



THIRD EDITION

**Brian Porter &  
Christopher Tooke**

# Carpentry and Joinery



2

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## Volume 2

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# Carpentry and Joinery

## Volume 2

**Third Edition**

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Elsevier Butterworth-Heinemann  
Linacre House, Jordan Hill, Oxford OX2 8DP  
30 Corporate Drive, Burlington, MA 01803

First published by Arnold 1984

Second edition by Arnold 1991

Reprinted by Butterworth-Heinemann 2001, 2002 (twice), 2003

Third edition 2005

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#### **British Library Cataloguing in Publication Data**

A catalogue record for this book is available from the British Library

#### **Library of Congress Cataloguing in Publication Data**

A catalogue record for this book is available from the Library of Congress

ISBN 0 7506 6504 1

For information on all Elsevier Butterworth-Heinemann publications visit our web site at <http://books.elsevier.com>

Typeset by Charon Tec Pvt. Ltd, Chennai, India  
[www.charontec.com](http://www.charontec.com)  
Printed and bound in Great Britain

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# Foreword

by W. R. Rose, author of *Carpentry and Joinery: Bench and Site Skills* and *Carpentry and Joinery: Work Activities*

The craft of the Carpenter and Joiner has a long and honourable history; from the time timber was first worked with stone tools. The great public and ecclesiastical buildings of the past and present are a testimony to the skill of those who chose to earn a living as workers of wood.

This skill, as in any other craft, depends upon the manipulation of the material, the proficient and confident use of machines and tools, an understanding of the characteristics of the material being fashioned, and the knowledge of how and why timber and timber products are worked and used.

Before the Great Fire of London in the 17th Century Carpentry and Joinery was based on custom and practice, but today with the speed of development of new materials, tools and techniques National, European and International legislation allows for the introduction of Regulations and Specifications which proscribe our actions as woodworkers, in order that we work in a safe manner, produce structures and products that are sound and fit for the purpose for which they are to be used, and conforming to prescribed requirements.

If the manufacture and installation of doors and windows do not meet the required standards and specifications warmed air is unnecessarily lost from the building, and additional carbon emissions are produced in replacing this heat loss.

Messer's Porter and Tooke in this revised 3rd edition of *Brian Porters Carpentry and Joinery 2* have provided information for the student and practicing Carpenters, details of the current legislation, the latest timber products, tools, and the craft techniques essential for the good practice of woodworking skills

# Foreword

by David R. Winson, Registrar of the  
Institute of Carpenters

Anybody having an interest in Carpentry and Joinery, whether they are undertaking an NVQ or SVQ, carrying out additional study to enhance the same by preparing for an Institute of Carpenters qualification, or even purely for reference, will find this book a valuable addition to their toolkit.

This book, the second in a series of three, provides the reader with step-by-step practical advice and sufficient knowledge to reach competency in a number of areas associated with on-site works. Its text is concisely written and the accompanying illustrations are clearly defined, helping the reader to quickly understand the subject matter.

Throughout its pages the book gives clear guidance, particularly in regard to Health and Safety and other equally important regulations, to enable the reader to carry out a wide range of different work both competently and safely.

It has been a privilege to review this further revised and updated edition of a much renowned textbook used extensively by those engaged in teaching the craft of Carpentry and Joinery. This book, along with the other two books of the series, has been included in the Institute of Carpenters' recommended reading list for nearly two decades and will continue to be so.

It has been particularly so in the knowledge that the authors, both members of the Institute, have more than seventy years' membership between them.

I wish all readers every success in their chosen careers and I am confident that this book will assist greatly in that success.

# Preface

The Building Industry is constantly changing with the introduction of new ideas and innovations. Since the last edition of Carpentry & Joinery Book 2 we have witnessed numerous changes to the Building Regulations and a movement to bring British Standards in line with Europe. Further pieces of legislation have also had a marked effect on our trade and how we operate – particularly in regard to Health and Safety.

Training needs for students have also seen major changes, with a much greater emphasis towards work based on the job training – qualifications now available to the Carpenter & Joiner now include:

Qualification	Level Available	Awarding Body
NVQ (National Vocational Qualification)	Wood Occupations: Levels 1, 2, & 3	CITB (Construction Industry Training Board) and C&G (City & Guilds)
SVQ (Scottish Vocational Qualification)	Wood Occupations: Levels 1, 2, & 3	
Construction Award	Wood Occupations: <ul style="list-style-type: none"> <li>● Foundation</li> <li>● Intermediate</li> <li>● Advanced</li> </ul>	
IOC Carpentry and Joinery	Carpentry & Joinery: <ul style="list-style-type: none"> <li>● Foundation</li> <li>● Intermediate</li> <li>● Advanced Craft (MIOC)</li> <li>● Fellow (FIOC)</li> </ul>	Institute of Carpenters
Master Certificate Scheme	<ul style="list-style-type: none"> <li>● Carpentry</li> <li>● Joinery</li> <li>● Shopfitting</li> </ul>	Institute of Carpenters The Worshipful Company of Carpenters City and Guilds The Worshipful Company of Joiners and Ceilers

With this revised new edition, we have taken into account all the changes we thought necessary in order to furnish the student or

craftsperson with updated information. This meets the requirements necessary for their endeavour to gain enough knowledge within their chosen Wood Occupation to be successful in their examinations and chosen career.

Because of the extensive cross-references and index in the book you should find navigating through it, and across the series quite a simple task.

Furthermore, references to Building Regulations, British Standards etc, are included at the end of each chapter.

This book has been revised to compliment new editions of *Carpentry & Joinery 1* and *Carpentry & Joinery 3*. As with all the books in the series, you will find that due to its highly illustrative content, it is very easy to follow. We believe that a textbook of this nature deserves well-detailed pictures and annotated diagrams which speak louder than words.

The first edition of this book came into print over 20 years ago and has proved itself time and time again as a valuable source of reference to students of all the wood trades across the world.

Finally, we both feel and ardently believe that Brian's final sentence of the Preface in his first edition, is as important as ever . . . "*Perhaps it could be said that the good craft worker is one who signs his or her work with pride.*"

Brian Porter & Christopher Tooke  
January 2005

# Acknowledgements

For this new 3rd edition we are both indebted to the help and assistance given by the following people and organisations, who helped us produce this volume and supplied all the necessary information. Also for their kind permission to reproduce photographs or illustrations.

Acrow plc: Fig. 3.20

Mrs B Cook of Building Research Establishment (BRE): Crown Copy-right extract Fig. 8.25, excluding diagram (d), originally from Defect Action Sheet DAS 83 (1986).

Bosch Ltd (UK): Figs 1.1, 1.4, 1.5, 1.24, 1.25, 1.30, 1.44. Source: Bosch Power Tools, [www.Bosch-pt.com](http://www.Bosch-pt.com).

Stacey Davis of British Gypsum (UK): Figs. 9.15, 9.16

Trevor Gibson of Gibson & Co Ltd: Fig. 8.13b

Noel Hall: Fig. 2.12

Health and Safety Executive (HSE)

Karphos GmbH & Co. KG, Germany: Fig. 9.14

Mowlem Northern Ltd: Figs 2.13, 3.13, 3.16, 3.18, 3.21

National House Building Council (NHBC)

Optical Measuring Equipment Cowley Ltd

Record Tools

Katherine Hughes of RMD Kwikform Ltd: Fig.10.18, 10.20

Peter Bond of SGB Scaffolding Ltd (UK) Ltd: Fig. 10.19

Andrew Burns of Stanley Tools Ltd: Fig. 8.13a, 8.18, 8.19. Figs. 8.18 and 8.19 re-drawn from Stanley QuickSquare Instruction Manual (1990).

Truss Rafter Association

Jeremy Vibert of TRADA: Fig. 8.20

York Survey Supply Centre: Figs 1.33, 1.34 (photo)

Amanda Wright of British Standards Institute (BSI), 389 Chiswick High Road, London W4 4Al, from whom copies of complete standards may be obtained:

Table 3.1 (BS 8110-1: 1997), Table 10.4 (BS 5973: 1993), (BS EN 60825: 1997), (BS 1282: 1999), (BS 4072: 1999), (BS 4261: 1999), (BS 5589: 1989), (BS 5268-5: 1989), (BS 5707: 1997), (BS 8110-1: 1997), (BS 5975: 1996), (BS EN 312: 2003), (BS 8103: 1996), (BS 476: 1997), (BS EN 39: 2001), (BS 1139: 1991, 1994), (BS 1129: 1990), (BS 5973: 1993)

Finally to Hilary Yvonne Porter for her continual help patience and support – to both of us, during the writing of this book.

Brian Porter & Christopher Tooke

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# 1

# Site setting-out

Setting-out involves different processes; one or more of which will be necessary before starting any constructional work. They include the following:

- linear measurement,
- working to a straight line,
- setting out angles,
- setting out concentric curves,
- establishing a datum,
- levelling,
- vertical setting-out.

The accuracy with which these are carried out will determine the final outcome of the work.

## 1.1 Linear measurement

Measuring distances greater than 1 m generally means using a retractable tape measure.

### 1.1.1 Measuring tapes

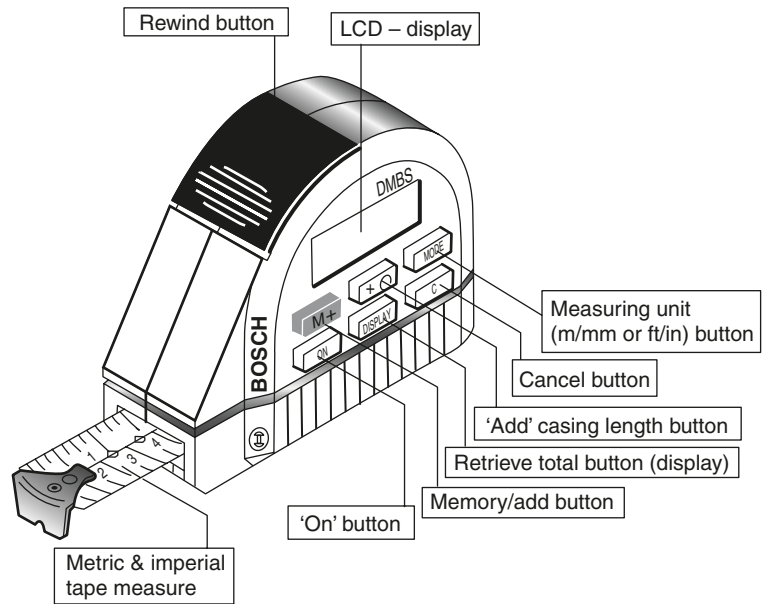
Available in a variety of lengths, made of steel or fibreglass coated with polyvinyl chloride (PVC) (linen tapes are now obsolete because of their tendency to stretch, they have been superseded by PVC-coated fibreglass types). Tapes under 10 m in length have a built-in lockable automatic retractable rewind mechanism (see Volume 1, Section 5.1.3), longer tapes are rewound manually.

Digital measuring tapes are available like the one shown in Fig. 1.1. Its liquid crystal display (LCD) panel is battery operated with automatic cut-off – measuring accuracies of  $\pm 1$  mm can be expected up to 5 m.

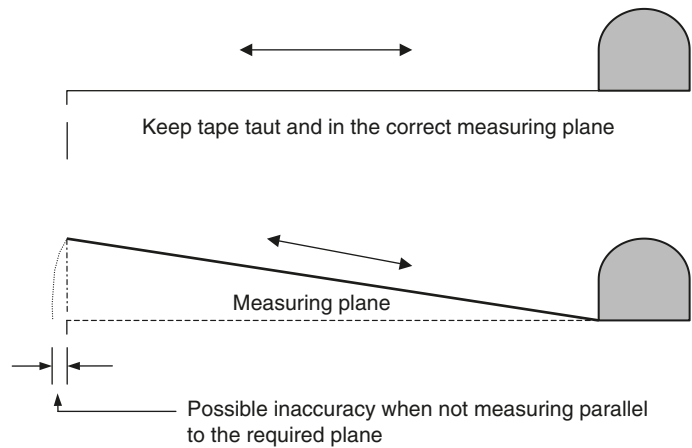
In use, the accuracy of a measuring tape will depend on:

- the clarity of its graduations;
- whether it is held in the correct plane (Fig. 1.2);





**Fig. 1.1** *Bosch digital measuring tape*



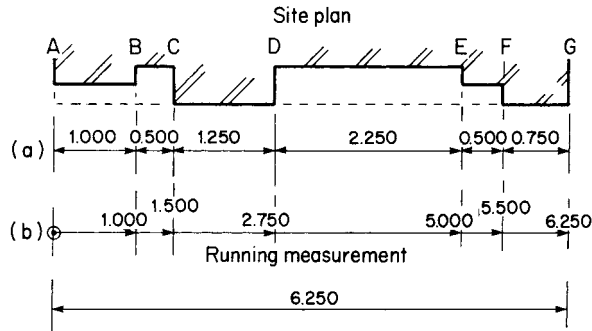
**Fig. 1.2** *Using a tape measure*

- the amount of, or lack of, tension being applied to the tape – very important when measuring long distances;
- readings being correctly taken from left to right.

Measurement errors frequently occur when measurements are transferred from drawing to site. An example of how errors can be reduced is shown in Fig. 1.3.

Figure 1.3(a) represents a plan view of individually dimensioned wall recesses. If, on transfer, one of these distances was wrongly measured it would not only affect the overall length of the wall, but also have a cumulative effect on all those measurements which followed.

**Fig. 1.3** *Transferring measurements from a drawing to site*



For example, an error between points B and C would result in points D, E, F, and G being wrongly positioned.

Figure 1.3(b) shows how measurements can be transferred by using 'running measurements'. The tape is run once from A to G (total length), all intermediate measurements are referred back to A as shown in the build-up of the running total.

### 1.1.2 Laser digital distance metres (Fig. 1.4)

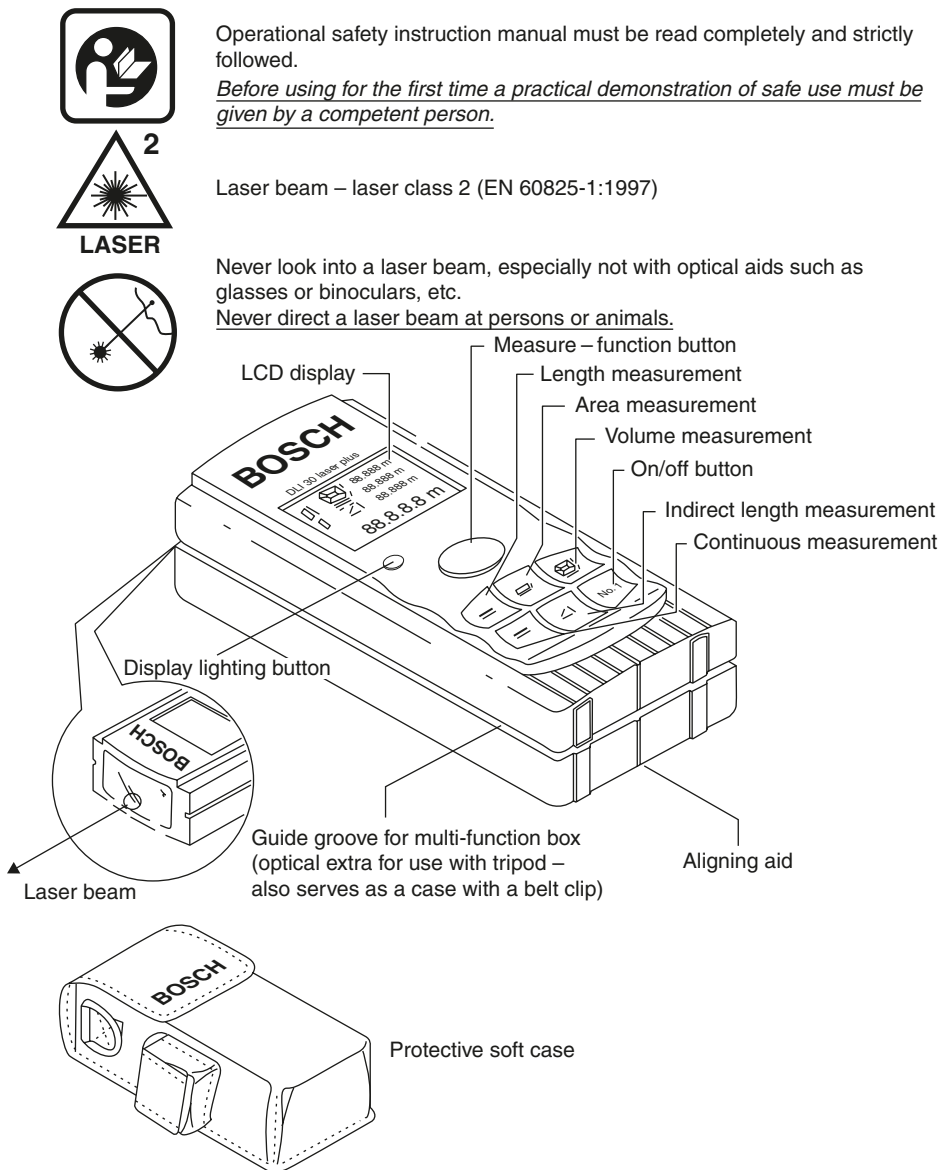
These instruments are intended to measure distances (lengths, heights), a typical example of use is shown in Fig. 1.5. When required the instalment can also calculate areas and volumes.

They operate by projecting an intensive beam of light (laser beam) onto a wall or object. When switched on to the required programme (Fig. 1.4) the length of the beam is automatically measured, the resulting distance, area, or volume is then automatically portrayed onto the LCD panel.

#### **Safety (also see section 1.7.8)**

As with any instrument or tool using an exposed laser beam as described in Fig. 1.4, special safety precautions must be taken before and during their use; for example:

- Operating manual (operational safety instructions) must be read completely, understood, and strictly followed before the instrument or tool is used.
- Operatives must be informed of the operating dangers and protective measures.
- Never remove warning signs from the unit.
- Never look into a laser beam, especially not with optical aids such as glasses or binoculars, etc.
- Laser-viewing glasses are not protective glasses against laser beams.

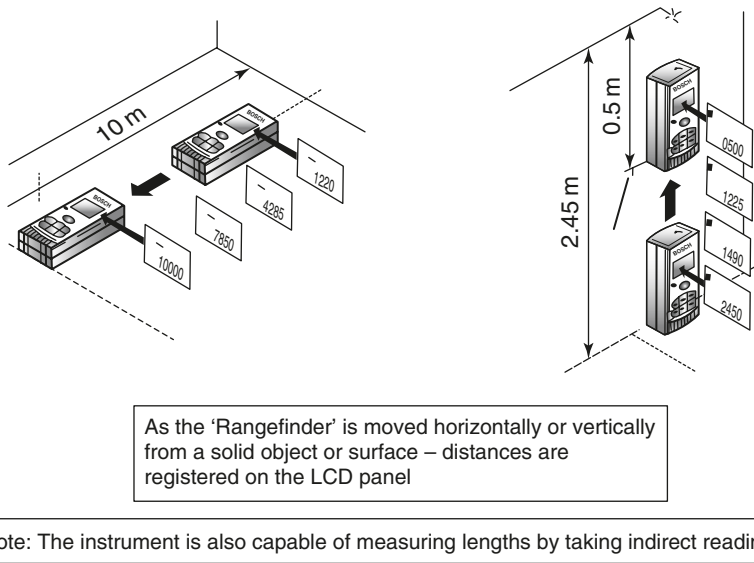


**Fig. 1.4** Bosch Laser 'Rangefinder'

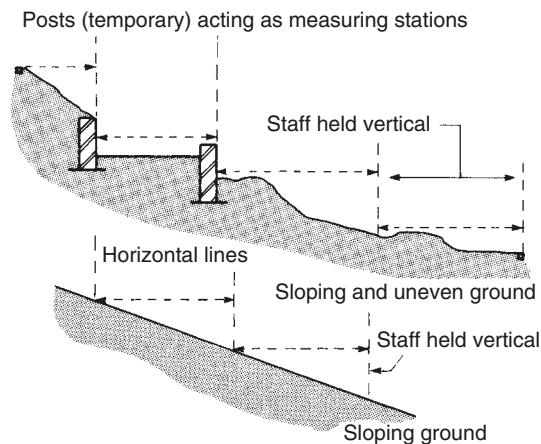
- Never direct a laser beam at persons or animals.
- Before using for the first time a practical demonstration of safe use must be given by a competent person.

### 1.1.3 Sloping sites

Figure 1.6 shows how horizontal measurements over sloping or obstructed ground are carried out. Pegs or posts are positioned on or



**Fig. 1.5** *Measuring distances using a Bosch Laser 'Rangefinder'*



**Fig. 1.6** *Measuring sloping sites*

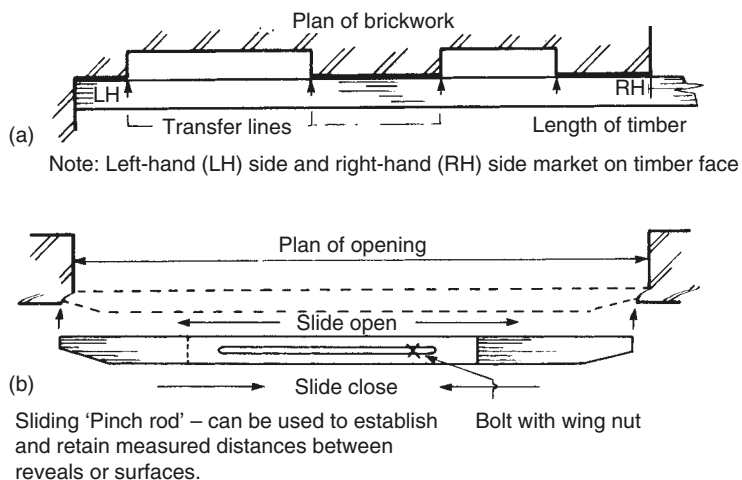
driven into the ground to act as intermediate measuring stations, each distance is registered separately to produce a final running total.

### 1.1.4 Transferring measurements

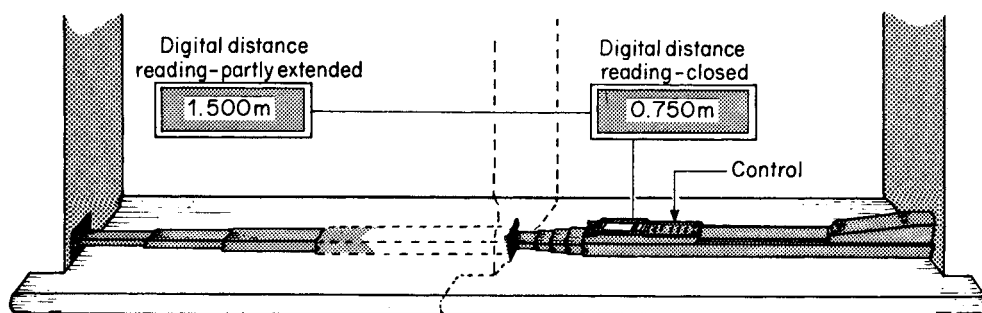
Simple measuring aids like those shown in Fig. 1.7 are very accurate and useful. Probably the simplest method as shown in Fig. 1.7(a) involves the use of a small-sectioned length of timber as a 'rod'. In this case the actual brick reveal distances are transferred directly to the rod with a pencil or marker. Measurement transfers of this nature are often made from site to workshop where an item of joinery has to fit over or into a specific space or opening.

A 'pinch rod' (Fig. 1.7(b)), on the other hand, consists of two short lengths of timber, one of which slides on the other to enable its total length to be varied. This is ideal for measuring between openings – once set, the pieces are held in that position with nails or a cramp, etc.

As shown in Fig. 1.8 a more sophisticated method of taking either vertical or horizontal internal measurements is by using a Rabone 'Digi-rod'. The rod is fabricated from steel, and consists of a body which houses a battery-operated LCD panel, level and plumb vials to ensure accurate readings, and telescopic sections which are manually extended. As the rod is extended the reading is simultaneously registered on the LCD.



**Fig. 1.7** Useful devices for transferring measurements



Model range:– 0.750 to 3.200 (illustrated)  
1.050 to 5.000 (not illustrated)

Both models can be used to accurately measure vertical and horizontal distances

**Fig. 1.8** Using a digital measuring rod to measure the distance between two vertical surfaces

## 1.2 Straight lines

Most work carried out by the carpenter and joiner relates to or from a straight line. Straight lines are easily established without the help of optical or other devices, by using the following methods:

- a length of string, cord, or wire held taut;
- a predetermined flat surface such as a straight-edge;
- visual judgement – sighting.

### 1.2.1 Builder's line

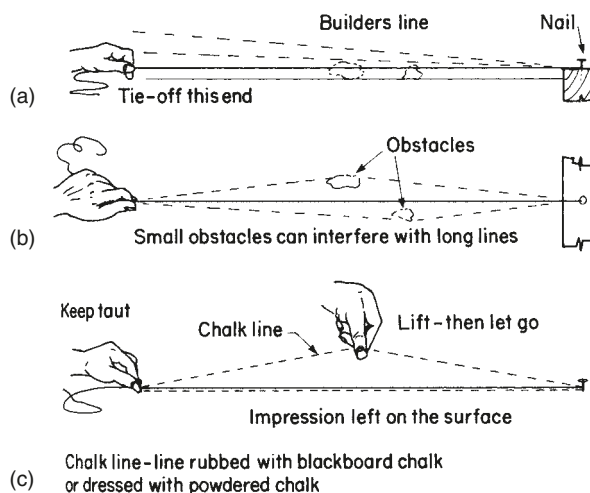
As shown in Fig. 1.9(a), the line can be held or left temporarily in place whilst operations are carried out, Figure 1.9(b) shows how small obstacles can (particularly over long distances) interfere with the line.

### 1.2.2 Chalk line

The line is first coated with chalk (blackboard chalk) – either manually, or by using a proprietary device that automatically coats the line as it is withdrawn from the case. The line is then stretched tight as shown at 1.9(c), then lifted just off the floor midway between its span and let go. On removing the line, it will be found that the chalk has left a clear impression of the line on the surface.

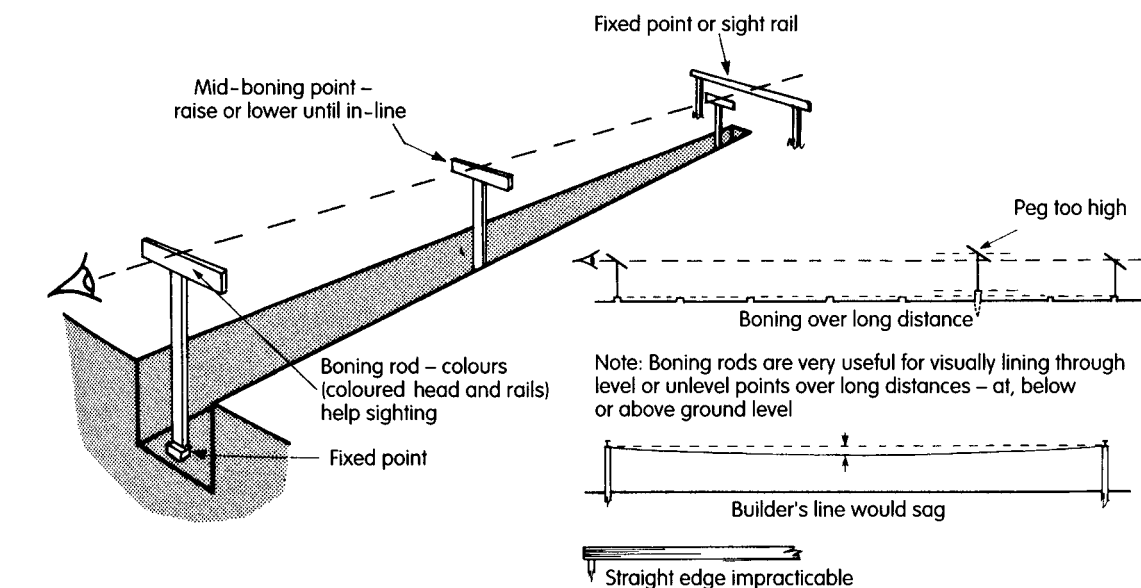
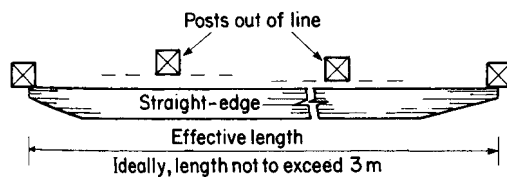
### 1.2.3 Straight edges

A length of timber or other similar material of a sectional size capable of resisting deflection when only supported at either end. Figure 1.10 shows one example of where a straight edge could be used – testing for misaligned posts or joists, etc. can quickly be recognised.



