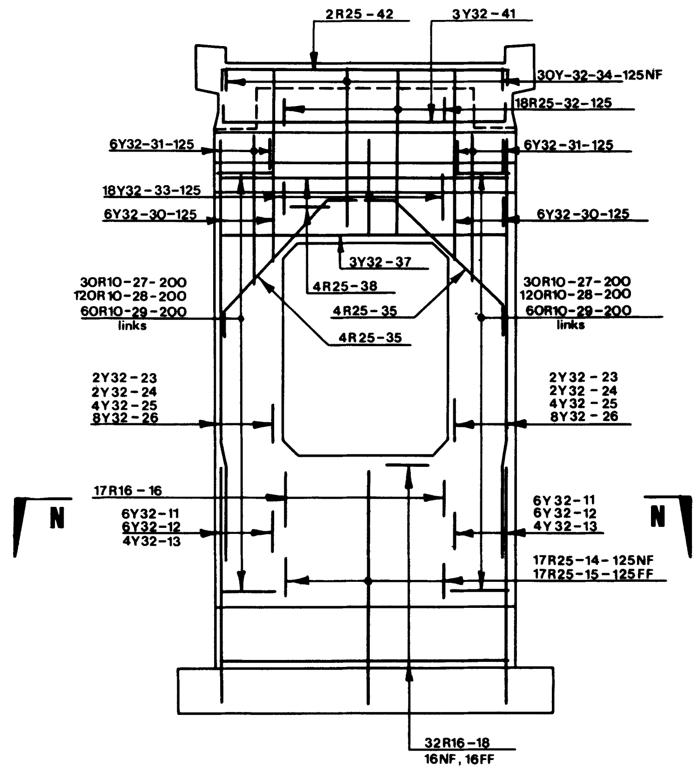


Figure 7.26 Base slab reinforcement detail

Figure 7.27 Column reinforcement detail – front elevation



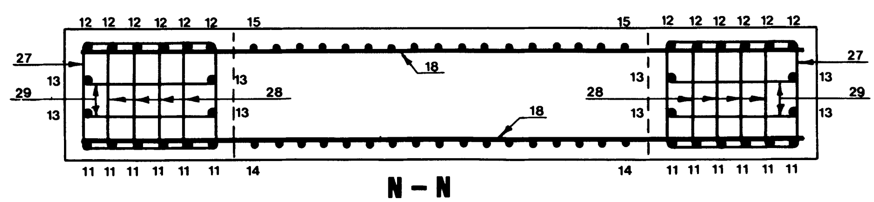


Figure 7.28 Section showing column reinforcement

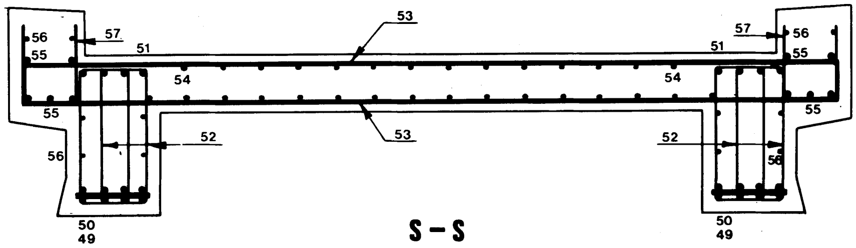


Figure 7.29 Section showing deck slab reinforcement

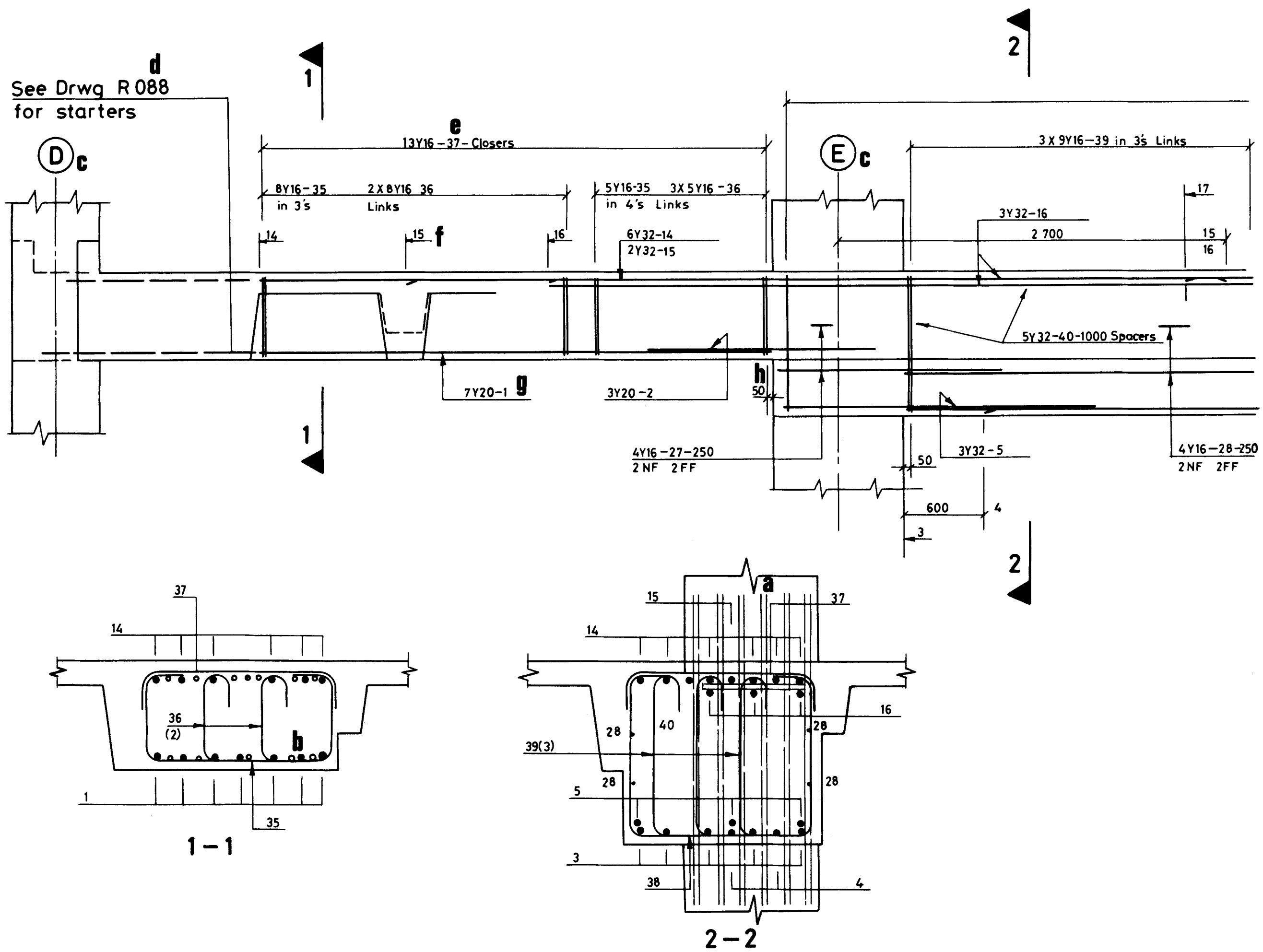


Figure 7.30 Beam reinforcement detail

a Long broken lines represent the main column reinforcement to indicate that they do not conflict with the beam reinforcement.

b The bars represented by the open circles are shown on a separate drawing. Note the simple leader lines which have been used to avoid the need to show the same bar mark against several bars. (Compare with figure 7.28.)

c Grid reference on the general arrangement drawing.

d Reference to another drawing for further details.

e and **g** Bars fully called up on the elevation.

f Representing the end of a bar.

h Bar location dimensions. The cover to the bars will also be given, either in the general notes if it is constant, or in specific notes if it varies in different parts of the structure.

INTERMEDIATE COLUMN FOUNDATION

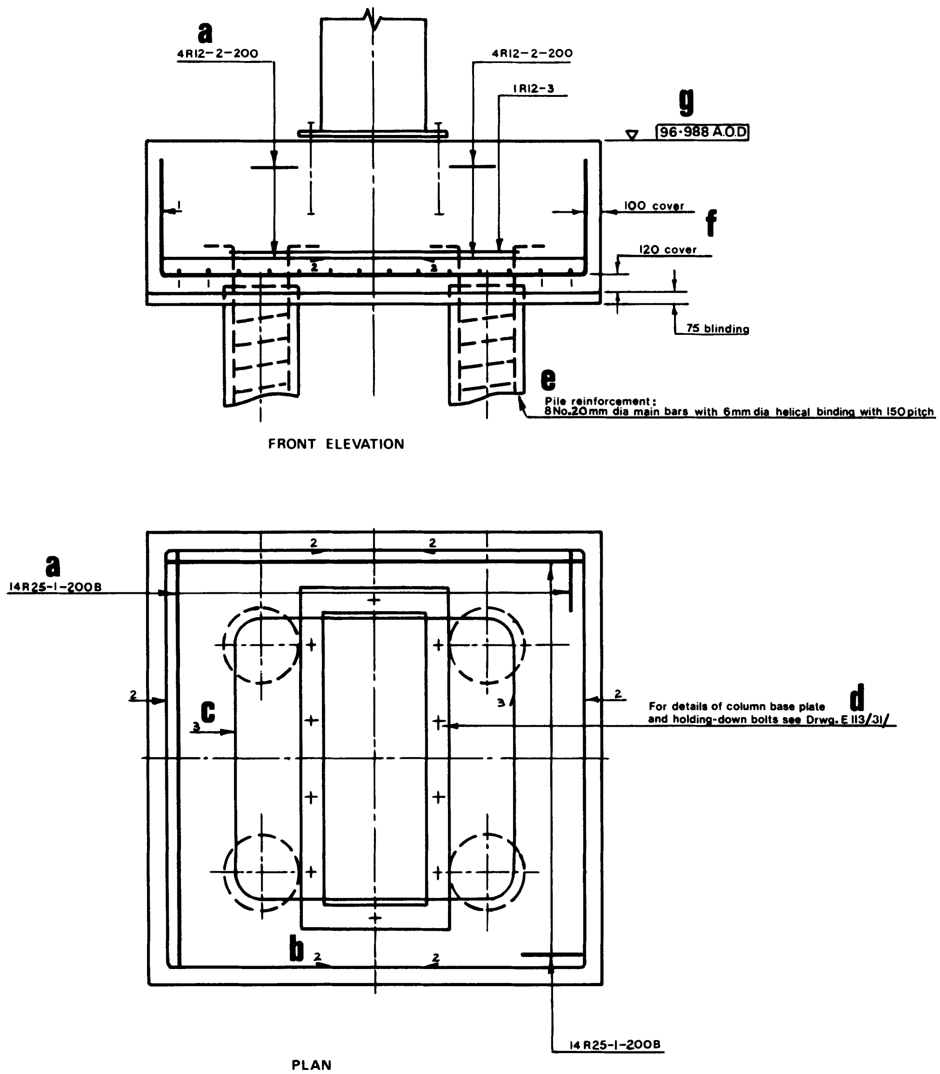


Figure 7.31 Bridge foundation – pile cap reinforcement detail

a Each group of bars completely called up once only.

b Ends of bars indicated by the bar mark and a short upturned line which also indicates the direction from which the bar has come.

c Bar marks shown on all views.

d Reference to related drawings.

e Bars from other structural parts indicated by broken lines. Bars are left protruding from the piles, to tie in with the pile cap reinforcement.

f Cover and any other dimensions required to locate the reinforcement must be shown.

g Method of representing levels on sections. Generally it is better to relate levels to Ordnance datum rather than an arbitrary datum. If an arbitrary datum is used this should be chosen such that all levels are positive.

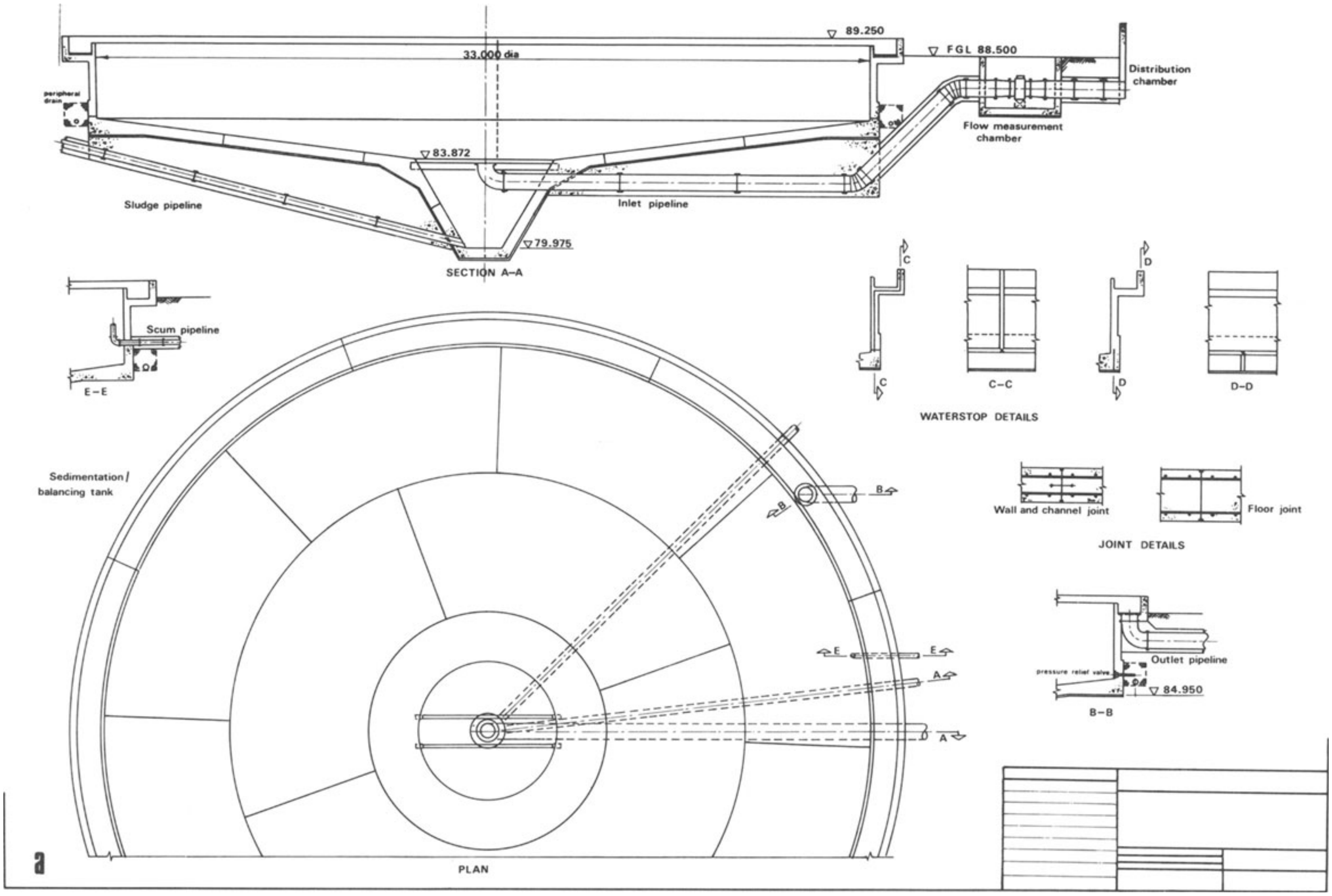


Figure 7.32 Sedimentation tank – arrangement of views

Although they do not include all the details given on the full-sized drawing, figures 7.32 and 7.33 illustrate how views can be arranged clearly and economically in such a way as to enable all the details to be shown. For example, it has not been considered necessary to show the complete plans in order to detail the floor and hopper reinforcement.

(4) Give careful consideration to the stacking of bars for the convenience of the steelfixers and to save unnecessary handling.

Figures 7.23 to 7.34 include many of the recommendations contained in the Standard Method. Although only two bars in any set of like bars should be shown on a particular detail, it is advisable to draw all the bars to scale on a part of the very first detail drawn, before showing them in the correct convention on the finished drawing. This will immediately highlight any areas of congestion or incorrect location of the bars. Having drawn the bars to scale, one may, for example, find that they cannot be positioned in accordance with the structural design requirements, or that the bars are too close together to permit the concrete to be vibrated properly.

The preferred sizes for reinforcing bars are 8, 10, 12, 16, 20, 25, 32 and 40 mm diameter. There are three types of steel used, which have the following reference abbreviations

- R Mild steel bars in the metric range of areas; BS 4449
- Y High-yield high-bond strength bars in the metric round range of areas; BS 449 and BS 4461
- X A general abbreviation for types not covered by R or Y; an explanation of the meaning of X is required in

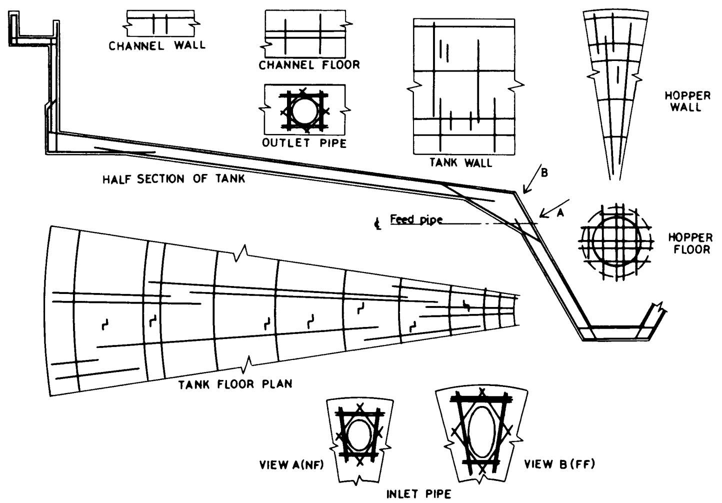


Figure 7.33 Sedimentation tank – plan and sections

(Key to Figure 7.34)

a Each group of bars has been called up completely once only.

b Bars around the tank have been made short enough to facilitate transport and are lapped. The contractor may find it easier to place the curved bars on top of the radial bars. Because most tanks of this type are designed to withstand flotation, the base thickness and the lever arms are larger than would be necessary for structural reasons. Note the absence of shear reinforcement. In order to minimise cracking in liquid-retaining structures, bars tend to be at closer spacings, the cover to the reinforcement greater and members thicker than in other similar reinforced concrete structures.

c Bar mark indicates end of bar, and the short inclined line and the arrow show from which direction the bar has come.

d These bars with the same mark in the top and bottom of the slab are likely to be placed at the same time. Bars that are the same and yet will be placed at different times and in different structures or parts of a structure, should be given different bar marks.

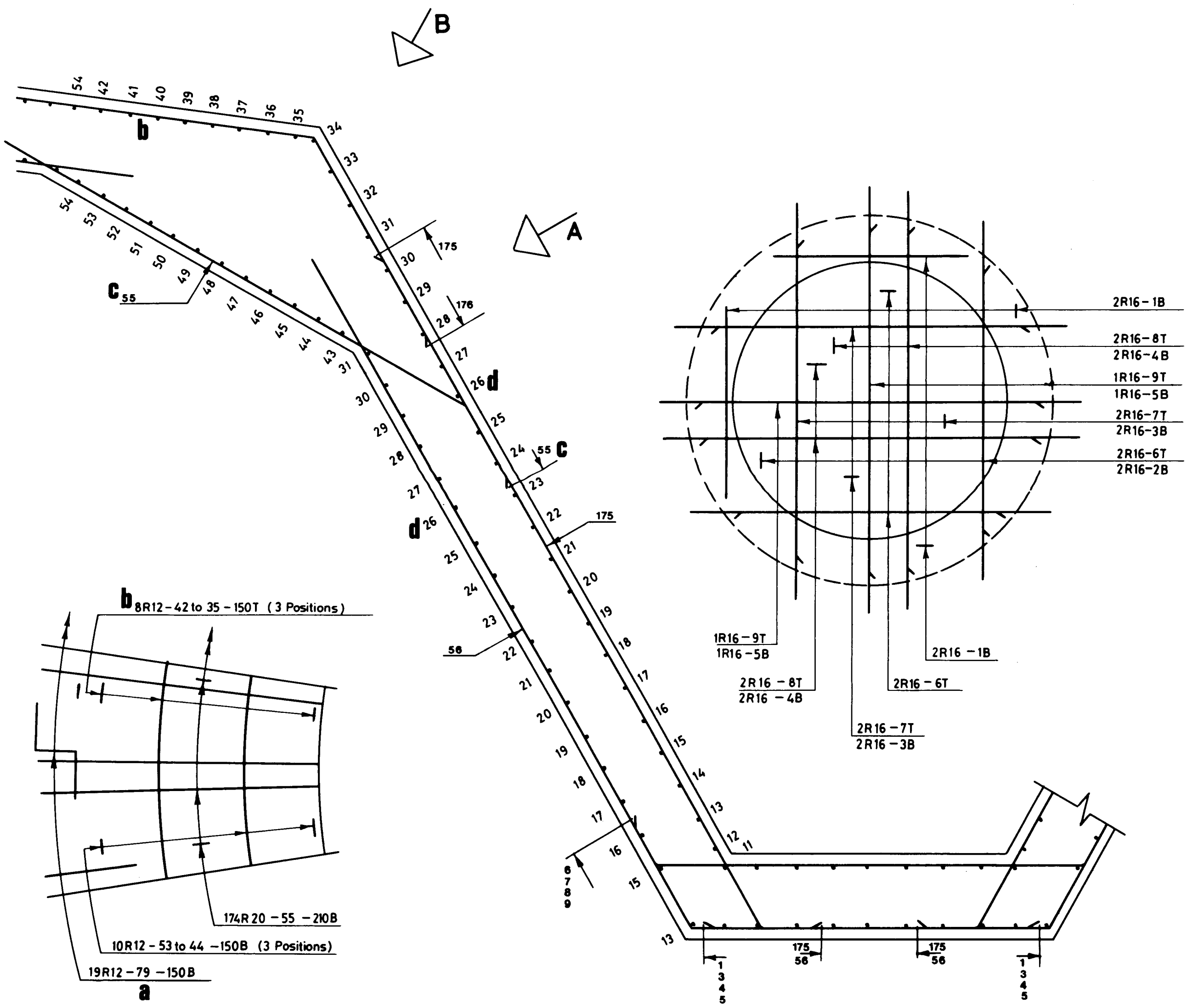


Figure 7.34 Sedimentation tank – hopper reinforcement detail

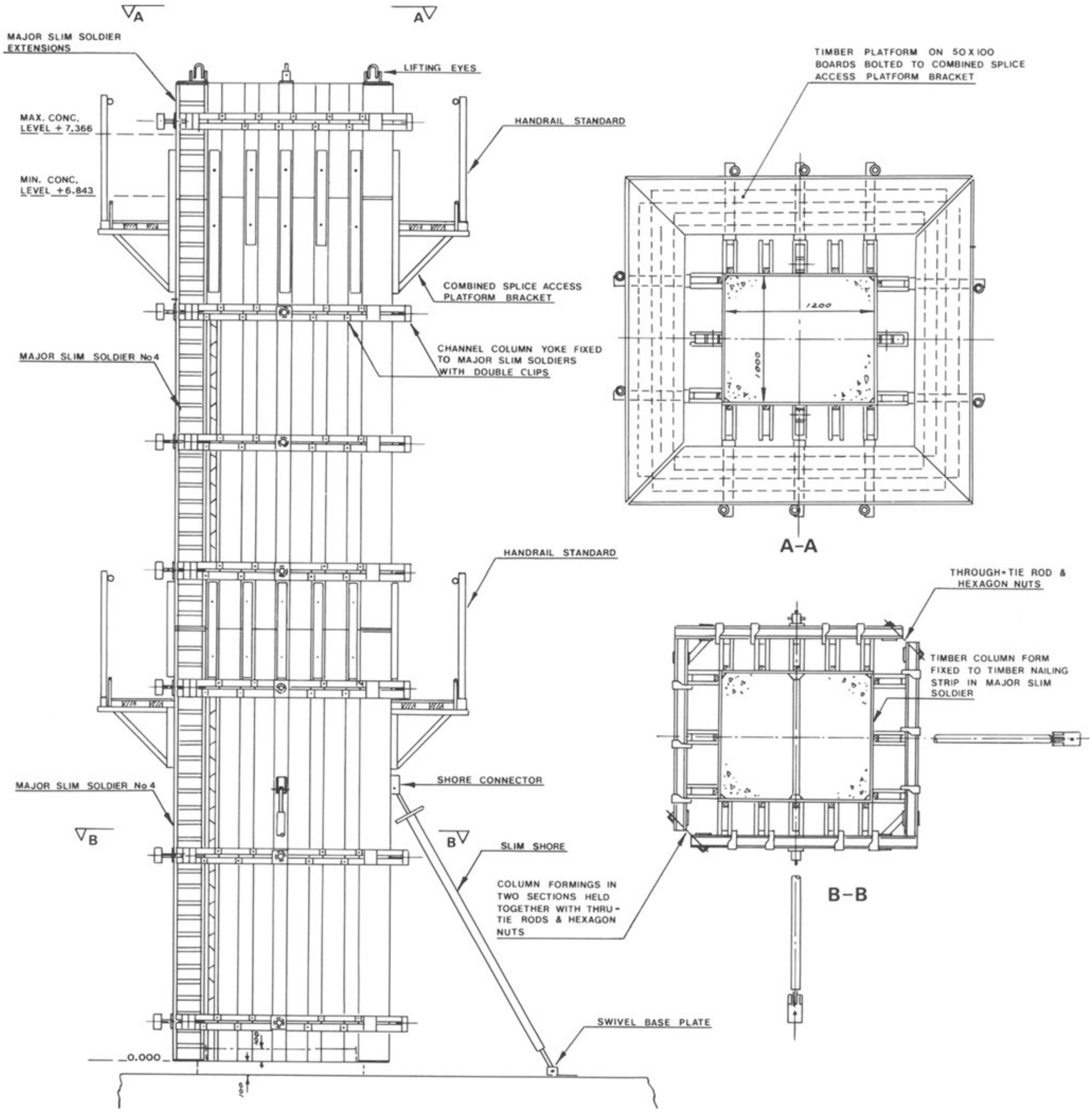


Figure 7.35 High column shuttering

the specification and also on the drawings and schedules.

The full references of the bars shown on the reinforcement drawing indicate the number of like bars in the group, the type of steel, the size of the bars, the sequential bar mark, the spacing of the bars and the position of the bars in the structural member. For example bar reference 20R12–5–150T means: 20 mild steel round bars of 12 mm diameter, with a bar mark 5, spaced 150 mm apart and situated in the top face of the member.

Full references are shown once only on

(1) the plan, in the case of foundations and slabs (except that with stairs full referencing is better shown on the section);
(2) an elevation, in the case of beams, walls and columns.

On the other views, including the sections, the bars are referenced by means of the bar mark only. On sections, only the bars cut by the section should be shown.