**Fig. 1.9** Using a builder's line to leave a straight chalk line impression on a flat surface

**Fig. 1.10** *Testing for misalignment with a wood straight edge*



**Fig. 1.11** *Sighting or lining along a straight line over a long distance*

### **Sighting a straight line**

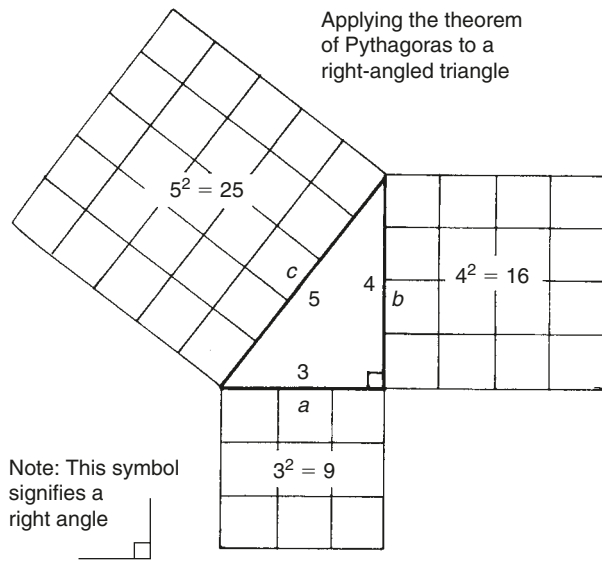
Neither the line nor the straight edge would be suitable for covering long distances – the line would sag and the straight edge for obvious reasons be impracticable. Without resorting to optical devices or other devices, sighting over long distances is possible by a method known as ‘boning’. Figure 1.11 shows how boning is carried out by using a minimum of three ‘boning rods’, usually tee shaped. The rods are held or stood above the required line. The middle one is positioned at a predetermined point until its adjustment is such that it is in line with the line of sight – at which point the tops and bottoms of all the boning rods are in a straight line with each other.

*Note: A straight line is not necessarily a level line.*

## **1.3 Right angles**

Let us first consider right angles (90° angles), and three simple methods of forming them:

- (i) by measurement – using the principle of a 3:4:5 ratio;
- (ii) by using a builder's square;
- (iii) by using an optical site square.



**Fig. 1.12** Using a ratio of 3:4:5 to form a right-angled triangle

### 1.3.1 Right angles using a 3:4:5 ratio

That is to say that, if the lengths of the sides of a triangle are in a ratio of 3:4:5 (no matter what size of unit is used), and are measured using the same unit, the resulting triangle will be right angled.

This principal stems from the theorem of Pythagoras, which states that in a right-angled triangle the square of the hypotenuse (the longest side) is equal to the sum of the squares of the other two sides.

Consider the triangle in Fig. 1.12, where side 'a' is 3 units long, side 'b' is 4 units long, and side 'c' (the longest side) is 5 units long:

$$a^2 = 3^2 = 9$$

$$b^2 = 4^2 = 16$$

$$c^2 = 5^2 = 25$$

$$\text{That is } a^2 + b^2 = c^2$$

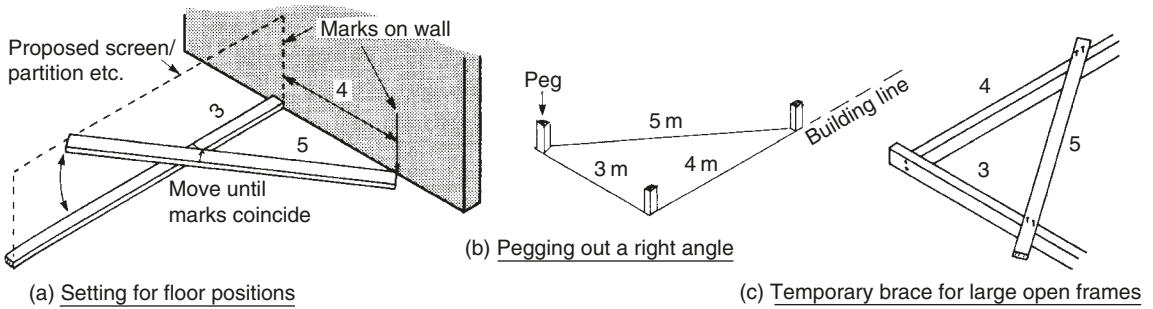
*Note: The same principle will also work with sides in the ratio 5:12:13 or 6:8:10.*

In other words, in a triangle with sides in the ratio 3:4:5, the square of the longest side is equal to the sum of the squares of the other two sides; therefore, such a triangle must be right angled.

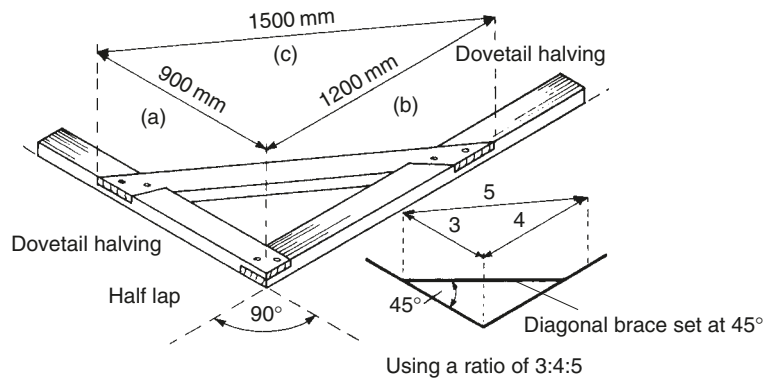
Figure 1.13 shows three ways of applying this principle to practical situations; for example:

- Positioning a timber sole plate for a screen or partition at right angles to an abutting wall.
- Pegging out ground work to form a right-angled corner.
- Positioning a corner brace to temporary hold a timber frame square.





**Fig. 1.13** Using the ratio of 3:4:5 to form right angles on site



**Fig. 1.14** Traditional builder's square

### 1.3.2 Builder's square

As can be seen from Fig. 1.14 this is a purpose-made timber set square. Its size will depend upon where and for what it is used. A useful size could be built around a triangle with sides 900, 1200, and 1500 mm, which fulfils the 3:4:5 rule; for example:

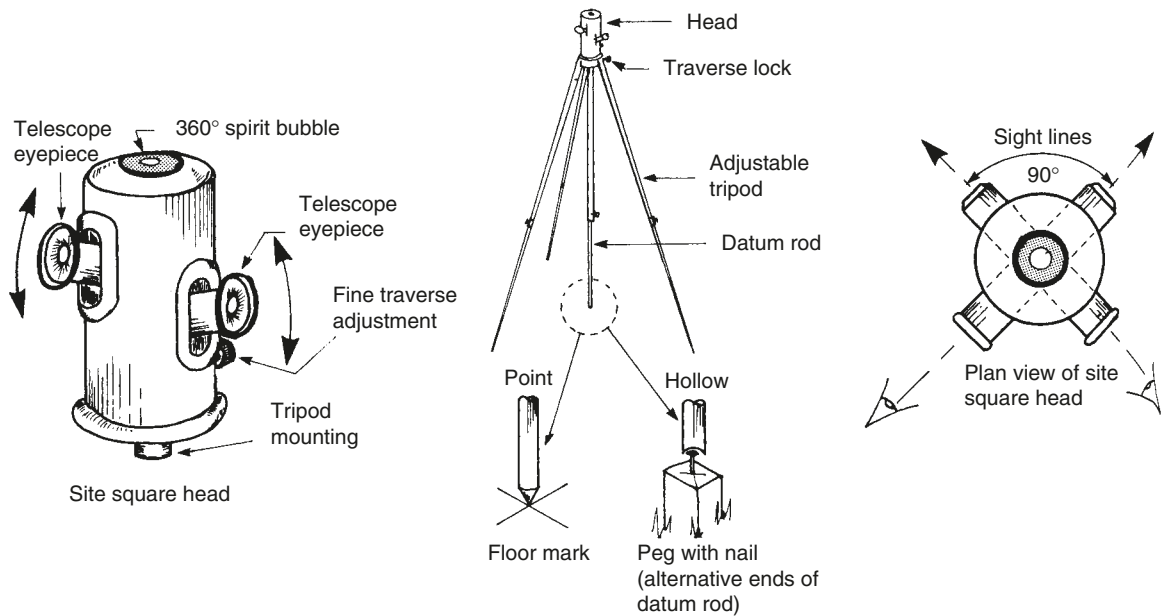
$$\begin{aligned} \text{Side 'a'} &= 3 \times 300 = 900 & \text{side 'b'} &= 4 \times 300 = 1200 \\ \text{side 'c'} &= 5 \times 300 = 1500 \end{aligned}$$

Its application is shown in Fig. 1.14.

### 1.3.3 Optical site square

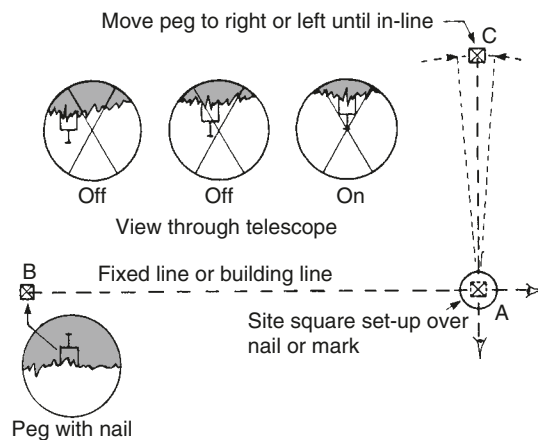
As shown in Fig. 1.15 optical site square consists of two fixed-focus telescopes permanently set at right angles to one another, each being capable of independent movement within a limited vertical arc. Once attached to its tripod, a circular spirit level set into the head enables the datum rod, which is suspended below the tripod, to be positioned plumb over a fixed point or peg.

Figure 1.16 show the stages in using an optical site square to set out a right angle.



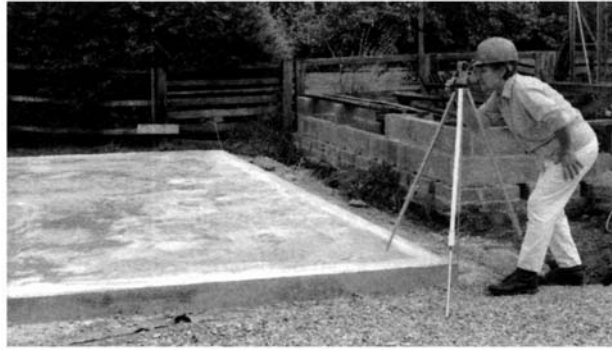
Note: Telescopes are set at right angles to one another – both move vertically

**Fig. 1.15** Optical site square

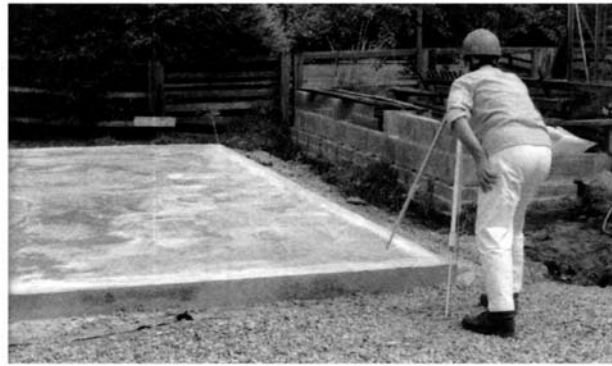


**Fig. 1.16** Setting out a right angle with an optical square

1. Measure the length of one side of the rectangle and mark the ends 'A' and 'B' with a 'cross' or 'peg'. A nail should be partly driven into the top of each peg as a sight marker (see Fig. 1.16).
2. Set up the square at position 'A', then after positioning the datum rod over the cross or nail. Plumb the datum rod using the spirit level and by adjusting the tripod legs.



**a** First sighting through lower telescope – using the fine traverse adjusting screen to bring the ‘cross-hairs’ in line with the front edge of the concrete raft (slab)

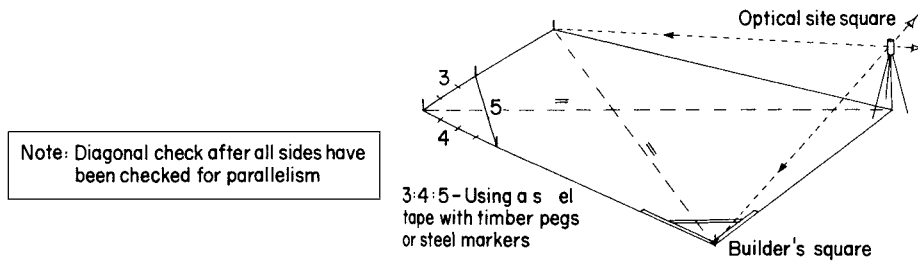


**b** Sighting through the upper telescope to ensure that the side edge of the concrete raft is at a right angle ( $90^\circ$ ) to the front

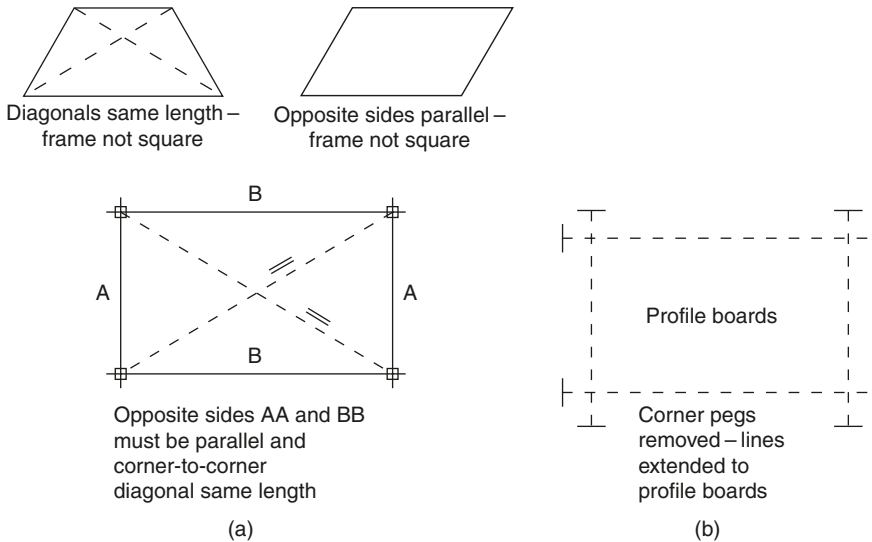
**Fig. 1.17** *An optical site square in use*

3. From position ‘A’, rotate the head and lock it when the telescope is in line with ‘B’ (Fig. 1.17(a)). Use the fine-adjustment knob to bring the cross-hairs (viewed through the telescope) exactly over the cross, or nail head (see Fig 1.15), or floor mark (1.16).
4. Keeping the head in the same position, move round  $90^\circ$  to look through the other telescope (Fig. 1.17(b)). Place a mark, or position a peg ‘C’, in line with the cross-hairs of the telescope and the correct distance from ‘A’. The two sides ‘AB’ and ‘AC’ are now at right angles.
5. Repeat the process from ‘B’ or ‘C’, or measure two lines parallel with those right-angled sides formed.
6. Diagonals must always be checked as shown in Fig. 1.18.

As an added bonus, this instrument can also be used to set work plumb (vertical), by raising or lowering the telescope about a horizontal axis so that its line of sight will follow a vertical path.



**Fig. 1.18** Squaring techniques



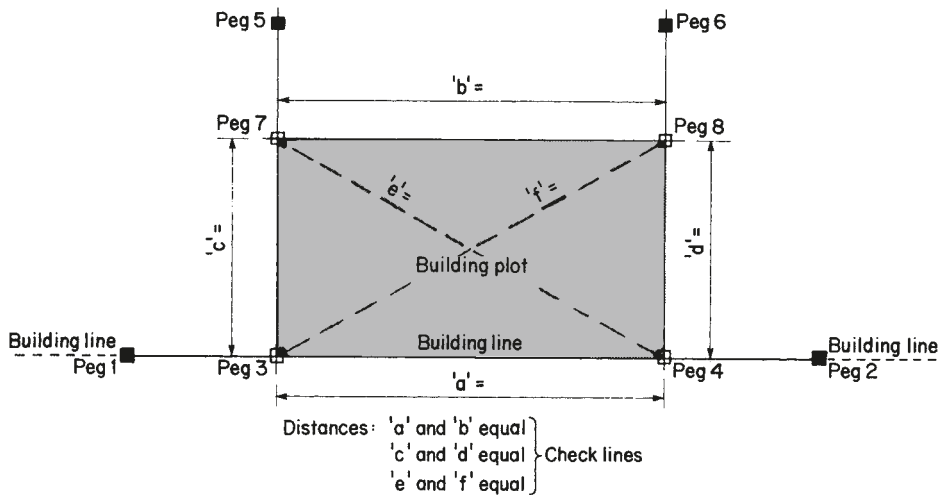
**Fig. 1.19** Setting out a rectangular area

### 1.3.4 Application of squaring methods

As shown in Fig. 1.18 no matter which method of setting out is chosen, the perimeter or framework of a square or rectangle must have both opposite sides parallel and diagonals of equal length, as shown in Fig. 1.19(a).

Where corner squaring pegs interfere with constructional work, lines are extended outside the perimeter and repositioned onto nails or set into saw kerfs cut into the top of pegs or boards as shown in Fig. 1.19(b). The corners are now located where the lines cross each other, and the lines may now be removed or replaced at will.

Figure 1.20 shows how a rectangular building plot can be set out from a known 'Building-line'. A 'Building-line' is a hypothetical line, usually set down by the Local Authority to determine the frontage of the proposed building. It may relate to existing buildings or a fixed distance from a roadway.



**Fig. 1.20** *Setting out a rectangular building plot*

Once the building-line is established via pegs 1 and 2, the following procedures can be followed:

- Frontage distance can be determined with pegs 3 and 4.
- Left-hand side line is set square from the building-line pegs 3 to 5.
- Right-hand side line is set square from the building-line pegs 4 to 6.
- Depth of building is marked with pegs 7 and 8.
- Check for square as previously stated in Fig. 1.19(a).

### 1.3.5 Profile boards

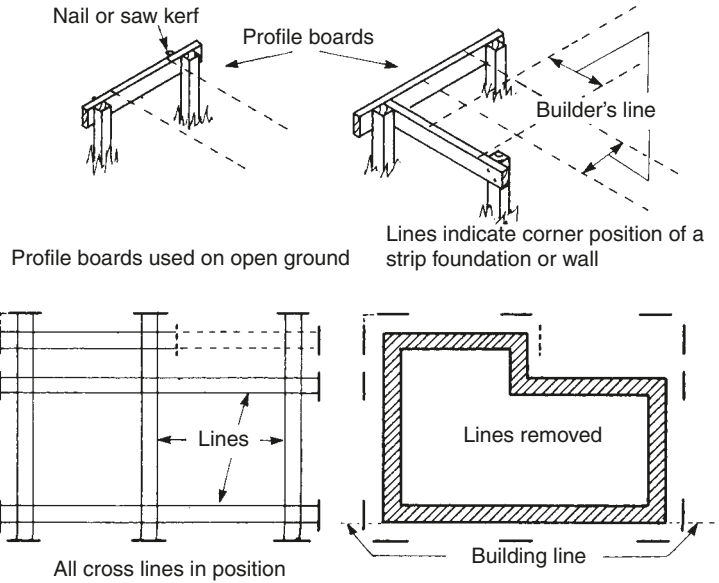
These, with the aid of a builder's line, indicate where corners, junctions or changes of direction occur. Figure 1.21 shows how these boards are assembled and positioned in line with the proposed walls and/or foundations, etc.

Timber stakes are driven into the ground and rails nailed to them; rails are positioned behind the stakes to resist the pull of the lines.

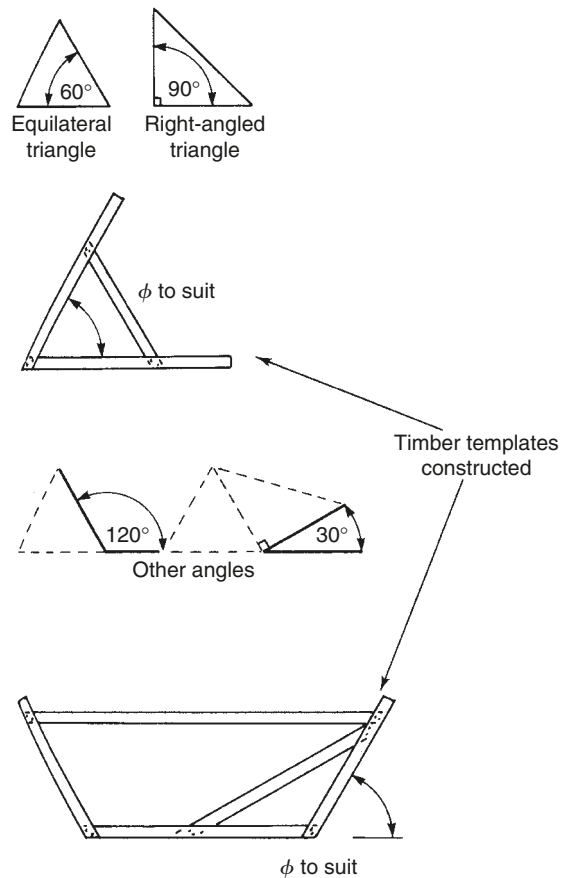
## 1.4 Angles other than right angles

These angles are set out by using on-site geometry or by mechanical means with the aid of either a *Stanley* or *Smallwood* Roofing Square (the roofing square, and its application in pitch roof construction is featured in Chapter 8), or an angle measuring device as featured at 1.4.2.

Figure 1.22 shows a means of fabricating templates based on an equilateral triangle.



**Fig. 1.21** Using profile boards to line out the position of a wall and/or foundation

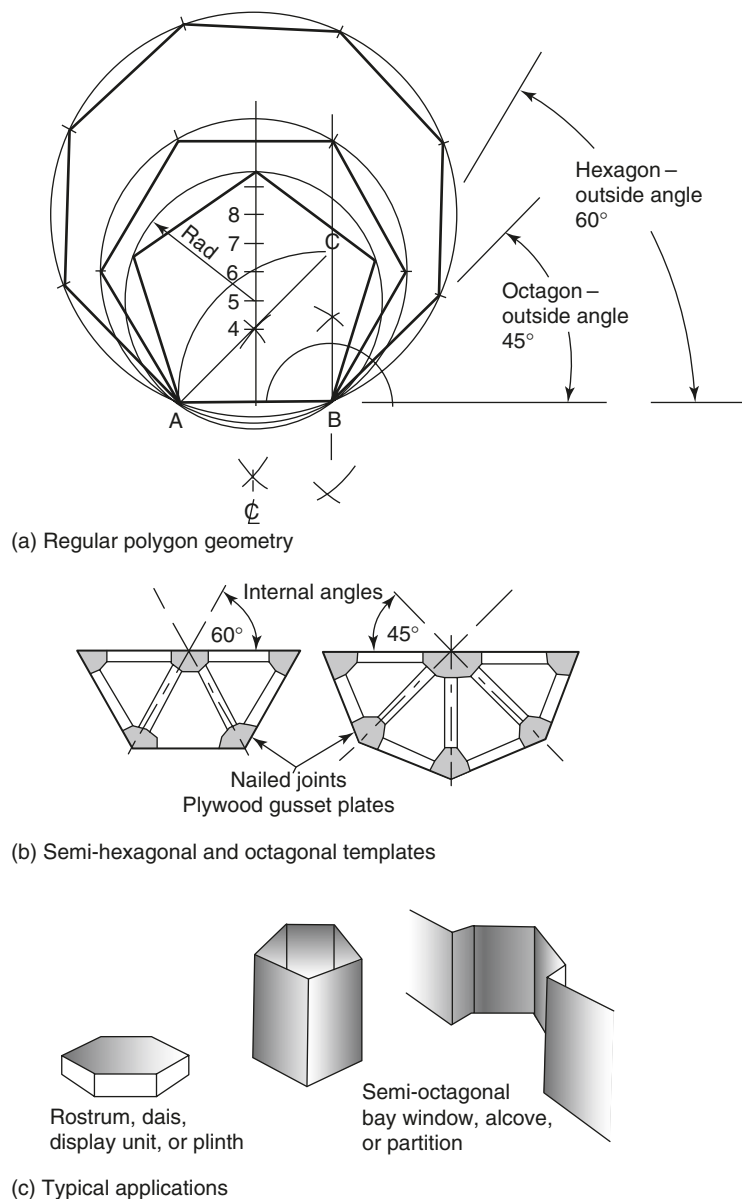


**Fig. 1.22** Fabricating angle templates

Figure 1.23 shows examples of where and how angles are applied to simple regular and semi-regular polygon shapes.

1.4.1 Regular polygons

These are figures of more than four sides, all of which are equal in length.



**Fig. 1.23** Regular and semi-regular polygons and examples of use

Each polygon has a specific name in relation to its number of sides; for example:

Number of sides	Name
5	Pentagon
6	Hexagon
7	Heptagon
8	Octagon
9	Nonagon
10	Decagon

Figure 1.23(a) shows one geometrical method of setting out regular polygons of five, six, and eight-sided figures; for example:

- Draw side AB.
- Bisect AB to produce the centre line.
- Erect the perpendicular BC.
- Using radius AB, scribe arc AC from B across the centre line to produce point 6.
- Join AC to produce point 4.
- Point 5 is midway between points 4 and 6.
- Points 4, 5, 6, 7, 8, etc. are the same distance apart.

*Note: There are other methods of constructing Regular Polygons – see Chapter 4.*

The numbered circle centre points are used to circumscribe the equivalent number of sides AB of the polygon.

Figure 1.23(b) shows how a semi-regular hexagonal and octagonal template can be fabricated by using nailed plywood gusset plates over both sides where members intersect. Figure 1.23(c) shows how regular polygon shapes can be applied in practical situations.

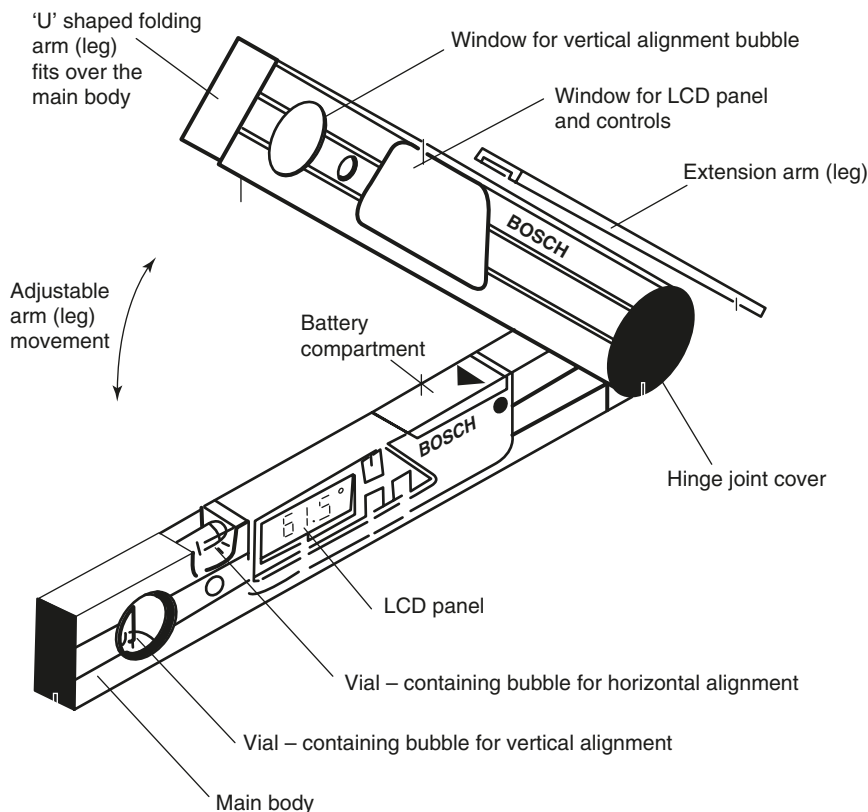
1.4.2 Angle measuring devices

There are many different proprietary devices on the market to help the carpenter and joiner measure and transfer angles. Those used in constructing and assembling items of joinery were dealt with in Volume 1.

One worth mentioning here is the ‘Bosch digital angle measurer’ as shown in Fig. 1.24. it has an accuracy of  $\pm 0.1^\circ$  with a measuring range of  $0^\circ$  to  $220^\circ$ . Whether you are measuring a corner angle, mitre, or simply determining a bevel. By pressing the appropriate button the resulting angles are stored in its memory and displayed on the LCD panel. Standard or rechargeable batteries power it.

Figure 1.25 shows a few examples of where this device can be employed.





**Fig. 1.24** *Bosch angle measurer*

## 1.5 Circles, arcs, and segments

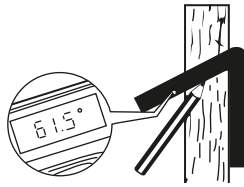
Figure 1.26(a) shows how a large circles, semicircles, and arcs can be formed by using a trammel board, pin and marker (in this case a pencil). We came across a trammel in Volume 1, Fig. 5.6 where it was shown how proprietary trammel heads fitted over hardwood trammel bar were used to circumscribe small- to medium-sized circles and arcs.

Figure 1.26(b) shows a practical site method using a triangular timber templates with differing apex( $x$ ) angles. Using this method, it is then possible to scribe large segmental arcs between the two fixed points. Note that the greater the rise from the chord to the apex( $x$ ) the greater the chord length (span).

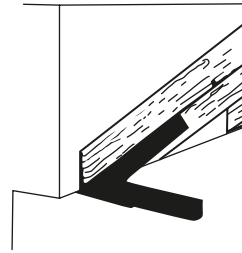
## 1.6 Datums

A datum is a fixed point or horizontal line to which a height or depth can be referred.

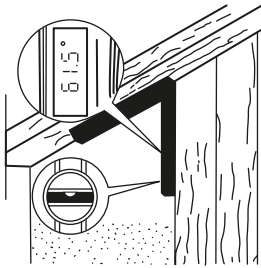
Before any levels can be taken on a building site, a fixed datum point must be established as shown in Fig. 1.27. This point is known as a



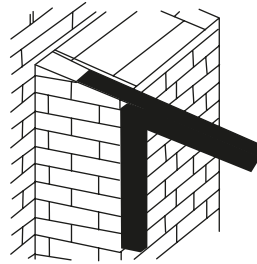
Marking a cutting angle



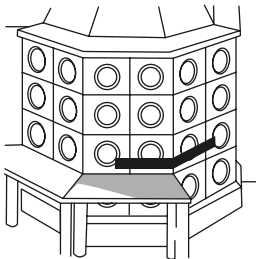
With extension arm checking a rafter angle



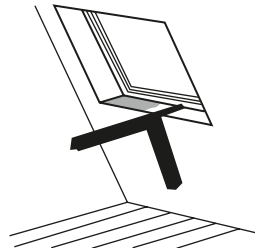
Checking or taking a reading of an internal angle



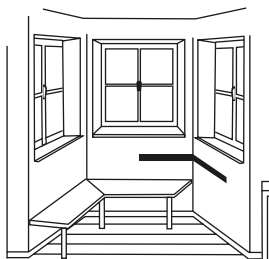
Using the extension arm where the folding would be too long



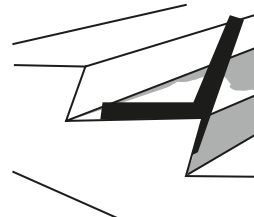
Checking or taking a reading of the intersections of the exterior of a bay window



Using the extension arm to measure the angle of an inclined window cill or bracket

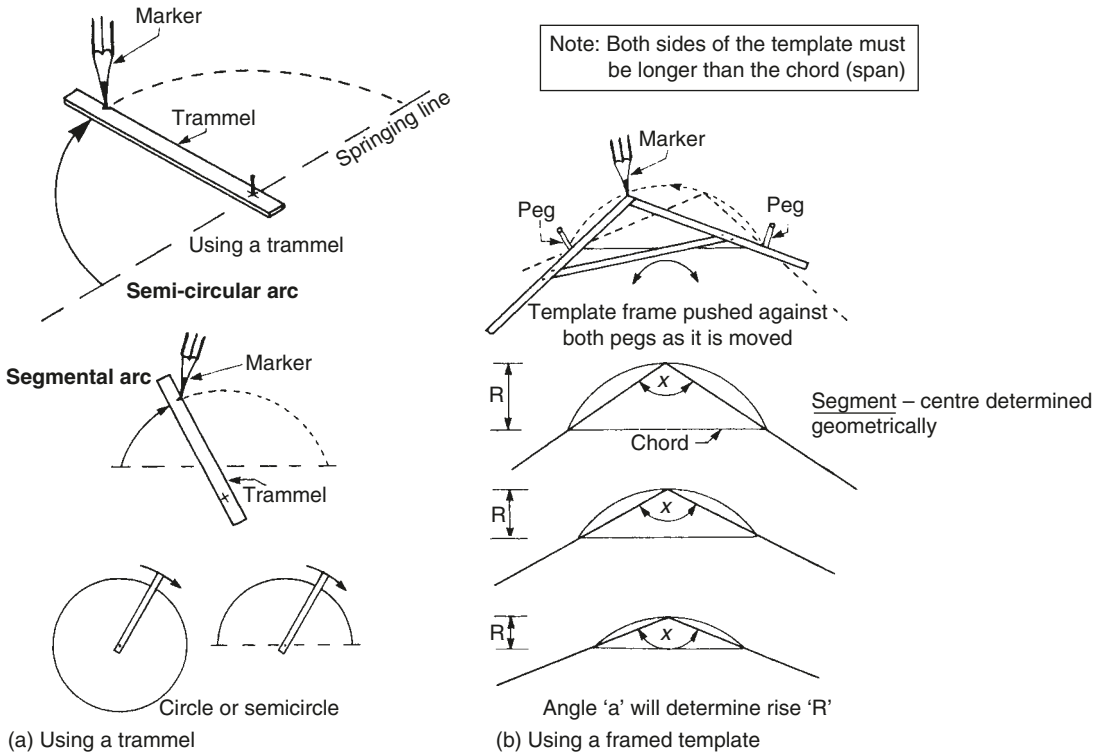


Checking or taking a reading of the intersections of the interior of a bay window

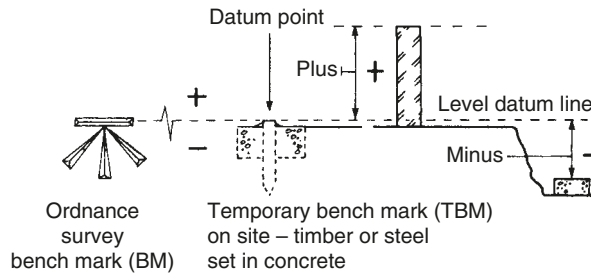


Using the extension arm to measure the angle between a stair tread and riser

**Fig. 1.25** Examples of applying the 'Bosch' angle measurer

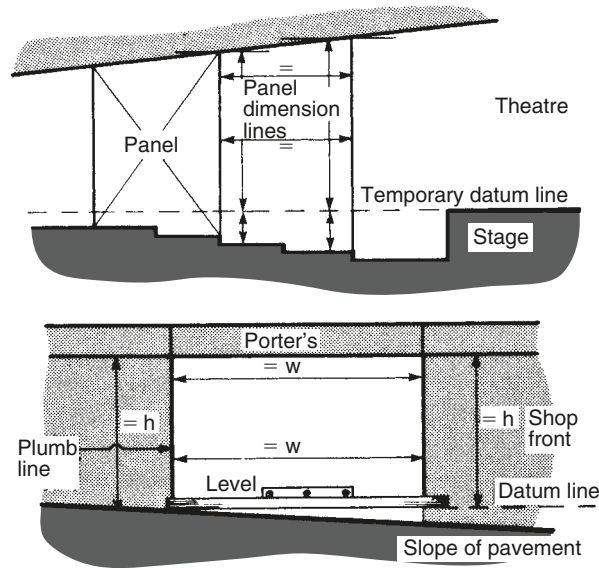


**Fig. 1.26** *Setting out large circles segments and arcs*



**Fig. 1.27** *Benchmarks*

temporary benchmark (TBM) to which all other site levels can be referred. It should however relate to a true ordnance benchmark (OBM). OBMs can be found cut into surfaces' permanent structures such as public buildings, or other landmarks which are not liable to any earth movement. They can be recognised by an arrow pointing up to a line – the line is the datum point signifying its position (height) as recorded on Ordnance Survey maps. The origin of this height is taken from the 'mean' sea level (middle distance between high and low tides) at Newlyn in Cornwall.



**Fig. 1.28** Datum lines

Datum lines shown in Fig. 1.28 need only relate to the work in hand. These are temporary horizontal lines, which have been struck at a convenient height so that floor and/or ceiling slopes can be measured and their dimensions be recorded.

## 1.7 Levelling

Levelling is the act of producing a line or surface which is horizontal (level). Any one of the following aids can be used to establish a level line:

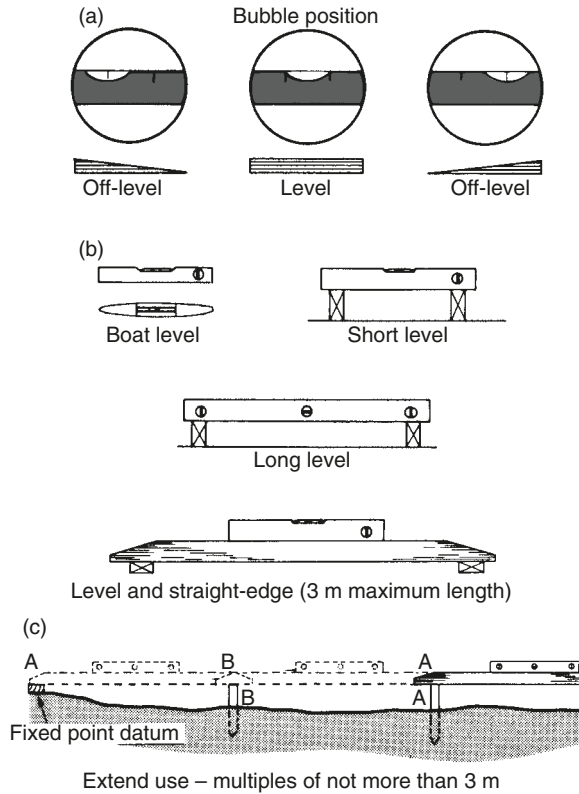
- Traditional spirit level
- Digital spirit level
- Water level
- 'Cowley' automatic level
- Laser level.

### 1.7.1 Traditional spirit level (see also 1.8.3)

It consists of a metal body (rule) with parallel edges into which are inset one or more plastic tubes containing a spirit and a bubble of air. The position of the air bubble indicates whether the spirit level is horizontal (Fig. 1.29(a)).

The accuracy of the level will depend on:

- how true the bubble tube is set,
- the level's effective length,
- the skill of the operative.



**Fig. 1.29** *Levelling with a spirit level*

Note: To test the level for accuracy (see 1.8.3).

Figure 1.29(b) shows how effective the length of the level is. With the aid of a straight edge, its efficiency can be increased for lengths up to 3 m; Greater distances can be covered by moving both level and straight edge together progressively forward. There is however, a danger of minor errors accumulating. This can as shown in Fig. 1.29(c) be avoided if, at each stage of movement, both level and straight-edge are turned through 180°. For example, end 'A' is rotated about end 'B' then end 'B' is rotated about end 'A' and so on. In this way any minor inaccuracies will be equalled out over the whole distance.

### 1.7.2 Digital spirit level

Similar to the traditional spirit level but includes a digital read-out and audio sound when the required angle or level has been established (Fig. 1.30).

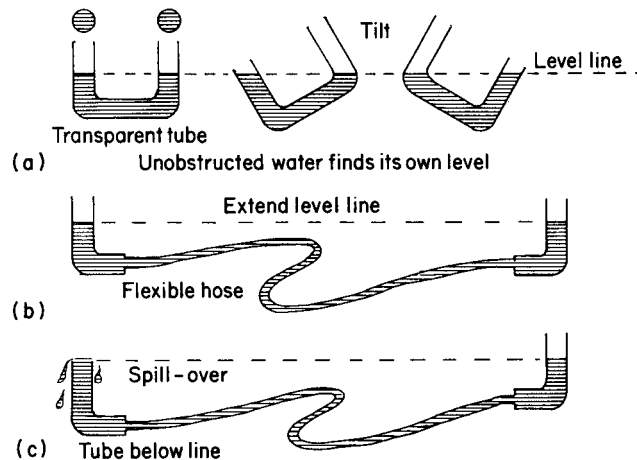
### 1.7.3 Water level

This works on the principle that 'water always finds its own level' which is true when it is contained in an open system.

Consider Fig. 1.31(a) – water is contained in a U-tube and, no matter which way the tube is tilted, the water level remains in a horizontal



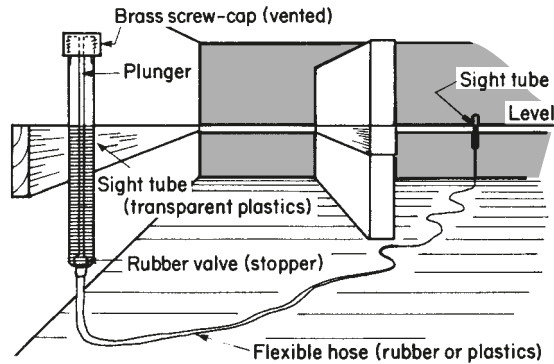
**Fig. 1.30** Bosch digital spirit level



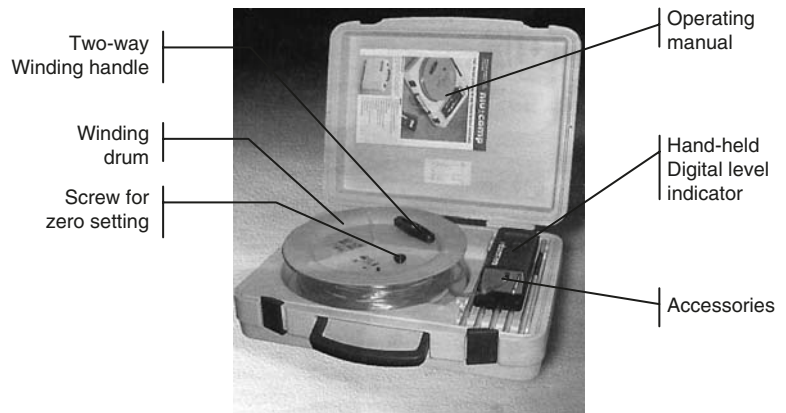
**Fig. 1.31** Basic principles of a water level

plane. In Fig. 1.31(b) the tube has been divided and base connections have been made with a flexible hose. Again, provided the hose is unobstructed, the water level will be the same at both ends. This is the basic principle on which the modern water level is founded. However, as can be seen from this model (Fig. 1.31(c)), if one end is raised or lowered too far, water will spill out – a problem that in the main has been overcome with the modern water levels.

A modern two-man-operated water level (Fig. 1.32) consists of two transparent (and in some cases graduated) plastic sight tubes. Each tube has in this case a brass sealable cap with vent holes. Attached to each cap is a brass rod (plunger) with a rubber stopper which acts as a valve by preventing air entering the hose when the cap is shut down and the level is not in use.



**Fig. 1.32** *Two-man-operated water level*



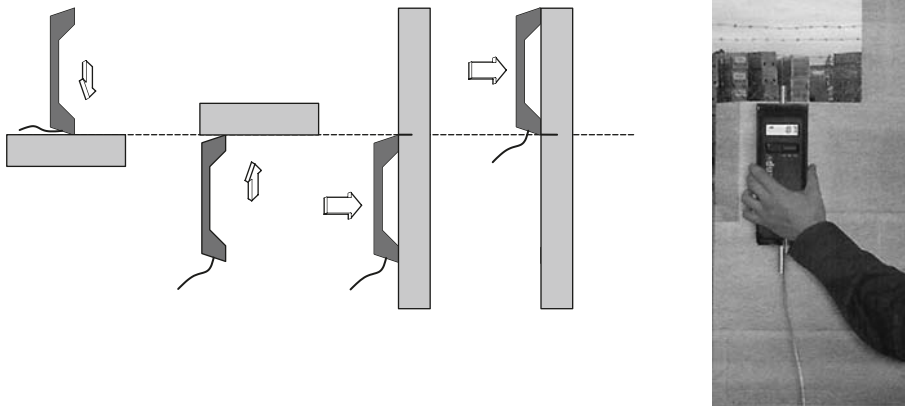
**Fig. 1.33** *The 'Comp-Mark' electronic level*

The long rubber or plastic hose makes this level particularly useful for levelling floors, ceilings, formwork, etc. especially around corners or obstacles.

#### 1.7.4 The 'Comp-Mark' electronic level

As shown in Fig. 1.33 all the components of this one-man-operated electronic level are housed within a durable carrying case, they include:

- a detachable winding drum with two-way winding handle;
- heavy-duty plastic hose (wound around a drum reservoir);
- hand-held digital level indicator;
- leveling accessories compartment to hold or contain;
- marker pencil;
- extendable staff (made up of short screw aluminium rod sections) which fits into the base of the hand-held digital indicator – an ideal attachment for taking existing floor levels, or below ground, etc.
- staff end stops (a small plain disc and a larger magnetic one);
- operating manual.



**Fig. 1.34** *Positioning the hand-held device*

The centre of the winding drum is fitted with a sealed unit (reservoir) containing an oil-based liquid. Also included is an adjusting screw for zero setting prior to use.

Inside the hand-held level indicator unit is a high-performance measuring device with a numeric digital readout that works in conjunction with the liquid within the drum. Levels are detected by means of the pressure difference between the fluid level in the drum and that at the hand-held device.

Levels are transferred to different areas or points by repositioning the hand-held device above or below the datum line as shown in Fig. 1.34 until a satisfactory level is achieved as indicated by the light-emitting diode (LED with its plus or minus ( $\pm$ ) readout) within the device.

Practical uses include:

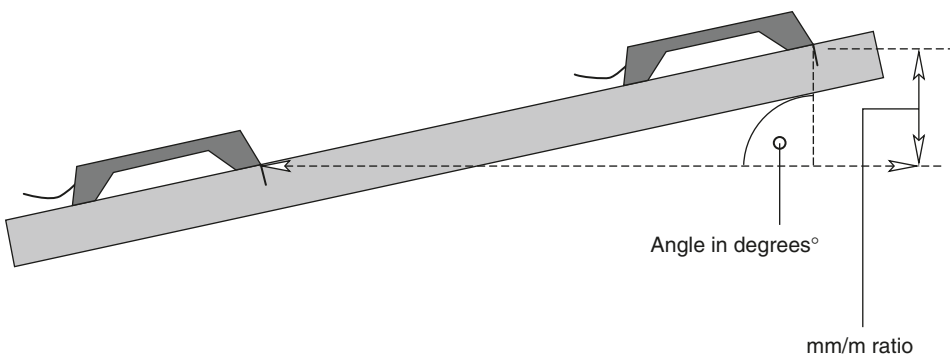
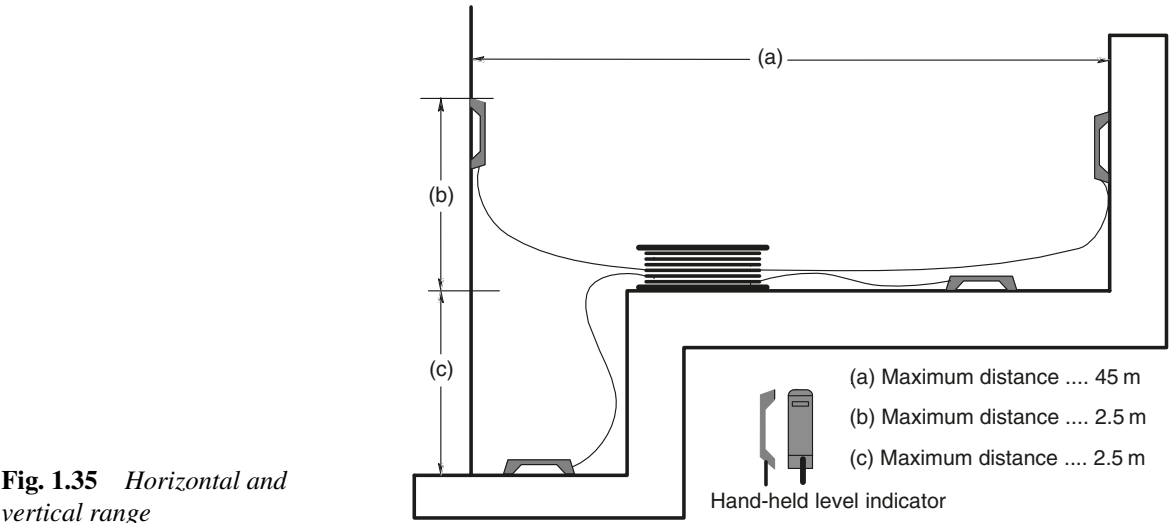
- suspended ceilings,
- floor construction,
- kitchen fitting,
- formwork.

Also see Figs 1.34–1.36.

Other uses include Horizontal and vertical operating in addition to transferring levels from a recess, i.e. trenches, etc. (Fig. 1.35).

Figure 1.36 shows how the level can be used for measuring inclined (sloping) surfaces or members, for example when constructing formwork (see Chapter 3, *Formwork*) for paths or driveways, etc.





**Fig. 1.36** *Positioning the hand-held device to inclined surfaces*

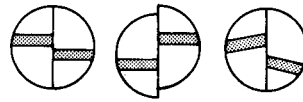
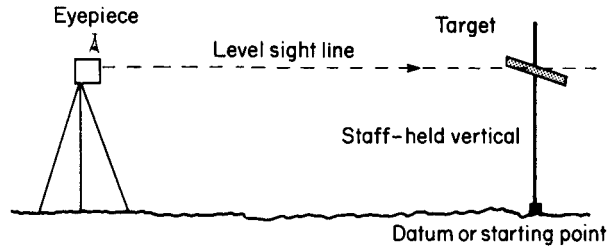
**Table 1.1** Inclination conversion table

Angle	* Millimetres per metre (mm/m)
1°	17.5
2°	35
3°	52.5
4°	70
6°	105
8°	141

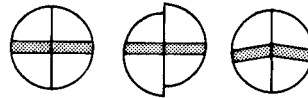
\* Figures listed have been taken to the nearest millimetre.

Table 1.1 gives the angle obtained for every one horizontal metre and vertical measurement. For example, a height of 105 mm over a distance of 1 m will give an incline of 6°.





(a) View of target – off – level

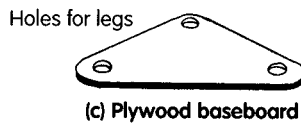
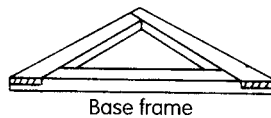
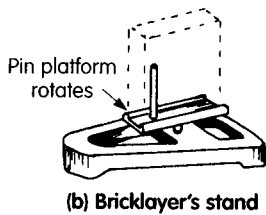
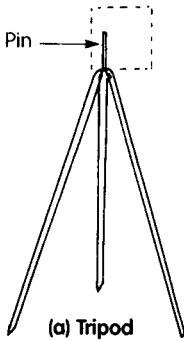


(b) View of target – on – level

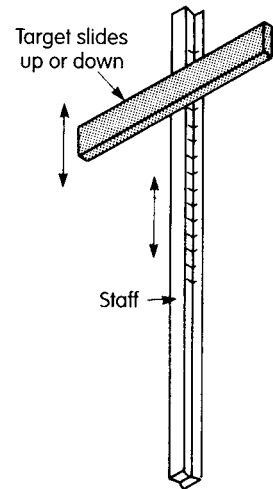
View through eyepiece

**Fig. 1.38** *Level application*

Free to rotate – sight on target



Baseboard – frame prevents legs slipping  
(Note: Slope attachment available)



**(d) Extendable graduated staff**

**Fig. 1.39** *Cowley level accessories*

### Using the level

The procedure for using the Cowley level is as follows:

- (i) Set the tripod, pin uppermost, on a secure footing – a base board may be necessary on smooth flat surfaces (Fig. 1.39(c)).
- (ii) Position the level on the tripod and see that it is free to rotate – the levelling mechanism is now unlocked.
- (iii) Position the staff and target on the ‘datum’ or starting point. The staff must be held as near to vertical as possible.
- (iv) Direct the level towards the yellow face of the target.
- (v) Sight on to the target. An assistant moves the target up or down until the ‘on-target’ position appears through the eyepiece as shown in Fig. 1.38(b).
- (vi) As soon as the ‘on-target’ position is achieved, the target is clamped to the staff ready to be transferred to other points requiring the same level as shown in Fig. 1.40.

Figure 1.41 shows that, by taking a reading of the graduated staff, different levels can be measured.

### Levelling situations

A Cowley level is ideal for pegging-out groundwork; levelling form-work, wallplates, floor joists, etc.; and establishing a datum line on the wall of a building (Fig. 1.40).

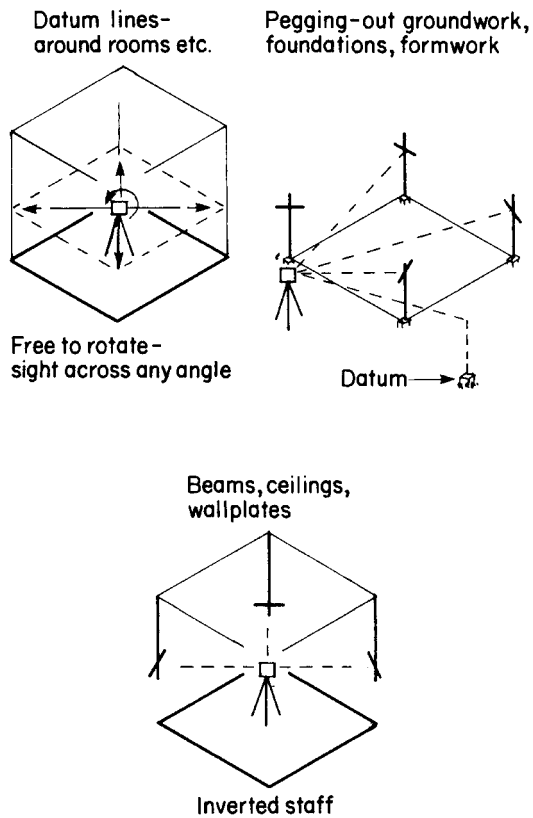
## 1.7.6 Laser levels

These types of levels are being used more and more within the construction industry as an alternative to the more traditional methods of setting datum lines.