Bars should be referenced in sequence and approximately in the order that they are likely to be placed in the structure. On small jobs it may be convenient to start at bar mark 1 and carry on through the whole job in consecutive sequence. On large jobs the referencing on each drawing should start at bar mark 1, in which case different bars with the same bar mark are distinguished on site, and on the bar schedule, by the schedule reference and bar mark combined. Each page of the bar schedule has a unique reference which has the drawing number and sequential page number coded into it. The labels on the bundles of bars delivered to the site contain the bar mark and the schedule reference. Hence the steelfixer knows

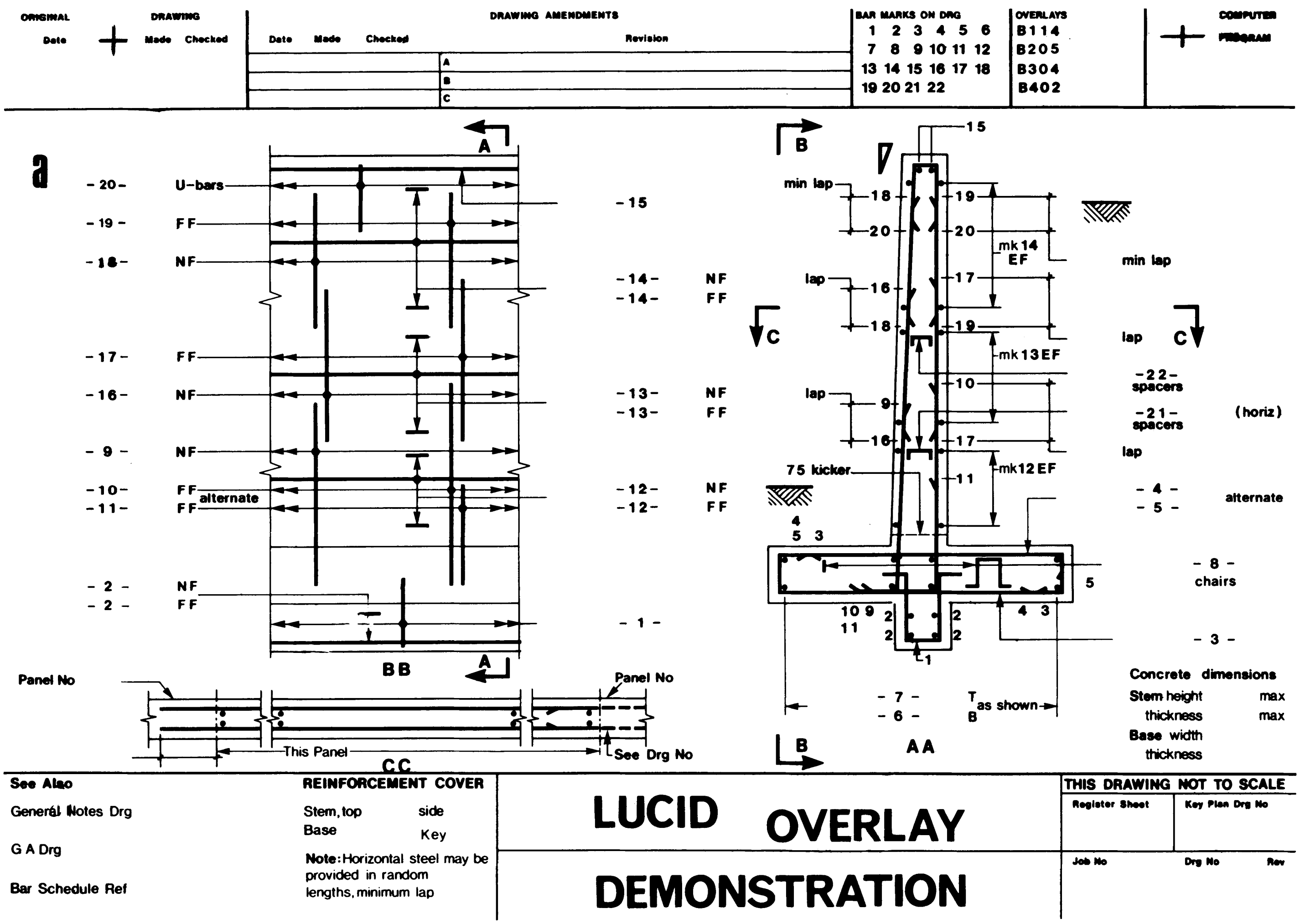


Figure 7.36a Standard details – retaining wall

from this the relevant bar schedule sheet and drawing number.

There are several potential constructional problems associated with reinforced concrete which can be eliminated or minimised by careful detailing.

(1) The reinforcing cages (interconnected arrangements of bars) must be strong and stiff enough to withstand the self-weight of the bars and the forces imposed by the wet concrete and vibrators. The possibility that the contractor may wish to fabricate the cage away from the member and then lift it into position should be considered. This involves ample provision of links, stirrups, chairs and other spacer bars, and distribution steel.

(2) The possibility of interference between the bars of adjoining members in the same structure must be taken into account. Large-scale details may be required where adjoining members intersect in order to ensure that this does not occur.

(3) If the main reinforcement is horizontal, the vertical reinforcement should be checked to ensure that it is strong and stiff enough to support the horizontal bars at all stages of construction.

(4) Due allowance must be made for holes in the member and the use of trimming bars.

(5) The possible sequence and placing of shuttering panels should be considered. A short section of a wall, called a kicker, should be cast with its foundation to facilitate the

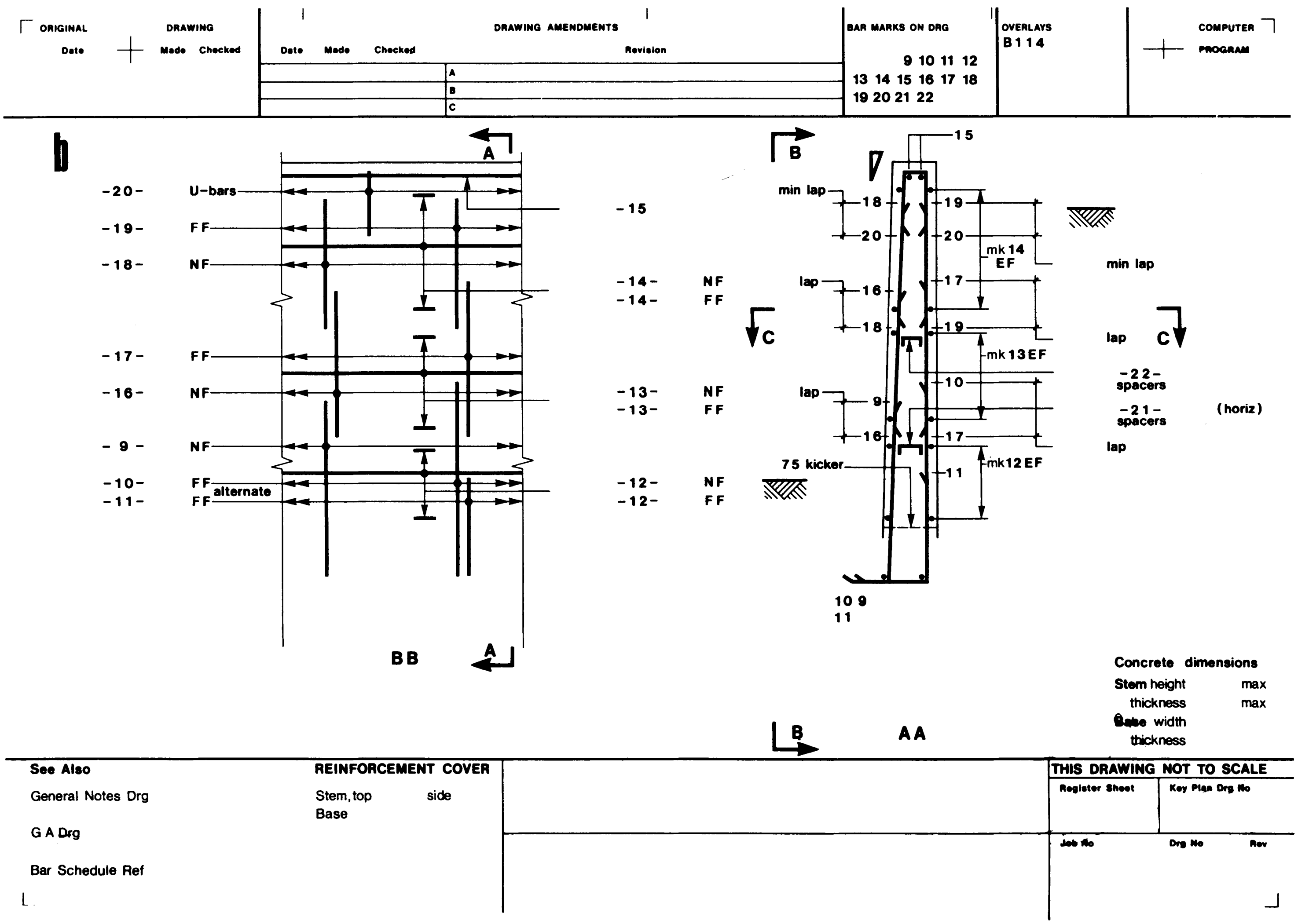


Figure 7.36b Standard details – retaining wall

fixing of the wall shuttering. Bars must protrude far enough above the kicker for the vertical wall bars to lap on to them.

(6) The over-all dimensions of the bars must be limited in order to facilitate transport to the site.

(7) Cantilevers pose particular problems and special precautions are necessary to ensure that bars are maintained in their correct position during concreting.

Abbreviations

(a) General

reinforced concrete	RC
brickwork	bwk
drawing	drg
full size	FS
not to scale	NTS
finished floor level	FFL
structural floor level	SFL
existing level	EL
horizontal	hor
vertical	vert
diameter	dia

(b) Relating to reinforcement

each way	EW
each face	EF
far face	FF
near face	NF
bottom	B
top	T

Line thicknesses

Outlines on general arrangement and detail drawings	0.6 mm or 0.4 mm
Outlines on reinforcement drawings	0.4 mm

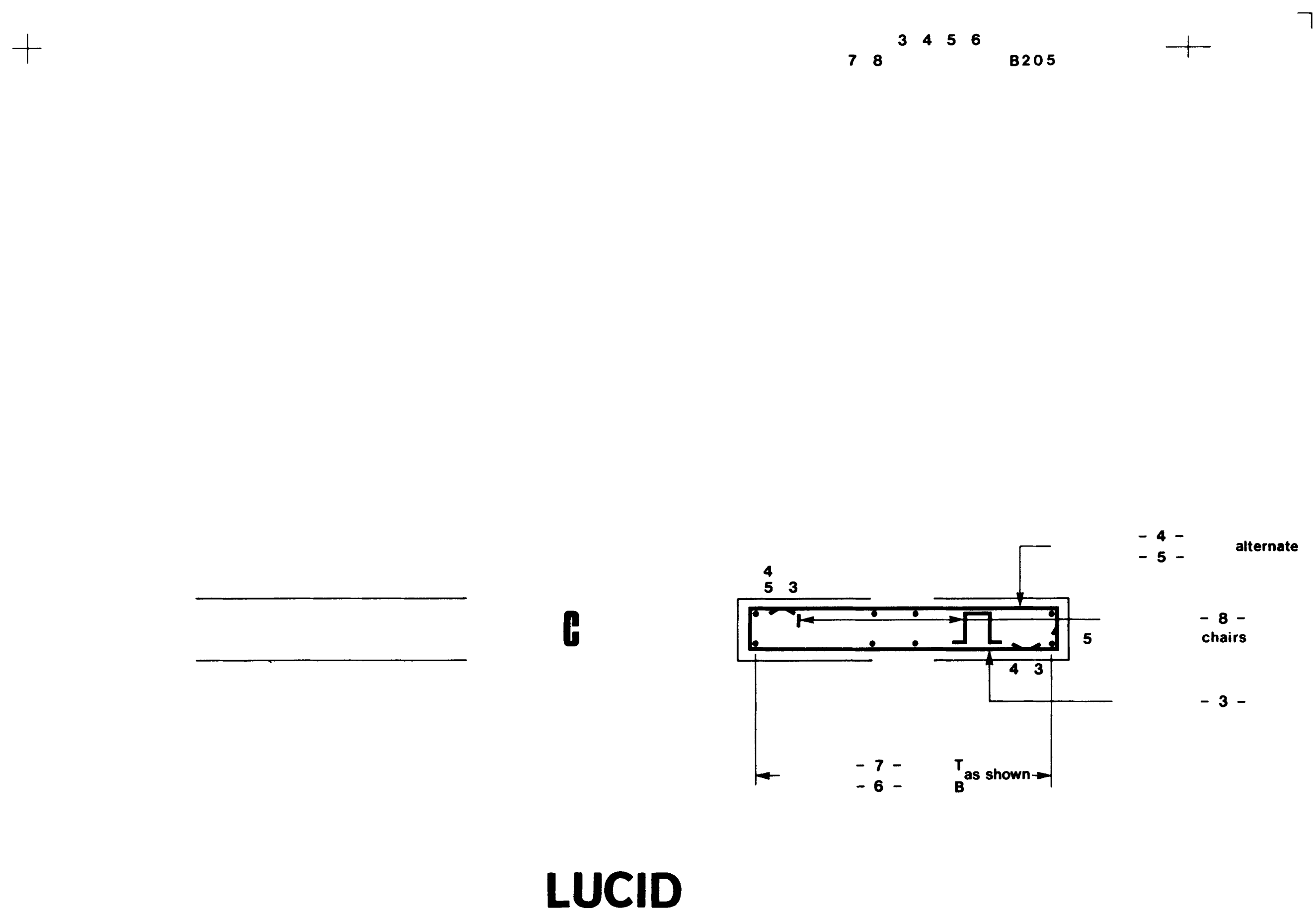


Figure 7.36c Standard details – retaining wall

Main reinforcing bar	0.6 mm
Links and stirrups	0.4 mm
Dimension lines and centre lines	0.2 mm

Cross-sections of bars should be drawn approximately to scale.

7.4.2 Standard Detailing

The reader will by now have a good appreciation of the high costs and the large number of drawings that can be involved in the general detailing of reinforced concrete in particular. It is with these factors in mind that staff at Loughborough University of Technology, in conjunction with 100 firms within the civil engineering industry, have been developing detailing aids which will both save time and present details in a form that can facilitate the adoption of more standardised automated procedures. The first essential step was to develop a standardised format for representing reinforcement details. One method has been proposed and the participating members of the research group have been involved in producing and checking details of typical structural elements in a standardised form, together with the instructions concerning their use. One of the problems associated with standard details is that a complete range of permutations must be covered for each element (member). A standard detail in the context of this research has been defined as 'a representation of part of a structure in which the general pattern of the bars is preconceived.' The spacings, covers, fixing dimensions, sizes, numbers and types of bars and the over-all concrete dimensions, are entirely at the discretion of the designer.

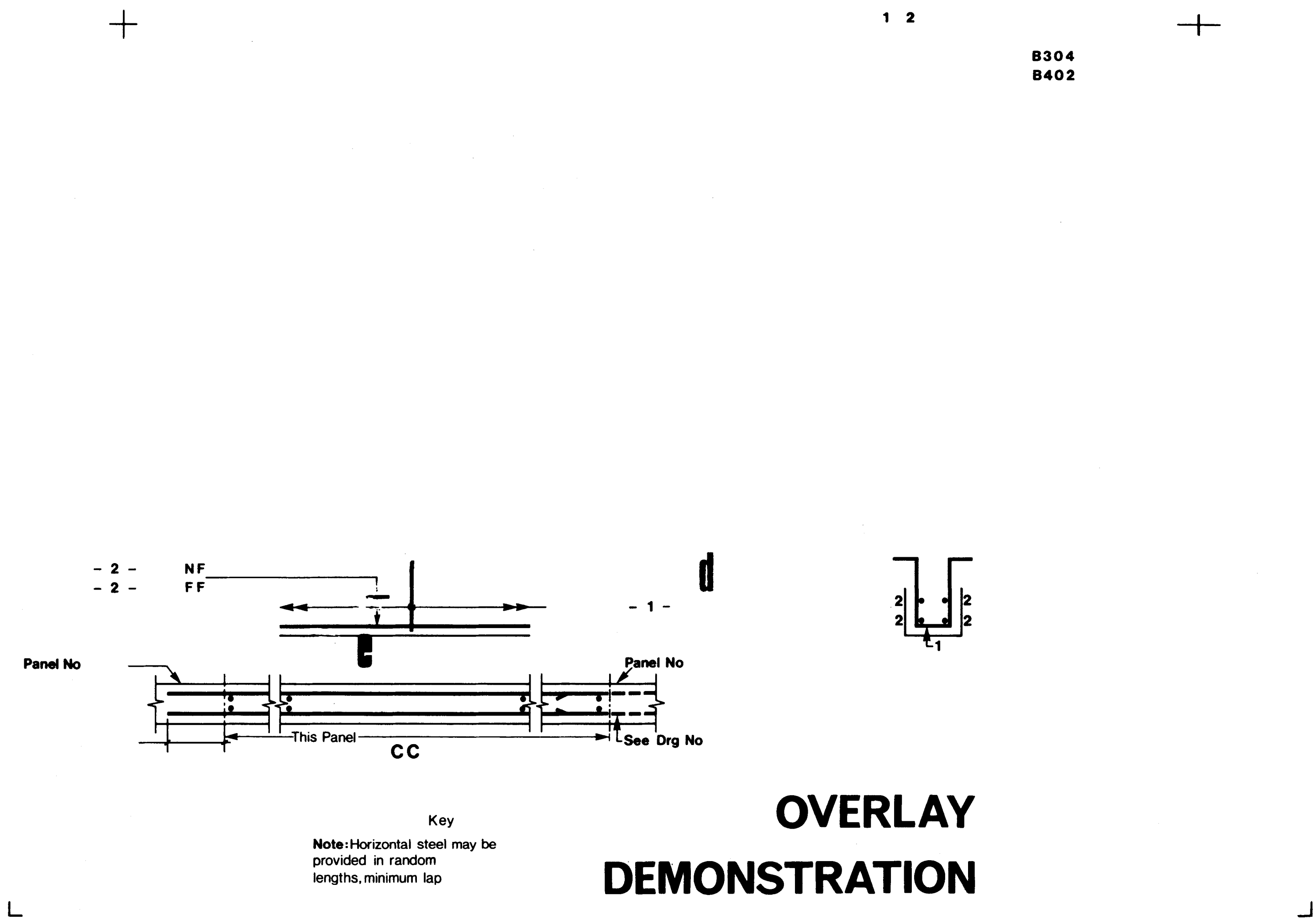


Figure 7.36d,e Standard details – retaining wall

'Standard' does not mean 'one only', and every detailing system offers many alternative standard details for each element.

An example of the method of representing the details for a typical structural element is illustrated in figure 7.36a. The complete detail, in this case a free-standing cantilever retaining wall, is built up with a series of transparent foil overlays, each of which is specifically referenced and shows the details of different parts of the element, as in figures 7.36b to e. The parts in the example are the stem, base and downstand, which can be permutated in a variety of ways depending on the height of the stem and its position in relation to the base, the position of the downstand if required, and the basic arrangement of the reinforcement. There are 20 possible stem

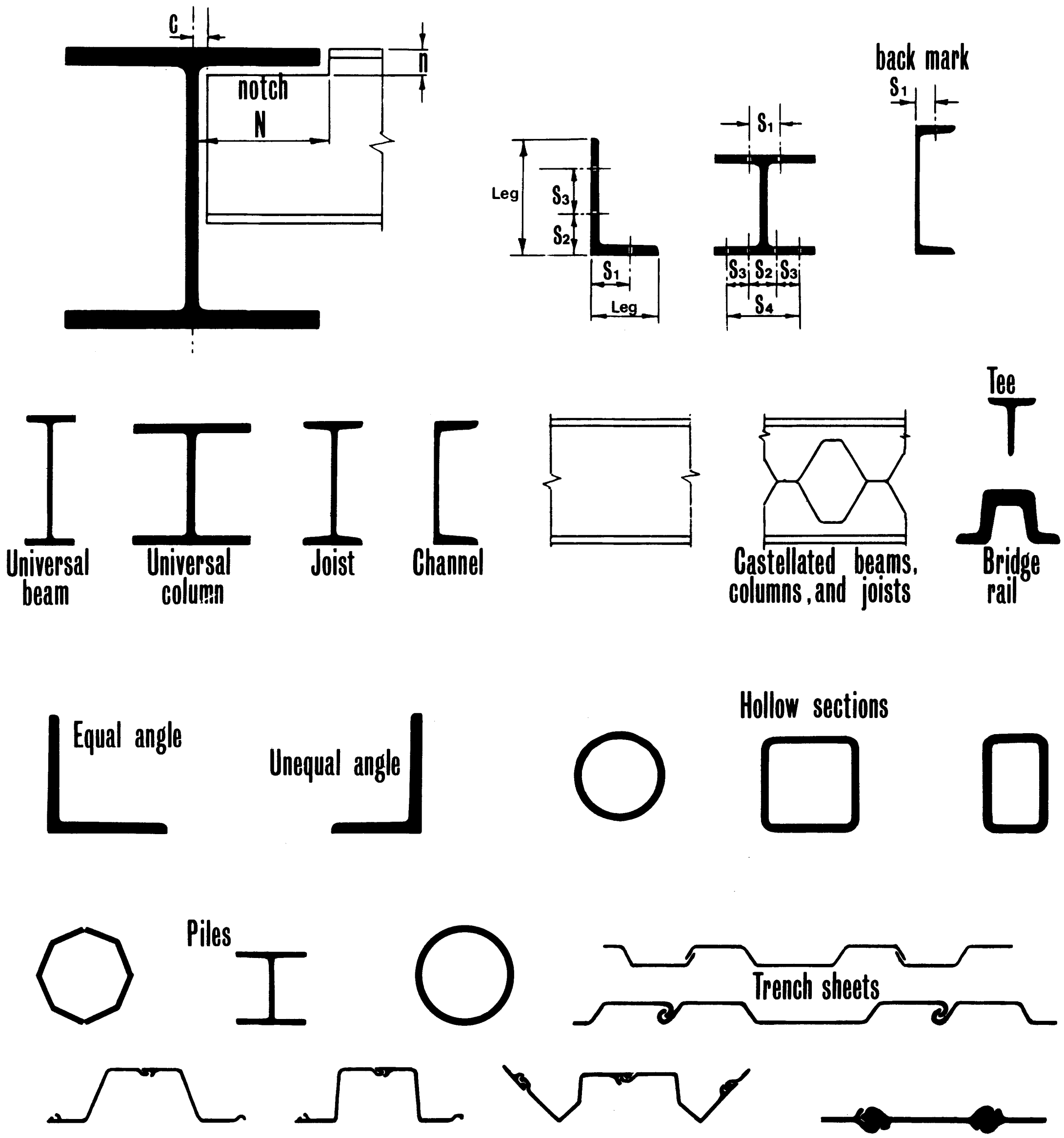


Figure 7.37 Structural steelwork sections
The properties of beams, columns, joists, channels, angles, hollow sections, bridge rails, bolts and welds are given in *Metric Practice for Structural Steelwork*.

overlays, 6 base overlays, 9 overlays concerning the wall longitudinal reinforcement and 2 overlays concerning notes on the drawing. The potential of this method of detailing can be appreciated when it is realised that a maximum of only 4 overlays is required for any single complete detail, and that $20 \times 6 \times 9 \times 2 = 2160$ permutations are possible using $20 + 6 + 9 + 2 = 37$ overlays.

7.4.3 Structural Steelwork Detailing

A guide to basic structural steelwork design and detailing, plus comprehensive information on the properties of steel sections, is contained in *Metric Practice for Structural Steelwork* published by the British Constructional Steelwork Association. This manual includes tables giving the properties of columns, beams, tees, channels, angles, bridge rails, joists, hollow sections and round and square bars. Both solid and hollow sections, some of which are shown in figure 7.37, have a wide range of civil engineering applications including buildings, bridges, oil rigs, pipelines, coffer-dams, piles, trench supports, parapets and safety fences. The suitability of any structural steelwork member for a given application will depend on such properties as its section modulus, radius of gyration, area and moment of inertia, its weight, and the strength of the member in bending, axial compression, axial tension, shear and bearing.

Commonly used symbols and abbreviations are as follows.

Joist	I	RSJ
Universal beam	I	UB

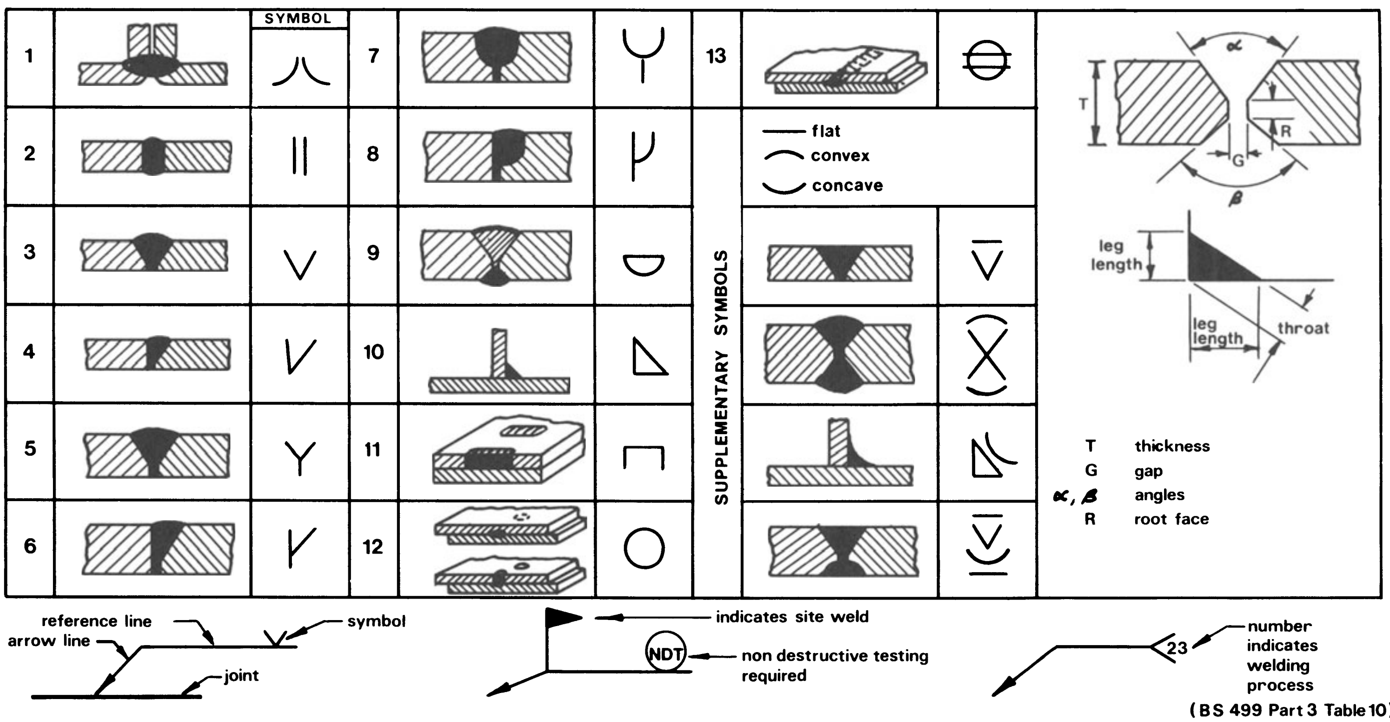


Figure 7.38 Welding symbols: BS 499: Part 2: 1980 (reproduced by permission of the British Standards Institution, 2 Park Street, London W1A 2BS, from whom complete copies may be obtained)

1 Butt weld between flanged plates (the flanges being melted down completely). Butt welds between flanged plates not completely penetrated are symbolised as square butt welds with the weld thickness shown.
2 Square butt weld. This symbol is used to indicate a stud weld when there is no end preparation and no fillet weld.
3 Single-V butt weld.
4 Single-bevel butt weld.
5 Single-V butt weld with broad root face.
6 Single-bevel butt weld with broad root face.
7 Single-U butt weld.
8 Single-J butt weld.
9 Backing or sealing run.
10 Fillet weld.
11 Plug weld (circular or elongated hole, completely filled).
12 Spot weld resistance welding (top diagram) and arc welding (bottom diagram) or projection weld.
13 Seam weld.

Note that symbol 12 has in the past been used to denote 'weld all round'.

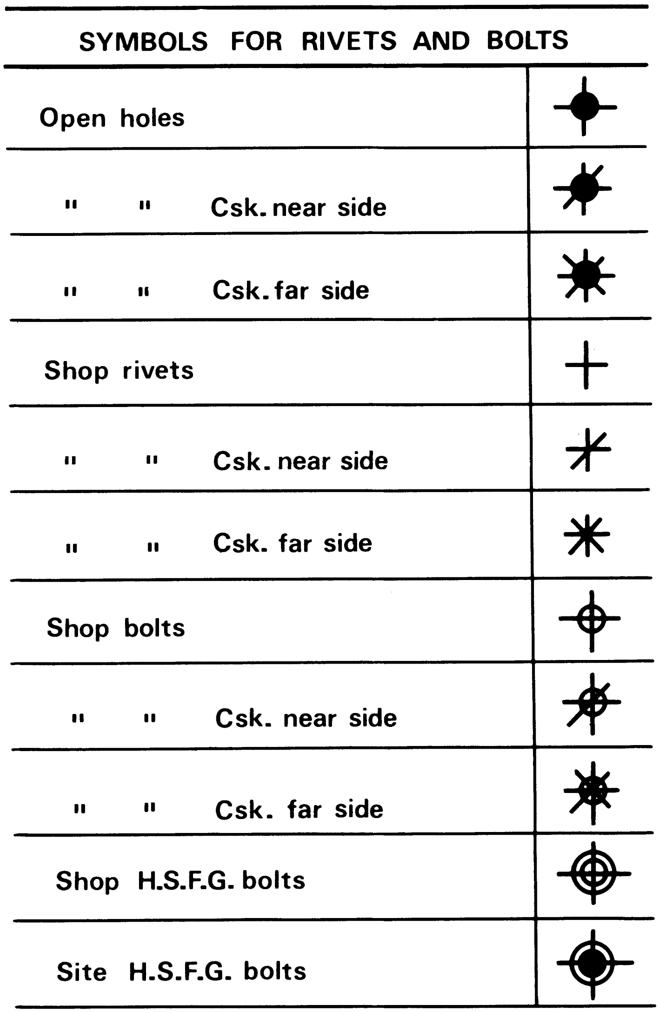


Figure 7.39 Symbols for rivets and bolts

Universal column	I	UC
Angle	∠	angle
Channel	[	channel
Tee	T	tee
Rectangular hollow section	□	RHS
Circular hollow section	o	CHS

The symbols can be arranged in various combinations to denote made-up sections.

Steel is commonly used for building frameworks. High-yield hollow sections, connected by special joints called 'nodus joints', are being increasingly used in space frames for the large-span roof systems of conference halls, theatres, swimming pools, churches, exhibition halls and similar buildings. Fabrication is relatively simple and welding is kept to a

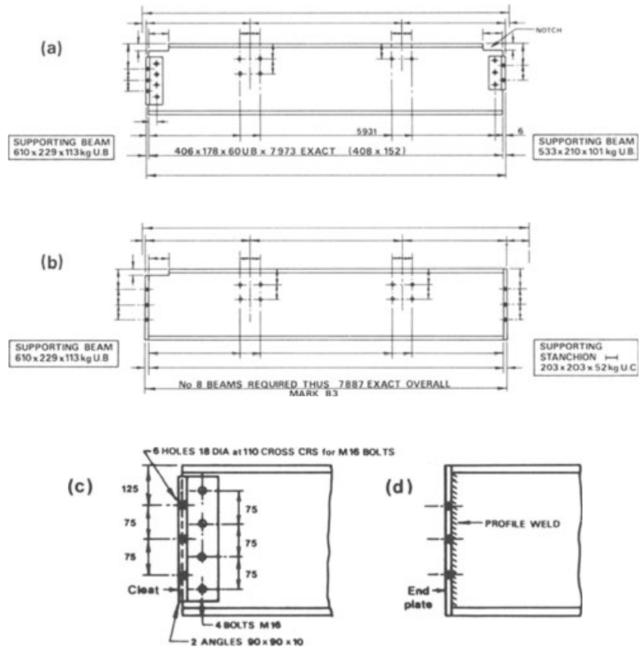


Figure 7.40 Typical beam details

minimum. Factors which need to be taken into account in the design of buildings include the choice and transport of materials, cost, fabrication and erection, painting, type of claddings and finishes, aesthetics, the likelihood of future extensions or change of use and fire protection.

As with reinforced concrete work, the design and detailing of structural steelwork must be such as to facilitate ease of fabrication and erection. The two most commonly used methods of joining structural members are by means of (1) welding and (2) bolting, using black bolts, high-tensile bolts, or high-strength friction grip bolts, the last being tightened to a pre-determined torque during fixing. Welding is usually limited to workshop fabrication. Joints can be welded on site but this operation could prove to be more expensive than bolting. There are standard conventions for representing welds and standard welding symbols, full details of which are contained in BS 499: Part 2: 1980 (see figure 7.38). The symbols used on drawings for rivets and bolts are shown in figure 7.39.

The recommended units of measurement are millimetres for dimensions, centimetres for section properties, kilograms for mass and newtons for force. The method of dimensioning and tolerances are important factors in eliminating errors in fabrication and erection of steel members.

There are standard recommended sizes for notches at beam to beam connections (related to member sizes), as well as recommended back marks and spacings between holes for

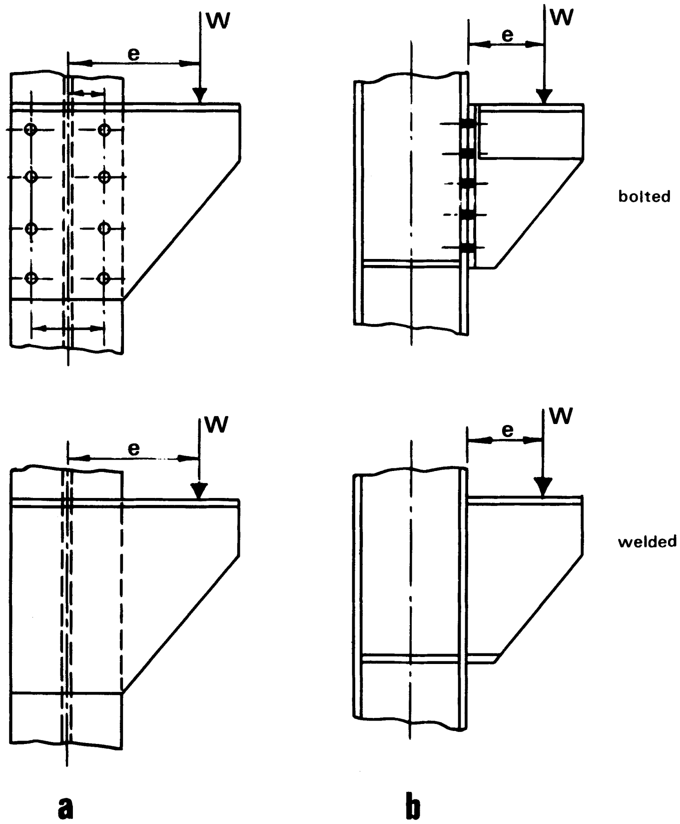


Figure 7.41 Brackets with eccentric loading

fasteners. Back marks do not have to be stated on detail drawings unless they are different from the recommended dimensions. Detailing practice varies in certain respects between individual firms particularly with regard to the method of referencing members, owing to the different layout and methods adopted in fabrication shops. Some typical and very practical examples are shown in figures 7.44 to 7.47. Chain dimensioning has been used on the beam details; Metric Practice recommends that dimensions start from one end of the member – see figures 7.40a and b. Typical load-bearing brackets are shown in figure 7.41. Adequate clearances must be provided for the operations of bolting or welding; stiffeners must be incorporated where necessary to prevent local distortion of column or beam flanges and webs and also to prevent buckling of the bracket itself. The web of the bracket must be adequate in both shear and bending. These types of connection fall into two main groups

(1) where the fastening is in the same plane as the force (figure 7.41a)

(2) where the fastening is at right angles to the plane of the force (figure 7.41b).

The connection can be made with bolts (or HSFG bolts), rivets or welds. Note that only one type of fastener must be used in any one connection.

The solution of bolted connections in which the fastening is in the same plane as the force is obtained using coefficients for various eccentricities, e, cross centres, S_1, and vertical pitches p. These coefficients are given in Metric Practice. The coefficient, c, equals the load, W, divided by the permissible load on one fastener, f. Coefficients and tables showing the properties of weld groups are also given to aid the solution of welded connections.

In the type of bolted connection where the fastening is at right angles to the plane of the force, the bending moment is taken by tension in the fasteners and compression between the bracket and the face to which it is connected. The reaction is taken by shear in the fasteners. For the welded bracket it is assumed that the top flange weld resists the bending moment rotating about the axis at the bottom of the beam and that the vertical shear is resisted by the bottom flange weld. (Note: The practice in some firms is to work about the neutral axis for bending and the vertical shear is resisted by all the weld, the resultant being

$$\sqrt{\left(\frac{f_s}{p_s} + \frac{f_b}{p_b}\right)}$$

Values of allowable bending moments and shears are given in Metric Practice.)

The most usual method of making beam-to-beam connections is by means of end cleats or end plates (figures 7.40c and d). In an end cleated connection with the incoming beam on one side only, the value of a bolt on the outstanding leg is usually governed by single shear but the bearing capacity must be checked. On the connected leg the bolts are subject to direct force and the force due to the moment. Where there is an incoming beam on both sides the bolts on the outstanding leg are subjected to double shear but again the bearing values must be investigated. This can be done by comparing the single shear value with one-half of the bearing value, taking the lesser of the two. The thickness of the end cleats or thickness of the end plate must not be less than one-half the thickness of the web. In the welded end plate type of connection shown in figure 7.40d the end plate must be capable of transmitting the end reaction to the web of the beam.

Concentrated loads on beams can produce local buckling, direct bearing (or crushing) shear and bending effects in various combinations. These must be investigated in

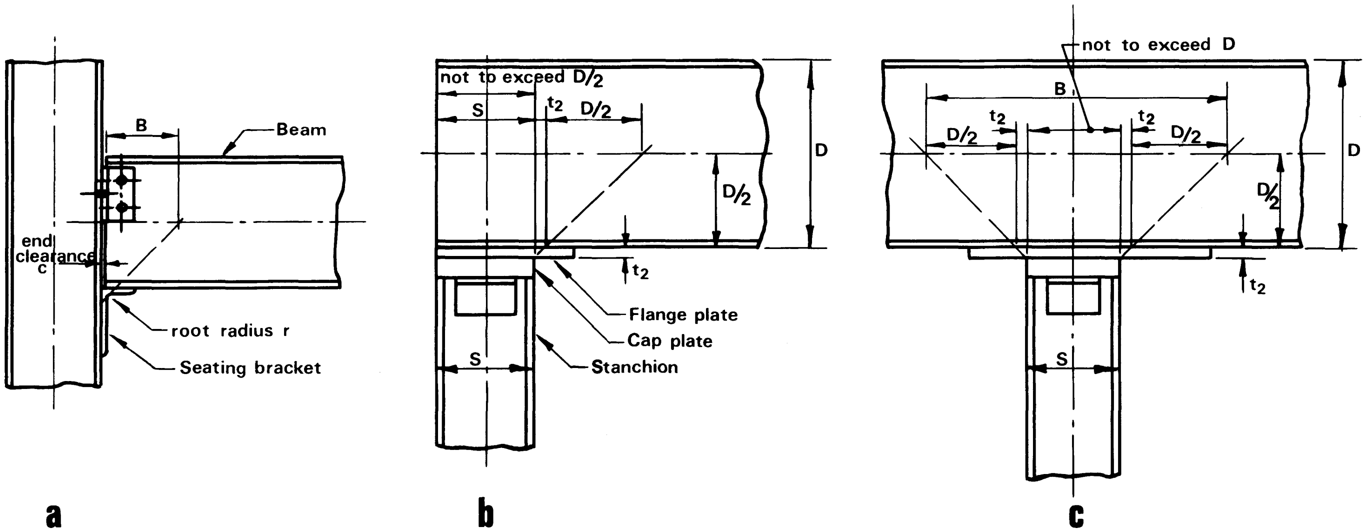


Figure 7.42 Seating brackets and beam ends over stanchions

accordance with BS 449. Load bearing stiffeners must be provided at points of concentrated loads (including points of support) where the concentrated load or reaction exceeds the safe buckling load x the web thickness x the dimension B (figure 7.42). Recommended bolt sizes are M12, M16, M20, M22 and M24.

In general terms there are two types of weld: fillet welds and butt welds. A fillet weld is any fusion weld approximately triangular in transverse cross-section which is not a butt weld but including a weld at a corner joint. A fillet weld, as deposited, is not to be less than the specified dimensions: the latter must be clearly indicated as throat thickness and/or leg length as appropriate. For concave fillet welds, the actual throat thickness is not to be less than 0.7 times the specified leg length. For convex fillet welds, the actual throat thickness is not to be more than 0.9 times the actual length. The effective length of a fillet weld is not to be less than 4 times the size of the weld.

A butt weld is defined as a weld in which the metal lies substantially within the extension of the planes of the surfaces of the parts joined, or within the extension of the planes of the smaller of two parts of differing sizes. The size of a butt weld is specified by the effective throat thickness of the weld, the effective throat thickness of a complete penetration butt weld being taken as the thickness of the thinner part joined; and the effective throat thickness of an incomplete penetration butt weld is taken as the minimum depth of weld metal, excluding reinforcement, common to the parts joined. Care should be taken at the ends of the weld and the use of run-on and run-off plates should be considered if the length of the weld is not to be curtailed.

In order to provide a complete indication of the position of a weld in a particular joint, relative to the parts being joined, an arrowhead is used to indicate the reference side of the joint. If the weld symbol is placed beneath the arrow extension line this indicates that the weld is on the arrow side. If the symbol is placed above the line then this indicates that the weld is on the other side of the joint. The former convention is preferable. When the arrow cannot point to a joint, symbolic representation cannot be used. Dimensions relating to the cross-section of the weld are shown on the left-hand side of the symbol and longitudinal dimensions of the joint on the right-hand side (distances between adjacent weld elements are indicated in parentheses). The cross-section dimension for a fillet weld is usually the leg length. If it is necessary to indicate the design throat thickness, then the leg length dimension is prefixed with the letter 'b' and the throat thickness dimension is prefixed with the letter 'a'. The preferred range of leg length dimensions is 3, 4, 5, 6, 8, 10, 12, 16, 18, 20, 22 and 25 mm.

7.5 THE DESIGN AND CONSTRUCTION OF A SMALL PEDESTRIAN SUBWAY

The methods likely to be used in the construction of any civil engineering project, and the legal aspects of a contract, will have some influence on the way in which the drawings are

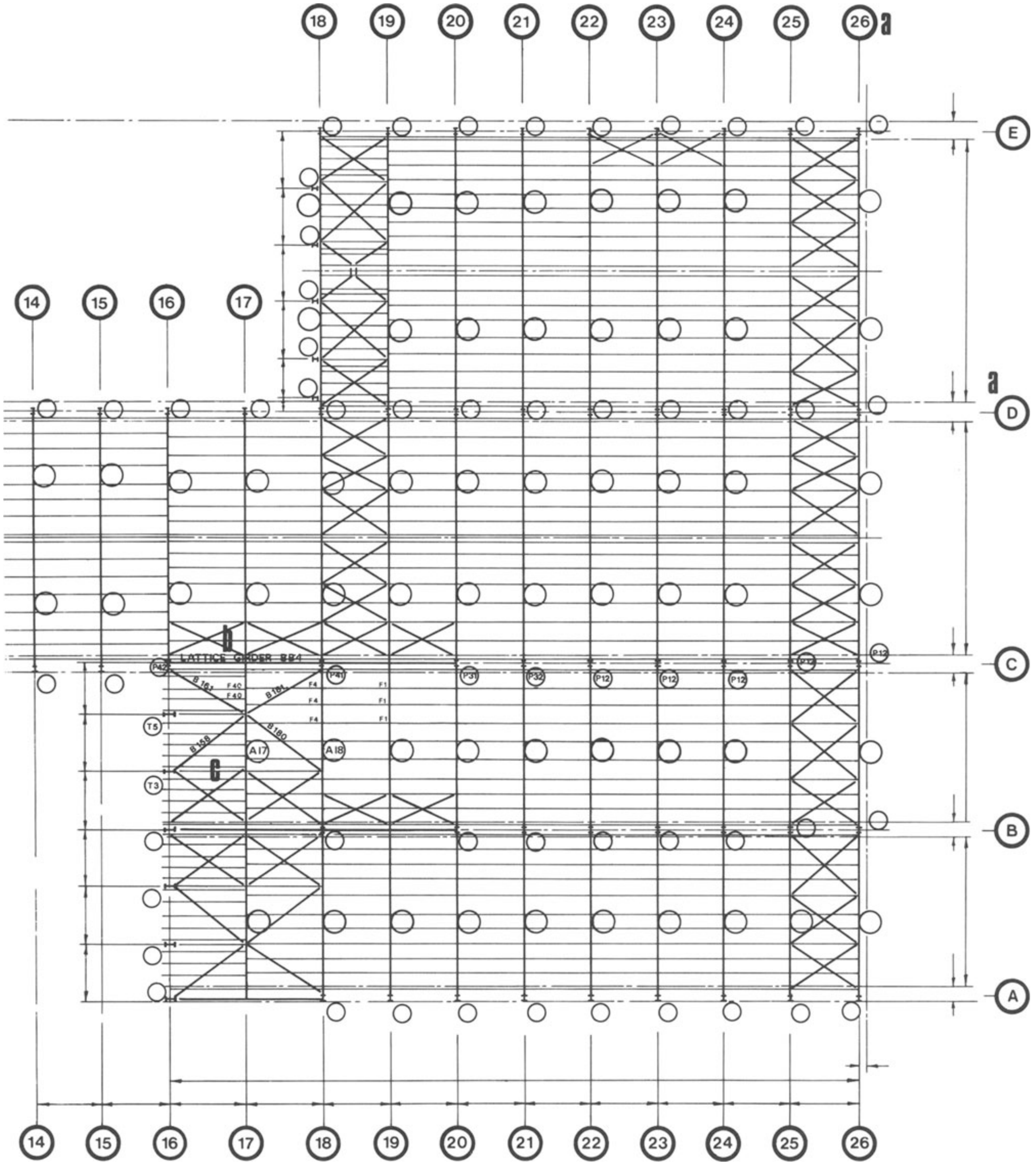


Figure 7.43 General arrangement drawing (part)

a Grid referencing.
b Part of the lattice girder detail is shown in figure 7.44.
c In this referencing system the reference for each type of structural member, for example, stanchions, trusses, girders, sheeting rails, bracing, etc., starts with a different letter which is followed by a sequential number; like members have been given the same reference.

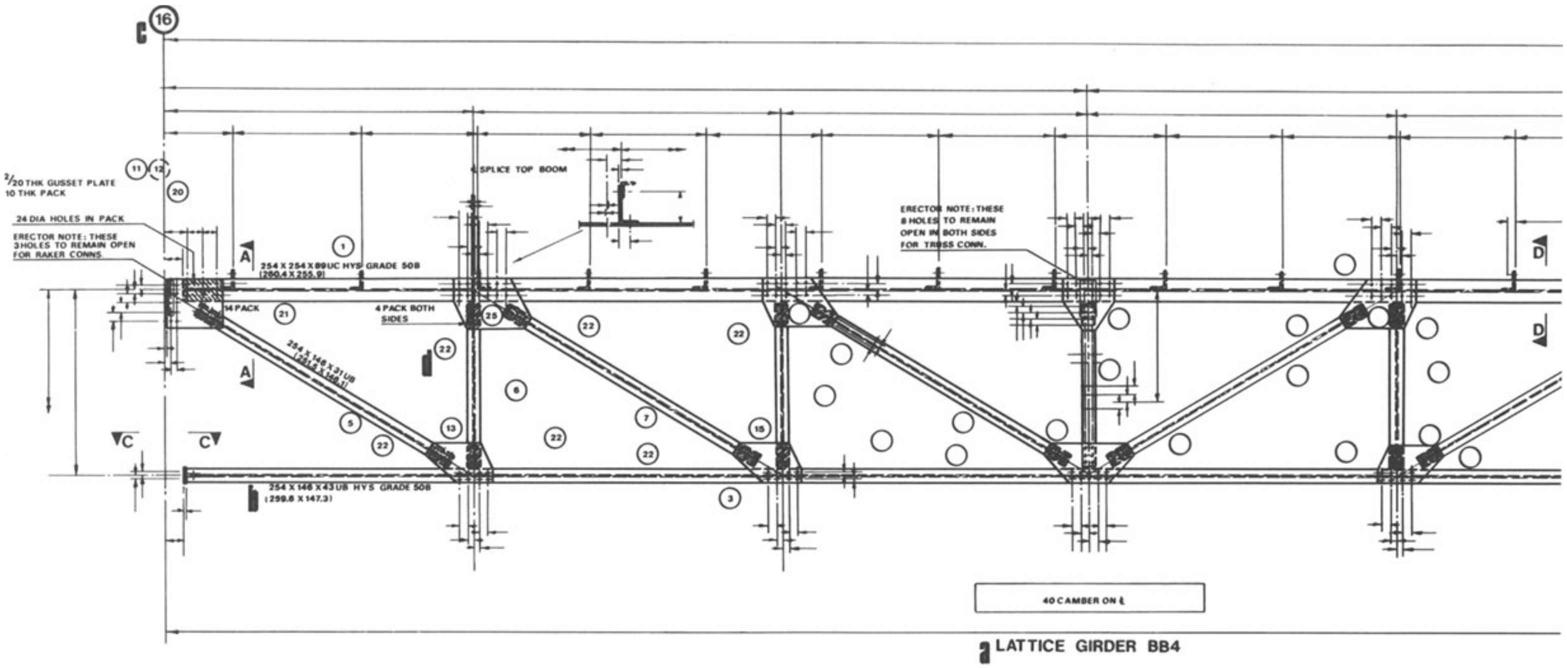


Figure 7.44 Lattice girder detail

a Lattice girder with piece mark BB4; see figure 7.43.
b Universal beam 254 × 146 × 43 kg m (exact size 259.6 mm × 147.3 mm).
c Grid reference on general arrangement drawing; see figure 7.43.
d Number corresponds with the number in the materials list; part of a typical form used for listing materials is shown below.

MATERIAL LIST

WORKS .... JOB No. ....

MATL. REQD. BY .... SHEET No. .... of ....

DRAUGHTSMAN .... DATE PREPARED ....

ITEM No.	SECTION	No.	IMPERIAL LENGTH	LENGTH IN MM	Kg PER M	WT IN Kg

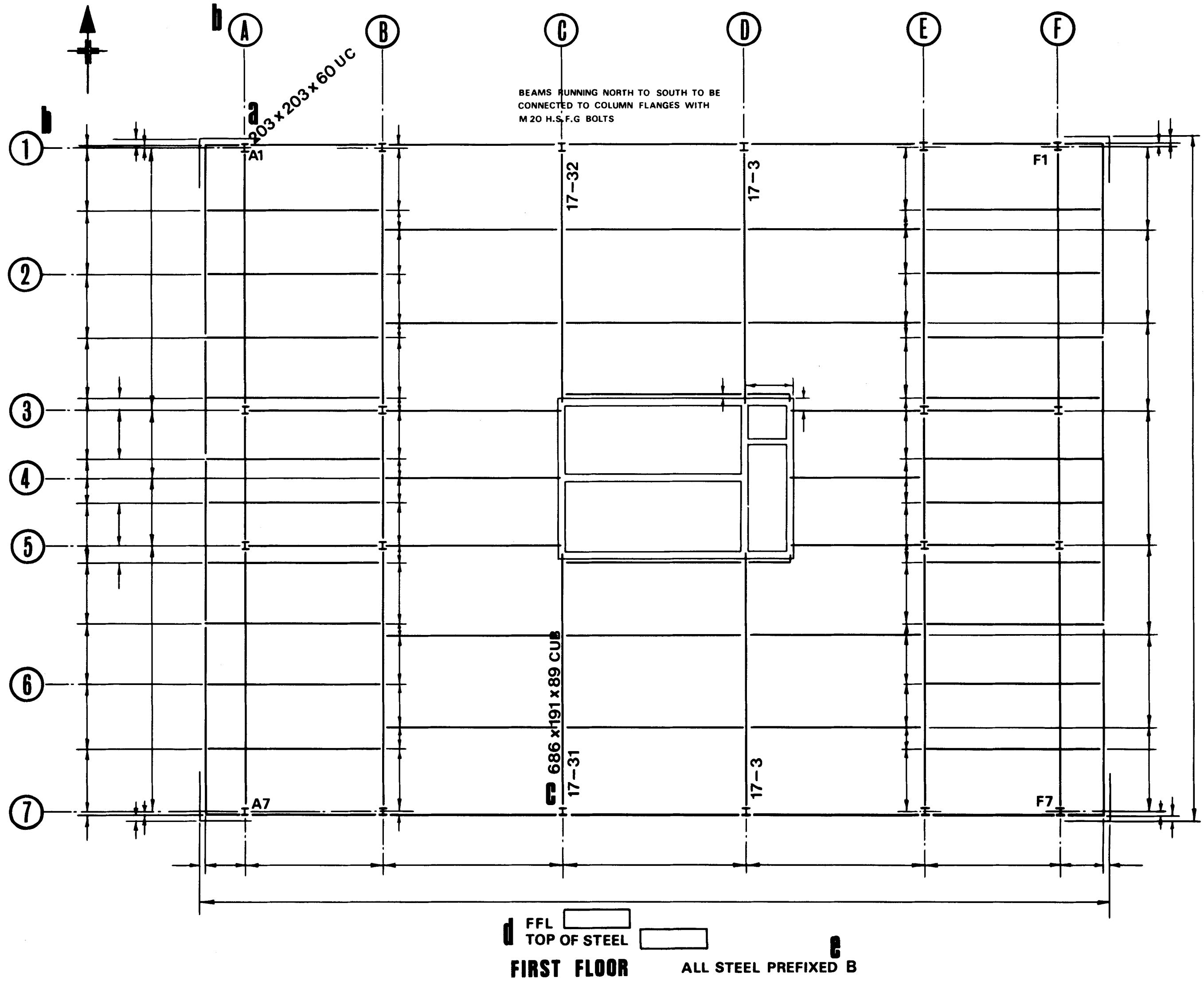


Figure 7.45 General arrangement drawing

a and **b** The column reference (also the piece mark) is defined by the intersection of the grid lines. The detail of column A1 is shown in figure 7.47.

c Beam references include (i) part of the number of the drawing giving details of the beam and (ii) the reference of the floor in which the beam is situated (see figure 7.46).

d Top of structural steelwork and finished floor levels shown.

e The prefix 'B' in the piece mark indicates that the beams are situated in the first floor.

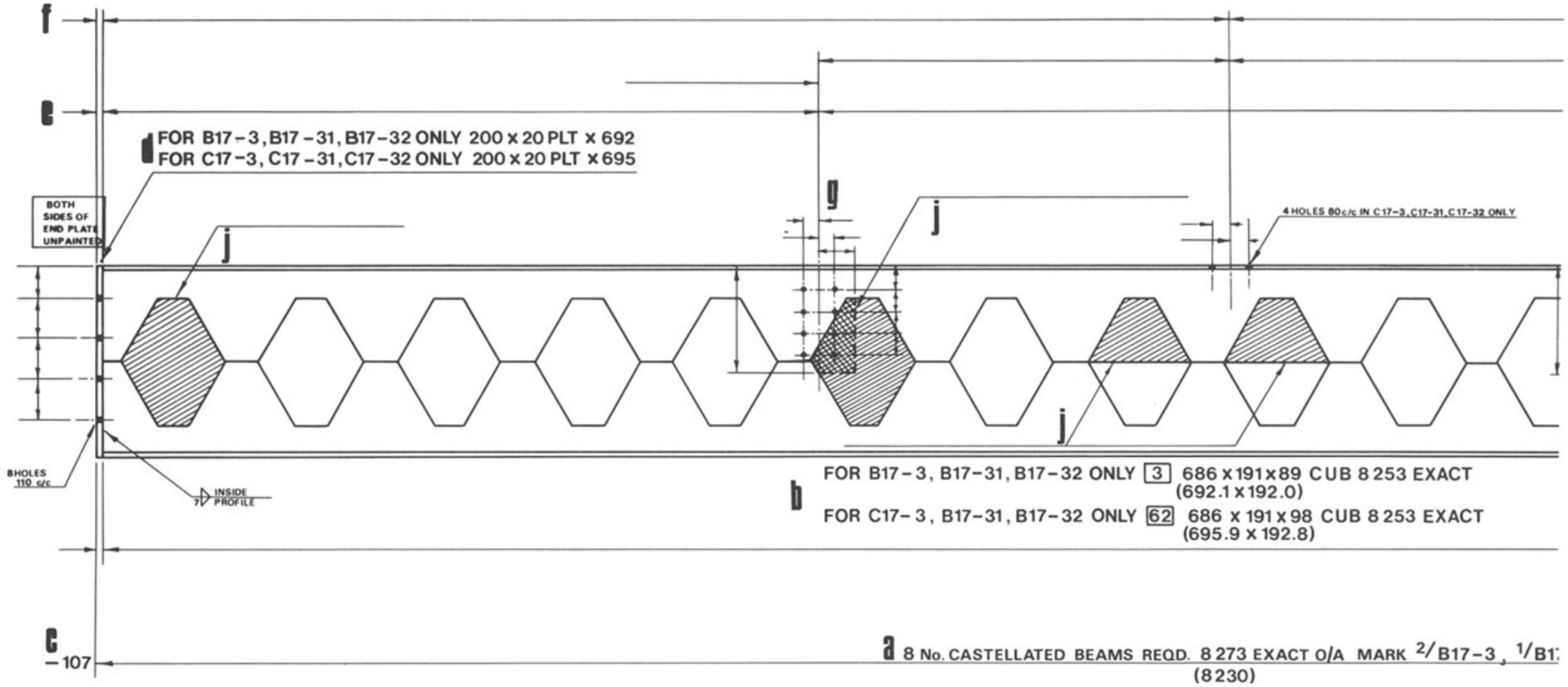


Figure 7.46 Castellated beam detail (part)

a Over-all length of beam, including end plate; and piece marks.
b Type and length of universal beams; the boxed numbers relate to the item numbers in the material list.
c Dimension to centre line of connecting column.
d Sizes of end plates.
e and **f** Primary dimensions to the centre of each group of holes for connecting beams.
g Secondary dimensions from the centre lines of each group of holes to the centre lines of the holes themselves.