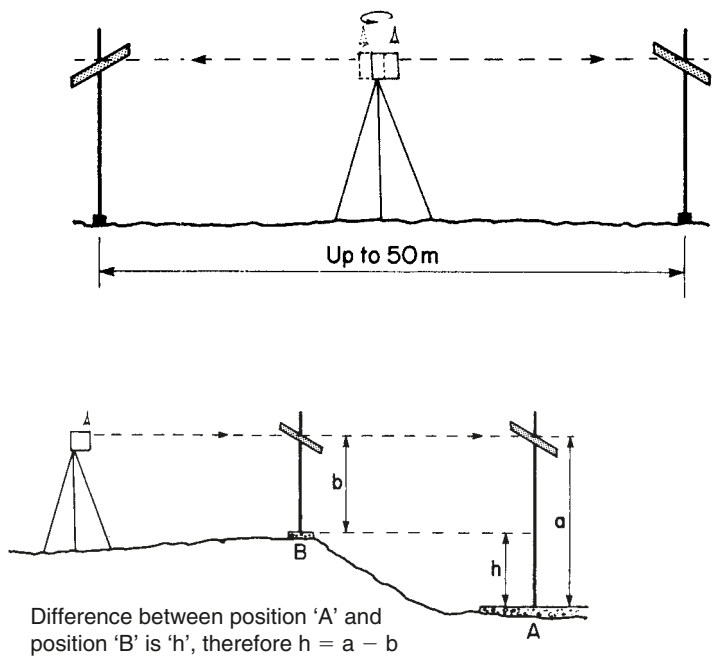
Consisting of a metal body containing electronics to produce a thin laser light, the unit can be placed on a tripod (Fig. 1.42(a)) and rotated through 360° to provide markings on walls or surfaces at different positions within an area. It can also be placed on a sturdy base (Fig. 1.42(b)) and leveled with the adjustment screw. Once levelled, the beam is activated and where it strikes the wall or surface a mark is placed. By using the dual beam prism, the unit can be set to provide two beams set at 90° lines horizontally and vertically (Fig. 1.42(b) and (c)) which is ideal for constructing stud partitioning. Another attachment is the beam spreader lens (Fig. 1.42(d)) which will provide a line, again both horizontally and vertically, for situations including fitting and levelling cupboard units, etc.

### Applications (Fig. 1.43)

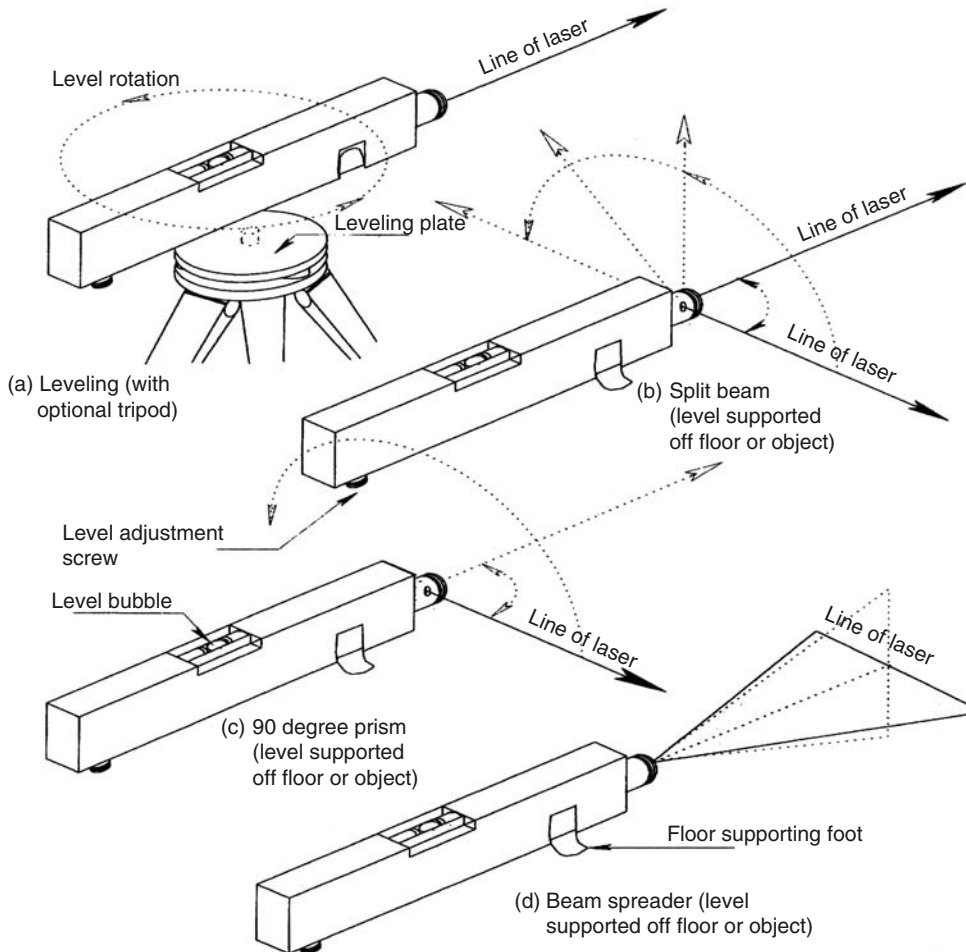
The laser level can be used for a variety of situations including establishing a level line around the wall or surface (Fig. 1.43(a)), where



**Fig. 1.40** *Levelling situations*



**Fig. 1.41** *Measuring different heights*

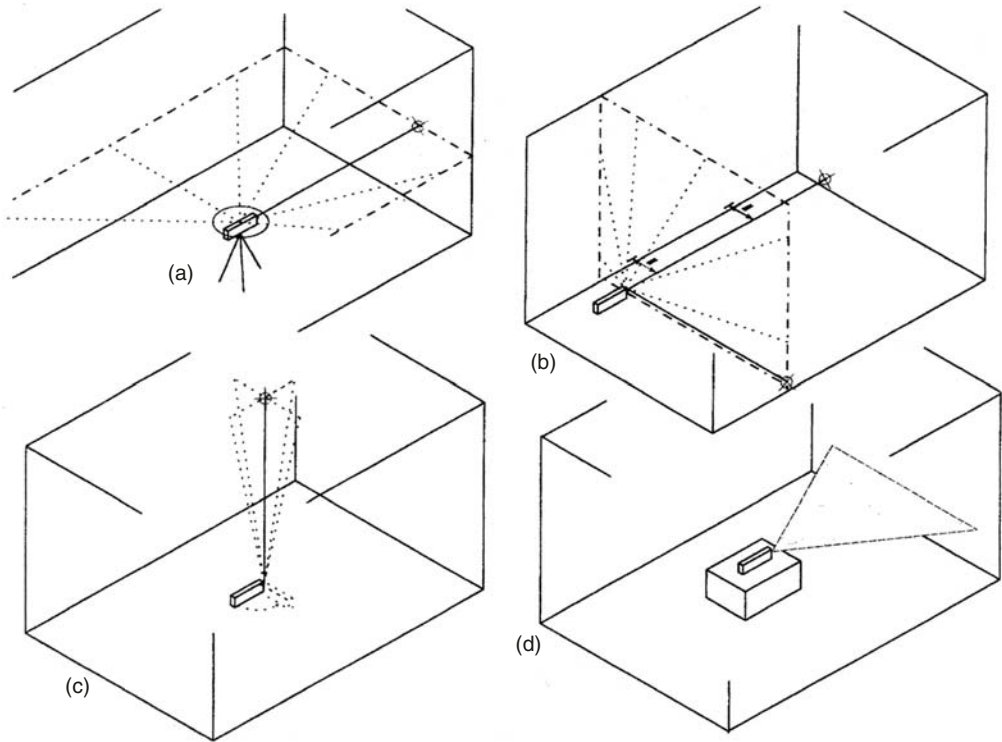


**Fig. 1.42** *Laser levels*

the level is placed on a tripod, or for setting out 90° angles in preparation for the sole plate for stud partitioning (Fig. 1.43(b)). Figure 1.43(c) illustrates a method of vertical setting-out for positioning on the ceiling. Finally, using the beam spreader (Fig. 1.43(d)) for levelling cupboard units, etc.

### 1.7.7 Auto rotating laser level (Fig. 1.44)

A more sophisticated compact piece of equipment which has similar uses. A rotating laser level with variable speed provides a continuous beam of light both horizontal and vertical on walls or surfaces. Examples of use include suspended ceilings, datum points and aligning partitioning. A hand remote control device is available with some models.



**Fig. 1.43** Applications: (a) Making a 'datum' level (perimeter of a horizontal plain); (b) Marking the perimeter of a vertical plain; (c) Transferring a ground point vertically; (d) Marking a straight line



**Fig. 1.44** Auto rotating laser level

### 1.7.8 Laser level safety

It must be stressed at this point to mention the dangers from misuse of laser levels. The laser beam that is created is classified as laser class 2 (EN 60825-1:1997) and the following points must be observed:

- Do not look directly into the beam, not even at a great distance due to the narrow focus of the beam. Also not with optical aids such as binoculars or glasses.
- Do not point at people or animals, particularly at head height.
- Wear the laser-viewing glasses to improve visibility in areas of poor light. Do not use as sunglasses or while driving. Laser-viewing glasses are not protective glasses against laser beams.
- Never tamper with the unit unless qualified to do so.

## 1.8 Vertical setting-out

It is essential that all constructional work is carried out with plumbness in mind – not just for the sake of appearance, but as an assurance of structural balance and stability.

Plumbness can be achieved with the aid of:

*Note: The more specialised optical instruments in this field are known as theodolites, used by professional surveyors in industry.*

- a suspended plumb-bob,
- a plumb-bob and rule,
- a spirit level,
- a site square (as already mentioned, see optical site square, 1.3.3).

### 1.8.1 Plumb-bob

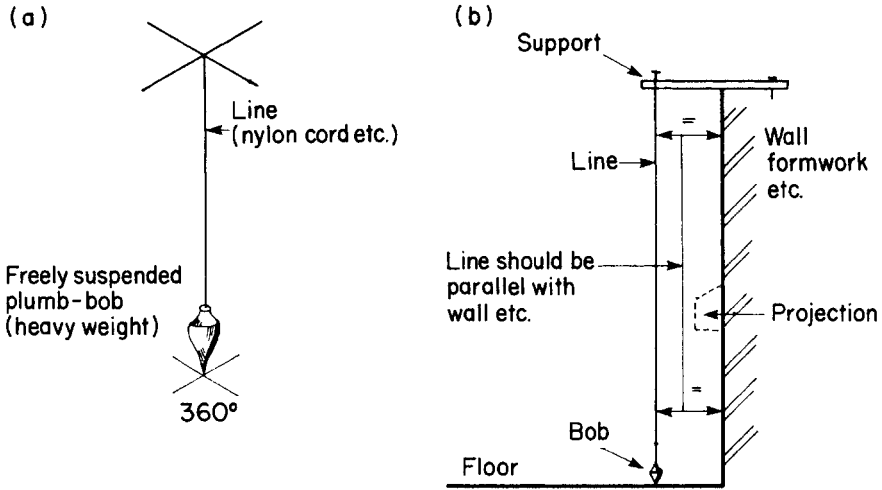
A plumb-bob is a metal weight which, when freely suspended by a cord or wire, produces a true vertical line. It is ideal for indicating vertical drop positions (Fig. 1.45(a)) or as a vertical margin line from which parallels can be measured or referred such as a wall (Fig. 1.45(b)) or a column box.

The size of the weight will largely depend on the type of work and the conditions under which they will be used. A very long plumb line may have to have its bob submerged in a container of water to help reduce the amount of swing.

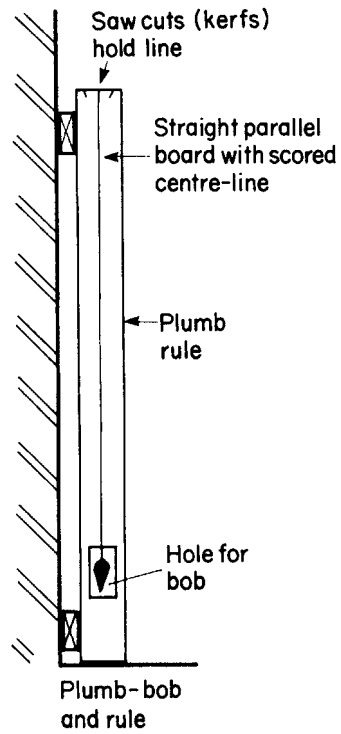
### 1.8.2 Plumb-bob and rule

A plumb-bob and rule (Fig. 1.46) allows the plumb line to make contact with the item being tested for plumb. The rule is made from a straight parallel-sided board – a hole is cut through one end to accommodate the bob and allow the line to make contact with the

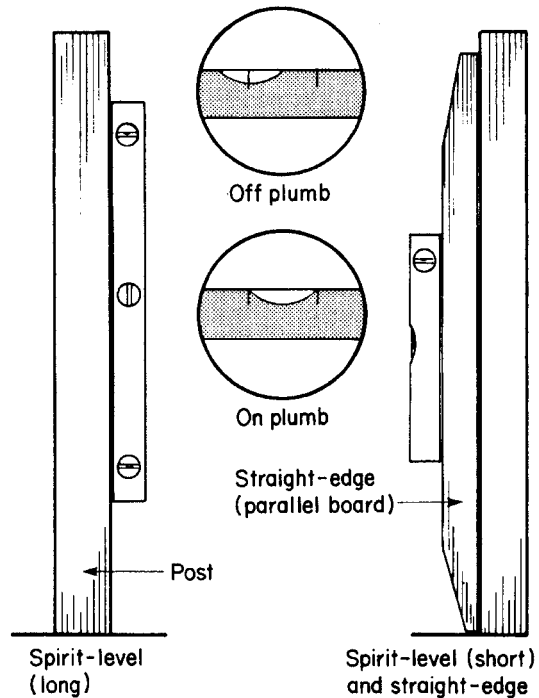




**Fig. 1.45** *Plumb-bob and line*



**Fig. 1.46** *Plumb-bob and rule*



**Fig. 1.47** *Testing for plumb with a spirit level*

face of the rule, and saw kerfs cut in the top grip the line. A central vertical gauge line is used as the plumb indicator.

### 1.8.3 Spirit level (Plumb stick)

With the exception of the very short level, all spirit levels can be used to test plumbness (Fig. 1.47). Accuracy will depend greatly on the level's length and bubble setting – most are factory sealed; others are provided with means of adjustment.

#### **Testing a bubble for accuracy**

The following steps can be followed:

- (i) Position the level against a firm straight vertical object. Note the position of the bubble in relation to the central margin on the tube (vial).
- (ii) Keeping the level in a vertical plane, turn it through  $180^\circ$ . The bubble has now been turned about (end for end).
- (iii) Reposition the level against the vertical object. The bubble should take up exactly the same position in the tube as before – even the smallest variation is unacceptable.

*Note: By substituting the horizontal plane for the vertical plane, the same testing principles can be applied to levelling.*

- (iv) If adjustment is necessary, the level should be returned to the maker or their agent; in the case of adjustable levels, the maker's instructions should be carefully followed.

Inaccuracies usually only occur as a result of accidental damage or misuse.

## **Reference**

BS EN 60825-1: 1997.

# 2

## Fences and hoarding

Land – whether used for building, farming, or leisure – will need to be divided up into partially or fully enclosed areas for the purpose of:

- (a) fixing its boundaries,
- (b) security of on-site materials and equipment,
- (c) protection of the general public and the workforce,
- (d) restricting the movement of animals, etc.

Where such areas are to be used as building sites, the extent to which they need to be enclosed often depends on site location. Rural (countryside) sites may require only limited security and protection, although free movement of animals and cattle may cause problems. Urban (town and city) sites, on the other hand, usually require optimum protection to restrain the public from inadvertently wandering into what is often a highly active area and so protect them from accidents as well as to help prevent theft and vandalism.

If a site has an existing boundary fence or wall, this may require heightening and modifying to meet the requirements mentioned. Where new barriers are to be constructed, consideration should be given to whether they will remain as a permanent feature or are only a temporary measure. The duration for which a temporary barrier is required will depend very much on the type of job. Perimeter barriers can be very costly, both in materials and labour. Rural and sub-urban (outskirts of a town or city) sites often permit less expensive inner enclosures in the form of a compound large enough to contain items of value and/or those which may put people at risk, for example, items of machinery, equipment, and dangerous substances, etc.

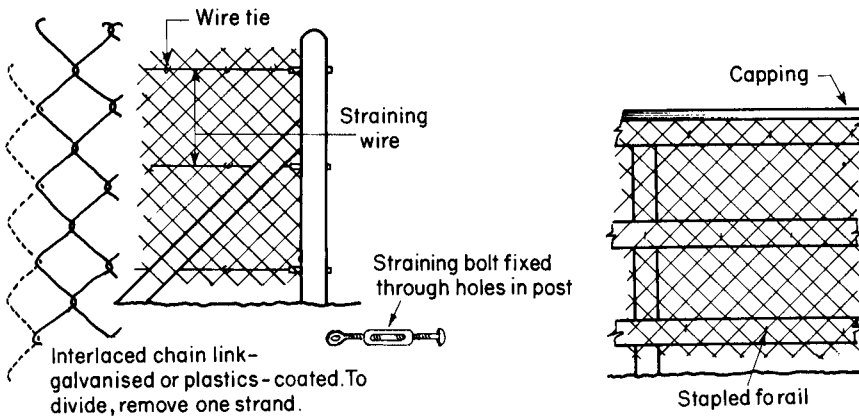
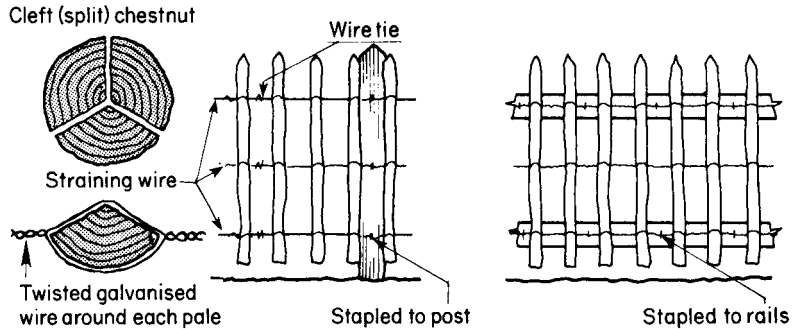
### 2.1 Fences

The degree of security and protection offered by a fence will depend on its height and construction. Apart from some recent developments with plastics and methods of preserving wood, styles, and constructional methods have changed little over the years.

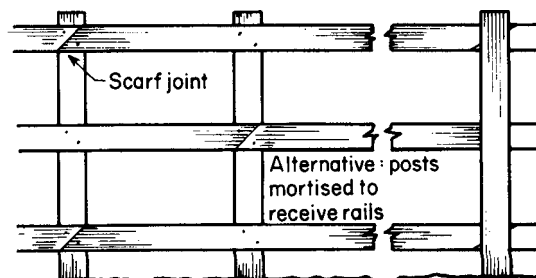
Broadly speaking, fencing can be identified as follows:

- (a) cleft chestnut pale (Fig. 2.1);
- (b) chain link (Fig. 2.2);
- (c) post and rail (Fig. 2.3);
- (d) palisade and close boarded (Fig. 2.4);
- (e) ranch (Fig. 2.5);
- (f) panel (Fig. 2.6);
- (g) feather-edge boarding (Fig. 2.7).

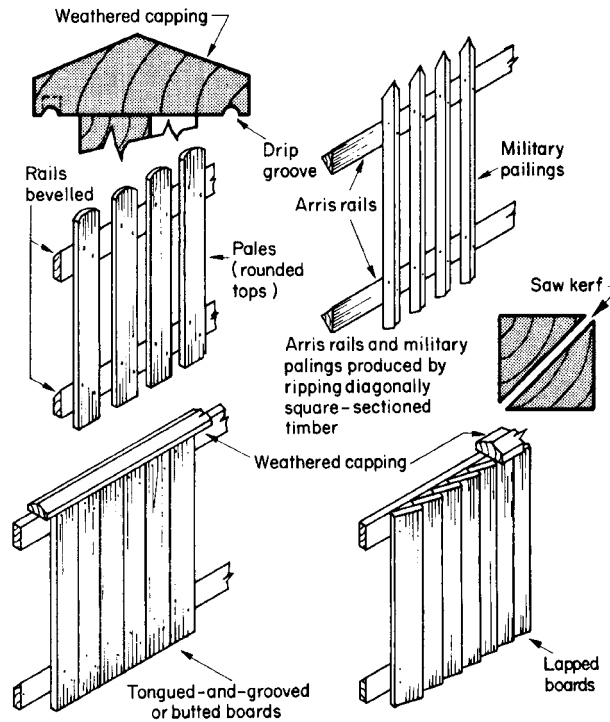
**Fig. 2.1** *Cleft-chestnut-pale fencing*



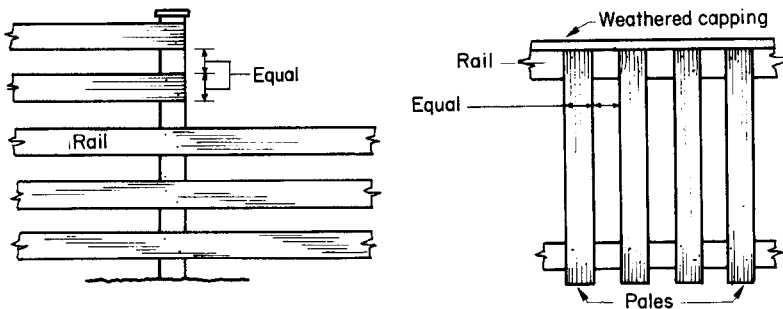
**Fig. 2.2** *Chain-link fencing (galvanised or plastics coated)*



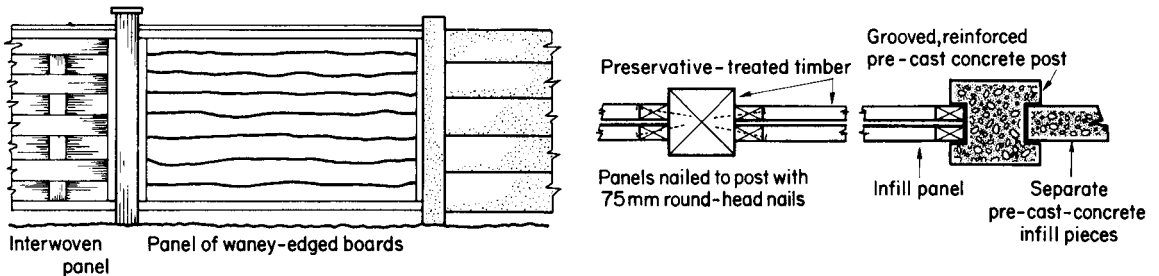
**Fig. 2.3** *Post-and-rail fence*



**Fig. 2.4** *Palisade and close boarded*

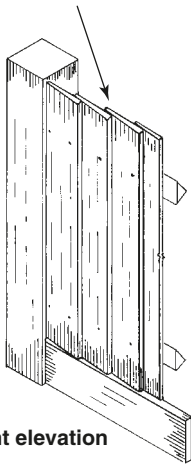


**Fig. 2.5** *Ranch fencing (boards and gaps of equal width)*



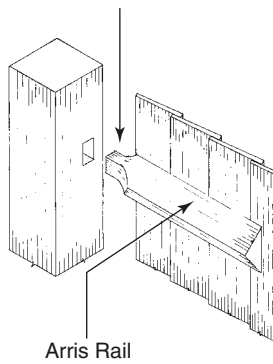
**Fig. 2.6** *Panel fencing*

Feather-edge boarding fixed to arris rail with galvanised nails



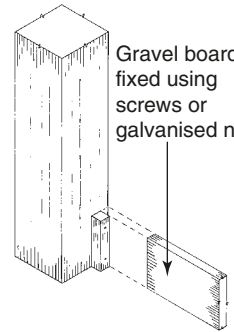
**Front elevation**

End of arris rail shaped to fit mortice



**Arris Rail**

Gravel board fixed using screws or galvanised nails



**Rear elevation**



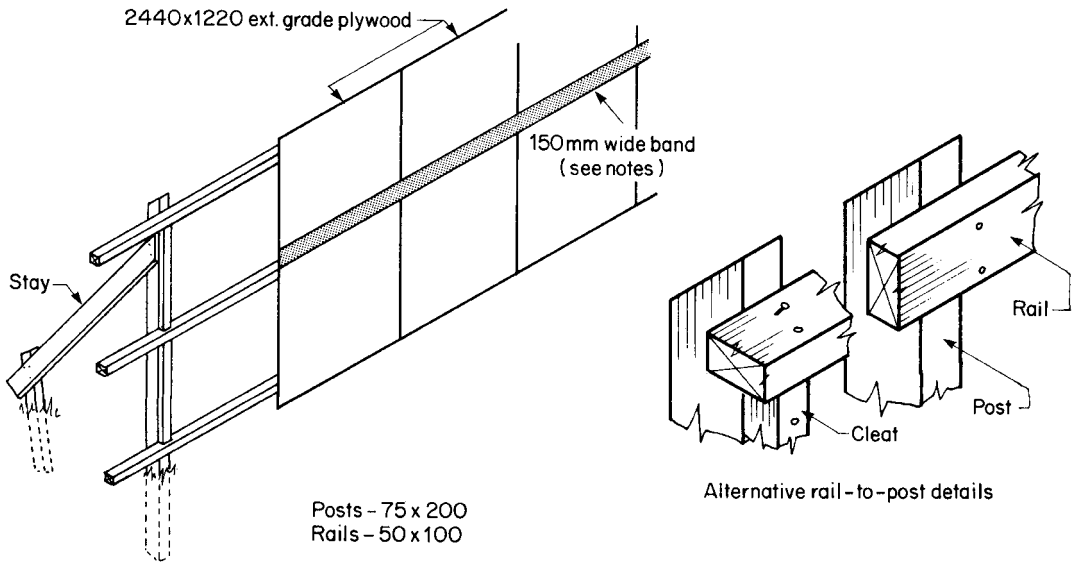
**Fig. 2.7** *Vertical-feather-edge boarding*

**Note:**

- *Post-and-rail and ranch fencing: both serve only as visual barriers – their ladder design would do little to discourage would-be intruders. The remaining types can be adapted to form a physical barrier.*
- *Close-boarded fencing: provision must be made between boards for moisture movement when tongued and grooved or butted boards are used (see Volume 1, Fig. 1.33).*

## 2.1.1 Laws on fencing

Before any new fence is erected the local authority (LA) planning department needs to be consulted regarding any regulations in height or design. Generally any garden fence over 1 m or any fence over 2 m adjoining a highway will need planning permission from the LA. This will of course vary over different areas of the country.



**Fig. 2.8** In situ sheet hoarding

## 2.2 Hoarding

Under the Highways Act 1980, Sections 172(1) and (2), before the start of any work involving the construction, alteration, repair, or demolition of a building situated in a street or court, a close-boarded hoarding or fence should be erected to the satisfaction of the appropriate LA to separate the building from any street, court, or public footpath, and thereby ensure public safety.

Hoardings must be designed with structural stability in mind – particularly with regard to resisting wind pressure and, in some cases, crowd pressure. Appearance matters greatly as a public-relations exercise – unsightly second-hand material such as old house doors or badly scarred ex-formwork plywood can serve only as bad publicity for the client and contractor alike – not to mention incurring the disapproval of any LA.

A typical arrangement for an *in situ* sheeted hoarding is shown in Fig. 2.8. Figures 2.9 and 2.13 shows typical types of hoarding used around a city building site.