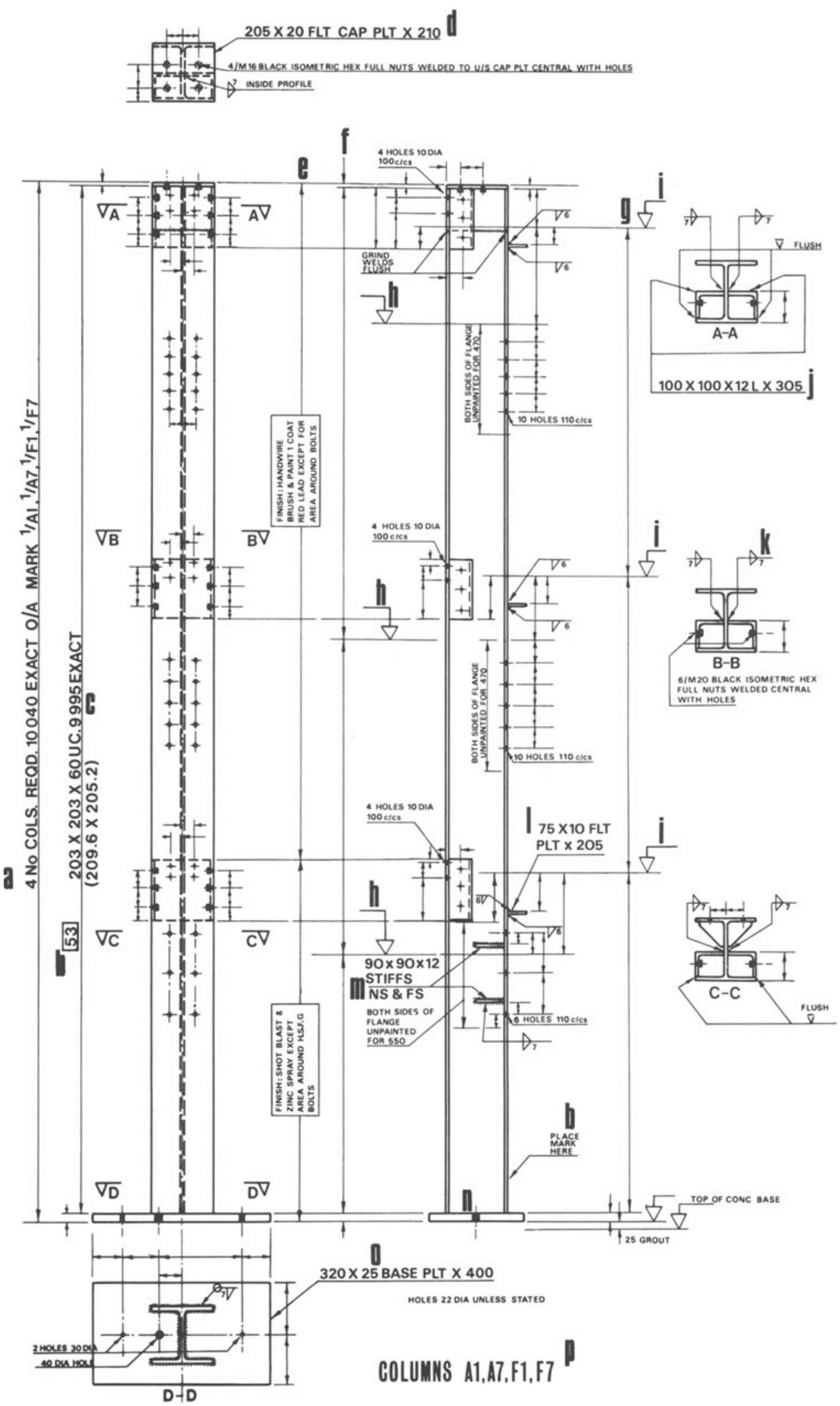

205 X 20 FLT CAP PLT X 210 d
4/M16 BLACK ISOMETRIC HEX FULL NUTS WELDED TO U/S CAP PLT CENTRAL WITH HOLES
INSIDE PROFILE
a 4 No COLS. REQD. 10 040 EXACT O/A MARK 1/A1, 1/A7, 1/F1, 1/F7
203 X 203 X 60 UC. 9995 EXACT c
(209.6 X 205.2)
b 53
FINISH: HANDWIRE BRUSH & PAINT 1 COAT RED LEAD EXCEPT FOR AREA AROUND BOLTS
FINISH: SHOT BLAST & ZINC SPRAY EXCEPT AREA AROUND H.S.F.G BOLTS
4 HOLES 10 DIA 100 c/cs
GRIND WELDS FLUSH
BOTH SIDES OF FLANGE UNPAINTED FOR 470
10 HOLES 110 c/cs
75 X 10 FLT PLT x 205
90 x 90 x 12 STIFFS NS & FS
BOTH SIDES OF FLANGE UNPAINTED FOR 550
6 HOLES 110 c/cs
PLACE MARK HERE
TOP OF CONC BASE
25 GROUT
FLUSH
A-A
100 X 100 X 12 L X 305 j
B-B
6/M20 BLACK ISOMETRIC HEX FULL NUTS WELDED CENTRAL WITH HOLES
C-C
320 X 25 BASE PLT X 400
HOLES 22 DIA UNLESS STATED
2 HOLES 30 DIA
40 DIA HOLE
D-D
COLUMNS A1, A7, F1, F7 p

Figure 7.47 Steel column detail

a Four columns of the type detailed, with an over-all dimension of 10.04 m are required. The reference marks are related to the grid on the general arrangement drawing; see figure 7.45.

b This number relates to the item number in the material list which is prepared at the very start of the job to enable the purchasing department to buy the necessary main material.

c A universal column with a nominal serial size of 203 mm × 203 mm and a weight of 60 kg/m. The exact over-all dimensions are 209.6 mm × 205.2 mm. Several different sections can be obtained in each serial size and hence the weight per metre and exact size must be stated.

d A 210 mm × 205 mm × 20 mm thick capping plate. Note that the length is stated at the end of the description.

e Brief basic specification notes concerning surface treatment.

f Dimensions to tops of connecting beams.

g Basic chain dimensioning to floor levels. Note that each set of bolt holes is dimensioned relative to the nearest floor level.

h Top of beam levels.

i Floor levels. If the ground floor is used as zero datum then some levels will be negative. If Ordnance datum is adopted then all levels will be positive and can also be directly related to existing contour and spot levels in the vicinity of the site. In order to avoid confusion where several specialist firms are supplying detail drawings for a project, the client company may stipulate the datum to be used.

j Equal angle 100 mm × 100 mm × 12 mm thick and 305 mm long.

k Method of representing the type, size and position of welds. The marking shown indicates that a 7 mm fillet weld is required on the inside and outside of the angle where it connects with the column.

l Flat plate 75 mm × 205 mm × 10 mm thick.

m Stiffening plate 90 mm × 90 mm × 12 mm thick on both sides of the flange.

n Holes shown black.

o Base plate 400 mm × 320 mm × 25 mm thick.

p Column references relate to the grid lines on the general arrangement drawing. This number is known as the piece mark and identifies where the member will be situated in the structure.

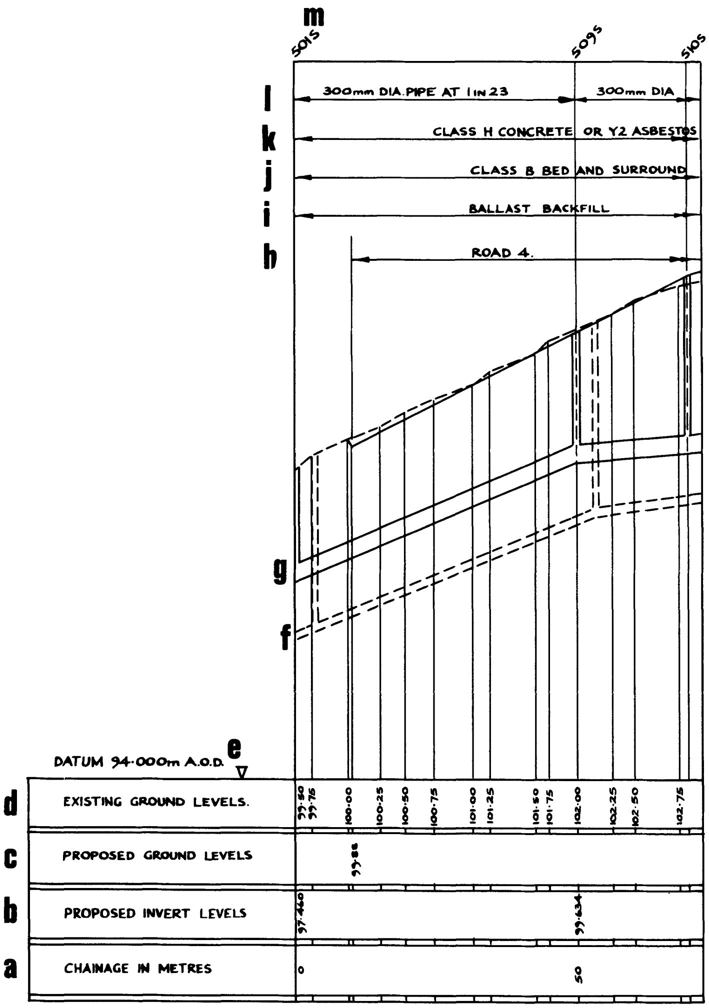


Figure 7.48a Sewer longitudinal section for proposed housing estate

Compare this longitudinal section for a housing estate sewer laid in virgin ground (note the absence of existing mains and services) with figure 7.51 which shows the section for a sewer laid in a town centre.

a to **d** Information about levels and chainages are shown in a box at the foot of the section. It is suggested that all chainage values, including those for branch sewers, be related to zero at the main sewer outfall. The branch chainages can be suffixed by letters to distinguish them from the main sewer chainages.

e Ordnance datum from which vertical scale measurements are made in plotting levels on the section.

h to **l** Pipeline details. Descriptions are necessary only at the manhole chainages and hence it is unnecessary to extend any of the other lines to the top of the section box.

m Manhole numbers. It is important to keep a register of all manhole numbers to ensure that no two manholes within a defined catchment or over-all drainage area have the same number.

Figure 7.48b Longitudinal section for proposed housing estate road

a Zero chainage is usually arranged to facilitate setting-out on the site, e.g. the intersection between the central line of the road and the channel line of the adjoining road.

b 'Left-hand' and 'right-hand' gullies are defined by looking in the direction of increasing chainage. 'Left-hand' and 'right-hand' in this context must not be confused with the definitions in the British Standard on storm gully gratings which are related to the direction of flow of surface water on the road surface.

c to **g** 'Left-hand' and 'right-hand' are defined by looking in the direction of increasing chainage. The sequence of representing the levels should be shown so that they are logically related to the cross-sections (if required) which are taken looking in the direction of increasing chainage.

h Existing ground levels.

i Datum line.

j The proposed road centre line is represented by a solid line and existing ground by a broken line. False channels, where required, are shown by means of long broken lines. The setting-out information on the longitudinal section relates to the road centre line. Where the road width varies, for example at junctions and roundabouts, the levels and the setting-out information are best shown on large-scale plans.

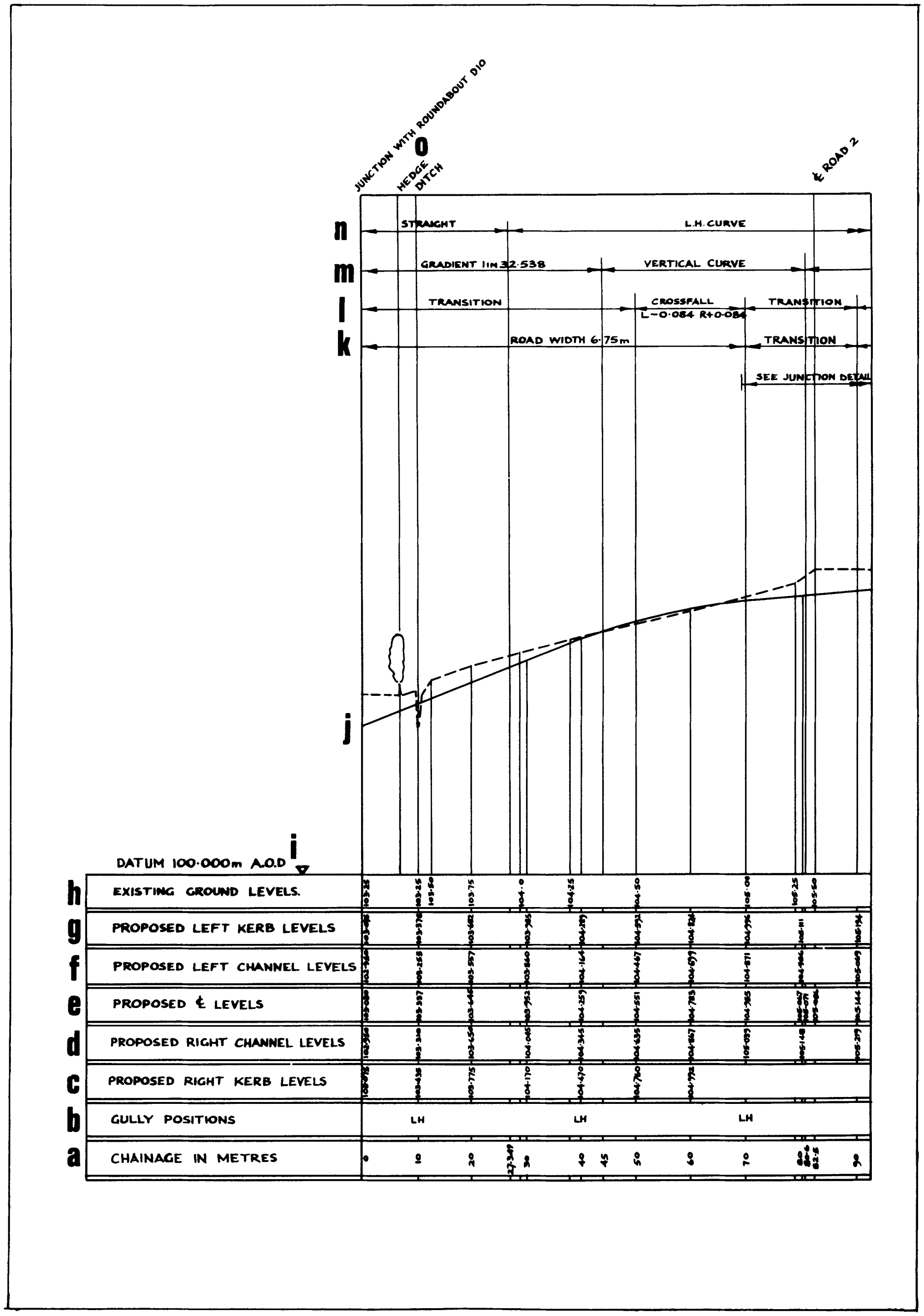
k Road width.

l Information about the cross-sectional shape of the road: camber, transition or cross-fall. L–0.084 and R+0.084 mean the left-hand channel is 0.084 m below the road centre line and the right-hand channel is 0.084 m above the road centre line.

m Information about the vertical profile of road centre line.

n Information about the horizontal alignment of the road centre line. Detailed setting-out information is best represented on a separate plan.

o Features crossing the line of the road.


JUNCTION WITH ROUNDABOUT D10
HEDGE
DITCH
℄ ROAD 2
n
m
l
k
j
i
o
STRAIGHT
L.H. CURVE
GRADIENT 1 IN 32·538
VERTICAL CURVE
TRANSITION
CROSSFALL
L−0·084 R+0·084
TRANSITION
ROAD WIDTH 6·75m
TRANSITION
SEE JUNCTION DETAIL
DATUM 100·000m A.O.D
h EXISTING GROUND LEVELS.
g PROPOSED LEFT KERB LEVELS
f PROPOSED LEFT CHANNEL LEVELS
e PROPOSED ℄ LEVELS
d PROPOSED RIGHT CHANNEL LEVELS
c PROPOSED RIGHT KERB LEVELS
b GULLY POSITIONS
a CHAINAGE IN METRES
LH
LH
LH

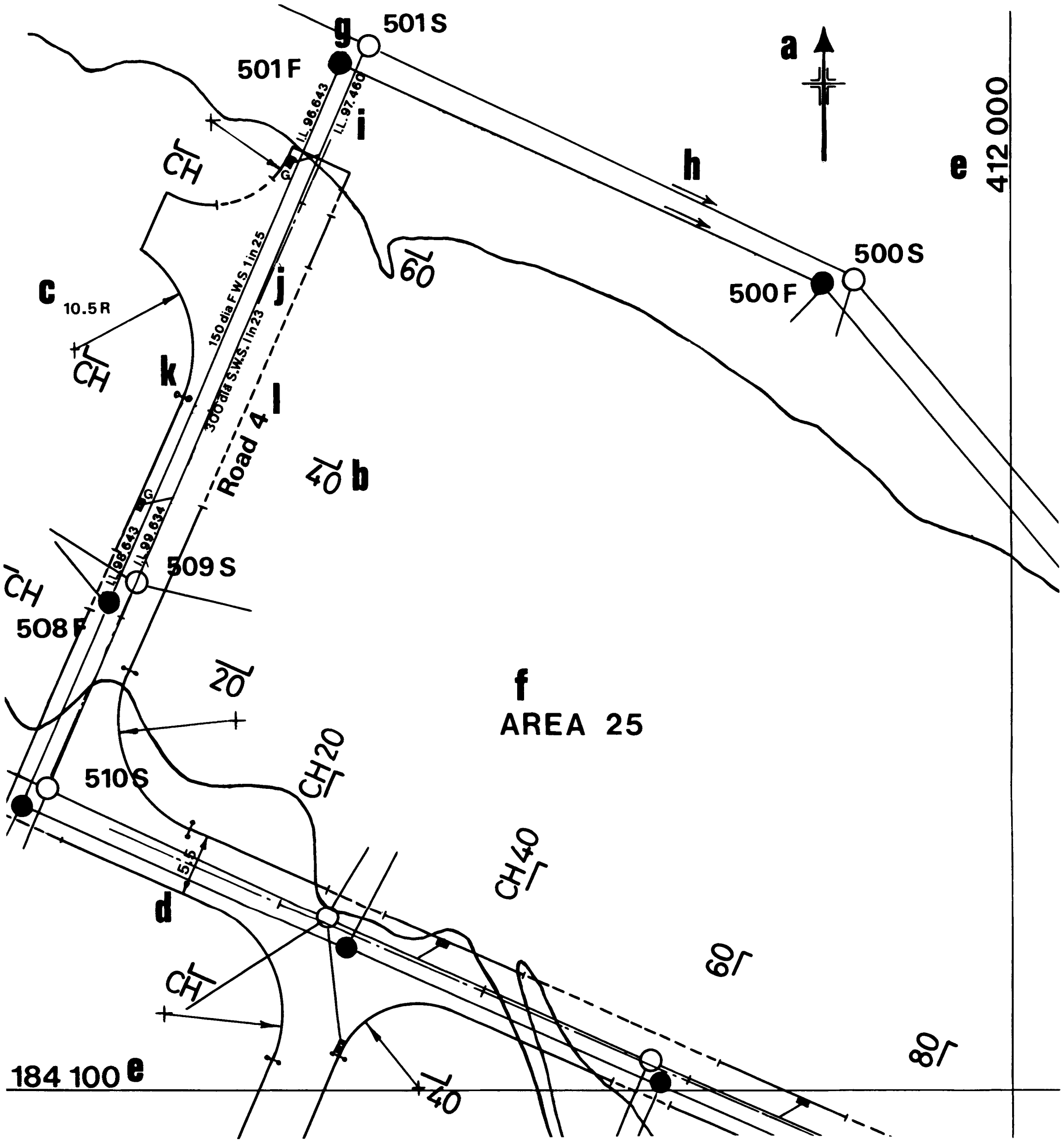


Figure 7.49 Housing estate road plan

a North point.
b Cross-section locations and chainages.
c Curve radius dimensions.
d Road widths.
e Grid line coordinates.
f Location identification.
g Sewer centre line only shown. Compare with the plan in figure 7.51 where the presence of large mains and the existing features make it advisable to show the outer outlines of the sewers. The outer outlines of the manholes have, however, been shown on both diagrams.
h Direction of flow in the pipes.
i and j Invert levels, gradients and diameters of the pipes are also shown on the plan.
k Tangent point.
l Preliminary road name.

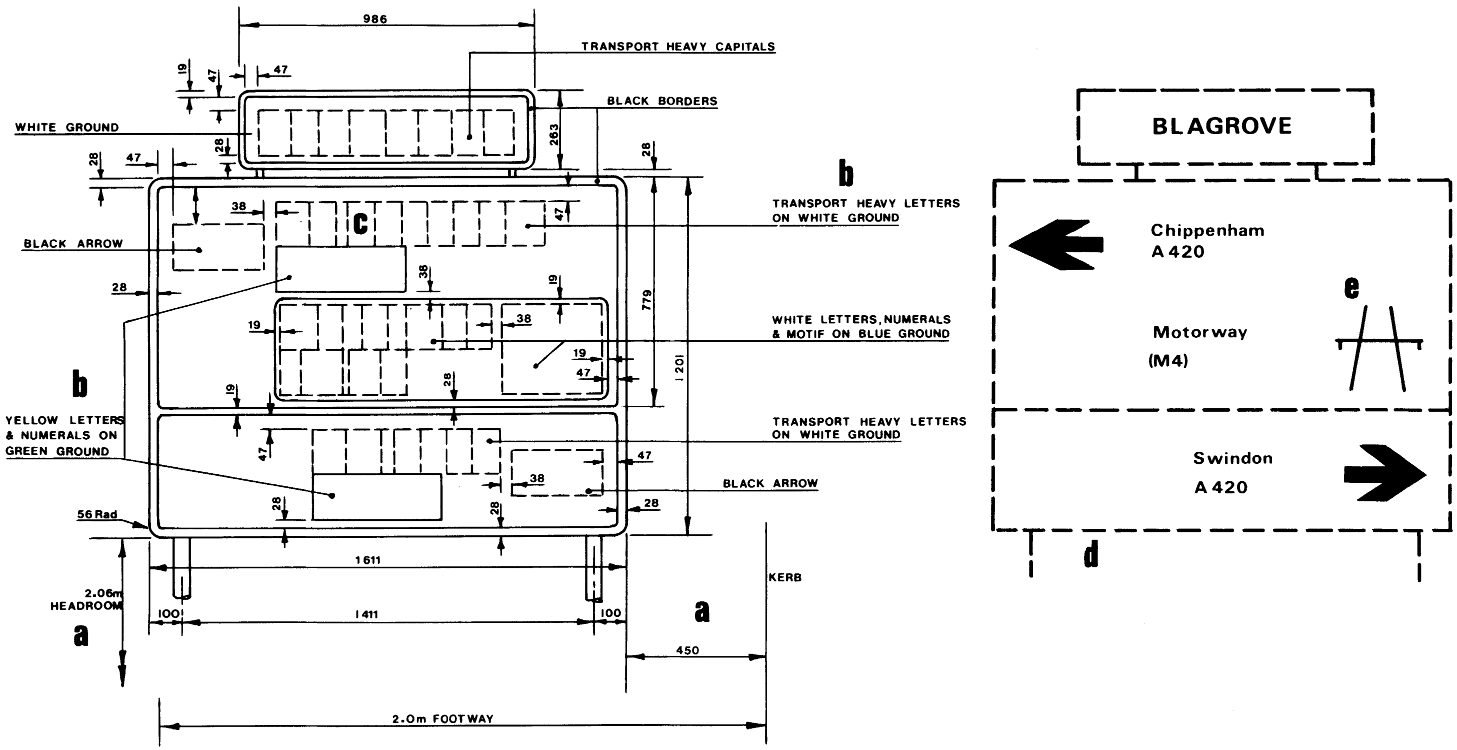


Figure 7.50 Advance direction sign

Most road signs are designed strictly in accordance with rules laid down by the Department of Transport, and their design is essentially concerned with correct interpretation of the regulations and accurate layout. Standard shape letters are used (usually 'transport medium' or 'transport heavy') which are arranged on standard 'tiles'.

Note that the diagram includes a fully dimensioned layout, and a diagrammatic arrangement of the wording, numbering and symbols on the sign. The 'X' height is the height of the lower-case letters. A complete specification should also be included on the drawing.

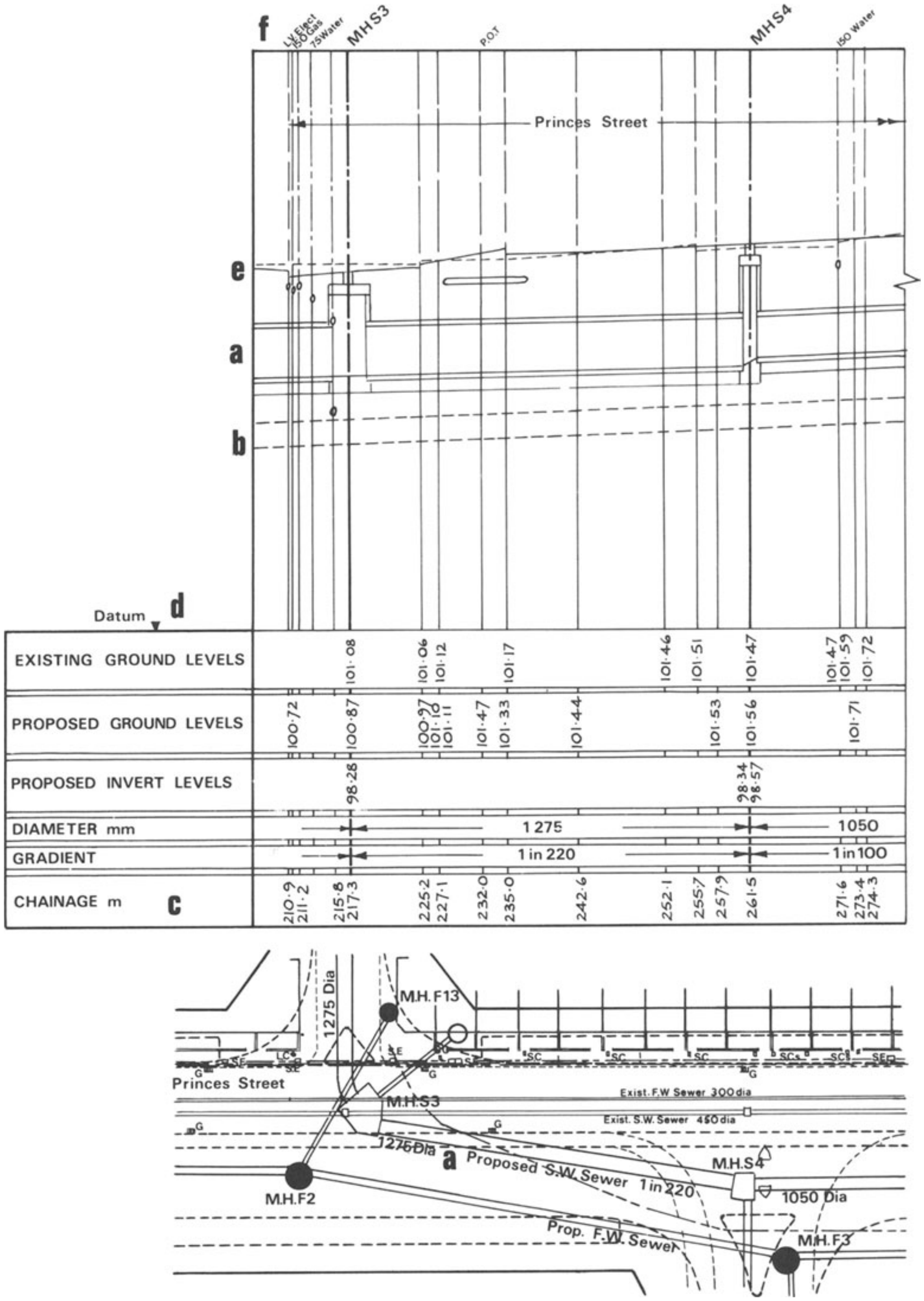


Figure 7.51 Main sewer longitudinal section and plan

a The main outlines of the proposed surface water sewer and manholes and existing mains and services are shown on the plan and longitudinal section.

b The proposed foul water sewer, details of which are shown on a separate drawing, is indicated with broken lines. The levels of proposed connections to the foul water sewer must be carefully checked to ensure that there is no conflict with other proposed and existing sewers and mains or any other structures.

c Method of representing the required information on existing and proposed ground levels, proposed invert levels, the chainage and the proposed pipe diameters and gradients. The levels of existing mains and services are more appropriately represented on the longitudinal section, for example

O ▽ 99.924

Chainages increase in the upstream direction from zero at the outfall. There is no relationship between the sewer and road chainages but it may be considered logical that they increase in the same direction if this can be arranged. The title box should be placed on the left-hand side of the longitudinal section as shown, but in some cases it may appear preferable to place the zero chainage on the right of the section with the chainage increasing from right to left so that the orientation is similar on both plan and section.

d Datum line; datum value and other levels are usually related to Ordnance datum.

e Existing and proposed ground lines shown.

f Descriptions of mains, services, etc., should be detailed and complete on the plan and the section to ensure that their relative importance is fully appreciated.

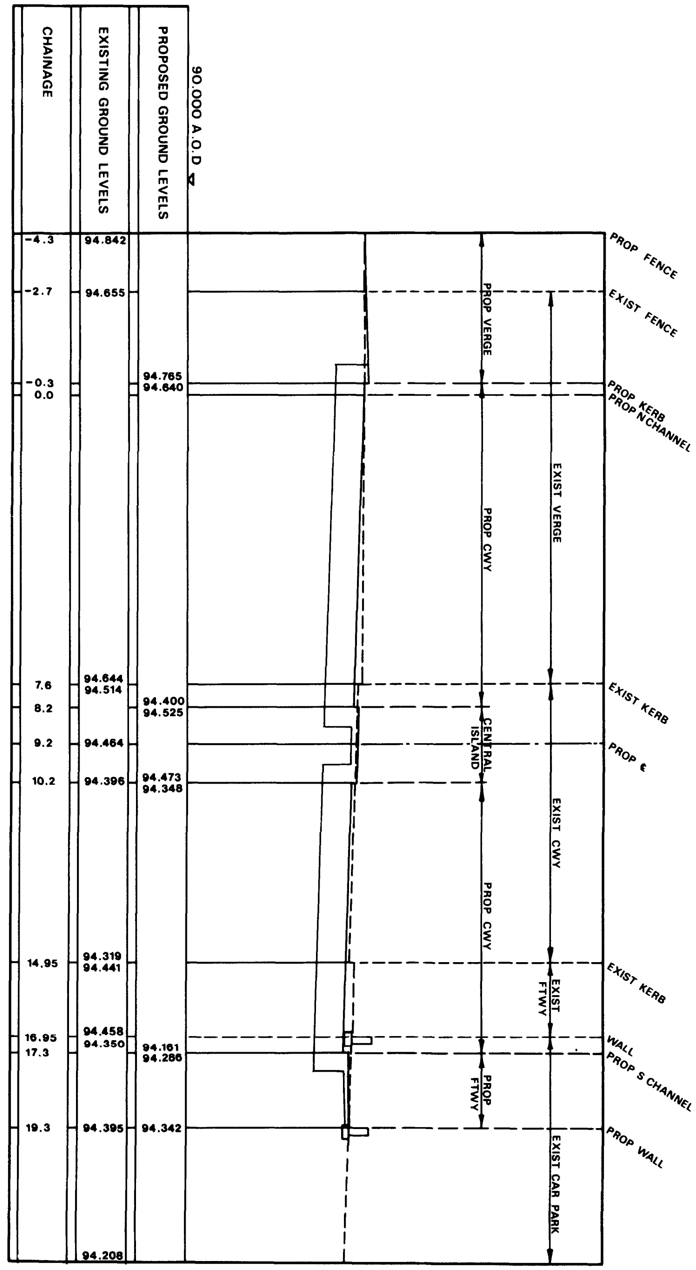


Figure 7.52 Main road cross-section

Main road kerbs and channels are often described by their geographical orientation. For example, the terms 'north' kerb and 'south' kerb are used instead of 'left-hand' kerb and 'right-hand' kerb. The author prefers the latter convention supplemented if necessary by the words 'north' and 'south' placed next to the top corners of the section box. Zero chainage is generally situated at the centre line of the road.

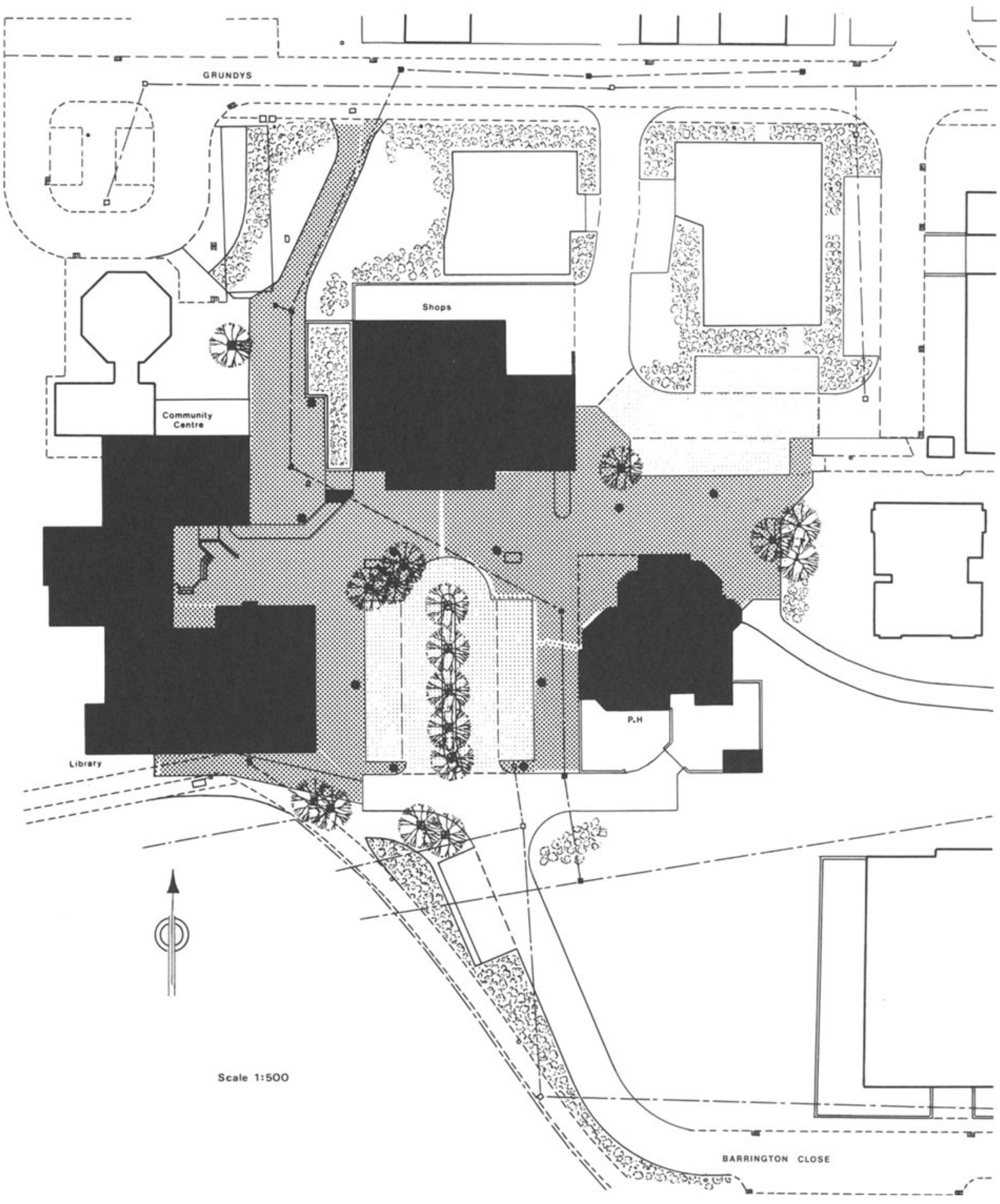


Figure 7.53 Village centre layout plan

In addition to the information shown all existing features should be briefly described. The proposals are shown in outline only. The scale of the full-sized drawing is 1:500. Details of the proposed civil engineering works are shown on separate large-scale drawings; see figures 7.54 and 7.56.

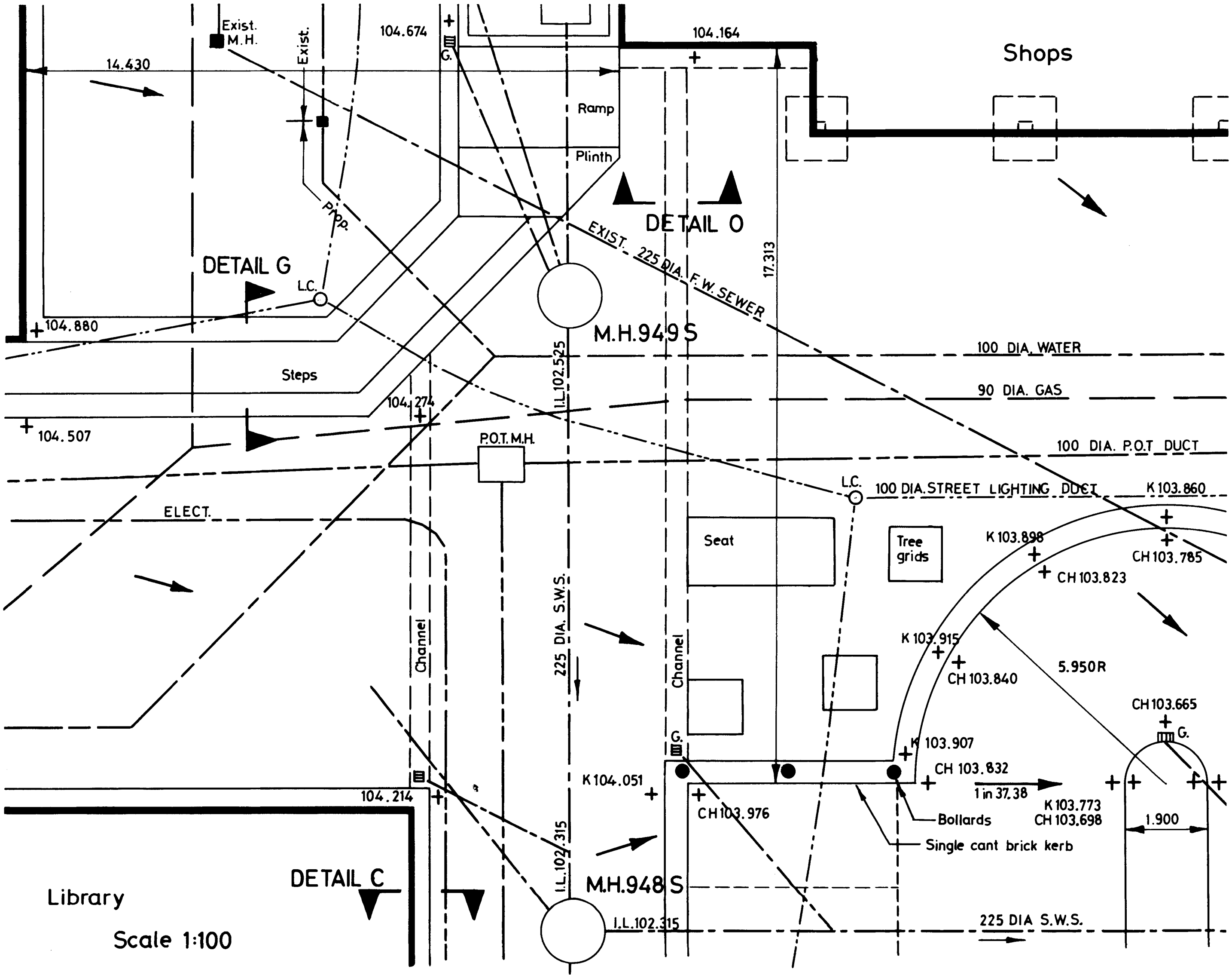


Figure 7.54 Layout of mains and services

It is good practice to show all existing and proposed Public Utility and other mains on the same drawing and to fix the scale of the drawing accordingly. The scale of this full-sized drawing is 1:100. Note that the basic outlines and levels of other proposed and existing features are also shown. The sections, for example, G, O and C, giving large-scale details were conveniently shown on A4 sheets for ease of handling by the workmen on site.

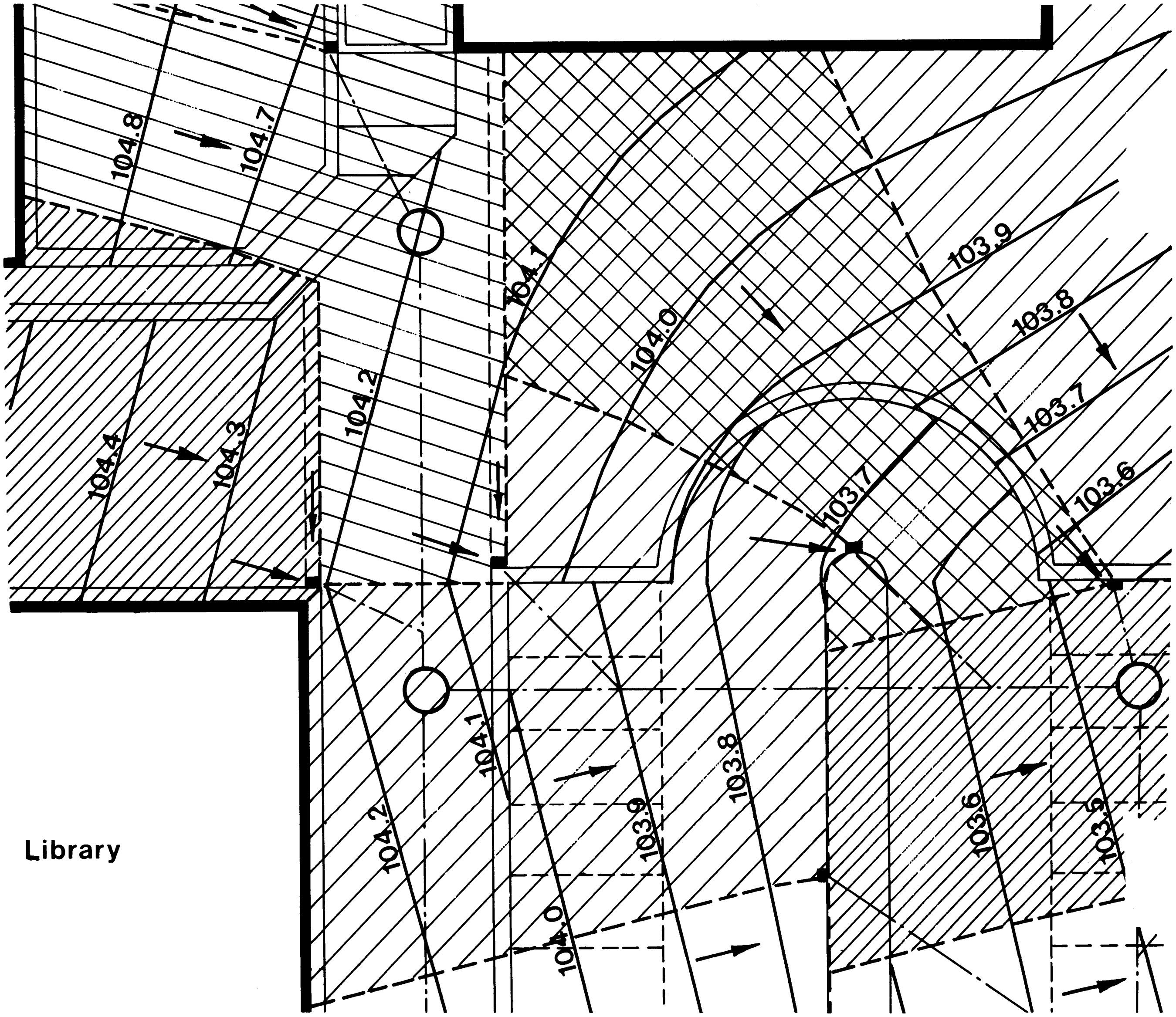


Figure 7.55 Contours and drainage areas

This diagram shows part of the preliminary drawing used to determine the limits of surface areas draining to each gully.

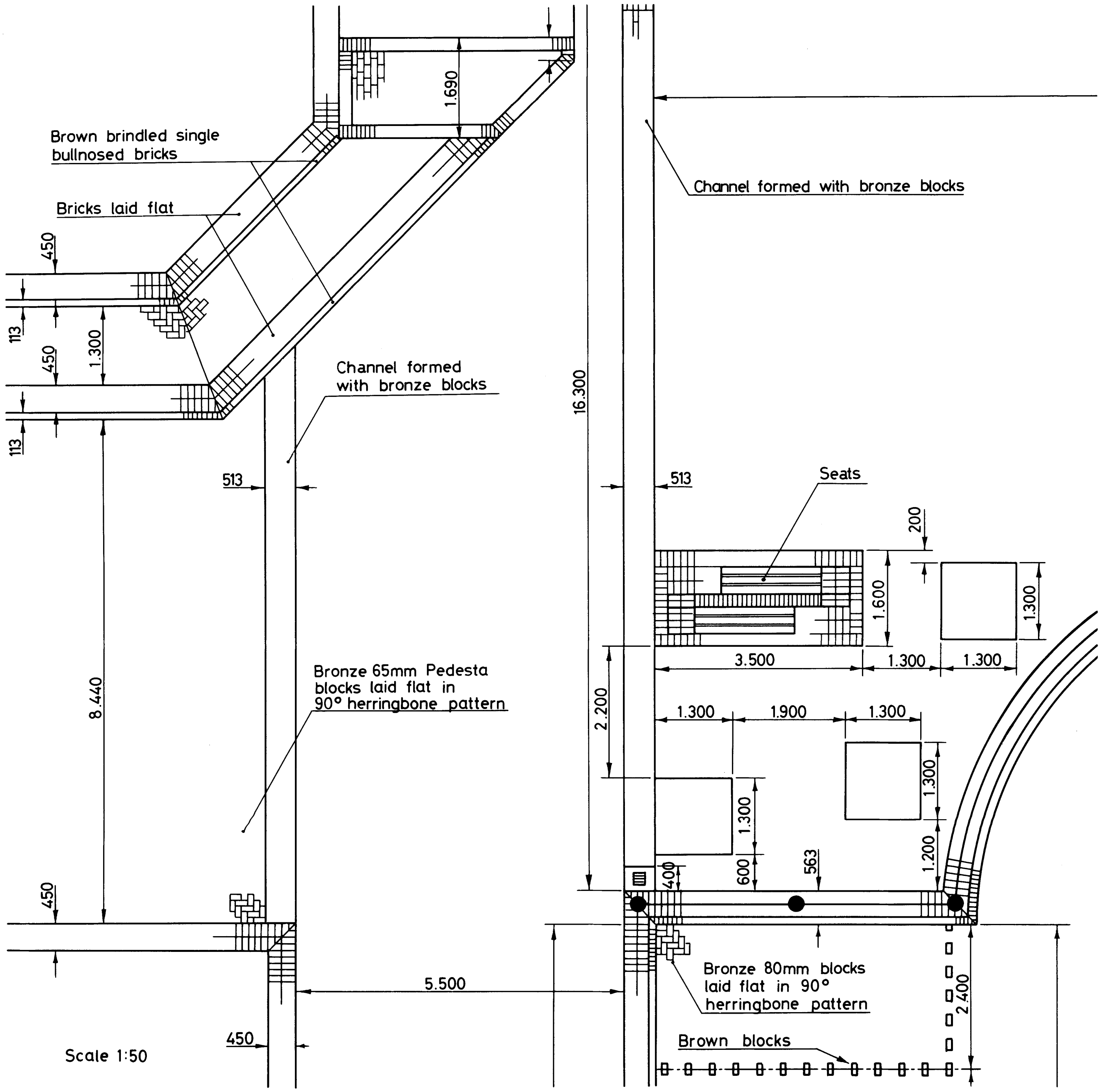


Figure 7.56 Paving and street furniture details

In order to avoid congestion and confusion, details of pavings, steps, street furniture and other surface features are described on a separate drawing, as shown above. The scale of the full-sized drawing is 1:50.

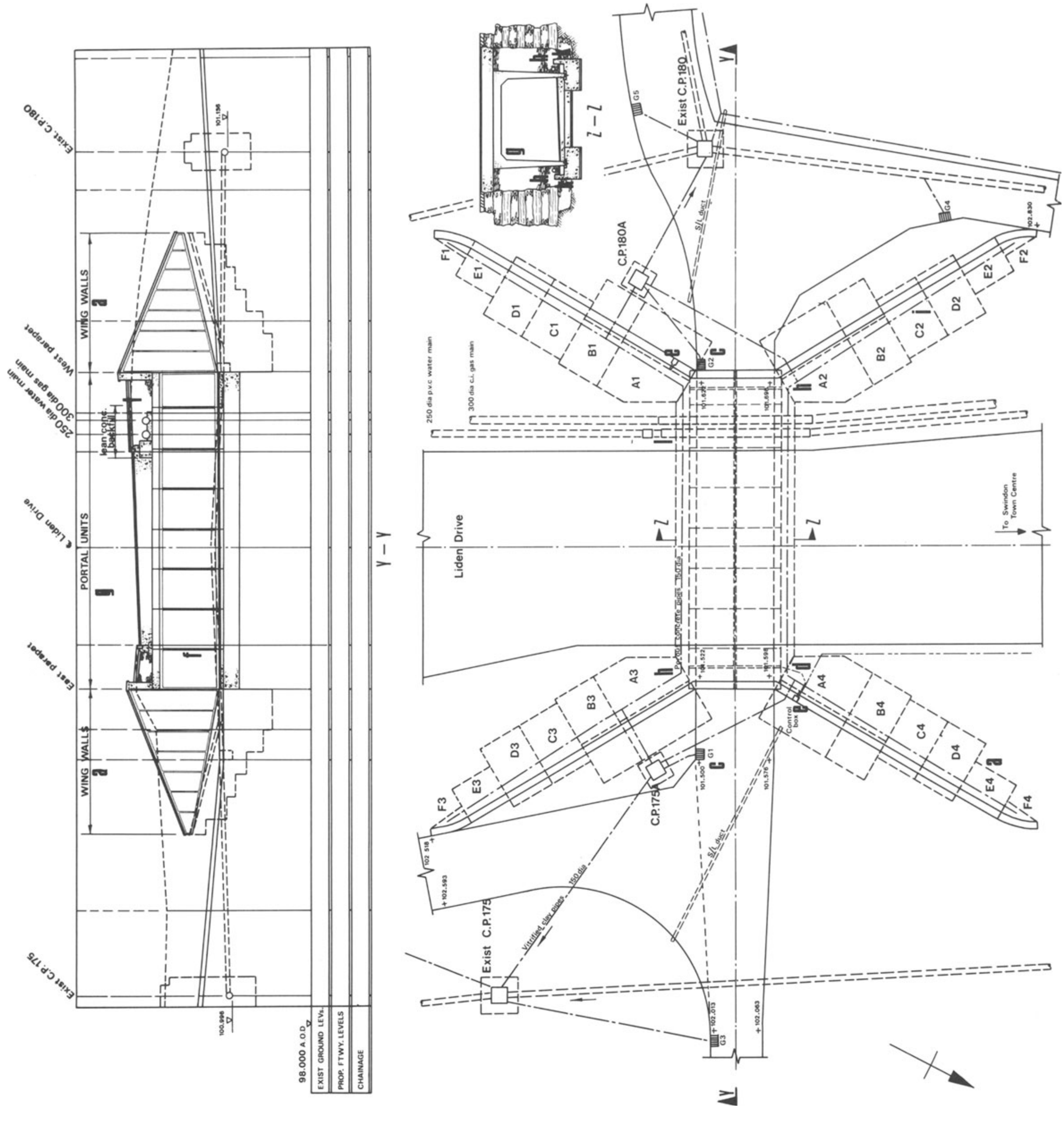

Y — Y
Z — Z
Exist. C.P.180
Exist. C.P.175
West parapet
East parapet
300 dia gas main
250 dia water main
€ Liden Drive
lean conc. backfill
WING WALLS
PORTAL UNITS
98.000 A.O.D.
EXIST GROUND LEVs.
PROP. FTWY. LEVELS
CHAINAGE
Exist C.P.180
C.P.180A
C.P.175A
Exist C.P.175
Liden Drive
To Swindon Town Centre
250 dia p.v.c water main
300 dia c.i. gas main
S/L duct
Control box
Vitrified clay pipes
150 dia
A1
A2
A3
A4
B1
B2
B3
B4
C1
C2
C3
C4
D1
D2
D3
D4
E1
E2
E3
E4
F1
F2
F3
F4
G1
G2
G3
G4
G5

Figure 7.57 Subway – layout plan and sections

a In order to reduce the 'tunnel effect' of the subway, the four wing walls are widely splayed. A pleasing appearance was achieved on the subway and wing walls by fixing textured polystyrene panels to the temporary formwork. All exposed concrete surfaces were then sprayed with coloured polyurethane (all smooth surfaces white and all textured surfaces a light stone colour) which enable graffiti to be removed easily. The coping was formed in situ with granolithic concrete to prevent its removal by vandals. Imposed design loads were less towards the end of each wall and hence the foundation depth was gradually reduced by stepping.

b Levels relating to the ends of every wall section were scheduled and also shown on detail outline drawings; see figures 7.58 and 7.60.

c Special shallow gullies had to be used because of the minimal available fall to the existing surface water sewers.

d A duct was incorporated at the rear of the wall and across the footway to facilitate the electrical supply to subway lamps, street lighting columns and the control box (**e**) recessed into the wall. Ducts were also set into the roofs of the portal units.

e Control box.

f The following measures were taken to prevent the ingress of ground water into the subway.

(1) Soft rubber–bitumen sealing strips 25 mm in diameter were fixed to the edges of the portal units before they were winched into position.
(2) Epoxy mortar was trowelled into the joints on the inside of the units. This is vandal resistant and provides a finish similar to that of the concrete.
(3) Cement/sand mortar trowelled into the fillet on the ground side of the units.
(4) All concrete surfaces in contact with the ground were painted with three coats of rubber–bitumen emulsion.
(5) Granolithic concrete was used to fill the small recesses below the portal legs, and hot-poured bitumen seals were provided at the base of the legs on the outside.
(6) 400 mm wide sealing strips (obtained in rolls) were fixed centrally over the ceiling and wall joints on the ground side of the units.
(7) High-strength sealing compound was trowelled into a recess formed at the rear of the wing walls at their junction with the portal units (the water bars which were left protruding from the units could not be effectively turned into the wing walls because of the acute junction angle).

g Pre-cast portal units were used to form the subway walls and ceiling in order to reduce the road closure period and this solution was, for this project, no more costly than an in situ concrete alternative. The quoted prices for providing pre-cast concrete wing wall units were, however, prohibitive. The subway lighting lamps were of a vandal-resistant type and were set into recesses formed in the subway ceiling.

h Groundwater drainage systems are usually provided behind earth-retaining structures to minimise water pressures and the possibility of leakage.

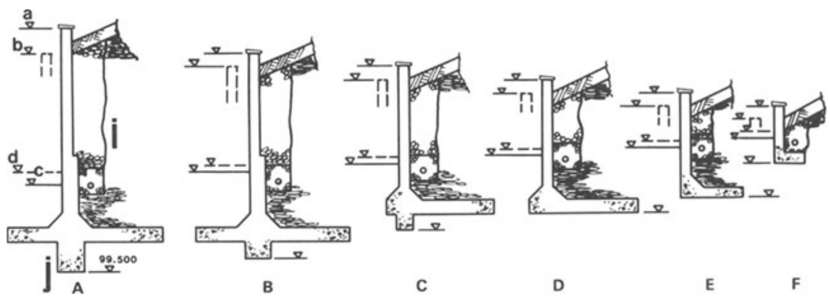
i A single-sized filter material was brought up behind the wall in conjunction with the graded stone backfill. Water pressures can be considerable and, if a drainage system is not provided, it must be assumed that a film of surface water could rise to the ground surface at the back of the wall; see figure 7.58.