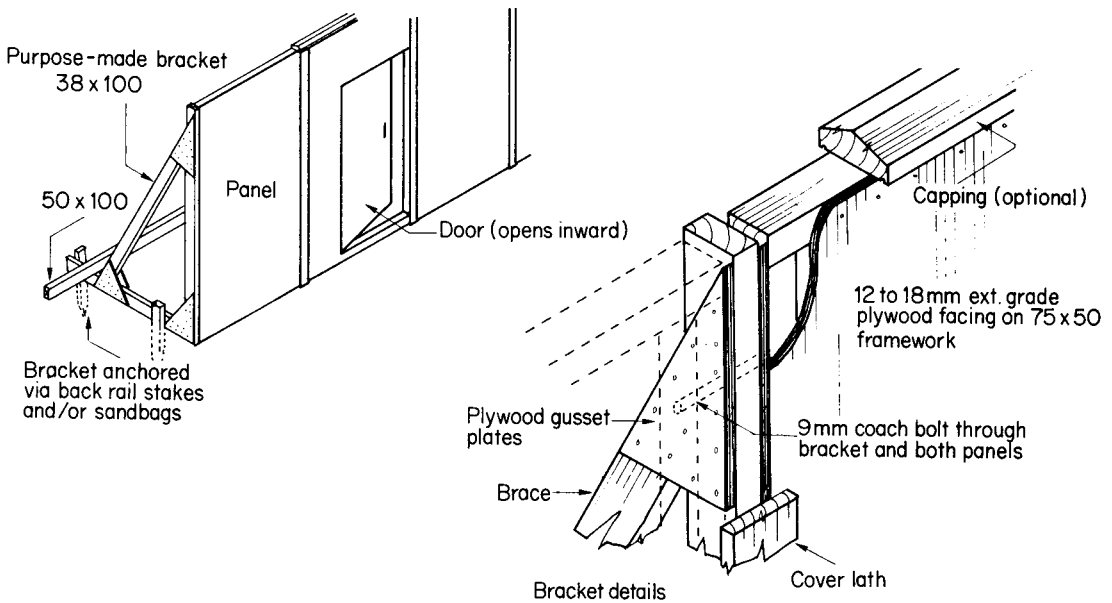
When hoarding is used on a regular basis, pre-fabricated panels like those shown in Fig. 2.10 may be used. Those which incorporate back brackets are particularly suited to paved areas.

A shopfitter may only require a short length of hoarding during the installation, replacement, or repair of a shop front – in which case a folding hoarding could be considered, as shown in Fig. 2.11. The number and size of leaves should be in keeping with its size, handling, and storage.





**Fig. 2.9** *Hoarding, viewed from outside a city-centre building site*

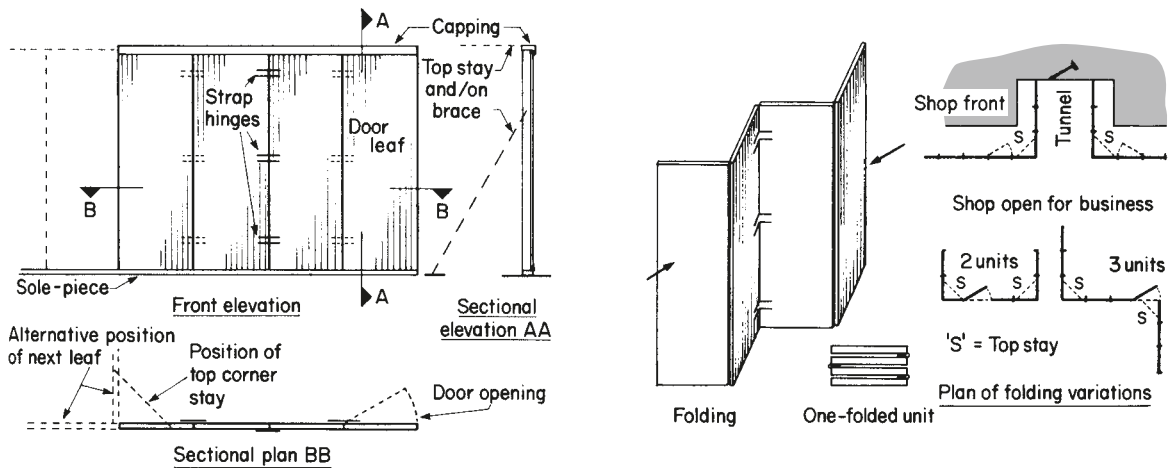


**Fig. 2.10** *Pre-fabricated panel and bracket*

Doors and gates in hoardings, to allow personnel and vehicles to enter and leave the site, must not open on to or impede a public footpath or roadway at any time.

### **2.2.1 Encroachment onto a public footpath**

Subject to the width of the existing footpath, and the approval of the LA, a minimum of 1.2 m should be allowed for pedestrian traffic.



**Fig. 2.11** Folding hoarding



**Fig. 2.12** Hoarding encroaching onto footpath with site offices above

Note: Where temporary structures are sited on, or adjacent to, an unlit pedestrian way, they should be brightly decorated, or marked with a continuous 150 mm wide white band, with its lower edge running 1.6 m above the ground (Fig. 2.8).

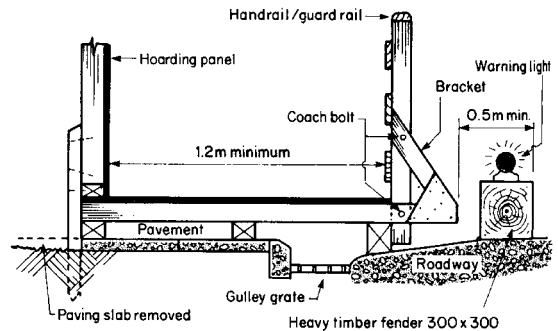
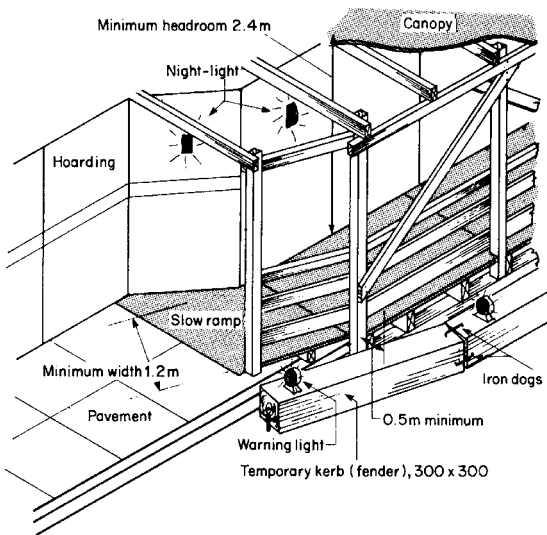
For reasons of safety, the roadway may have to be encroached upon to provide a walkway, in which case an arrangement similar to that shown in Figs 2.9, 2.12 and 2.14 may have to be considered and agreed upon with the LA.

The highway authority may ask for some advanced warning signs (works and road narrow signs, etc.) for approaching traffic. In some cases the contractor may be asked to provide 'chevron' markings at the start of the temporary walkway.

Provisions must also be made to ensure that both the hoarding and walkways, etc. are sufficiently lit during the hours of darkness.



**Fig. 2.13** *Hoarding viewed from inside a city-centre building site*



**Fig. 2.14** *Encroachment on to a public footpath and roadway*

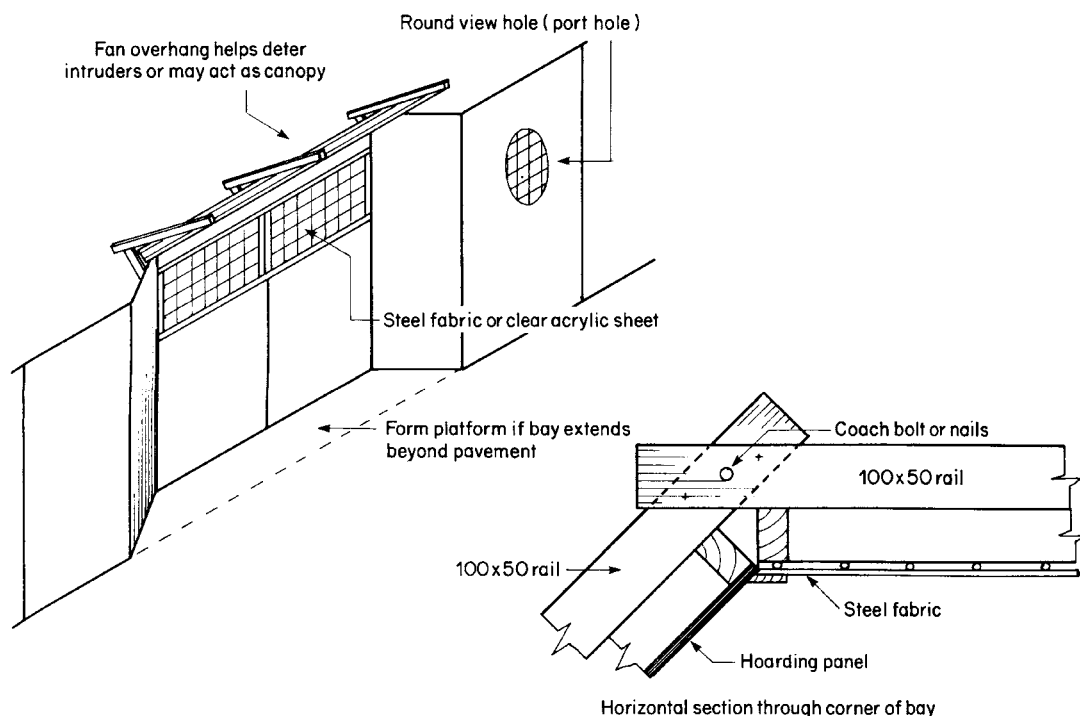
## 2.2.2 Observation windows

By virtue of its solid screening, hoarding prevents the general public from viewing site activities; therefore, unless provision can be made elsewhere, it is often advisable to provide openings in the form of windows in the hoarding panels. This should discourage the athletic from peering over the top, or peepers from looking through knotholes or panel joints. If pavement congestion is likely to be a problem, a viewing bay or platform as shown in Fig. 2.15 could be incorporated in the design.

Strategically positioned windows could give an overview of the whole site, making night policing less of a problem.

## 2.2.3 Fan hoarding

The Construction (Health, Safety and Welfare) Regulations 1996 specify that persons must be protected against falling objects. If,



**Fig. 2.15** *Observation bay*

therefore, there is any chance that a person may be put at risk – in this case, outside the confines of the site hoarding as a result of any activity from within – then an arrangement similar to that shown in Fig. 2.16 or 2.17 should be assembled. Its construction must be such as to form a safe catchment to direct whatever may fall back into the confines of the site.

## 2.3 Signboards

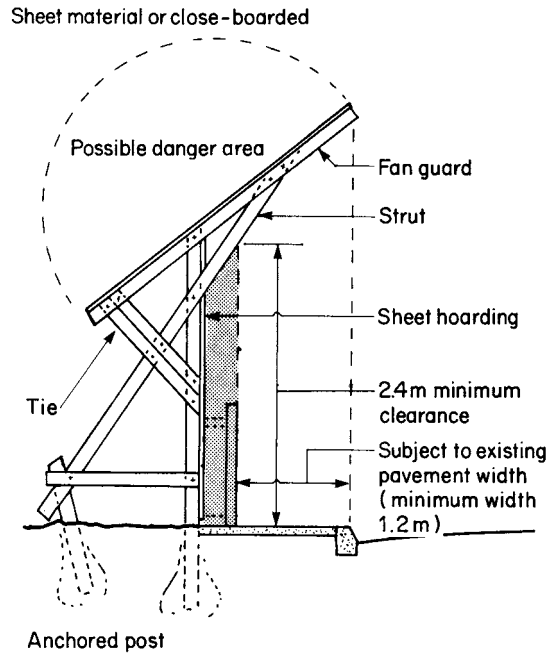
Signboards are necessary to publicise the nature of the work and the names of the companies participating in its development. A typical signboard and its construction are shown in Fig. 2.18.

Advertising in a general sense on a hoarding is prohibited unless permission is granted by the area planning authority.

## 2.4 Posts

Methods of sinking and anchoring posts as shown in Fig. 2.19 are chosen according to:

- (a) the type of fence or hoarding;
- (b) the height of the fence or hoarding;



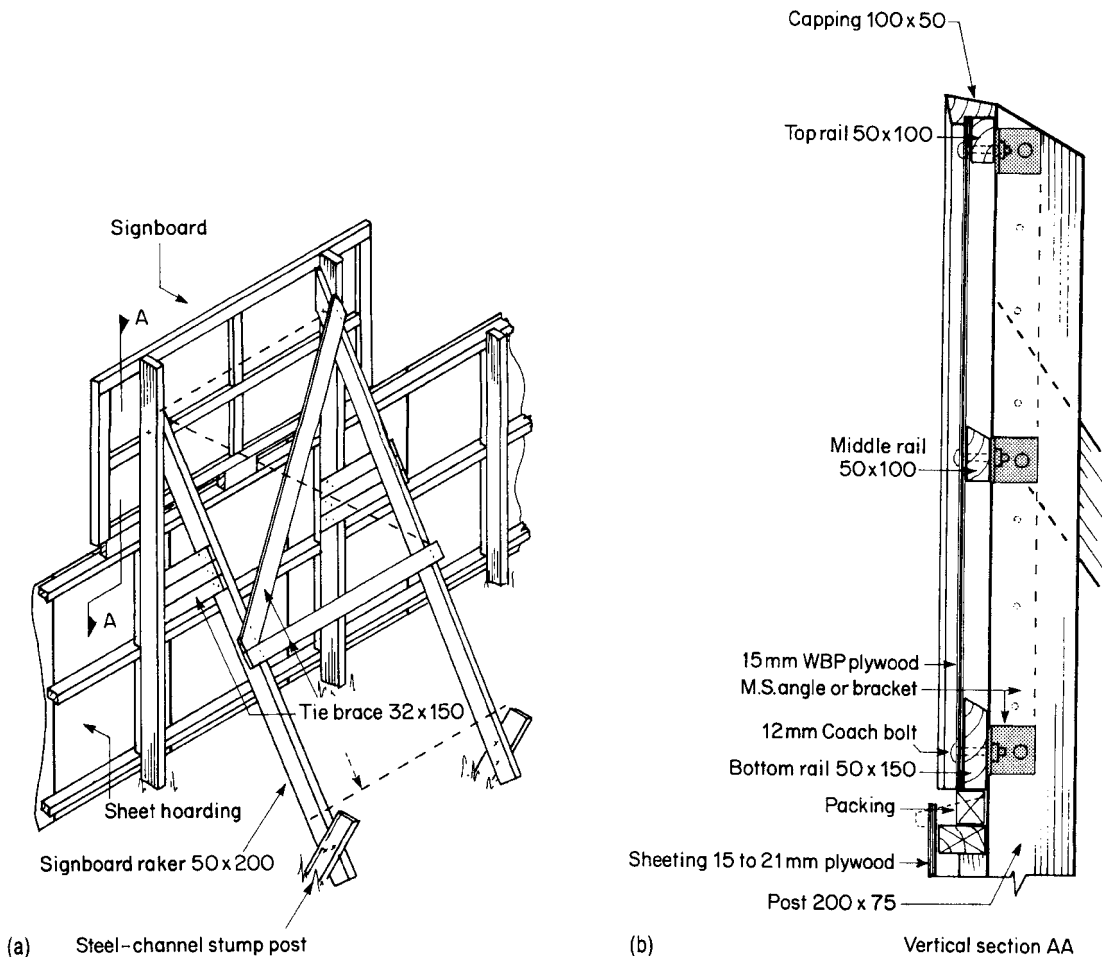
**Fig. 2.16** *Fan hoarding: a diagrammatic representation*



**Fig. 2.17** *Fan hoarding*

- (c) the post material – timber, concrete, or steel;
- (d) the required ground penetration with regard to load and earth condition.

Posts often rely on the added support of a stay or brace to help prevent any deflection and for stiffening. Sloping ground is not too



**Fig. 2.18** A typical signboard

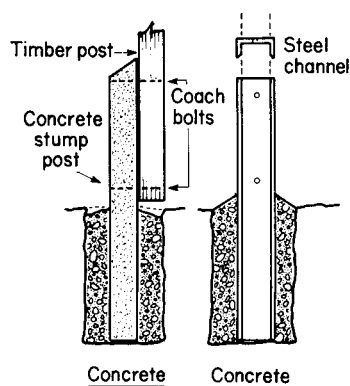
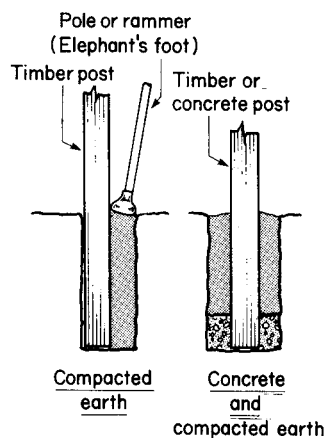
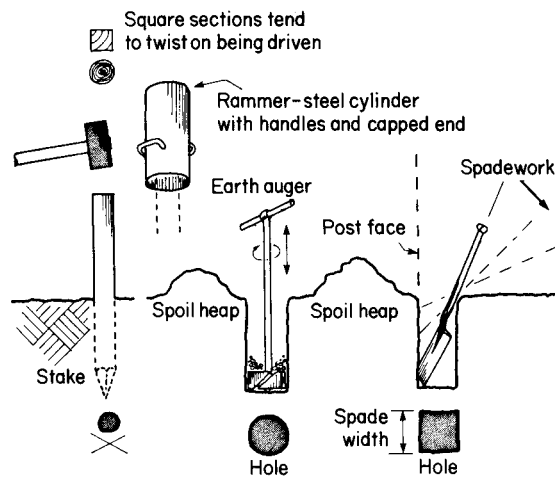
much of a problem provided a 'stepping' method (Fig. 2.20) is used to offset any gradient – running rails in the slope of the ground should be avoided for the sake of appearance, unless the ground is very steep.

## 2.5 Weathering and maintenance

Fences, hoardings, and signboards should be designed and constructed in such a way that rain-water is dispersed from their surfaces as quickly as possible – particularly end grain.

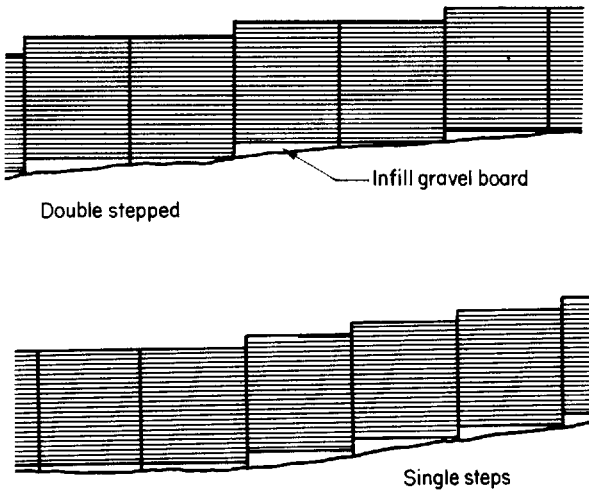
Tops of posts should be treated in a similar manner by either:

- shaping end grain (Fig. 2.21);
- a weathered capping (Fig. 2.22);

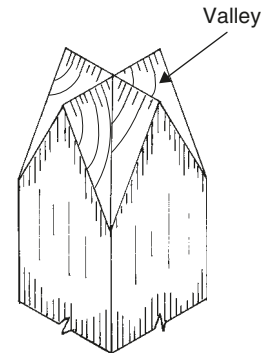


NOTE: If a timber post is to be capable of quick easy removal, it could be temporarily wedged (at ground level) with hardwood wedges into the neck of a sunken (concreted-in) stoneware or plastics sleeve (drain pipe)

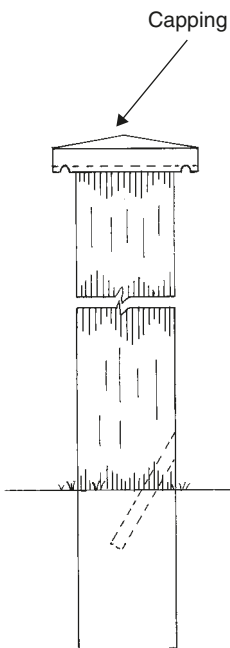
**Fig. 2.19** *Sinking and anchoring posts*



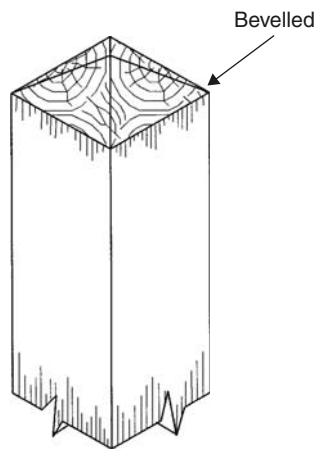
**Fig. 2.20** *Dealing with sloping ground*



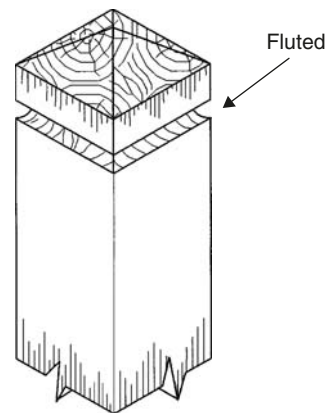
**Fig. 2.21** *Shaping the end of the post*



**Fig. 2.22** *Using capping*



**Fig. 2.23** *Bevelled*

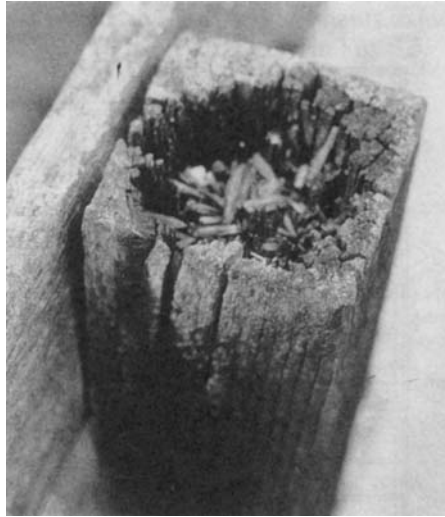


**Fig. 2.24** *Bevelled and fluted*

- bevelling all four sides (Fig. 2.23);
- bevelling (in this case a decorative groove (flut) has been included) (Fig. 2.24).

Although the timber has been treated with a preservative, this may only last a number of years. Regular coating with a suitable preservative or paint will ensure a long life span. Preservative treatment of timber situated below and just above ground level is essential (see Volume 1, Chapter 3 with regard to treating timber against fungal decay).





**Fig. 2.25** *The effect of weather on flat-top timber posts*

*Note: End grain is particularly susceptible to decay by wet rot, as shown in Fig. 2.25.*

### **Safe care of wood preservatives – see Vol. 1, Section 3.7.1**

Figure 2.22 shows an angled hole bored into the post at about ground level. This will allow a preservative to be introduced at this most vulnerable part.

### **References**

- The Highways Act 1980.
- The Construction (Health, Safety and Welfare) Regulations 1996.
- BS 1282: 1999, Wood Preservatives. Guidance on choice use and application.
- BS 4072: 1999, Preparations for wood preservatives.
- BS 4261: 1999, Wood Preservation, Vocabulary.
- BS 5589: 1989, Code of practice for wood preservation.
- BS 5268-5: 1989, Structural use of timber, code of practice for the preservative treatment of structural timber.
- BS 5707: 1997, Specification for preparations of wood preservatives in organic solvents.

# 3

## Formwork (temporary work)

Formwork is best described as a temporary construction designed to contain wet concrete until it has set.

There are two distinct types of formwork:

(a) *Pre-cast work (mould boxes)*

Used when concrete units are *pre-cast* by forming them in a mould, either at a convenient position on site or under factory conditions (often by a firm that specialises in concrete products) to be used as and when required such as:

- building blocks,
- paving slabs,
- lintels,
- coping stones,
- cappings,
- kerbstones,
- sills,
- beams,
- stairs (see Volume 3, Chapter 7),
- cladding.

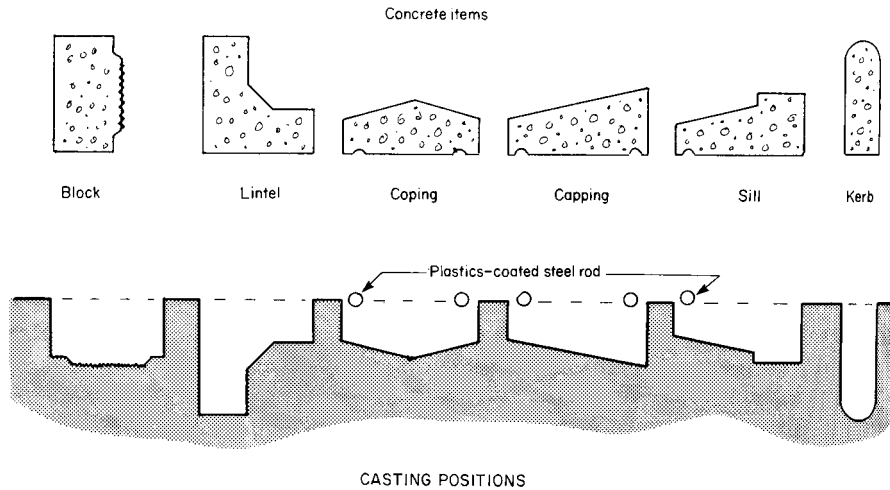
Some examples of the above are shown in Fig. 3.1.

(b) *In situ formwork (Shuttering)*

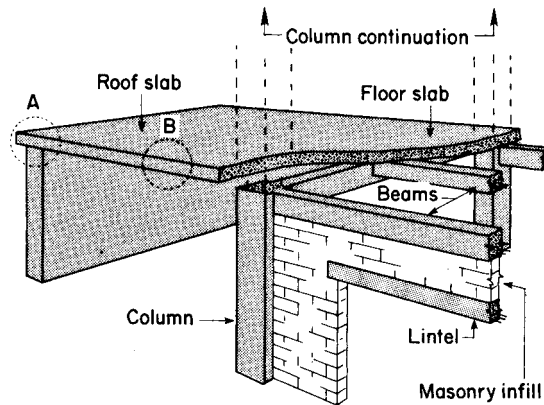
In this case formwork is assembled on site for casting elements that will form part of the structure in their actual position relevant to the building such as:

- columns,
- walls,
- suspended floors and roofs,
- steps and stairs (see Volume 3, Chapter 7).

Figure 3.2 shows examples of possible locations – details for ‘A’ and ‘B’ can be found in Fig. 3.17.



**Fig. 3.1** *Common pre-cast concrete products*



**Fig. 3.2** *Key to in situ structural elements*

## 3.1 Design

As wet concrete is a heavy semi-fluid material, its formwork must be capable of restraining not only its mass but also its fluid pressure. The deeper the formwork, the greater the pressure it has to bear. It is important to remember that the finished concrete surface will reflect the surface of its formwork. For example, sawn timber will produce a textured finish, just as planed timber, plywood (weather and boil proof, WBP; see Volume 1, Section 4.1.2), tempered hardboard (see Volume 1, Section 4.6.5), or sheet steel, etc. will produce a smooth finish, provided their surfaces do not adhere to the concrete, which may be the case unless they are pre-treated with some form of parting agent or release agent (see Section 3.3.3 & Volume 1, Section 3.6.1). If a mould oil is used for this purpose, which also helps prevent air holes being left on the surface of the set concrete, its application must be strictly in accordance with the manufacturer's instructions.

For reasons of economy, formwork (particularly mould boxes) can be re-used many times, therefore initial design must include quick, simple, and in some cases mechanical methods of assembly and striking (dismantling) without undue damage, by such means as wedges, bolts, cramps, and nails which can be easily redrawn without damaging the structure – preferably duplex-head types (see Volume 1, Table 12.1).

Formwork should be designed and suitably constructed to be capable of:

- (a) withstanding dead and live loads (Section 3.1.1),
- (b) being easily assembled and dismantled,
- (c) accurately producing or reproducing concrete items of correct size and shape,
- (d) producing the desired finish on the concrete face,
- (e) reusability for reasons of economy.