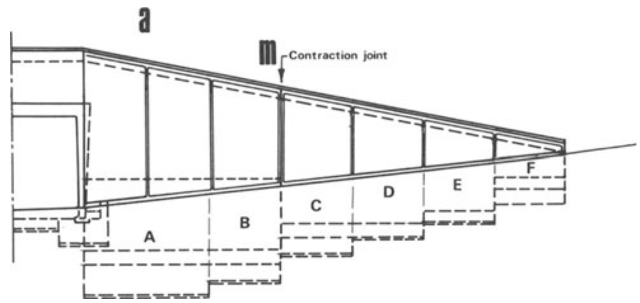
j The length of the heel was limited by site restrictions and hence a toe was also incorporated to provide the necessary resistance to overturning and reduce ground bearing pressures. The downstand was required to provide resistance to sliding; see figure 7.58.

k The vertical reinforced upstands on the base provided the means of (1) preventing side sway of the portal legs and (2) support to the bottom waling of the trench timbering while the portal units were being winched into position.

l In order to ensure effective permanent support, lean-mix concrete was used to fill the working space below the gas and water mains. The pipes were wrapped with fibre board (Flexcell) and polythene sheet to allow for thermal movements and the pipe bedding was formed with granolithic concrete.

m Contraction joints were provided in the wall stem only (down to kicker level) at the major change in wall section between B and C to accommodate shrinkage in the concrete. (Note: expansion joints would also have been necessary had the wall been longer.) See figure 7.58.





b

	SECTION		A	B	C	D	E	F
WALL 1	TOP OF WALL	a	105.350					
		b						
	GROUND	c						
		d						
WALL 2		a						
		b						
		c						
		d						
WALL 3		a						
		b						
		c						
		d						
WALL 4		a						
		b						
		c						
		d						102.540

Figure 7.58 Retaining walls

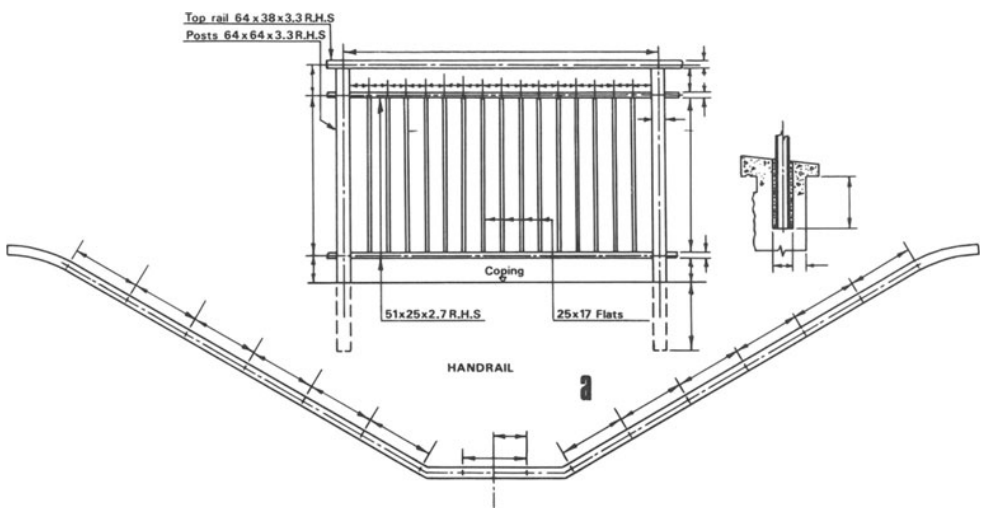


Figure 7.59 Handrailing

prepared and presented. For example, the documents that an organisation may prepare for work carried out by its own direct labour force will be different from those needed for a formal contract.

The purpose of this section is to introduce the reader to some general aspects of civil engineering. Reference is made to the case history for the design and construction of a small pedestrian subway wherever this is considered to be helpful.

7.5.1 The Project and the Promoter

As explained in the Introduction the need for a scheme must be established, and there must be a promoter who will finance the design, construction and future maintenance. The subway which is the subject of the case history described in this section was intended for the safety and convenience of people living in the vicinity, and its construction was phased in with the development of a community and shopping centre and the completion of a network of major footways. The promoter was a local authority.

The site of the subway was established during the early over-all planning stage for the whole development area, and the longitudinal design alignment of the road over it was raised locally to avoid the need for pumping, and to provide more convenient gradients on the approach footways to the subway. The subway was not constructed at the same time as the road because of cut-backs in public expenditure at that time.

7.5.2 The Site

From a planning and traffic engineering point of view, the location for the subway was ideal and lent itself to a design approach in accordance with the latest recommendations of the Department of Transport. However, the design and construction were complicated by the presence of major Public Utilities mains adjacent to the road, and also by the levels of these mains and the sewer into which the subway was proposed to drain. Because the subway was to be constructed beneath an existing road on an embankment, the effect of the work on vehicular traffic had to be taken into account.

Site investigations involved establishing the nature of the foundations of flats being constructed near the site, and a trial hole to confirm the nature of the ground. Discussions with the contractors' agent for the flats, and also with the foreman who was involved with the road construction, yielded useful information.

A site survey and levelling were carried out, and the position and levels of existing mains and sewers likely to influence the design and construction were established.

7.5.3 The Design

People generally will not use a subway except when the sheer continuous volume of traffic or a physical barrier prevents them from doing otherwise, or unless it is made convenient for them to do so. They may also be discouraged from using a subway which has dark corners, for fear of assault. It follows that any subway (underpass) should ideally be (1) as short as possible, (2) high enough to permit shallow gradients on approach paths and facilitate gravity drainage and (3) straight from end to end. It should be said that in developed areas all three ideals can rarely be achieved.

For any scheme, a great deal of time can be saved if the essential considerations likely to influence the design can be grasped at the outset. Having completed the survey and site investigations for this subway the essential factors were considered to be

(1) disruption to traffic and inconvenience to pedestrians.
(2) problems associated with the location and levels of the existing mains and sewers (figure 7.57).

This scheme was estimated to take 6 months to complete. The cost of a substantially constructed complete road diversion was considered prohibitive, and would have involved encroachment on to private property. After discussions with various bodies and consideration of alternative routes, a 2 month complete road closure for the main construction, plus the operation of a single line signal-controlled system after that time, was considered feasible.

7.5.4 Approvals

Since the County Council adopted and assumed the responsibility for maintenance of the subway, the detail drawings were submitted to them for technical approval. Prior to this, internal approval of the basic proposals and of the expenditure on the project was required from a committee appointed by the Local Authority.

7.5.5 The Contract Documents

A decision was made to employ a contractor for the construction of the subway. Most organisations have established rules governing the manner in which contractors are invited to tender for schemes. The procedures to be followed will invariably be related to the estimated cost of the work.

Local Authorities are empowered under Acts of Parliament to enter into contracts and establish strict financial regulations called 'standing orders' which govern their activities. Many contracts are entered into under seal. Most contracts for civil engineering work in the United Kingdom include the following documents

(1) form of contract
(2) general conditions of contract
(3) specification
(4) bill of quantities
(5) contract drawings
(6) form of tender.

The *form of contract* is the formal agreement of the two parties to the terms of the contract.

The *general conditions of contract*, which stipulate the terms under which the contract is to be conducted, are usually the 'General Conditions of Contract' prepared by the Institution of Civil Engineers and the Federation of Civil Engineering Contractors.

The *specification* is a detailed description of the standards of materials and workmanship to be used in the construction, and directions regarding the manner in which certain sections of the work must be undertaken. Unfortunately, despite the amount of work that goes into the preparation of a specification, often not all those who need to study it will do so. This gives the drawings an even greater importance. Notes on drawings often contain, in an abbreviated form, essential information drawn from sections of the specification.

A *bill of quantities* is a list of the various items of work included in the contract, against which the contractor (tenderer) will enter a price. If the *Standard Method of Measurement of Civil Engineering Quantities* issued by the Institution of Civil Engineers is adopted, then a coding system can be used which enables the length of item descriptions to be drastically reduced. Figure 7.63 shows an example of taking off the quantities from the drawings, before the preparation of the bill of quantities, and also as a measure of finished work during construction. The code numbers (which are entered in front of item descriptions in the bill of quantities) used in the example have the following significance

F | 1 | 5 | 7
- 7 — Sulphate-resisting cement; 20 mm aggregate
- 5 — Grade 30 (CP 110)
- 1 — Designed mix for ordinary structural concrete
- F — In-situ concrete

F | 7 | 4 | 3
- 3 — Thickness 300 to 500 mm
- 4 — Wall
- 7 — Reinforced concrete
- F — In-situ concrete

The *contract drawings* are the drawings issued by the engineer to the contractor before and during the course of the works. A distinction must be made here between 'tender documents' and 'contract documents'. Both have legal importance, but it must be remembered that the contractor has based his price for the work on the tender documents, although it is the contract documents that govern the way in which the work is to be carried out. The reason for the distinction is that the engineer is empowered to issue amendments to the specification, drawings and quantities at any time, but the contractor may then claim for any additional costs that these might entail. It is the tender documents that form the basis of the signed legal contract, but the contractor is still obligated under these terms to carry out the work in accordance with the contract documents. It is worth bearing in mind that any tender drawings produced subsequent to the signing of the contract, for legal purposes, must be exactly the same as the originals in every detail. The production of copy negatives may be considered advisable, but, in any event, it is always worth while making a few extra copies of the tender drawings in case the negatives are amended.

The *form of tender* is the formal offer by the contractor to carry out the works in accordance with the contract within a stated period.

Figures 7.57 to 7.64 amplify some of the above remarks and also illustrate some of the stages of construction.

7.6 RECORDS

The keeping of accurate and comprehensive records should be a feature of every civil engineering project. However, it is important to remember that there may be instances when site staff are unable to maintain all the records considered desirable when the construction works started. When problems arise or alterations prove necessary, the importance of keeping records will be at its greatest, whereas, because of the increased supervisory workload, the time available for keeping them will be at its lowest. In this unsatisfactory event a decision may then have to be made as to which records are absolutely essential. They should include the following.

(1) A site diary in which a daily record is kept of activities and events, verbal instructions given or received, visitors to the site, comments regarding progress and site problems, weather conditions, unforeseen ground conditions, etc. Site diaries will be kept by both the employer's and the contractor's site staff. A hard covered A4 size book with lined paper is normally used. The title of the project, the name of the person keeping the records, and both the

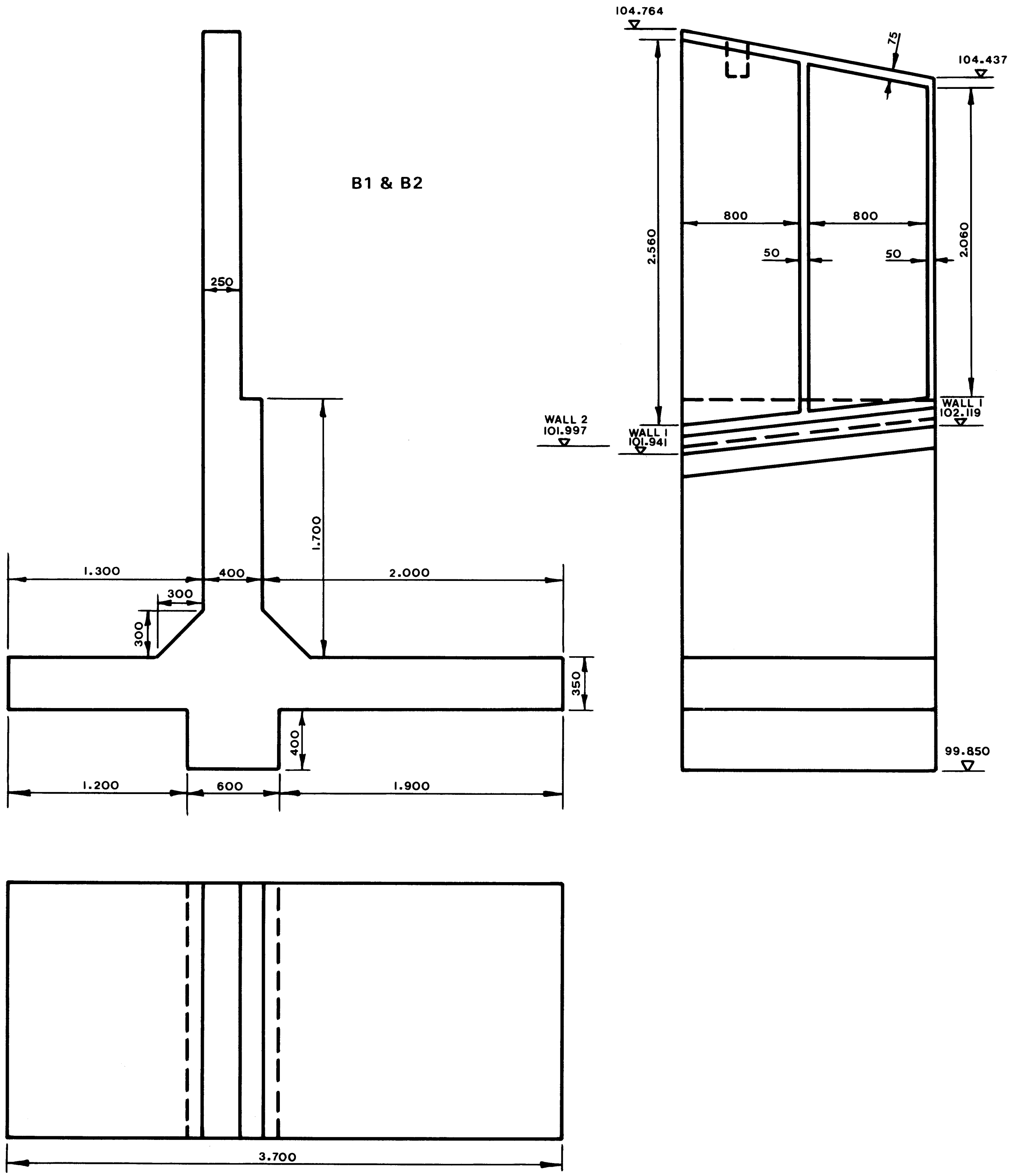


Figure 7.60 Retaining wall – outline detail

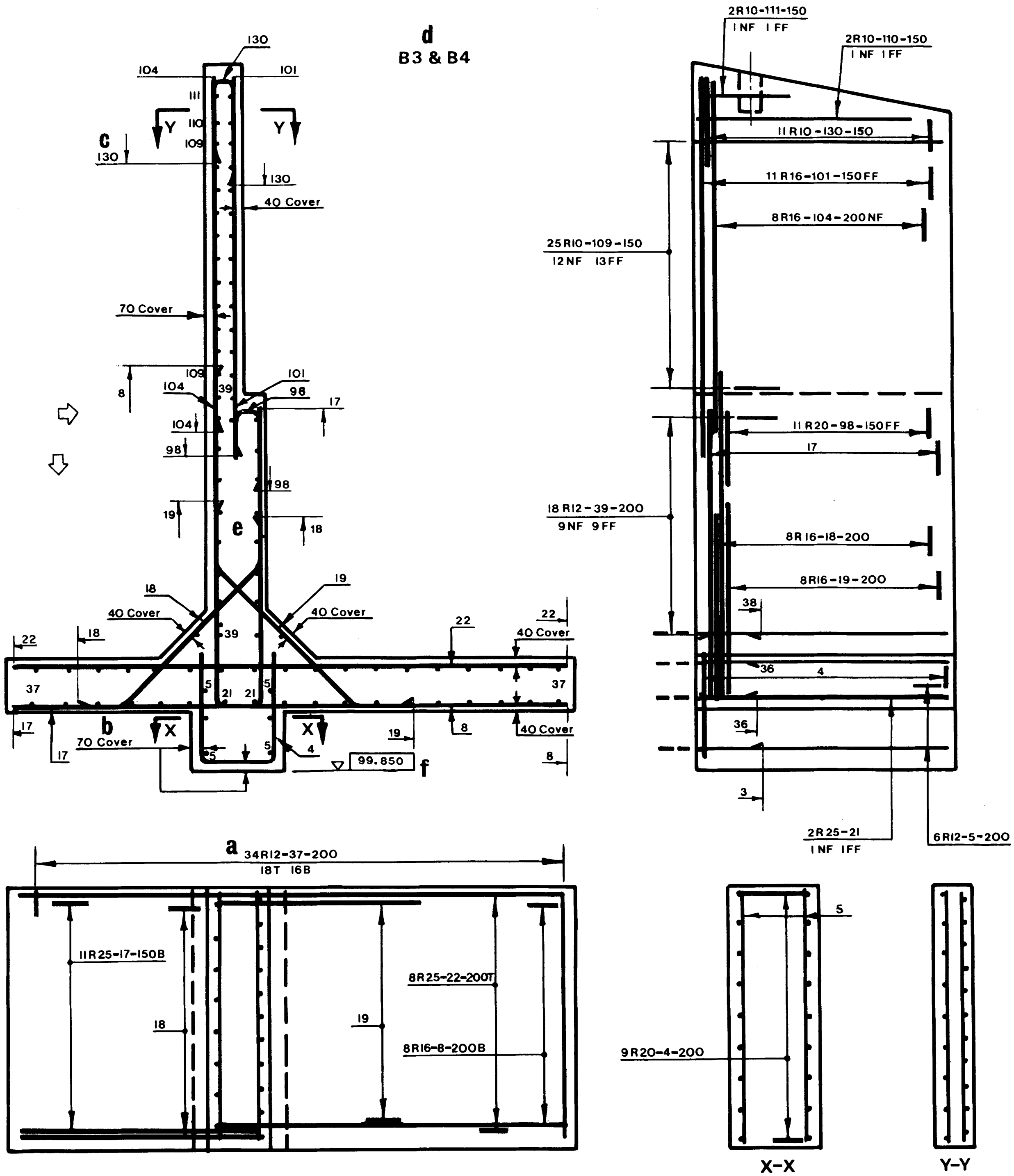


Figure 7.61 Retaining wall – reinforcement detail

a Each group of bars completely called up once only. (34 mild steel bars 12 mm diameter with a bar mark 37 at 200 mm centres. 18 bars in the top of the slab and 16 in the bottom.)

b Concrete poured directly against the clay sides of the downstand. Hence the cover to the reinforcement has been increased to 70 mm.

c Mark to indicate the end of the bar.

d The locations of the wall sections B3 and B4 are shown on the layout (general arrangement) plan.

e Corner splays and diagonal bars provided at the junction of the stem and base to resist high moments.
'U' bars (mark 98) should be used, rather than cranked bars, where the stem is reduced in thickness.
The cover to the reinforcement on the front of the stem has been increased to 70 mm where a textured finish to the wall is required.
Note that all bars are shown in full on the section.
'U' bars (mark 130) have been provided at the top of the stem to act as spacers between the two layers of vertical reinforcement and provide some resistance to possible impact forces against the top of the wall.

f Base level indicated. Other levels and dimensions are shown on the outline detail drawing. (See figure 7.60.) The shape of wall sections B1, B2, B3 and B4 are the same up to the point where the stem reduces in thickness, in order to simplify the steelfixing and formwork.

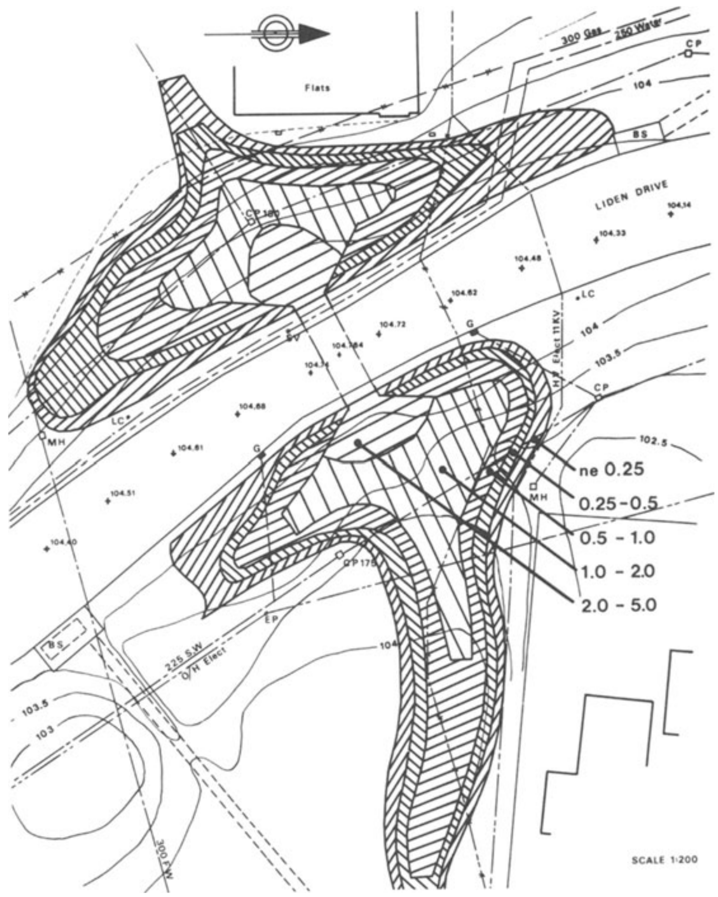


Figure 7.62 Plan showing excavation isopachytes

Isopachytes, which are lines of equal depth, provide a convenient means of measuring and representing bulk excavation. The depth ranges shown on the diagram correspond to those stipulated in the *Standard Method of Measurement of Civil Engineering Quantities.* An even clearer picture can be obtained on prints by colouring. The colouring of each depth range is gradually darkened as the depth increases. The limits of drainage areas can be established by a similar technique.

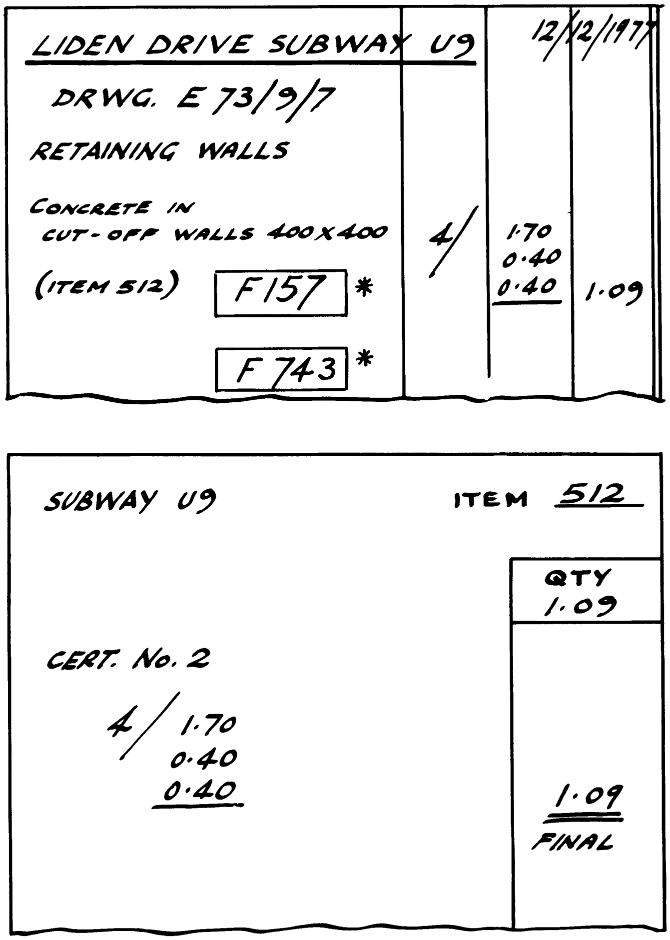


Figure 7.63 Bill of quantities – initial taking-off and interim measurement during construction

Figure 7.64 Stages of construction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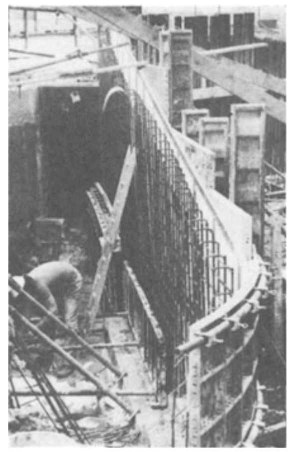

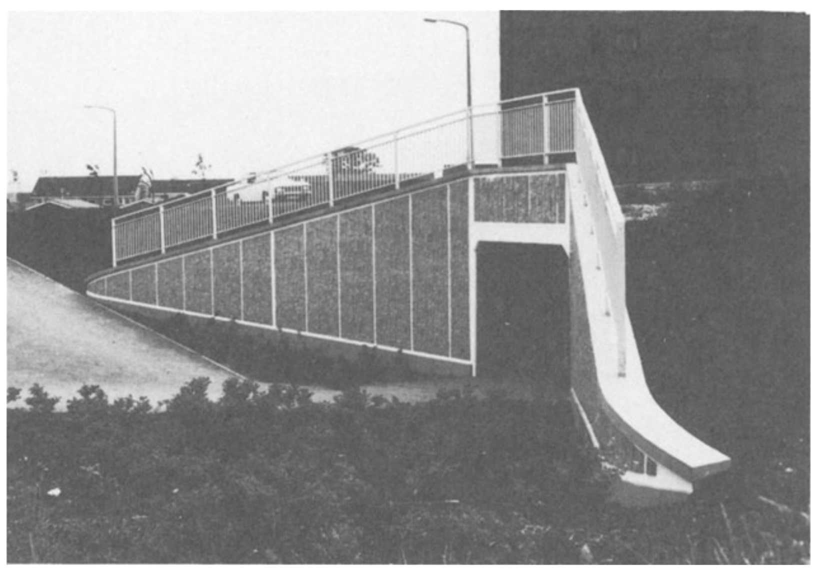

employer's and contractor's names, addresses and telephone numbers should be entered at the front. The date and weather conditions should be recorded at the start of each entry. A line should be ruled across the page immediately below each entry and there should be no space between successive entries.

(2) A daily record of all the plant, labour and materials used on the job and where it was used. The contractor will be responsible for keeping these records and will usually be asked to supply the employer's resident engineer with copies. The clerk of works should also keep similar records.

(3) A complete 'as built' set of drawings showing all the modifications to the scheme together with a record of the ground conditions and the positions and details of cables, pipes, buried structures and similar features encountered during the course of the works. Figure 7.65 shows a hastily produced sketch later used in the production of a record drawing.

(4) A record of the progress made on each section of the works which is then compared with the programme.

(5) A diary for reminders, lists of subjects for diary entries, sketches, dates when photographs were taken, etc., which are more conveniently entered in a pre-printed day-to-a-page diary. It is also helpful to fix photograph strip prints, which are easier to inspect than negatives, into this diary prior to proper indexing.

(6) A 'schedule of condition', including photographs, of all property in the vicinity of the works. Schedules of condition should be made just before the job starts and at periodic intervals thereafter, and should be agreed by all parties to the contract.

(7) Record and progress photographs to substantiate and illustrate recorded works or events. Proper indexing of negatives is essential.

(8) Minutes of formal site meetings.

It is strongly recommended that a site supervisor keeps records on a daily basis, even if this means working long hours on occasions. The use of a portable tape-recorder may be a help, particularly for schedules of condition.

A sharing of factual records between the contractor's and employer's staff should also be encouraged; this should help to minimise the chances of disputes.

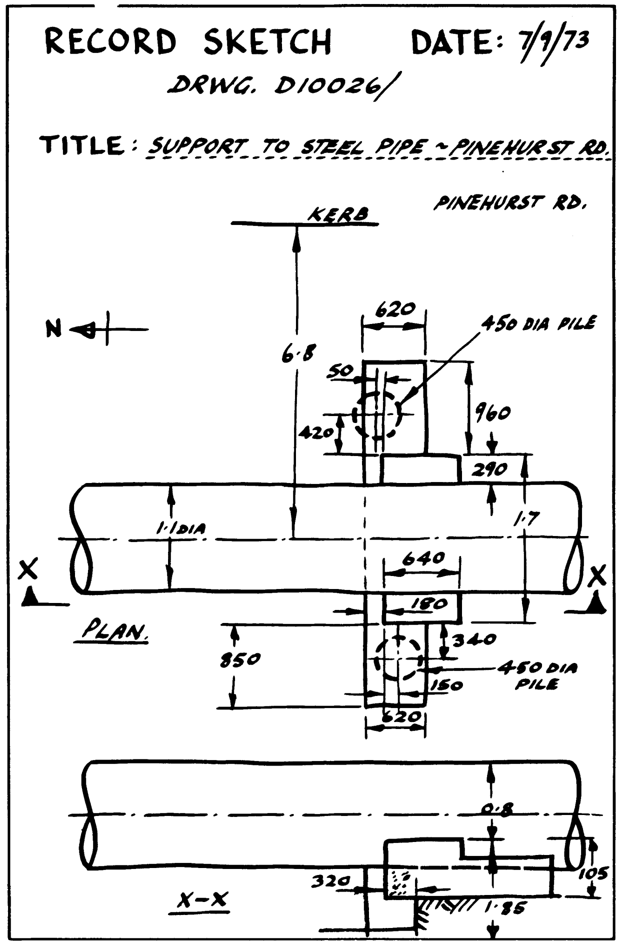

Figure 7.65 Record sketch

7.7 CONCLUSION

It is important for politicians, planners, engineers, architects and social workers alike to appreciate the considerable influence that technology has on society. Civil engineers will increasingly be expected to make social and moral judgements as well as financial and technical ones when presenting their proposals. Most people in the United Kingdom would agree that technological advancement has generally assured them of a high standard of living, but individuals who find themselves living within a few metres of a motorway, beneath the main flightpath from an airport or at the top of a high-rise block of flats, may not be so sure.

In the same way that written words are the tools of the philosopher and numbers those of the mathematician, drawings are undoubtedly the essential international language of the engineer. Gone are the days when one person or a small group of people, could be responsible for the conception, choice and completion of a project. Frequently many professional disciplines and the general public are now involved in the decision-making process and a greater responsibility rests with the engineer to present alternative proposals in the most effective and realistic manner, using, if necessary, three-dimensional drawings, models and photographs. The satisfactory completion of the chosen project will depend both on the adequacy of the design and on the quality of the construction drawings.

APPENDIX I EXAMPLES OF CONSTRUCTED PERSPECTIVE

A LARGE FOOTBRIDGE DRAWN IN PARALLEL PERSPECTIVE

Figure I.1 Plan and elevations

(1) Draw a plan and elevations of the basic outlines only of the bridge.

(2) It is assumed that the view required will be that of a motorist driving towards the bridge. The eye level EL is therefore taken to be 1.2 m above the ground and the centre of vision CV is 2.0 m from the kerb. The picture plane has been fixed to coincide with the nearside edge

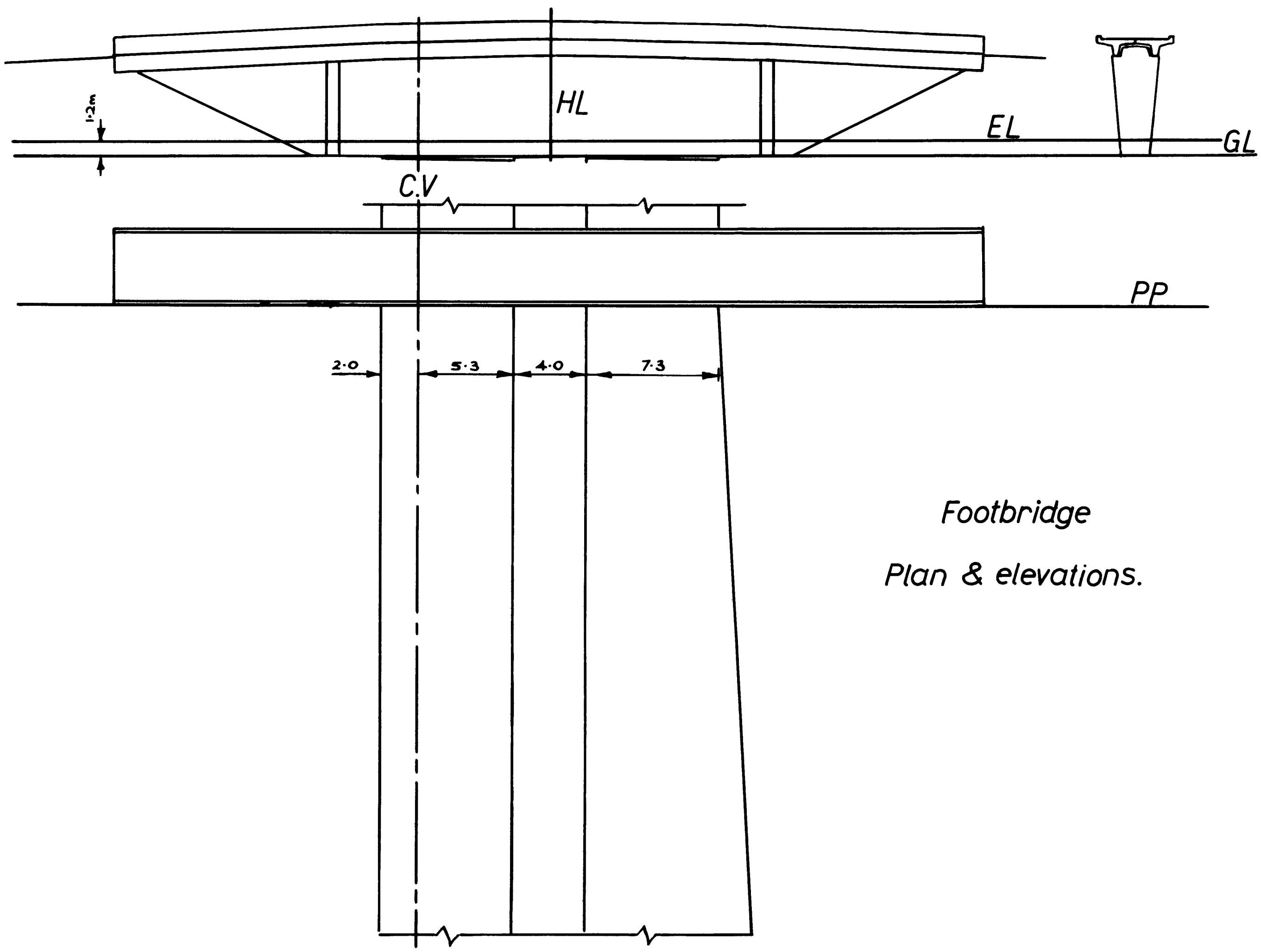

Figure I.1

of the bridge deck. The height line HL is a convenient vertical reference line on the picture plane PP along which measurements can be made to scale. In this case the height line is on the centre line of the bridge. The horizontal reference line has been taken as the ground line where it lies on the picture plane. Note that scale measurements can only be made along lines which lie on the picture plane and will be taken along the two reference lines HL and GL in this example. Draw GL, EL, CV and HL on the front elevation.

(3) The central visual plane is at right angles to the picture plane. The kerb line, adjacent to the observer, is also at right angles to the picture plane. Draw in the line of the central visual plane on the plan. The station point will lie on this line.

Figure I.2 Fixing the position of the station point

(1) As explained in section 4.3.3, all the features to be illustrated must be encompassed within the cone of vision, which is usually assumed to extend horizontally to 30° (but 20° if possible) either side of the central visual plane, and to 22½° (15° if possible) vertically above and below the eye level plane. These angles are called the angle of vision AV. Applying these two criteria, it is established that the station point must be 116.5 m from the picture plane.

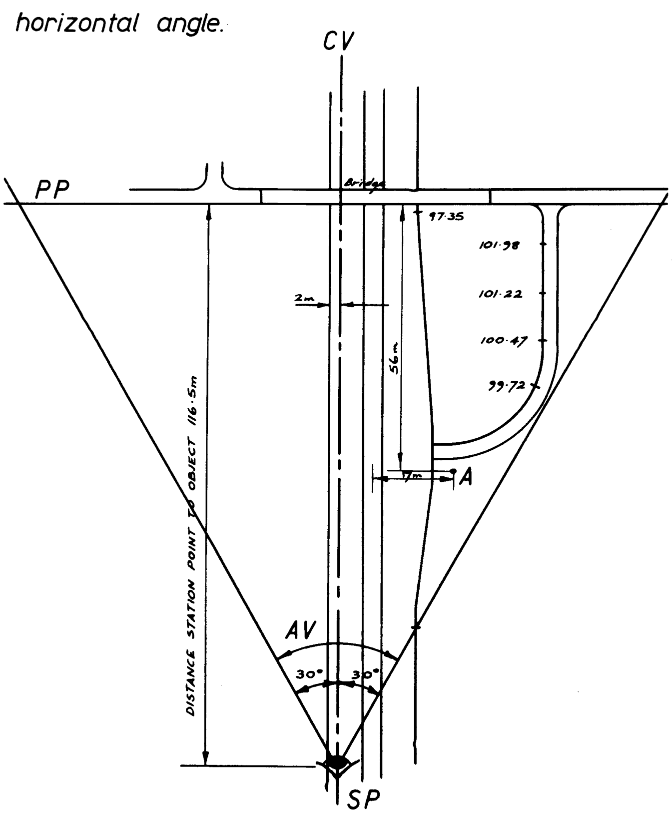

Figure I.2

Figure I.3 Setting-up

(1) The lines and points necessary for the perspective construction are now established. Draw in EL, GL, CV, HL and SP to a suitable scale.

(2) The single vanishing point VP is at the intersection of CV and EL.

(3) For the purpose of determining the dimensions to points which are not on the picture plane, a point called the 'measuring point' MP is now established. With VP as centre, draw an arc from SP to intersect EL at MP.

Figure I.4 Method of construction

(1) The lamp column shown at point A in figure I.2 will be established on the perspective view to illustrate the method of construction.

(2) The column is 56 m from the picture plane, measured in a direction parallel to the central visual plane. Set off this distance a–c to scale along GL to the right of HL. Note that for points behind the picture plane the distance will be set off to the left of HL. Draw a line from MP through c to intersect the HL at d.

(3) The column is 17 m to the right of HL. Set off this distance a–b to scale along GL to the right of HL. Draw a line from VP through b, to intersect a line parallel to a–c from d at e, the foot of the column.

(4) The column is 7 m high. Set off this height b–f to scale parallel to HL. Note that b–f is on the picture plane and can therefore be measured to scale. The line b–f would have represented the column had it been situated on the picture plane, that is, just in front of the bridge. Draw a line from VP through f, to intersect a vertical line from e at g. The line e–g represents the column in its true position.

Figure I.5 The finished perspective.

A SMALL FOOTBRIDGE DRAWN IN ANGULAR PERSPECTIVE

Figure I.6 Plan and sections

(1) Draw the plan and elevations of the bridge.

(2) It has been assumed that the bridge is viewed from a point somewhere along a line parallel to a–c and 14 m from the centre of the bridge.

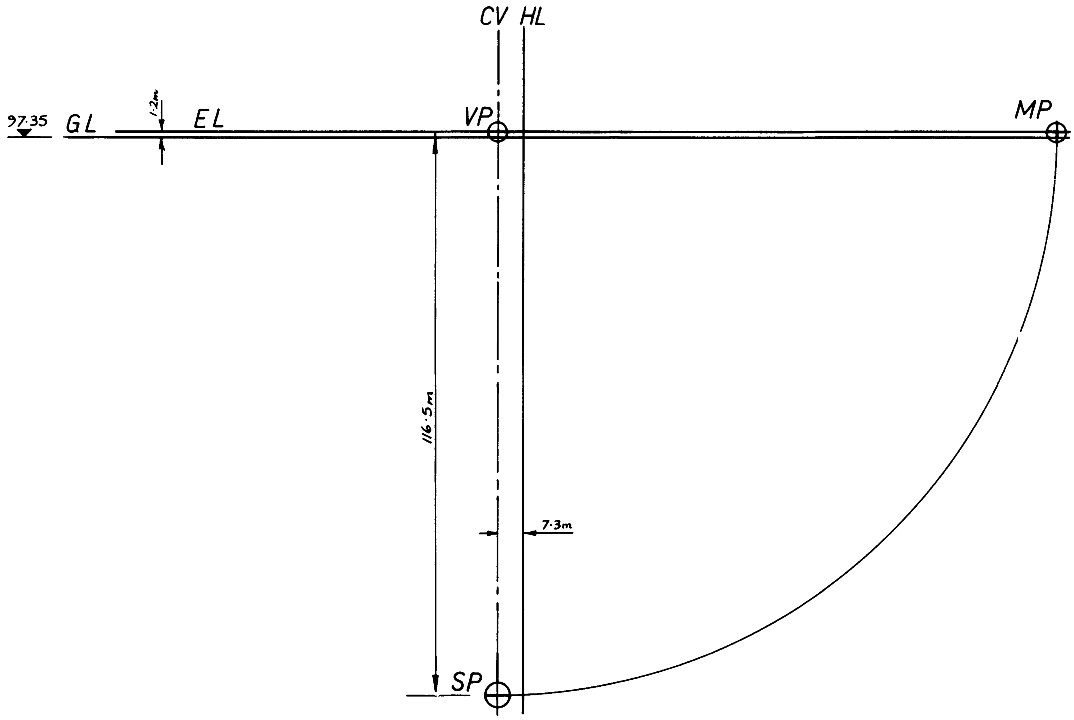

Figure I.3

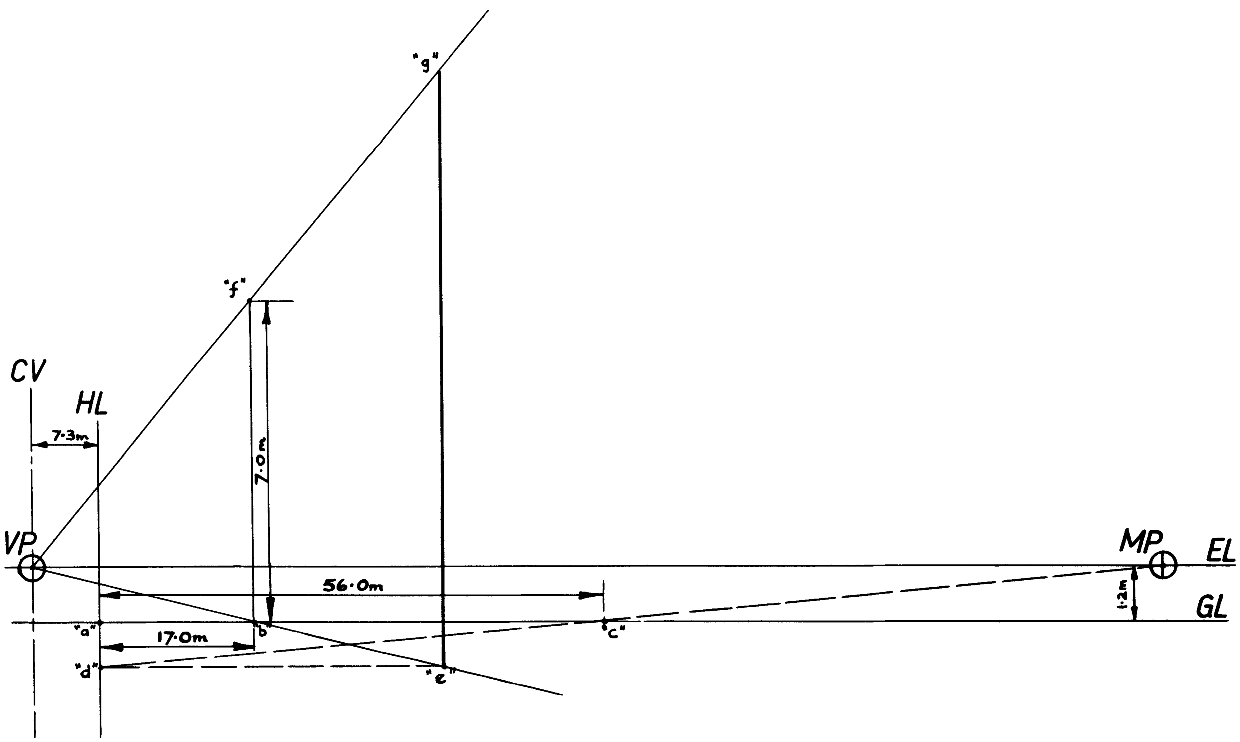

Figure I.4

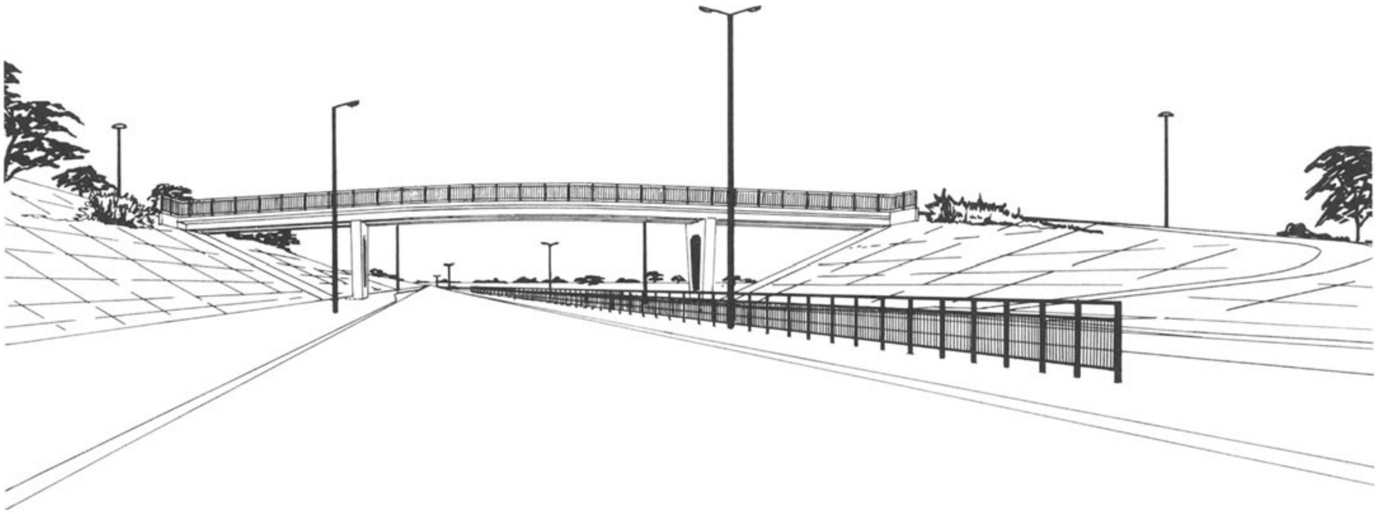

Figure I.5

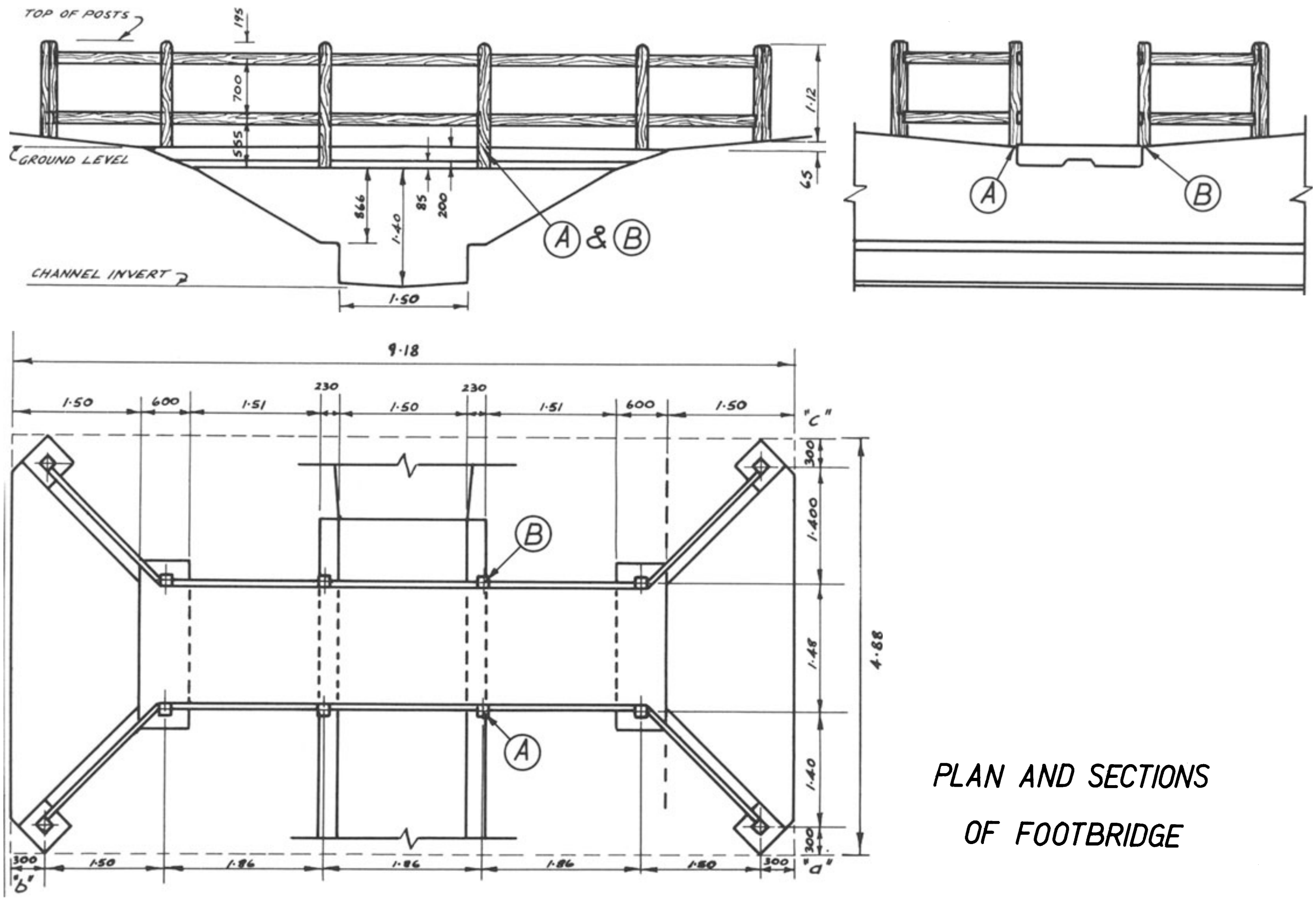

Figure I.6

Figure I.7 Fixing the position of the station point

(1) The elevation of the bridge which has the greatest prominence in the perspective view will depend on the orientation of the plan in relation to the picture plane. In order to give the sides a–b and a–c equal prominence they have been arranged at 45° to the picture plane PP. Draw PP through a which has been chosen as the point through which the height line HL will be drawn.

(2) Applying the horizontal and vertical angles of vision criteria, as in the previous example, it is found that the station point must be 16.6 m from the picture plane.

(3) Draw the central visual plane from the station point and at right angles to the picture plane. The distance along the picture plane from the corner a to the centre of vision is scaled as 1.62 m.

(4) The observer is standing on ground that is higher than the bridge deck. The eye level EL is 2.70 m above the ground level GL (65 mm above deck level) at the bridge. Measurements will be made to scale along the two reference lines HL and GL.

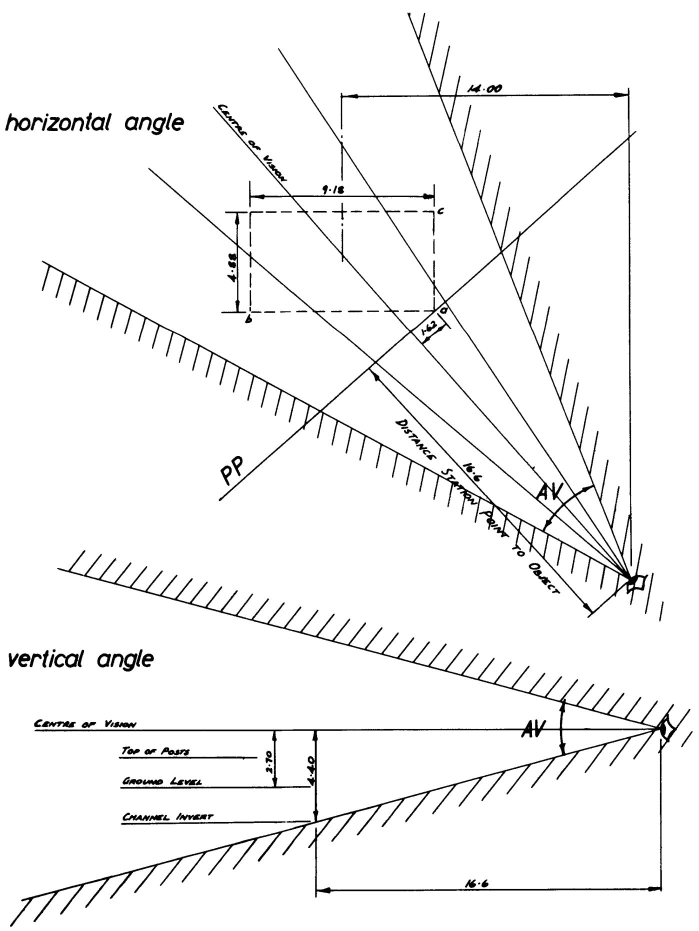

Figure I.7

Figure I.8 Setting-up

(1) Draw the horizontal ground line GL and the eye level EL spaced 2.70 m, to scale, apart.

(2) Draw the centre of vision line CV and height line HL 1.62 m apart.

(3) Establish the station point SP on CV at a distance of 16.6 m from EL.

(4) Draw a line from SP parallel to side a–b and establish the vanishing point VP left at the intersection with EL. Establish VP right as shown.

(5) With VP left as centre, draw an arc through SP to establish the measuring point MP left at the intersection with EL. Establish MP right as shown.

Figure I.9 Example of construction

(1) The points A and B in figure I.6 will be established on the perspective view to illustrate the method of construction.

(2) The plan coordinates of point A are 3.66 m in the direction a to b, and 1.70 m in the direction a to c. Point A is also 65 mm below GL. Hence fix d on HL 65 mm below a, locate e on GL 3.66 m, to scale, to the left of a, and h 1.70 m to the right of a.

(3) Draw lines from e and h towards the measuring points and lines from a towards the vanishing points, to intersect at f and m. The lines joining the vanishing points to the intersection between the reference lines HL and GL are termed measuring lines ML.

(4) Draw lines from d towards the vanishing points, to intersect verticals from f and m, at g and n. From g and n draw lines towards the vanishing points, to intersect at one of the required points A.

(5) The distance between A and B parallel to a–c is 1.48 m. Locate i on GL 1.48 m, to scale, to the right of h. Draw a line from i towards MP, to intersect the line from a towards VP at j. Draw a line from d towards VP, to intersect a vertical from j, at k.

(6) Draw a line from k towards VP to intersect the line from g towards VP at the other required point B.