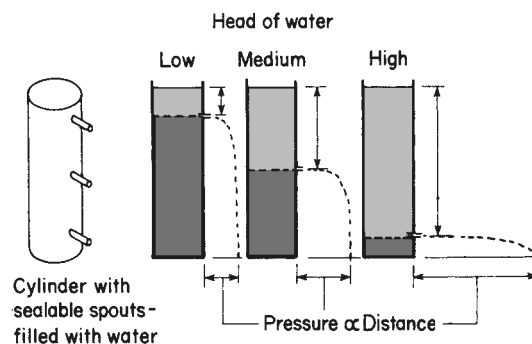
### 3.1.1 Loads on formwork

Dead loads are static loads such as the weight of the formwork and wet concrete. The dead load on the formwork due to the concrete and its steel reinforcement will become less as the concrete hardens and becomes self-supporting.

Live loads are those which are imposed during the erection of the formwork and the placing of concrete. They include the movement of the workforce, their materials, and equipment.

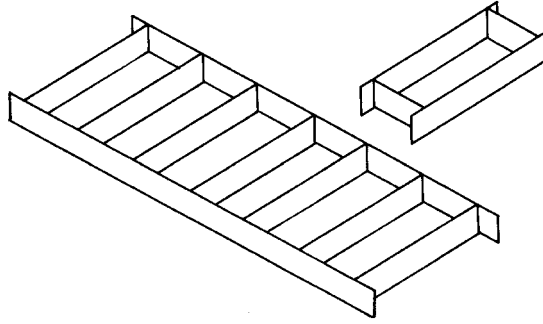
Unlike formwork used for suspended floor or roof slabs, which in the main is subjected to vertical loads. Formwork for columns, walls, and deep beams will have to resist varying degrees of lateral (side-ways) pressure as a result of the build up of concrete in its fluid state (fluidity is increased during its compaction by vibration) within the confines of the formwork.

Fluid pressure exerted on the formwork can be compared to the pressure built-up under a head of water, known as 'hydrostatic' pressure. Figure 3.3 shows how the head of water affects the pressure exerted on the cylinder walls at various levels; the same principle will apply to columns, walls, and deep beams.

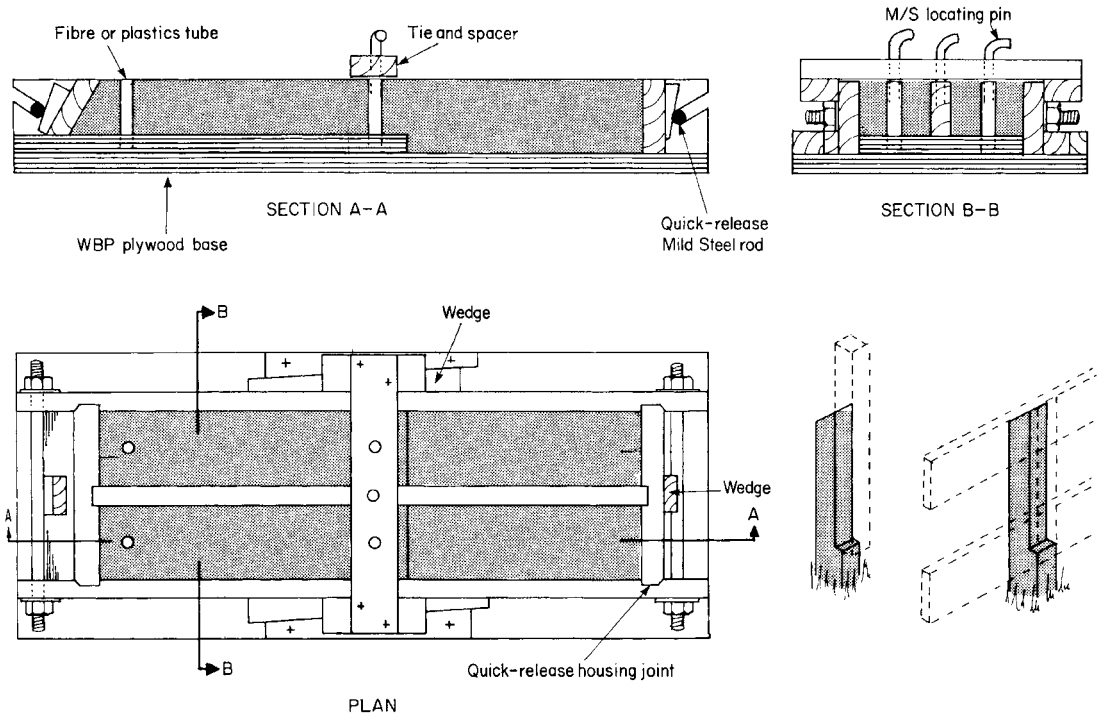


**Fig. 3.3** *The effects of hydrostatic pressure*

Note: Each section should be capable of being dismantled as shown in Fig. 3.5–3.7.



**Fig. 3.4** *Single and multiple casting units*



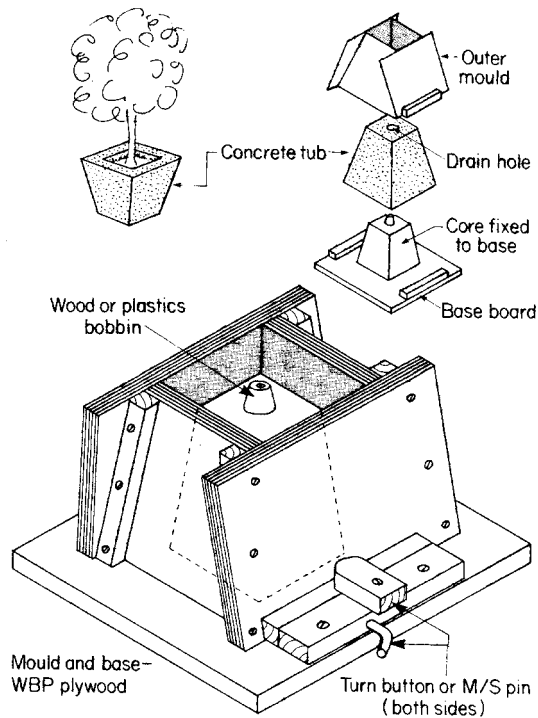
**Fig. 3.5** *Double mould box for pre-cast concrete posts*

## 3.2 Pre-cast work (mould boxes)

The shape of even a simple moulded object such as a jelly or a sand castle will hopefully reflect that of the mould from which it was produced. Similarly, concrete items such as those shown in Fig. 3.1 should also accurately reproduce the shape of their respective moulds.

Due to the weight of their contents, or the need to cast several items together (Fig. 3.4), mould boxes used for concrete products are usually made to dismantle easily.

Figure 3.5 shows in orthographic projection how a double-mould box could be constructed for a stump post, suitable for anchoring



**Fig. 3.6** *Mould box for plant tub or litter bin*

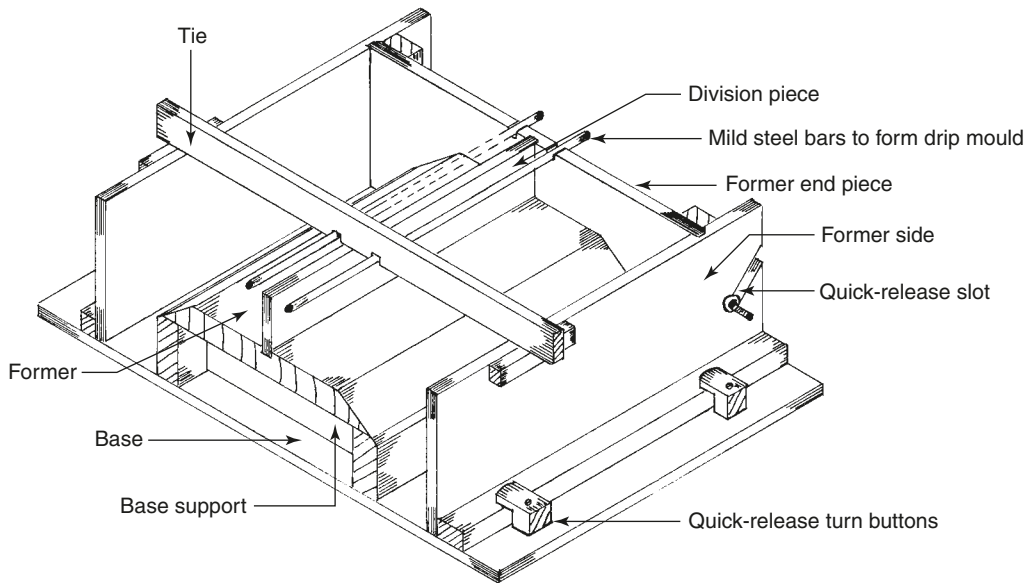
fence posts, etc. to the ground. The holes in the post are formed by casting plastic or cardboard tubes into the concrete. Notice how the bolts which hold the box sides in position can be slid out without removing the nuts, and how the end-stop housings are bevelled for easy seating and removal.

The mould box for a plant tub or litter bin shown in Fig. 3.6 is kept intact, because the shape of its outer shell allows it to be lifted off, leaving the casting on the core mould until the concrete is cured (completely hardened).

Figure 3.7 shows the construction of a mould box for the casting of a pair of boot lintels with the same principle of dismantling.

The quality of pre-cast components will depend upon:

- (a) The quality of the concrete and the way it is placed and vibrated in the moulds.
- (b) The stiffness of the mould box, its dimensional accuracy, and the finish of the surface in contact with the concrete. Open joints or poor detailing of the mould box will lead to poor surface finishes on the finished product.



**Fig. 3.7** *Formwork details of a mould box for casting a pair of boot lintels (part section only)*

### 3.3 *In situ* formwork (shuttering)

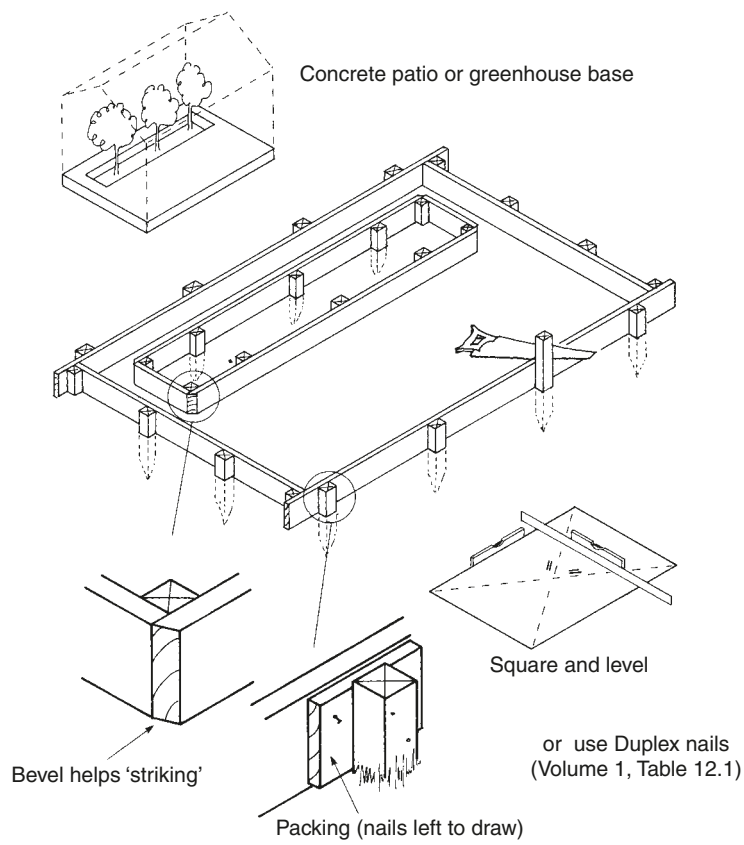
The simplest forms are those which provide only side and/or end support, such as for a concrete drive, path, or base for a light garage or shed, etc. Figure 3.8 shows a simple layout of formwork for a concrete patio or greenhouse base. Notice how a space has been left to one side to allow plants to be grown from the ground. Side boards are held by stakes firmly driven into the ground – packings between form board and stakes may be necessary where stakes are driven out of line. Stakes should be left long until the boards are fixed level. To avoid trapping encased boards, the corners have been cut back.

#### 3.3.1 Form (shutter) support and formwork hardware

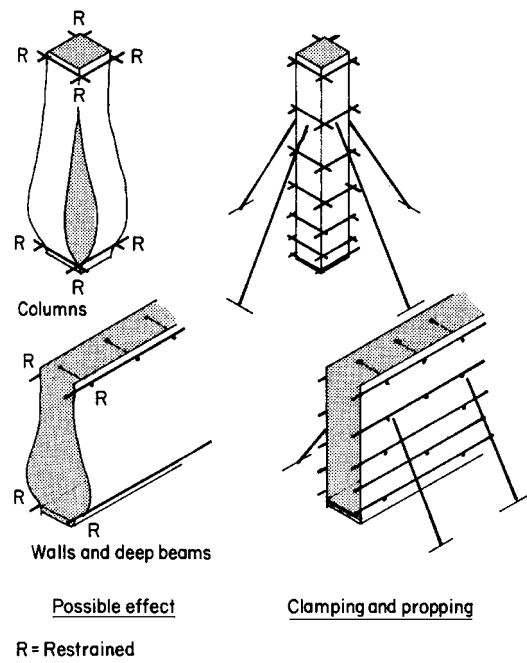
Forms' consist of those parts of the formwork that come into contact with the concrete (sheeting) together with their stiffening members, and they are often made up into panels. They will not be strong enough to withstand the loads and pressures mentioned without added support.

Forms for suspended floor and roof slabs require an arrangement of evenly distributed 'ledgers' (horizontal members supported by props or steel hangers) and either props of timber with hardwood folding wedges for adjustment or adjustable steel props (Fig. 3.17), to give support to the joists and decking (form) against vertical loads.

Figure 3.9 shows how a column-box, wall, or deep-beam form might react to the lateral (sideways) pressures of the wet concrete if only top and bottom restraints were used. In all cases it will be seen that greater restraint will be required towards the base. In the case of



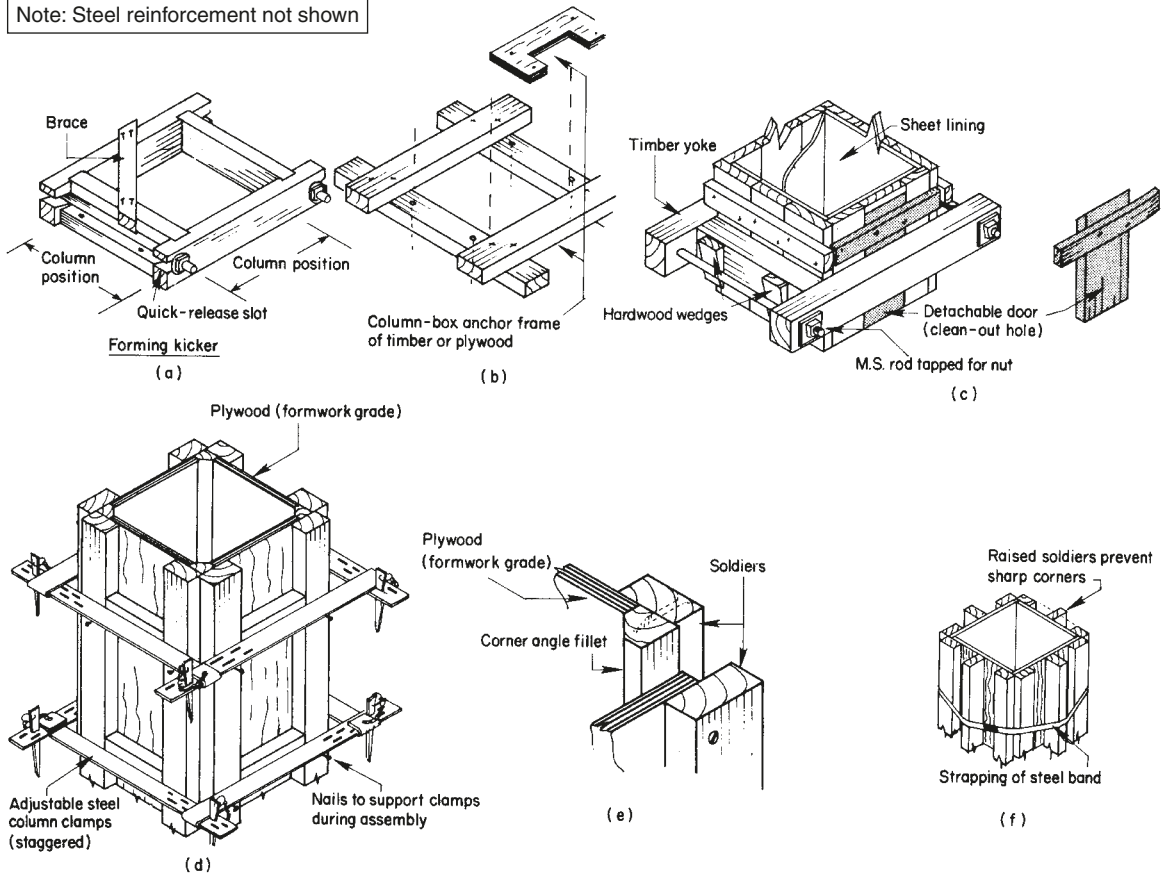
**Fig. 3.8** Formwork for an in situ concrete patio or base



**Fig. 3.9** Resisting the effects of hydrostatic pressure



Note: Steel reinforcement not shown



**Fig. 3.10** *Column-box construction and anchorage*

column forms, various types of 'yoke' (a clamping arrangement fixed around the forms to restrain lateral pressures, as shown in Fig. 3.10) and raking props are used. Wall forms use 'form ties' (devices for restraining both side forms as shown in Fig. 3.12 to 3.14), 'walings' (horizontal members), and/or 'soldiers' (vertical members) as well as raking props. Beam forms may take their support from 'beam clamps' (vice mechanisms supported by adjustable steel props as shown in Fig. 3.19), 'head trees' (strutted bearers on top of props as shown in Fig. 3.19), and props, or suspended steel hangers.

### 3.3.2 Sheeting (sheathing) and form lining

As mentioned above, sheeting makes contact with the concrete. Form linings also contact the concrete but refer to those materials applied or fixed to the inside face of the form to give the face of the concrete a special finish (see Fig. 3.10(c)).

Sheeting materials include boards of timber, but in the main these have been superseded by sheets of exterior (formwork-grade) plywood

(see Volume 1, Section 4.1.2). Moisture-resistant chipboard and oil-tempered hardboard (see Volume 1, Section 4.6.5) are other alternatives which, like plywood, can produce an almost unblemished joint-free finish on the concrete. Steel is used either as an all-steel panel system or as a form framework for plywood sheeting. Forms made up of glass-fibre-reinforced plastics (GRP) which have been pre-fabricated under factory conditions can be used where complex shapes have to be cast.

### 3.3.3 Preparing forms for concrete

The above materials may also be used as a form lining to produce finishes ranging from the very smooth, through the textured, to those with special patterned features. Best results are obtained by coating the lining with plastics solutions or film overlay, in fact their impervious nature gives good release qualities (reduces adhesion). However, some form linings will remain permanently in place after the formwork is struck, to provide the surface of the concrete with either acoustic or thermal-insulation properties – fibreboard and foamed plastics are two materials which may be considered for this purpose.

Screw and nail holes which may affect the finish should be filled with a waterproof stopper. Sheeting and lining cut edges should be sealed, and their surfaces should be clear of dirt, sawdust, chippings, or any foreign matter which could effect the ‘keying’ (adhesion to kickers and reinforcement) and setting qualities of the concrete. Deep formwork may require a purpose-made clean-out hole (Fig. 3.10(c)).

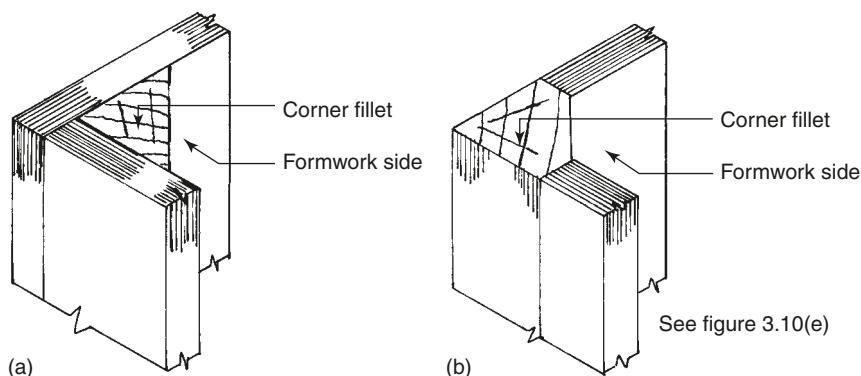
To prevent concrete sticking to the surface of the forms, a parting or release agent is used. Release agents may be in the form of an oil (mould oil), an emulsion, or a synthetic resin or plastics compound, the latter two may also require oil treatment. Treatment of this nature also increases the life of the forms (reusability) and helps reduce the number of surface blemishes and ‘blow-holes’ (holes left by pockets of air) appearing on the finished concrete.

*Note: Care should be taken not to get mould oils, or any release agents, onto steel reinforcement or areas where adhesion is important.*

Some treatments are not suitable for metal forms, as they tend to encourage rusting – maker’s recommendations should always be observed with regard to use and application. Application methods may include spraying, but mould oils are more usually applied by swab or brush.

### 3.3.4 Column formwork

Figure 3.10 shows various stages and arrangements for constructing formwork suitable for a square or rectangular column. Formwork must be securely anchored at its base, to ensure that it does not move from its appointed place during its construction or while the concrete is being poured. This can be achieved by one of two ways: by using formwork as shown in Fig. 3.10(a) to cast a kicker (a short concrete



**Fig. 3.11** Forming chamfers in column work

*Note: Care must be taken to prevent grout (cement slurry) from entering behind the feather edge of the triangular fillets when using chamfered timbers. This will cause an imperfect finish (Fig. 3.11(a)). However, Figs 3.10(e) and 3.11(b) shows a construction where this can be avoided.*

upstand above floor level, around which the formwork above is anchored) or by fixing an anchor framework to the floor (Fig. 3.10(b)) into which the whole column box sits and is securely fixed to it.

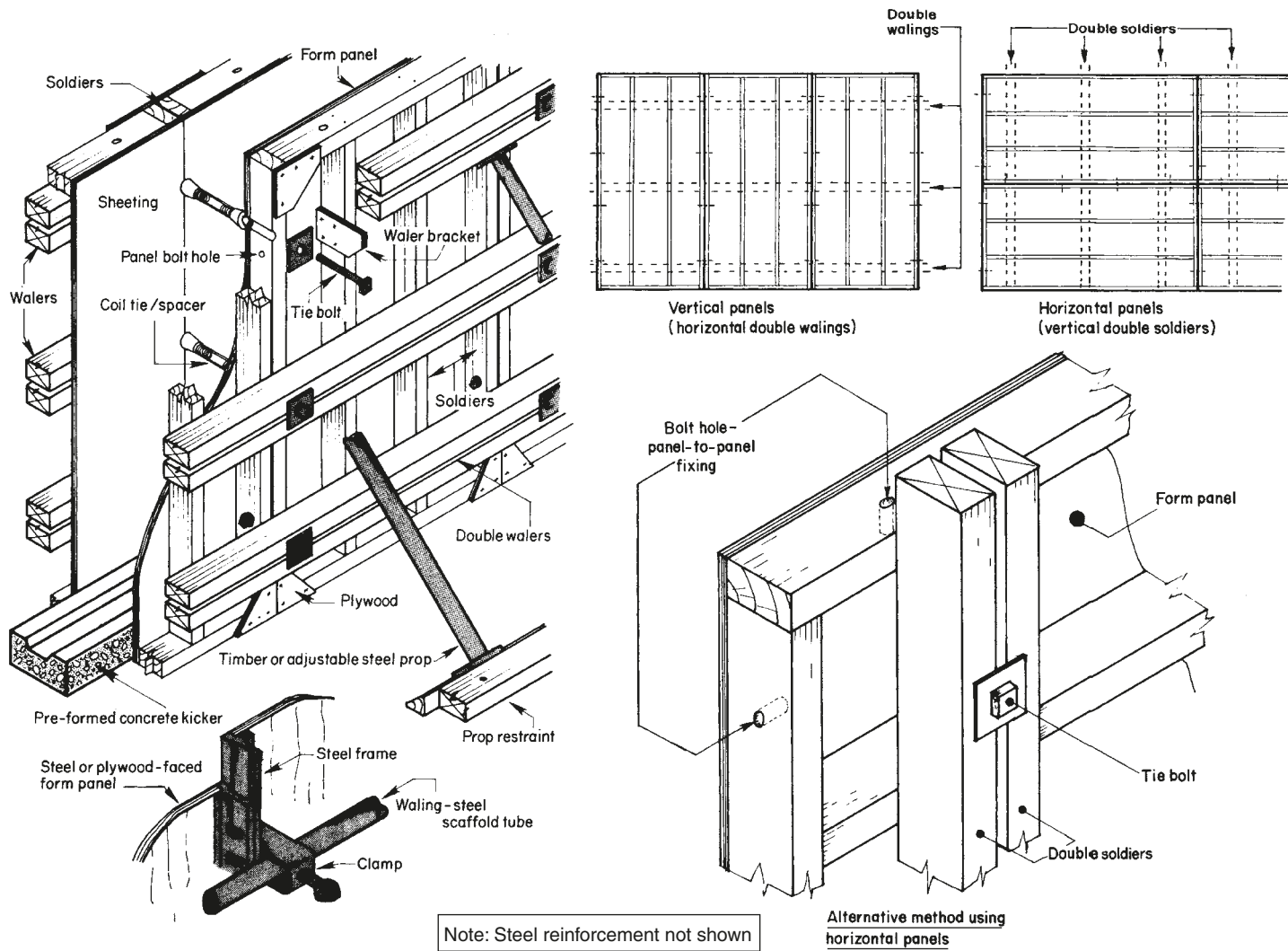
Figure 3.10(c) shows the bottom section of a column box. Its boarded forms are held in place by traditional timber yokes, double-ended steel bolts, and hardwood wedges. A clean-out hole with a detachable door is also shown.

Yokes made up of adjustable steel column clamps are shown in Fig. 3.10(d). They have been assembled in a staggered manner so that, when the wedges are tightened, they do not twist the formwork. Nails are used at all clamp location points, as a means of holding the clamps in position while they are being tightened. Figure 3.10(e) shows plywood sheeting being used – corner fillets prevent sharp corners, which otherwise tend to become damaged on striking and while the concrete is green. Joint details are shown in Fig. 3.11(a & b) (see note).

A steel strap has been used as a yoke in Fig. 3.10(f). Yokes of this type are applied in a similar manner to straps used to bind packing cases. Additional soldiers have been introduced midway along each side, to avoid sharp corners and provide extra bearing. Forms can be temporarily nailed together in pairs to form an 'L' shape – two of these pairs then form the column box. After the yokes have been fixed, the formwork is plumbed and held that way with raking props (Fig. 3.9). Prop heads should rest against form bearers – not the yokes – and feet should be restrained from sliding (Fig. 3.12).