Figure I.10 Detailed construction

(1) The reader will probably by now have observed two of the main problems associated with angular perspective. In order to locate the vanishing points on the drawing, the perspective construction must be drawn to a small scale. It

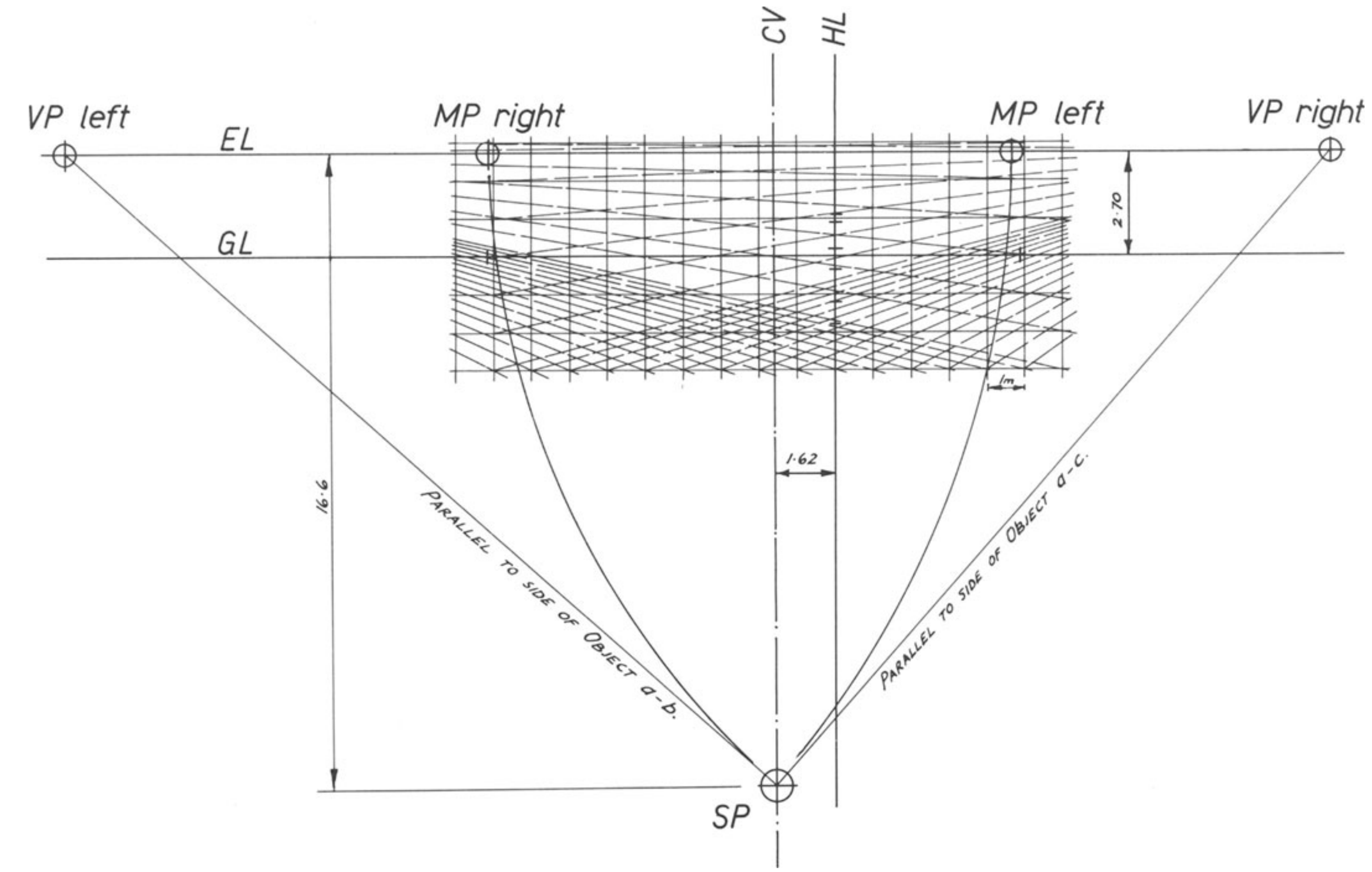

Figure I.8

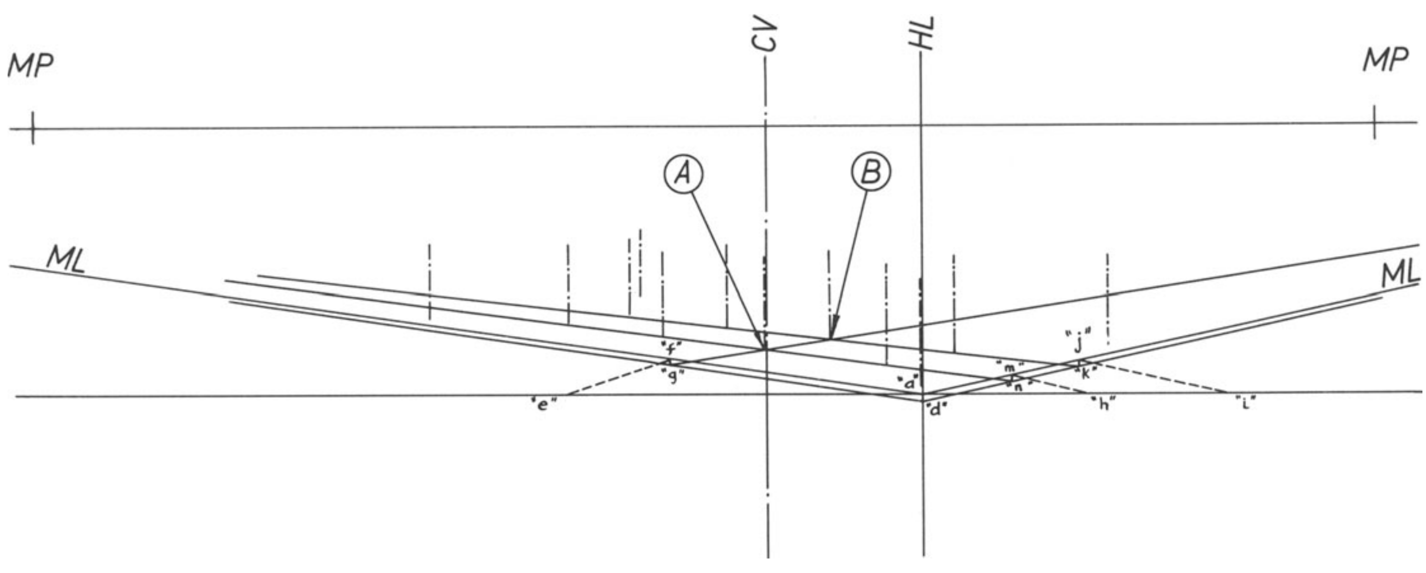

Figure I.9

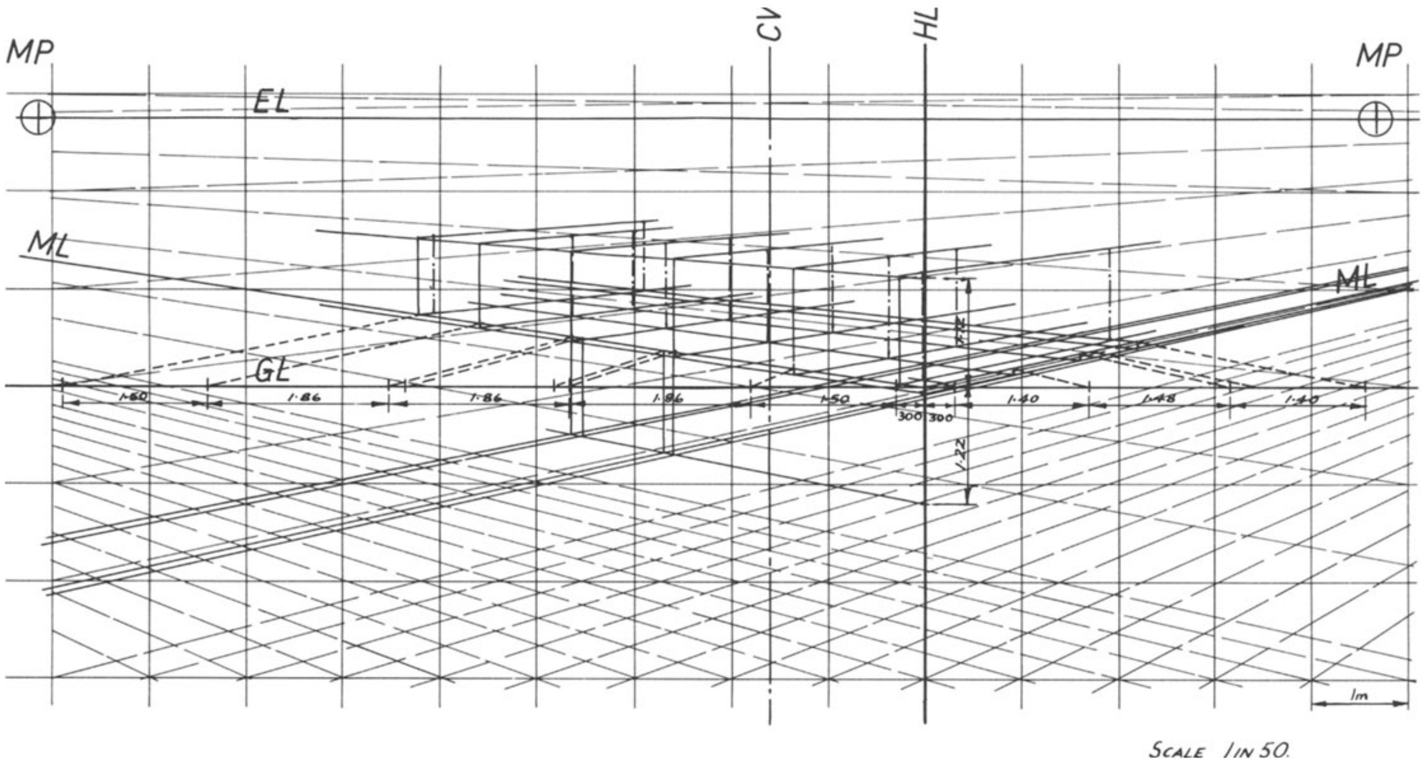

Figure I.10

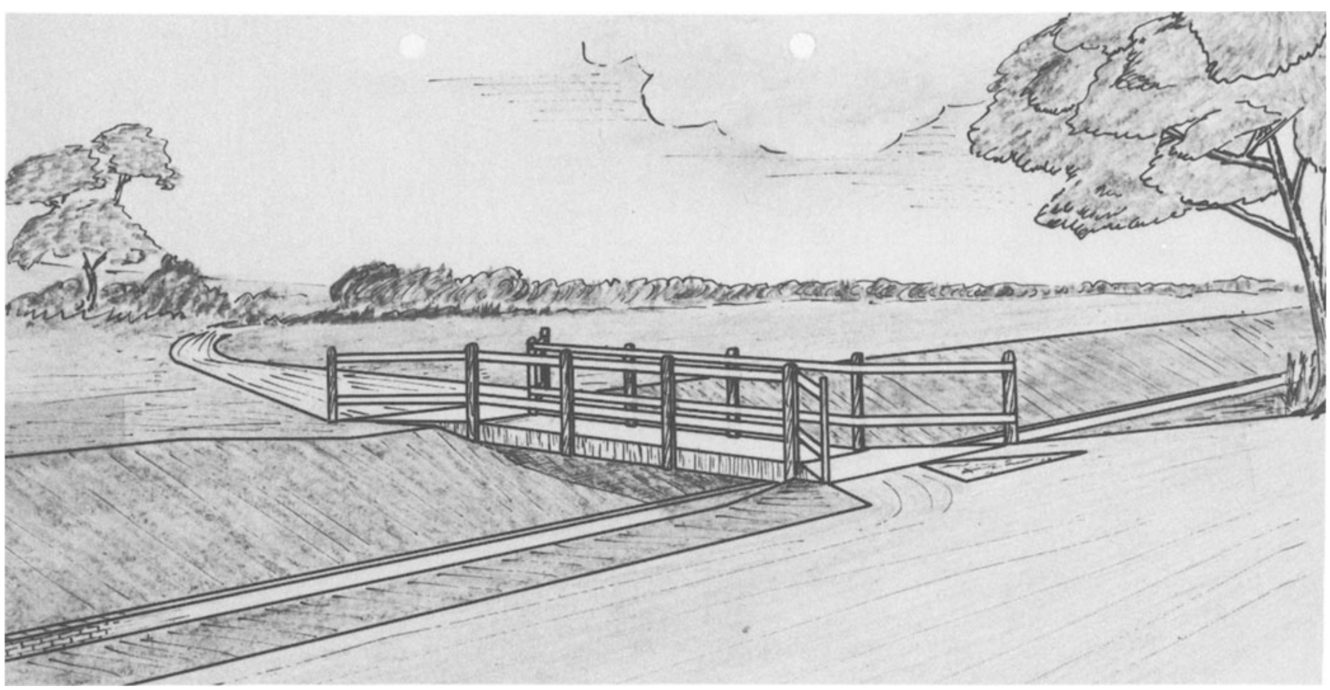

Figure I.11

will also be apparent that the lines radiating from measuring and vanishing points cross at acute angles, which can make the accurate location of points on the perspective view difficult.

(2) These problems can be partly overcome by drawing a grid with a series of lines radiating from vanishing points, as shown in figure I.8. The construction is then completed on an enlargement of the grid, as shown in figure I.10.

Figure I.11 The finished perspective

APPENDIX II
THE USE OF CALCULATORS IN THE DESIGN OFFICE

It is commonly accepted that calculators are now used widely in civil engineering design offices. An organisation may think twice about purchasing a sophisticated computer, particularly having regard to the recent rapid changes in computer science and technology. However, the purchase of calculators, even the more expensive programmable types, can usually be easily justified by the amount of technical time they save. Many of the calculations which have been performed by engineers in the past have been both tedious and laborious, and the use of calculators now enables them to devote more time to creative thought and the assessment of alternative schemes.

The reader given the task of selecting a calculator for personal or office use will be faced with a bewildering array of different models. Although dealing only briefly with this subject, it is hoped that this appendix will assist in making this choice.

First it is essential to ask the right questions.

(1) Is the office work principally concerned with statistics, engineering, science or business forecasting, for example?
(2) Are the functions required principally trigonometrical, statistical, financial, arithmetical or mathematical? For example, which of the following might be most useful: logarithms and antilogarithms, reciprocals, squares, square roots, powers, factorials, π, sines, cosines, tangents, degrees to radians, etc.?
(3) How much money is available for purchase?
(4) Is the calculator required principally for site or office use?
(5) Do calculations often involve many steps or solving long equations?
(6) Do results need to be displayed quickly?
(7) What degree of accuracy is required?
(8) What size keys are preferred and is a positive click sound favoured when the keys are pressed?
(9) Would a print-out of the steps performed be an advantage?
(10) Are the same formulae used frequently?
(11) How robust and reliable does the calculator need to be?
(12) How small or portable does it need to be?

Most calculators use one of two logic systems.

(a) 'Standard (algebraic) logic' in which simple calculations are performed in much the same sequence as they are stated. For example, in the 'sum' $8 \div 2 = 4$, the 8 is first keyed in and appears in the display which is called the X register. When the function key $\div$ is pressed the 8 is copied into the Y register, which is not visible. When the 2 is pressed this figure replaces the 8 which was previously in the X register. Pressing the = key or another function key combines these figures in the X and Y registers in the way specified by the function key and displays the answer, in this case 4, in the X register.
(b) 'Reverse Polish notation' (RPN) involves a stacking procedure. Using the above example, first the 8 is keyed in and then appears displayed in the X register. This number is then copied into the Y register, by pressing the ENTER key. When the 2 is pressed this figure replaces the 8 in the X register as before. Pressing the function key $\div$ then displays the answer. The = key does not feature in this system.

Generally, the RPN system involves fewer key strokes than algebraic logic and does not require the use of parentheses.

There are also two basic types of display. Those using light emitting diodes (LED) have a relatively high power consumption. Batteries will last several hours and can be re-charged. The displays appear very quickly, which is an advantage in long programs. The display is difficult to see in direct sunlight. The other type of display uses a liquid crystal diode (LCD) which has a very low power consumption. Batteries can last 2000 hours or more and are replaced at the end of their life. The build-up of the display is slower than for LCD (but still very quick) but is easier to see in direct sunlight.

Calculators can be obtained with the following features.

(1) trigonometric, statistical, financial and many other function keys.
(2) A print out of the operations performed.
(3) Appreciable memory capacity.
(4) Programmable.
(5) A feature which makes it possible to retain a program in memory with the calculator switched off.
(6) A facility to store programs permanently on small magnetic cards. This avoids the need to step in a program manually each time it is required thus saving time and eliminating the possibility of an error caused by pressing a wrong key.
(7) The means to check and alter a program.
(8) An alpha (letters) mode.

The following example in the use of the Hewlett Packard HP67 programmable calculator is included to help the reader to appreciate the potential of these instruments. Only a few of this calculator's capabilities are used in the example.

Required
To determine the National Grid coordinates of points on the centre line of a circular horizontal road curve and the bearing of the tangent to the curve at each point, given the radius of the curve, the bearing of the tangent at the start of the curve, the coordinates and chainage at the start of the curve, and the chainages of the required points on the curve. (See figure II.1.)

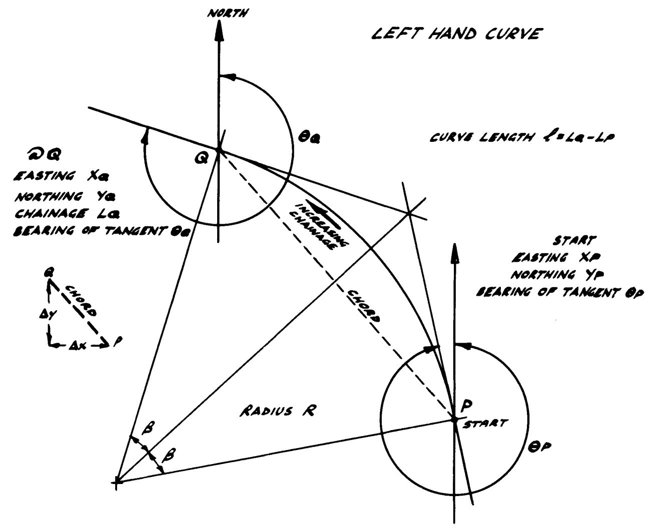

Figure II.1

Input	Radius in metres:	R
	Bearing of tangent at P:	p
	Coordinates at P:	Xp and Yp
	Chainage at P:	LP
	Chainage at Q:	LQ
Output	Coordinates at Q:	Xq and Yq
	Bearing of tangent at Q:	θ Q

Input and output angles are in degrees, minutes and seconds e.g. 13° 24′ 22″ would be keyed in or displayed as 13.2422.

A 'right-hand' curve is defined as a curve which bends to the right when looking in the direction of increasing chainage; a 'left-hand' curve bends to the left when looking in the direction of increasing chainage.

Procedure
Derive the required formulae and key in the program as shown in figure II.2 and then transfer the program on to a magnetic card.

Each time the program is used all the user has to do is to load the magnetic card which transfers the program back into the calculator automatically, and then follow the procedure shown in figure II.3.

With the lower-priced calculators in the HP range the program would have to be keyed in manually each time.

The HP 41C hand-held calculator has a large basic storage capacity, an alpha mode and a facility for the attachment of modules to enlarge the memory capacity, and a magnetic card reader. It has a 'program mode' and also a 'user mode' which enables the user to assign his own functions to certain registers in the calculator. This calculator therefore has a capability which not so long ago could only have been obtained on a computer.

LEFT HAND CURVE | R.H. CURVE

STEP	KEY ENTRY	KEY CODE	COMMENTS	KEY ENTRY (R.H. CURVE)
001	f LBL A	31-25-11	PROGRAMMED ONTO LABEL A	f LBL B
	DSP 3	23-03	DISPLAY TO 3 DEC PLACES	DSP 3
	RCL 1	34-01	LQ	RCL 1
	RCL 0	34-00	LP	RCL 0
	−	51	LQ − LP	−
	RCL 2	34-02	R	RCL 2
	÷	81	(LQ − LP) ÷ R	÷
	9	09	9	9
	0	00	0	0
010	×	71	90(LQ − LP) ÷ R	×
	h π	35-73	π	h π
	÷	81	90(LQ − LP) ÷ R ÷ π = β	÷
	STO 7	33-07	β COPIED INTO REGISTER 7	STO 7
	f SIN	31-62	sin β	f SIN
	2	02	2	2
	×	71	2 sin β	×
	RCL 2	34-02	R	RCL 2
	×	71	2R.sin β	×
	STO 6	33-06	2R.sin β COPIED INTO REGISTER 6	STO 6
020	RCL 7	34-07	β	RCL 7
	CHS	42	−β	RCL 3
	RCL 3	34-03	θ	f H→
	f H→	31-74	θ CONVERTED FROM ° ′ ″ TO °	+
	+	61	θ − β	RCL 6
	RCL 6	34-06	2R.sin β COPIED INTO X REGISTER	f R←
	f R←	31-72	CHORD AND CHORD BRG. CONVERTED TO RECT.	h x⇄y
	h x⇄y	35-52	COORDS. & FIGS. IN X & Y REGISTERS INTERCHANGED	RCL 4
	RCL 4	34-04	XP	+
	+	61	XP + Δx = XQ	R/S
030	R/S	84		h x⇄y
	h x⇄y	35-52	FIGS. IN X & Y REGISTERS INTERCHANGED	RCL 5
	RCL 5	34-05	YP	+
	+	61	YP + Δy = YQ	R/S
	R/S	84		RCL 7
	RCL 7	34-07	β	2
	2	02	2	×
	×	71	2β	RCL 3
	CHS	42	−2β	f H→
	RCL 3	34-03	θ	+
040	f H→	31-74	θ CONVERTED FROM ° ′ ″ TO °	f x>0
	+	61	θ − 2β	GTO 0
	f x>0	31-81	IF θ − 2β IS GREATER THAN 0....	3
	GTO 0	22-00	THEN GO TO STEP 48 (LBL 0).....	6
	3	03	IF NOT...	0
	6	06	ADD 360°	+
	0	00		f LBL 0
	+	61		g H.MS
	f LBL 0	31-25-00		DSP 4
	g H.MS	32-74	ANGLE θQ CONVERTED FROM ° TO ° ′ ″	h RTN
050	DSP 4	23-04	DISPLAY TO 4 DEC. PLACES i.e. ° ′ ″	
	h RTN	35-22		

REGISTERS USED :-

0	1	2	3	4	5	6	7
LP	LQ	R	θ	XP	YP	2R.sin β	β

Figure II.2

STEP	INSTRUCTIONS	INPUT DATA	KEYS	OUTPUT DATA
1.	LOAD CARD - SIDE 1			
2.	INSERT CARD IN WINDOW SLOT			
3.	STORE START CHAINAGE LP	LP	STO 0	
	STORE CHAINAGE AT Q : LQ	LQ	STO 1	
	STORE RADIUS R	R	STO 2	
	STORE BEARING OF TANGENT AT START θP	θP	STO 3	
	STORE START EASTING COORDINATE XP	XP	STO 4	
	STORE START NORTHING COORDINATE YP	YP	STO 5	
4.	GO TO STEP 5 FOR LEFT HAND CURVE			
	GO TO STEP 6 FOR RIGHT HAND CURVE			
5.	FOR LEFT HAND CURVE		A	XQ
			R/S	YQ
			R/S	θQ
6.	FOR RIGHT HAND CURVE		B	XQ
			R/S	YQ
			R/S	θQ

EXAMPLE. INPUT : NORTHING YP = 128 000 m. EASTING XP = 494 000 m
BEARING AT START θP = 347° 20′ 20″
RADIUS OF CURVE R = 50·08 m
CHAINAGE AT START LP = 421·23 m

OUTPUT : FOR LQ = 441·23, 461·23 and 474·98 :-

LQ	XQ	YQ	θQ
441·23	493991·887	128018·135	324° 27′ 26″
461·23	493977·361	128031·689	301° 34′ 32″
474·98	493964·811	128037·201	285° 50′ 40″

Figure II.3

APPENDIX III PUBLIC UTILITIES

Public Utility Undertakings in the United Kingdom have been established by Acts of Parliament to supply gas, water and electricity.

THE ELECTRICITY SUPPLY INDUSTRY

The present structure of this nationalised industry was established by The Electricity Act, 1957, and is organised as follows.

(1) The Central Electricity Generating Board is responsible for developing and maintaining the supply of electricity in bulk and transmitting it to twelve area Electricity Boards in England and Wales. In some cases the Generating Board supplies electricity direct to heavy consumers such as the United Kingdom Atomic Energy Authority and British Rail. The twelve Area Electricity Boards in England and Wales come under the Secretary of State for Energy (including the CEGB and the Electricity Council).

(2) The Scottish Electricity Boards (the South of Scotland Electricity Board and the North of Scotland Hydro-electric Board) are directly under the general control of the Secretary of State for Scotland.

(3) The Electricity Council has a coordinating and advisory role between the Generating Board, the twelve Area Boards and the Secretary of State for Energy.

All these bodies are autonomous and are directly responsible to the Secretary of State and through him to Parliament.

Approximately 226 000 million kilowatt hours of electricity were produced in 1978/79, 89 per cent by coal, oil and gas-fired power stations and 11 per cent from nuclear power stations. The main consumers were

domestic	37%
commercial	18%
industrial	40%

THE WATER INDUSTRY

The Water Act, 1973, brought about a major reorganisation of the water industry. Water supply, sewerage, sewage treatment, fisheries and recreation and land drainage functions in England and Wales are now provided by ten Regional Water Authorities.

Water supplies are obtained from rivers, canals or from water-bearing strata. The piped supply in 1978 averaged approximately 21 000 million litres per day, of which 40 per cent was for household use. A public water supply is piped to 99 per cent of the dwellings in England and Wales.

Sewerage services are usually provided by Local Authorities acting as agents for the Water Authorities and some private water companies provide the water supply in some areas. Total abstractions of water amount to 19 per cent of the average residual rainfall but most of this is returned to rivers. Total abstractions are made in almost equal proportions from (1) upland reservoirs and streams, (2) rivers, (3) ground-water, taken over the country as a whole but the proportions vary widely between one region and the next.

Household water consumption in 1978 amounted to an average of 120 litres per head per day.

The amount of sewage sludge, measured as dry solids, processed in 1978 was approximately 1.1 million tonnes. Approximately 95 per cent of dwellings are connected to public sewers.

THE GAS SUPPLY INDUSTRY

The present structure of the gas industry, which comprises a Headquarters organisation and twelve Regions, was formulated after the Gas Act, 1972, which established the British Gas Corporation and gave it the responsibility to acquire and distribute gas and also to plan and organise the industry in the United Kingdom.

The main gas transmission system has evolved as a result of the discovery of natural gas beneath the North Sea. By 1975 approximately 95 per cent of the gas used in the United Kingdom was obtained from the North Sea fields.

There are two categories of pipe used in the gas supply system, as follows.

(1) High-pressure transmission pipelines – all welded high-strength steel pipelines operated at pressures of up to 70 bar. They are used to carry gas in bulk quantities from reception terminals on the east coast to the major areas of demand – the fringes of cities and large towns. In addition to these 3000-odd miles of pipeline the twelve regions of British Gas operate some 7000 miles of pipelines.
(2) Lower-pressure 'distribution' mains operate generally in the urban and suburban areas and collectively amount to some 130 000 miles of pipe. A variety of materials including steel, plastics and ductile iron are used for these pipelines. A large proportion of the existing mains are cast iron and these are progressively being replaced by the modern materials.

In 1976 approximately 6200 million therms of gas were produced for domestic use, 6100 million therms for industrial use and 1500 million therms for commercial use.

POST OFFICE TELECOMMUNICATIONS

This industry operates more than 25 million telephones (17 million connections) in the United Kingdom and has installed over 6600 exchanges. Nearly 2 million telephones were installed in 1979 and the exchanges handled approximately 19 300 million telephone calls (53 million per day) in 1978/79.

Over 400 million telephones in 96 countries are now obtainable by International Direct Dialling. About 85 per cent of international calls are dialled direct. Equipment ranges from cables running 3 miles below the Atlantic to Intelsat communications satellites 23 000 miles above the Earth.

An important consideration which arises in relation to the provision of underground cables in streets is that, although gas, water and electricity supplies can be provided by a branch connection to the main, an additional telephone requires an exclusive pair of wires all the way from the customer to the local telephone exchange. As the number of customers for telephone service increases, new cables have to be installed from the exchange to provide the additional pairs required. If the streets had to be dug up each time additional cables were provided, the cost and disruption involved would be enormous. The Post Office have therefore built up an extensive network of underground ducts and jointing chambers over the country which are used as and when required. Most of the old ducts are earthenware but the Post Office is now introducing plastics because of its reduced weight, better impact resistance and the need for fewer joints.

The Water Authorities and the British Gas Corporation have statutory powers to carry out works in highways and private land, and to establish right of access to facilitate future maintenance and repairs to their apparatus. However, British Gas must initially seek to acquire easements by negotiation. The Post Office and Electricity Boards have similar powers but have to establish easements or wayleaves in private land by negotiation. (The Post Office is bound by the rules of the Wireless Telegraphy Act, which give it certain powers of insistence.)

A large proportion of the Public Utilities' main spinal supply networks extends across open country, but in urban and suburban areas in particular every effort is made to confine mains to highways. Broadly speaking, underground gas, water, Post Office and electricity mains follow ground contours, whereas sewers (except for pumping mains) must be laid in straight lines between manholes to gradients determined by hydraulic considerations. Sewers are generally deeper than other mains and are usually confined to carriageways, the footways being reserved for the other utilities in order to facilitate repairs and connections and minimise the risk of damage by traffic.

There are strict procedures to which Public Utilities and Highway Authorities must adhere in their activities, and these are laid down in the Public Utilities Street Works Act, 1950. This Act also applies to Street Managers, Sewer Authorities, Transport Authorities and Bridge Authorities or Managers.

Public Utilities are vital to prosperity, health and living standards in an industrialised society and civil engineering is associated with their activities in a number of ways.

(1) Most Public Utility projects involve civil engineering works to varying degrees. The work carried out by the Water Authorities is generally civil engineering in nature.
(2) Utility apparatus is frequently incorporated into civil engineering structures.
(3) Certain projects, although not requiring Utility apparatus as a part of their function, may nevertheless have to incorporate ducts or other facility to enable mains to be

carried through or over them at some future date, for example in bridges.

(4) Alterations to Utility apparatus are often required to facilitate civil engineering construction works.
(5) All too frequently underground and overhead Utility apparatus is damaged during the course of civil engineering construction works, often causing considerable disruption, injury and even loss of life. Repairs to mains are invariably costly and affect third parties.

Drawings have an important role to play in the measures needed to safeguard Utility apparatus. Layout and general arrangement drawings must show and describe accurately all the various existing and proposed apparatus of both Statutory and Non-statutory Undertakings. Records of existing apparatus should be verified by site investigations including hand-excavated trial holes. Precautions to be taken during construction works include the erection of 'goal posts' and bunting below overhead cables, fixing warning notices and marker signs and establishing procedures for informing site personnel about the locations of underground mains and the requirements of the Utility Authorities.

It is usually better to show existing Utility apparatus on the layout or general arrangement working drawing rather than on a separate plan. In order to avoid congestion on the drawing it may be advisable to use a larger scale than usual.

Important note: The word 'services' is often used loosely as a general term to describe Public Utility apparatus, but the temptation to use the expression in this context is best avoided. Services are the connections, often small in size, between mains and individual consumers or small groups of consumers, and misunderstandings could be serious.

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