### 3.3.5 Walls

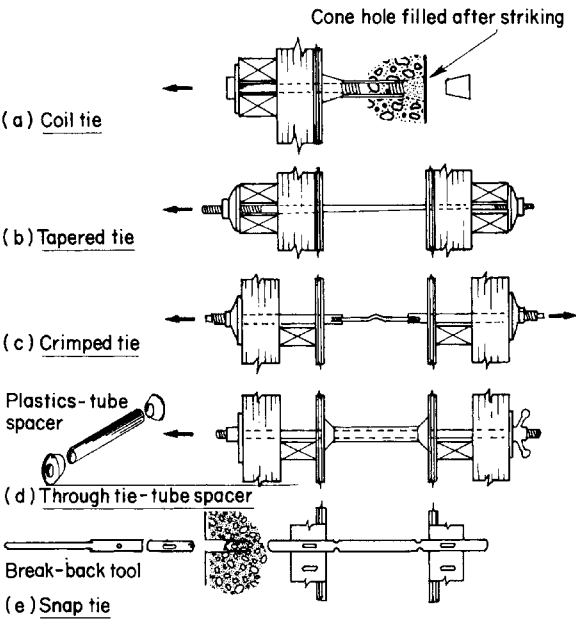
Wall forms are usually made up of pre-fabricated units or panels. A typical formwork assembly is shown in Figs 3.12 and 3.13 and includes soldiers, walings, props, form ties, bolts, and clamps. Some proprietary form ties and spacers are shown in Fig. 3.14. The 'coil' tie (Figs 3.14(a) and 3.15) is made from two coils of steel bar, held



**Fig. 3.12** *Wall formwork*

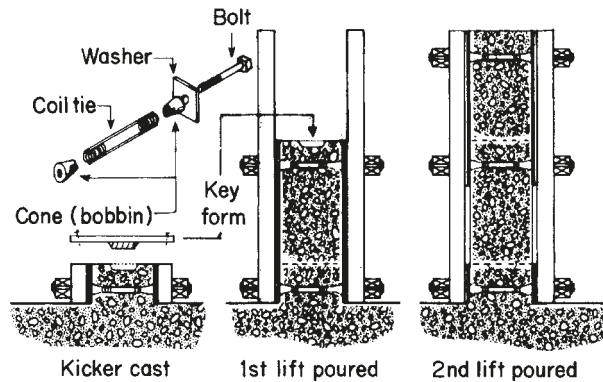


**Fig. 3.13**    *Erection of wall form*



Note: Ties withdrawn in the direction of the arrow

**Fig. 3.14**    *Form ties and spacers*



**Fig. 3.15** *Climbing formwork*

Note: Props and ground anchors not shown

apart by two short lengths of bar welded to them. The coils receive the thread of the bolts. Coil ties remain embedded in the concrete. The plastics cone ends and tie also serve as a distance piece, to keep both forms the correct distance apart. After the formwork is struck, the cones are removed and their holes are either filled with fine concrete or left as an anchor point (Fig. 3.15). A 'tapered' tie (Fig. 3.14(b)) is a through tie, that is, the whole tie is withdrawn after the formwork is struck. As it is taper, it can easily be withdrawn by applying pressure with a spanner to the wide end of the tie in the direction shown. Once the nuts/washers are fixed to the forms, a tapered tie also becomes a distance piece. The centre portion of the 'crimped' tie (Fig. 3.14(c)) remains in the concrete. The end pieces are withdrawn as shown and the holes are filled. Figure 3.14(d) shows basically a long double-ended bolt which passes through a tube and two cones (distance pieces). The tube remains embedded.

'Snap' ties (Fig. 3.14(e)) are used with steel forms. As the name implies, the ends of the ties are snapped off, using a special tool, leaving the break within the concrete. The holes are filled. Where, because of their height, walls are to be cast with two or more lifts of formwork, an arrangement similar to Fig. 3.15 could be used. A kicker is cast and, via the retained coil ties, is used as anchorage for the first lift. Subsequent lifts similarly use previous lifts as anchorage. Progression in this manner is termed 'climbing formwork'.

Note: Clean-out holes may be required at the base of column and wall formwork.

Figure 3.16 shows pieces of formwork at different stages of construction; notice that as a legal requirement hard hats are being worn by the operatives.



**Fig. 3.16** *Formwork at different stages of construction*

### **3.3.6 Suspended floor and roof formwork**

Decking units (forms) are usually pre-fabricated into standard sizes. These framed panels, made up of joists and decking, are positioned on to a pre-arranged assembly of ledgers, props, and bracing as shown in Fig. 3.17(a) or are positioned by crane as a table form (Fig. 3.18). Provision must be made for easy removal of all the formwork from within the structure – sizes of openings and doorways should be taken into account, as these may be the only exit once the floor or roof is cast.

### **3.3.7 Edge treatment**

Props or steel hangers (Fig. 3.17(b)) may be used where forms abut walls. The concrete cut-out on which the hangers rest can be packed with expanded polystyrene which can be easily removed and the hole filled once the slab is cast.

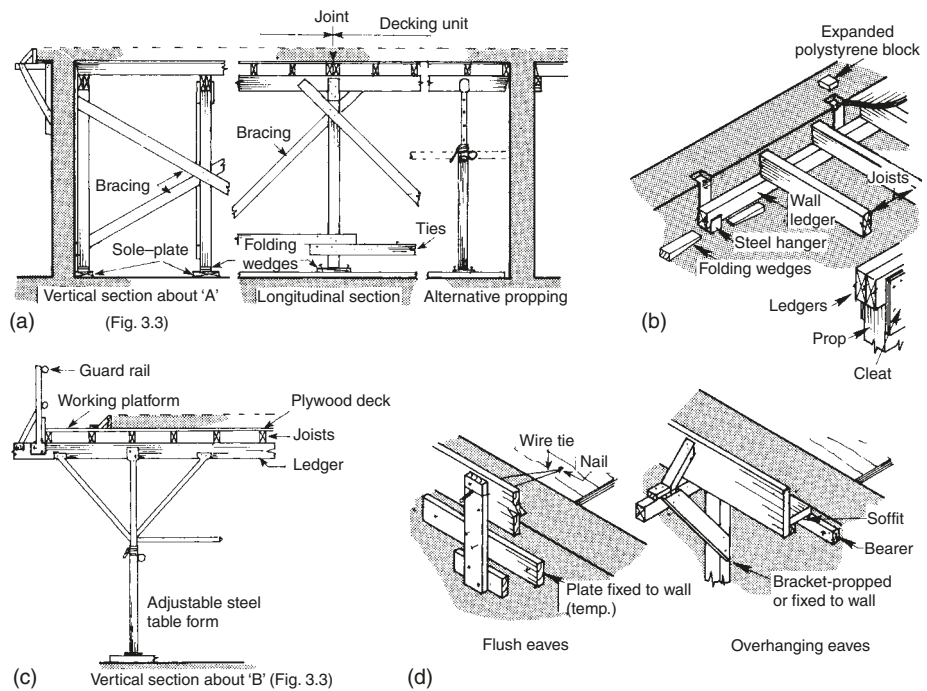
Figure 3.17(c) shows how slab edges to openings or overhangs may be formed (this detail includes a working platform as part of the formwork).

Figure 3.17(d) shows how eaves and verges can be formed. If the walls had been cast, retained coil ties could have provided the anchorage for brackets or soldiers. The straining wire used to restrain the edge form will be cast in the concrete.

### **3.3.8 Beam formwork**

Beam and lintel formwork both require side and soffit support, as shown in Fig. 3.19. As it takes most of the load, the soffit and its

Note: Section sizes of members will depend on loading and span, etc.

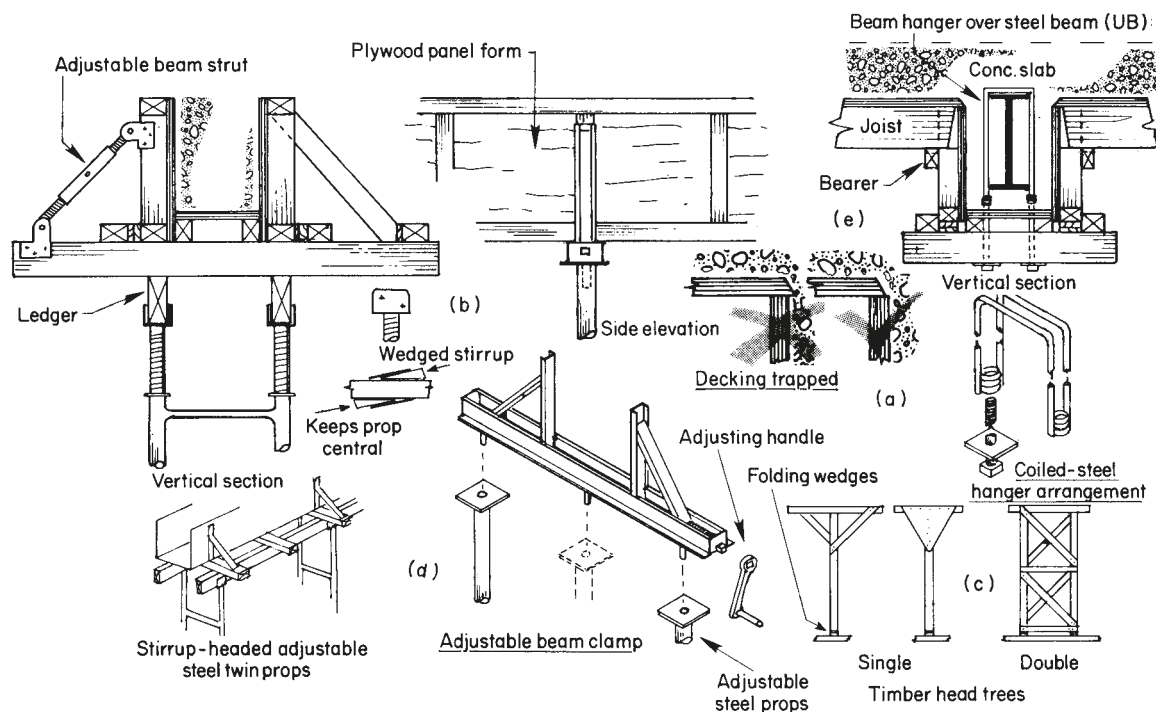


**Fig. 3.17**  
*Formwork for a  
suspended floor or  
roof slab*



**Fig. 3.18** *Crane handling a  
table form*



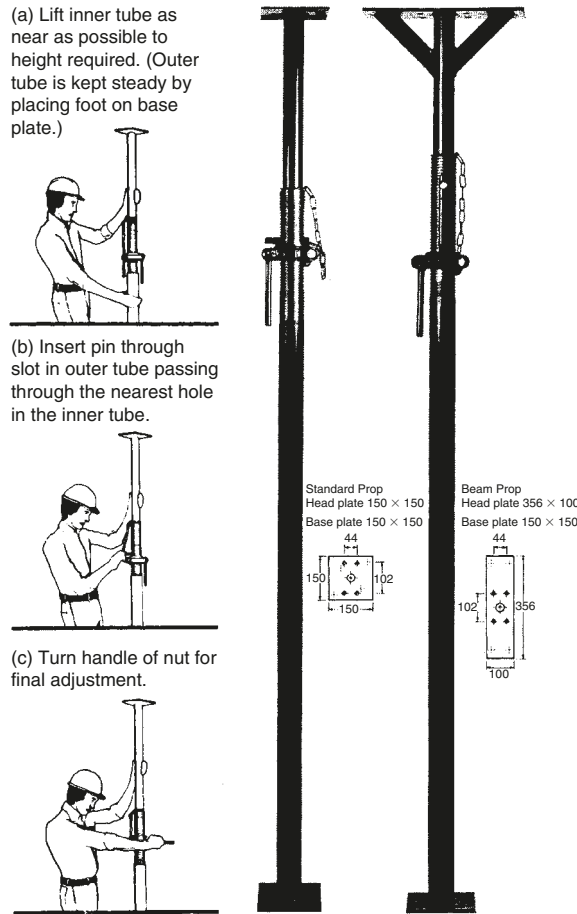


**Fig. 3.19** *Beam and lintel formwork*

supports will be struck last. To avoid members becoming trapped or boxed-in, attention should be paid to the sequence of striking, particularly when beam and slab formwork are as one. An example of how a decking may become trapped within a beam side is shown in Fig. 3.19(a). Figure 3.19(b) shows a soffit form sat on a head tree made up of a timber bearer sat across two ledgers, propped by an adjustable twin steel prop. The stirrup heads are wedged cornerwise to ensure that the bearing is centralised over each leg. Alternative head trees which use hardwood folding wedges for adjustment are shown in Fig. 3.19(c). Adjustable beam clamps (Fig. 3.19(d)) supported by adjustable steel props (Fig. 3.20) provide support to soffit and side forms which otherwise would require either a timber strut (raking) or an adjustable steel beam strut (Fig. 3.19(b)). If the concrete is to be cast around structural steelwork (Fig. 3.19(e)), steel beam hangers may be a possible means of support for both soffit and side forms. The hangers are retained in the concrete like coil ties.

### 3.3.9 Striking formwork

Formwork must not be removed from any structural concrete until the concrete is strong enough to carry both its own weight and any weight which may be superimposed upon it. *Approval to strike formwork should come only from the engineer in charge of the project.* Table 3.1 should only be used as a guide as to when forms may be available for reuse.



**Fig. 3.20** 'Acrow' adjustable steel props

**Table 3.1** Guide to minimum period before striking formwork. For ordinary Portland Cement (BS 8110-1: 1997)

Type of formwork	Surface temperature of concrete	
	16°C and above	7°C
Vertical formwork to columns, walls, and large beams	12 hrs	18 hrs
Soffit formwork to slabs	4 days	6 days
Soffit formwork to beams and props to slabs	10 days	15 days
Props to beams	14 days	21 days

Striking must be a gradual process carried out with care to avoid giving the concrete any sudden shock. In the stages of formwork construction, provision should have been made for column forms to be removed without disturbing beams and soffits, and beam side forms before soffits, etc.



**Fig. 3.21** *Concrete columns*

As each form is struck, it should be de-nailed and cleaned, with any damage made good, then stacked flat (out of twist) ready for retreatment and reuse.

Figure 3.21 shows a column that has just been struck, and a further two with props removed waiting to be struck.

### **References**

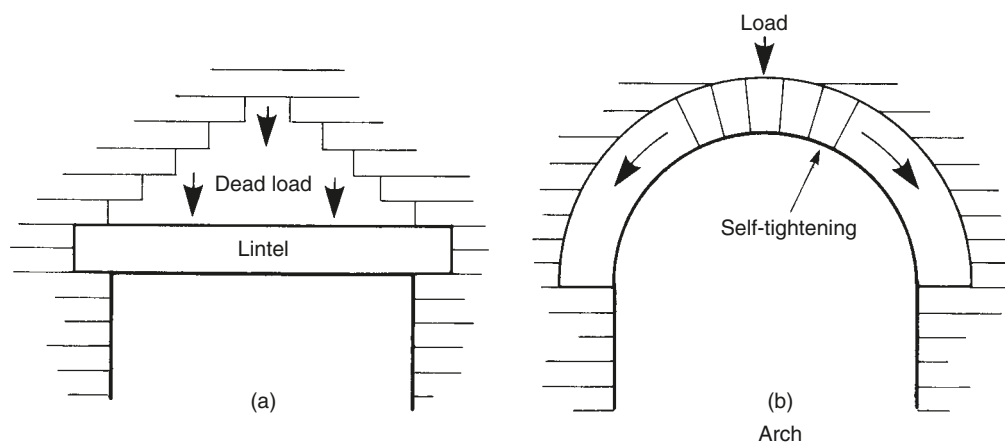
The Construction (Health, Safety and Welfare) Regulations 1996.  
HSE Safe erection, use and dismantling of falsework (Construction Information Sheet No. 56).  
HSE Cement (Construction Information Sheet No. 26).  
BS 8110-1: 1997.

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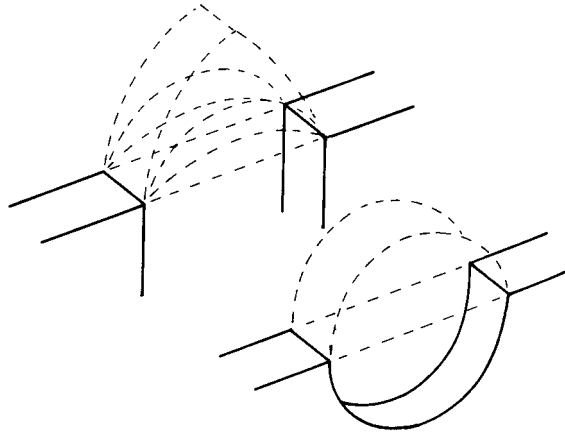
## Turning pieces and arched centres up to 1-m span

Where an opening is to be left in a wall as a passage, or to house a door or window frame, the load above it will need permanent support. A lintel (beam) can be used for this purpose, as shown in Fig. 4.1(a), or an arch can be formed. Arches allow the load above them to be transmitted around their shape as shown in Fig. 4.1(b).

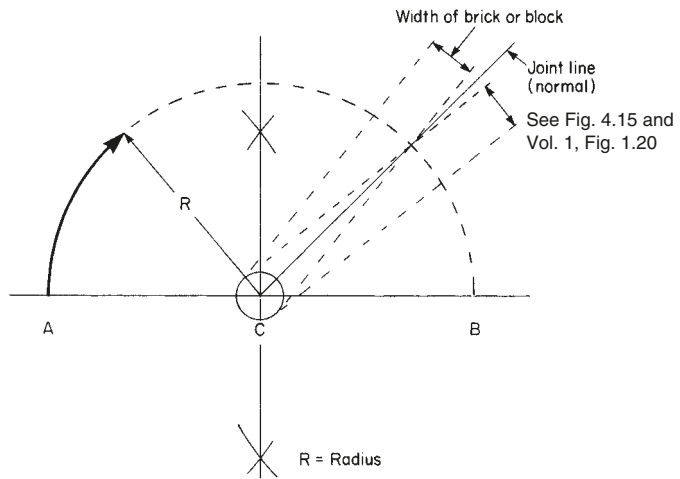
The construction of an arch necessitates substantial temporary support until it has set. A centre not only provides this support but also provides an outline of the arch on which the bricklayer lays bricks or the mason blocks. Several arch outlines are shown in Fig. 4.2.



**Fig. 4.1** *Support above an opening*



**Fig. 4.2** *Centres predetermine the shape of an opening*



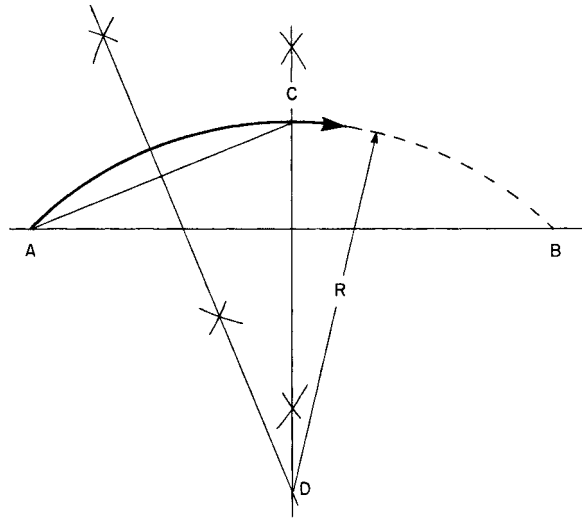
**Fig. 4.3** *Semicircular arch*

## 4.1 Methods of setting-out geometric arch shapes

### 4.1.1 Semicircular arch (Fig. 4.3)

Figures 4.3–4.7 illustrate methods of producing simple arch outlines. Arcs are scribed with the aid of a trammel bar and heads, (as shown in Volume 1, Fig. 5.6), or by similar improvised means.

1. Bisect AB to produce point C.
2. Using radius  $R$  (CA), scribe a semicircle from point C.

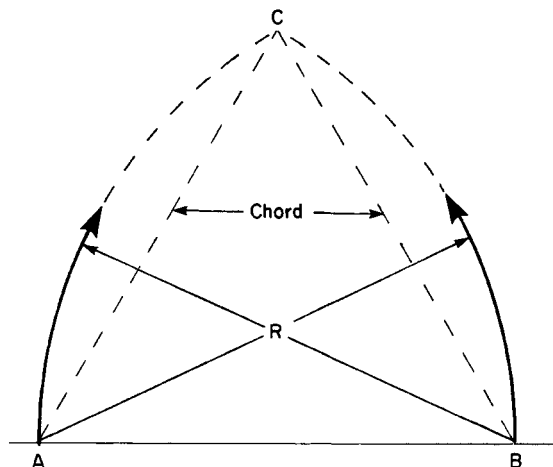


**Fig. 4.4** *Segmental arch*

#### 4.1.2 Segmental arch (Fig. 4.4)

1. Bisect AB to produce a perpendicular line cutting AB.
2. Determine rise C (less than half of AB).
3. Draw a line from A to C.
4. Bisect the chord AC to produce point D.
5. Using radius R (DA), scribe an arc from A through C to B from point D.

See Fig. 4.8 and Section 4.2 showing an alternative method of determining the length of the radii by calculation for scribing the arcs.



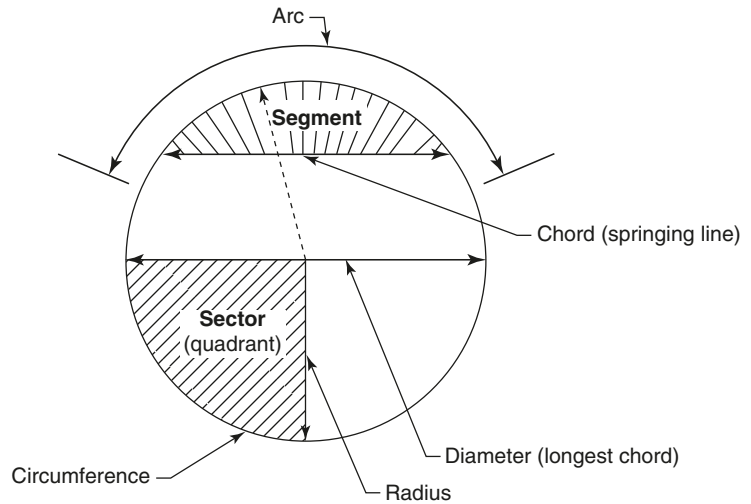
**Fig. 4.5** *Equilateral arch*

#### 4.1.3 Equilateral arch (Fig. 4.5)

Note: Chords AC and BC will be the same length as span AB.

1. Using radius R (AB), scribe the arc BC from point A.
2. Similarly scribe arc AC from point B, point C being the intersection of both arcs.





**Fig. 4.8** Parts of a circle (also see Volume 1, Fig. 1.20)

All the above outlines are derived from the arc of a circle as shown in Fig. 4.8, to produce the different forms.

As an example, a segment is a portion of a circle bounded by a *chord* (a straight line both ends which terminate at the circumference, the longest chord is called a *diameter*) and an *arc* (a portion of a circumference).

## 4.2 Determining the length of radii by calculation to form an arc

Figure 4.9(a) shows a line drawn horizontally and vertically through the centre of a circle. The resulting four lines (*a*, *b*, *c*, *d*) radiating from that central point would all be the same length (in this case represent the circles radius or radii).

Which is the basis for a formula we can use to calculate the radius of any segment of a circle. That is:

$$a \times b = c \times d$$

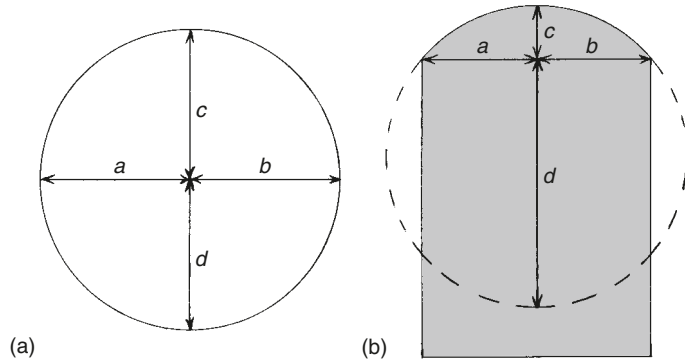
Wherever the horizontal or vertical line is moved, either up or down, left to right, the formula remains the same. Figure 4.9(b) shows this as part of a segmental arched opening.

As an example:

If we assume that the geometrical springing line (see Figs 4.8 and 4.11) of the arch in Fig. 4.9(b), is '*a*', (0.6) + '*b*', (0.6), and its rise (*c*) is 0.4 m, then the length of '*d*' will be unknown.



**Fig. 4.9** Calculating the radii for an arc



Then in order to determine this, we will first need to rearrange the formula ( $a \times b = c \times d$ ) to find the length of 'd'.

Now to get 'd' on it's own we need to divide both sides by 'c' to keep each side of the equation in balance, so:

$$\frac{a \times b}{c} = \frac{c \times d}{c}$$

As now, on the right-hand side we have a 'c' above and below the divisor line they can be cancelled out, so:

$$\frac{a \times b}{c} = \frac{\cancel{c} \times d}{\cancel{c}}$$

This now leaves:

$$\frac{a \times b}{c} = d$$

This can now be written so:

$$d = \frac{a \times b}{c}$$

Now we can substitute the letters (a, b, c) for the original dimensions so:

$$d = \frac{0.6 \times 0.6}{0.4}$$

$$d = \frac{0.36}{0.4}$$

Therefore the length of 'd' will be: **0.9m**.

The formula to find the centre point for your compass or trammel radius is:

$$\text{Radius (R)} = \frac{c + d}{2}$$

Therefore by adding the sizes to the formula the calculation is:

$$R = \frac{0.4 + 0.9}{2}$$

*In this case the radius for the arc will be: **0.65 m.***

Now 0.6 m (650 mm) can be measured from the top of the rise, down the centre line, to obtain the position of the compass point to scribe the arc to form the top of the segmental arch.

Another method of calculating the position of the compass radius is to use the following formula:

$$\frac{1/2 \text{ the span}^2 + \text{rise}^2}{2 \times \text{rise}}$$

for example:

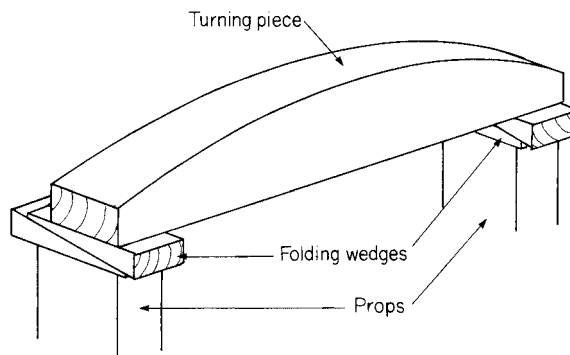
$$\frac{0.6^2 + 0.4^2}{2 \times 0.4}$$

$$0.36 + 0.16 = \frac{0.52 \text{ m}}{0.8}$$

*Therefore the radius for the arc is: **0.65 m.***

## 4.3 Turning pieces

A turning piece is used where the rise and span of the arch is small. It consists of a single length of timber with its top edge shaped to suit the soffit (underside) of the arch where it acts as a temporary beam. Figure 4.10 shows a turning piece supported by props, with folding wedges as a means of adjustment, easing, and striking (see Section 4.7).



**Fig. 4.10** *Turning piece*

## 4.4 Centres

*Note: All centres should be just narrower than the wall thickness, otherwise they will hinder the bricklayer or mason when lining the wall through with a builder's line.*

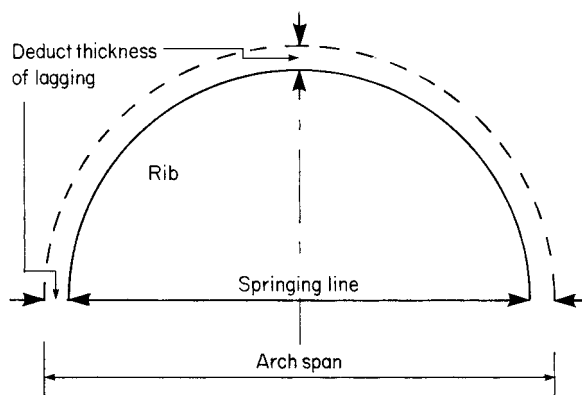
Centres are wooden structures built up of the following members:

- **Ribs:** Form the profile of the arch and are made from sheet material (plywood) or solid sections joined with plywood or metal plates or are built up of two thicknesses of timber with their joints lapping (built-up rib construction, see Fig. 4.15). Ribs provide support and fixing for lagging.
- **Lagging:** Wood battens or plywood, nailed on to the ribs to form a platform for the walling material. Lagging is termed either *closed* or *open*: open lagging has spaces left between battens and is used in conjunction with large stone or blockwork.
- **Ties:** Prevent built-up ribs from spreading and provide a fixing for bearers.
- **Struts:** Stabilise the framework by helping to redistribute some of the load placed on the ribs.
- **Bearers:** Tie the base of the centre and provide a sole piece, under which the centre is wedged and propped.

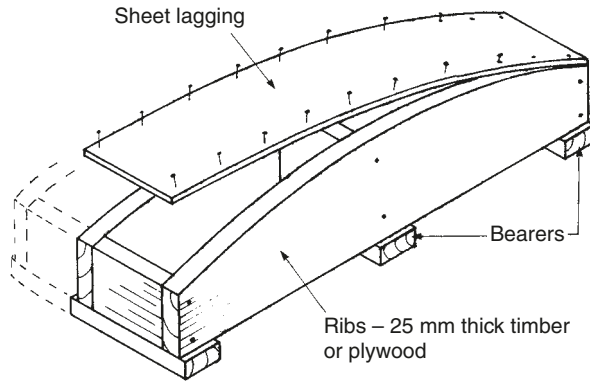
## 4.5 Centre construction

Start by drawing a full-size outline of half the centre. Remember to deduct the thickness of the lagging (except for centres for segmental arches) before setting out rib positions, etc. as shown in Fig. 4.11. Figure 4.12 shows a centre suitable for a segmental arch and how its width can be increased by adding an extra rib. Plywood has been used as close lagging.

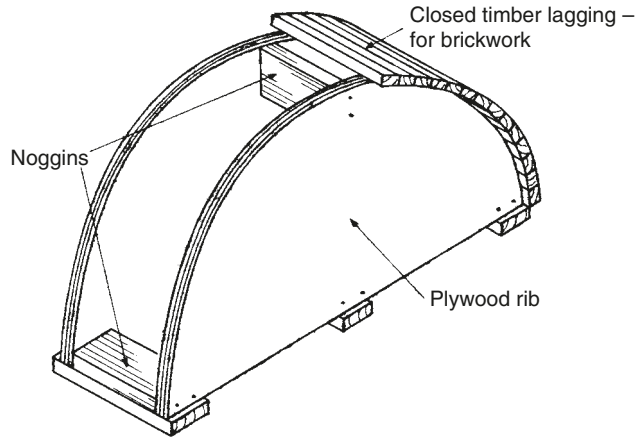
Figure 4.13 shows a semicircular centre with plywood ribs and timber noggins, bearers, and lagging. By using two or more ribs for each outline, larger spans become possible and more economical. The way ribs are joined gives them their identity, as mentioned above. A solid rib uses plated butt joints as shown in the centre for an equilateral arch (Fig. 4.14).



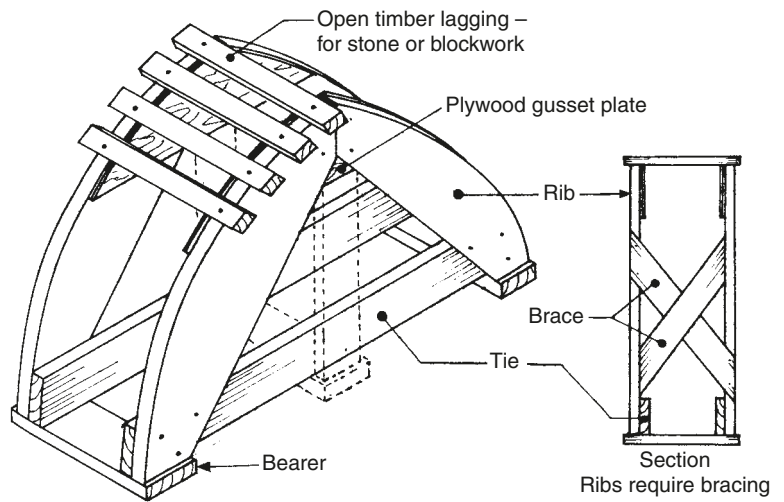
**Fig. 4.11** *Allowing for lagging*



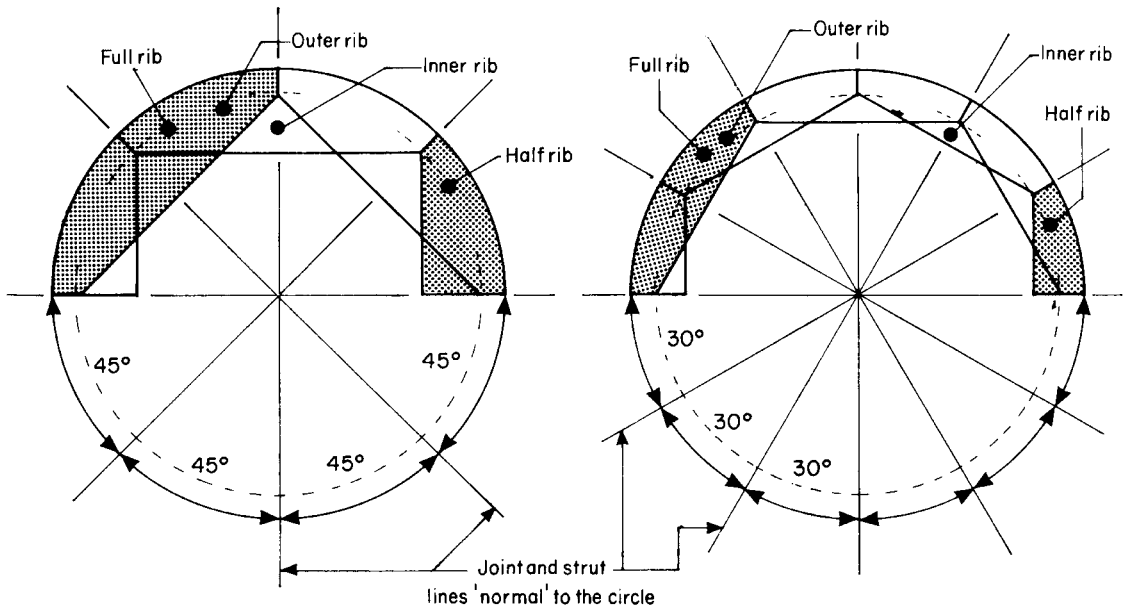
**Fig. 4.12** Centre for segmental arch



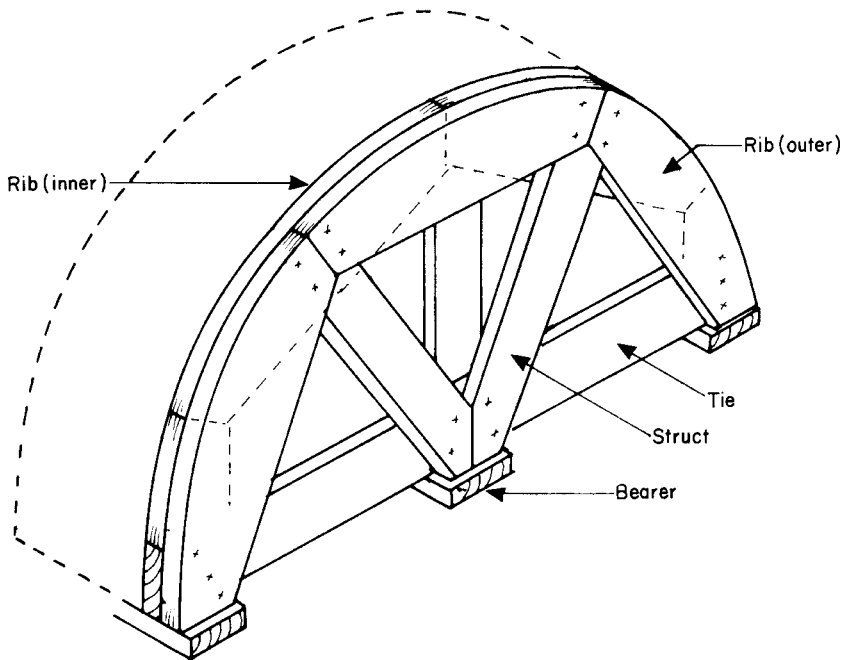
**Fig. 4.13** Centre for semicircular arch



**Fig. 4.14** Centre for equilateral arch

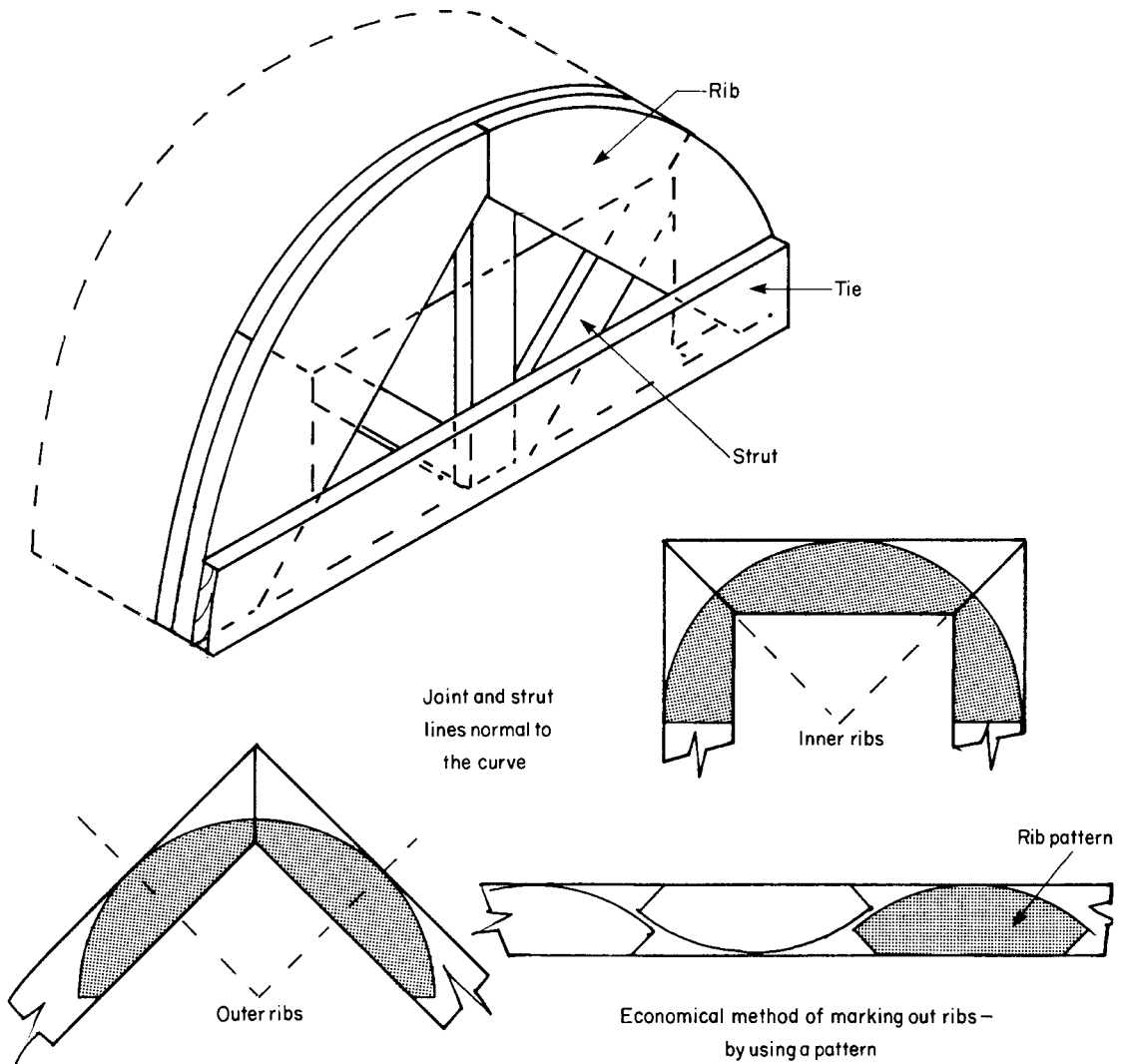


Note: the greater the number of ribs the more economical use of materials, but more labour intensive



Note: a set of two laminated frames are required for each centre— assembled similarly to Fig. 4.14

**Fig. 4.15** *Built-up rib construction*



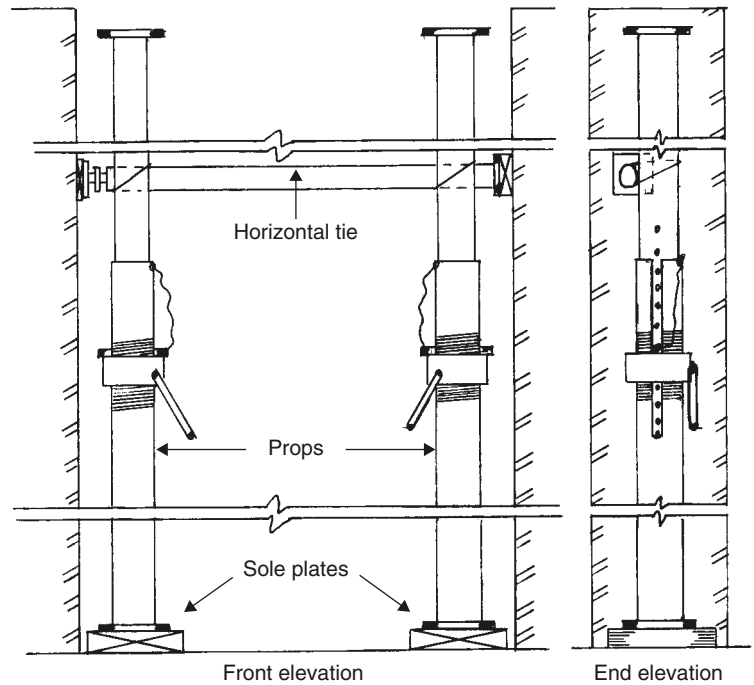
**Fig. 4.16** *Alternative built-up arrangement*

Figure 4.15 and 4.16 shows a centre with built-up ribs and how a rib pattern enables ribs to be cut economically. Patterns can be cut from hardboard or thin plywood.

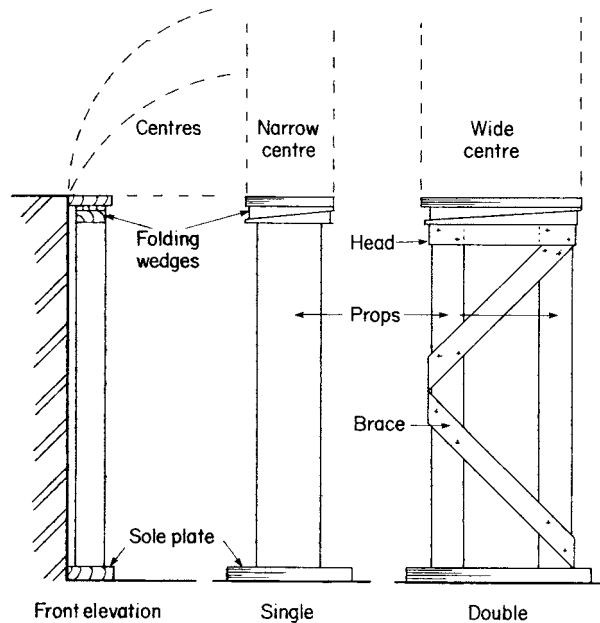
## 4.6 Erecting centres

After the wall has been built up to the height of the springing line of the arc (Fig. 4.11) the centre will need to be supported by either adjustable metal props (Fig. 3.20 & 4.17) or timber (Fig. 4.18). The erection procedure is as follows:

- The sole plates are placed in level and stable against the reveals. Wall thickness of up to 400 mm will only require a prop at each



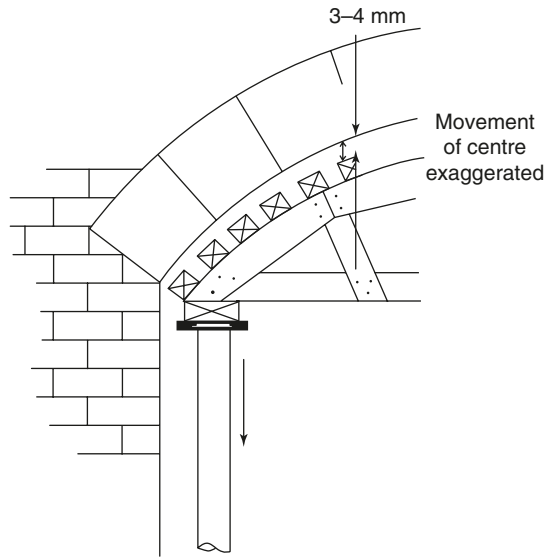
**Fig. 4.17** Supporting props levelled to receive arch centre



**Fig. 4.18** Centre placed on timber props and levelled in place

side of the opening. However, for thicker walls pairs of props on either side are recommended.

- The centre is placed onto the top of the secured props and held in place by nailing through the holes in the prop head plate. Props



**Fig. 4.19** *Easing the arch centre*

can be vertically adjusted either by wedges (timber props) or by turning the turn screws on metal adjustable props.

## 4.7 Easing and striking

- *Easing*: Once the arch is formed and the mortar set, the centre is eased from the arch soffit (underside of arch) by gradually lowering the centre 3 or 4 mm (Fig. 4.19) over a period of time.

This procedure is carried out by gently releasing the wedges or turn screw. If the arch settles without any distortion, the centre can be lowered further and the props removed over a period of time.

- *Striking*: The final operation is known as striking, or dismantling. In the case of metal adjustable props, it is essential that any mortar or concrete that may be present is removed, and the prop cleaned and oiled for future use. All nails must be drawn from timber supports and components, and disposed of safely.

### References

HSE safe erection, use and dismantling of falsework (Construction Information Sheet No. 56).

BS5975: 1996 Falsework.

The Construction (Health, Safety and Welfare) Regulations 1996.



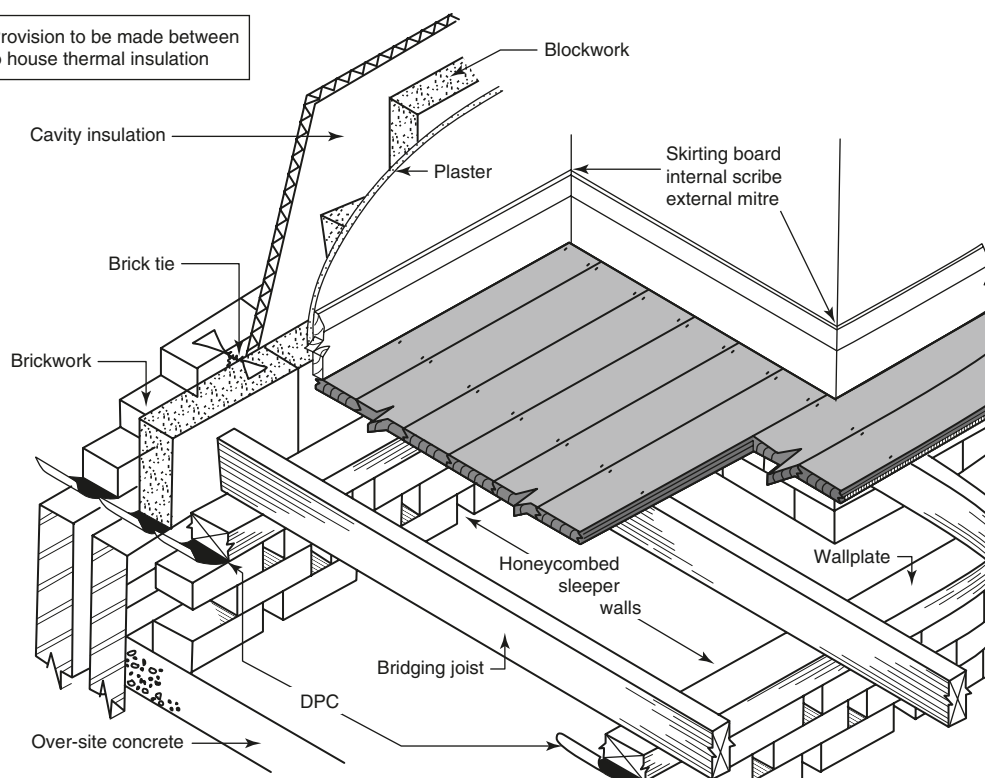
# 5

## Ground floors

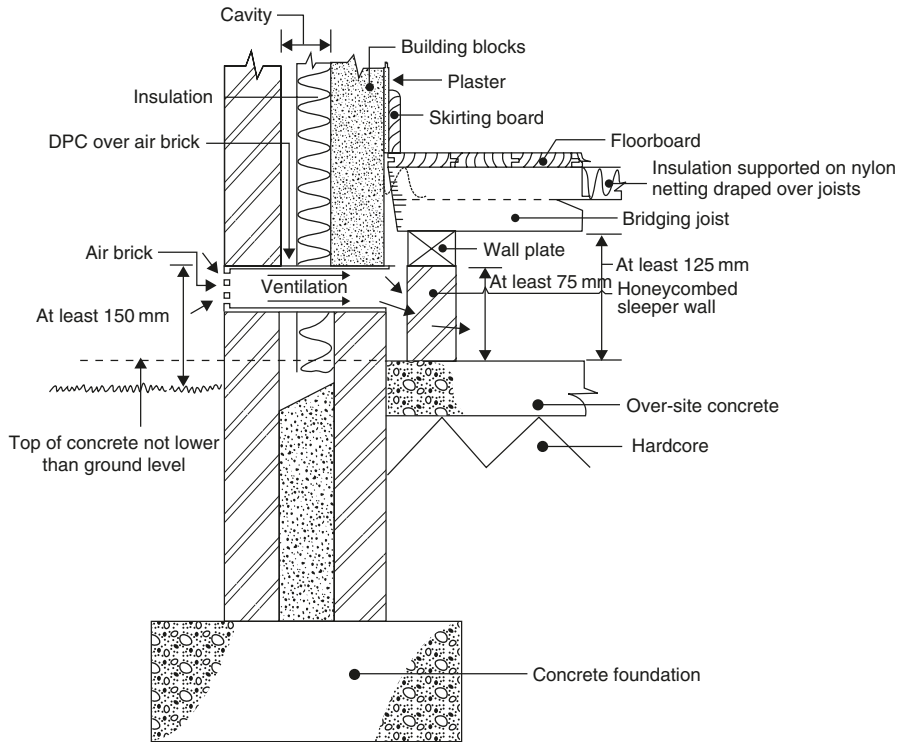
Note: Thermal insulation is not shown.

As can be seen from Fig. 5.1 this type of floor – also known as a ‘hol-low’ floor – is made up of a series of timber beams, called *joists*, covered with boards. The whole floor is then supported by wallplates resting on purpose-built *honeycombed* sleeper walls (Figs 5.1 and 5.2). Alternatively, the joist ends can be built into the inner leaf of the perimeter cavity walls (Fig. 5.3), provided they are protected from cavity moisture. However, this is now not recommended due to shrinkage and reduction of thermal insulation.

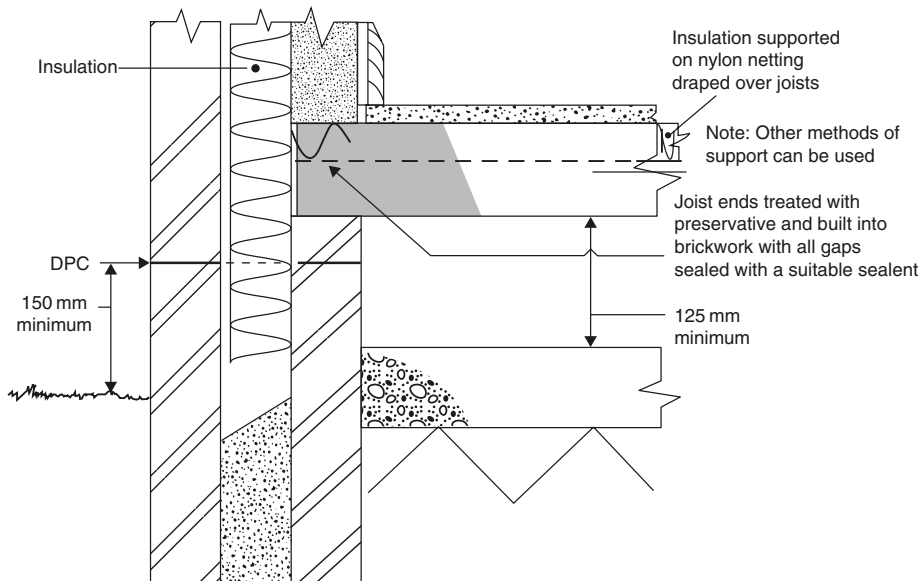
Note: Provision to be made between joists to house thermal insulation



**Fig. 5.1** *Suspended timber floor*



**Fig. 5.2** Using sleeper walls to support floor joists



**Fig. 5.3** Building-in floor joist (not recommended)

These floors have of recent years been the subject of many outbreaks of dry rot, primarily due to the timber used in their construction having been allowed to come into contact with sufficient amounts of moisture to raise its moisture content (MC) above the danger level of 20%. This problem can often be traced to the omission or breakdown of the damp-proof course (DPC – a continuous layer of thin impervious material sandwiched between the brick or blockwork) which acts as a barrier against any rising damp. Alternatively, it may be due to moisture-laden air having been allowed to condense on the underside of the floor, due to inadequate ventilation of the subfloor space. Free circulation of air to the whole of the subfloor space is therefore essential, and is achieved by the provision of air bricks (purpose-made perforated blocks, Fig. 5.2) in the outer perimeter walls and the honeycombing of sleeper walls. Dividing walls must also be strategically pierced. Before any flooring (decking) is fixed to the joists, all debris – particularly short ends and wood shavings – must be removed from the under-floor space (where moisture could be picked up from over-site concrete) so as to discourage fungal attack.

Construction of these floors is strictly controlled by the Building Regulations 2000 Part A, and Timber Research and Development Association (TRADA), to ensure both structural stability and protection against the ingress of moisture (Fig. 5.2). To achieve the correct overall balance in the design of the floor, the following factors covered by approved document A and TRADA (see Section 6.1) must be taken into account:

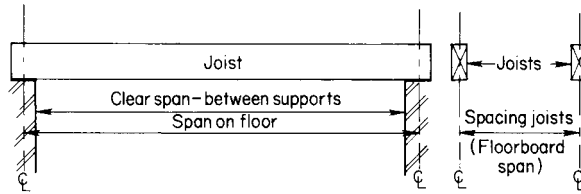
- clear span,
- joist sectional size,
- joist spacing,
- grade of timber to satisfy ‘C’ – DRY and KD classification,
- dead load supported by the joist,
- flooring material,
- flooring-material thickness.

## **5.1 Construction of floors**

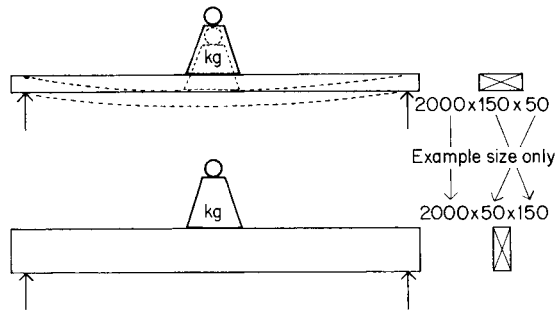
### **5.1.1 Floor joists**

The floor design is usually such that the joist is laid to bridge the shortest distance between room walls. This distance may however be further reduced by the introduction of sleeper walls (Fig. 5.1). The effective span of a bridging joist is shown in Fig. 5.4. A joist end section in relation to its span must be strong enough not only to withstand the dead weight of the floor but also to safely support any load that may be placed upon it. The importance of stating timber sizes on a drawing as *length*  $\times$  *width*  $\times$  *depth* (or *thickness*) should be stressed at this point, particularly for those sections which are expected to withstand heavy loads. Figure 5.5 shows the effect of dimensioning out of sequence.

**Fig. 5.4** Floor joist span and spacing



**Fig. 5.5** Floor joist end section in relation to its span



Note: the order of dimensioning drawings—length x width x depth

Joist spacing means the distance between the centres of adjacent joists, as shown in Fig. 5.4. These centres range between 400 and 600 mm, depending on the factors previously stated. However, joist centres should start and finish 75 mm in from the wall face (providing the joists are 50 mm wide). This will leave a 50 mm gap between the wall and the joist running parallel to it, so allowing air to circulate freely.

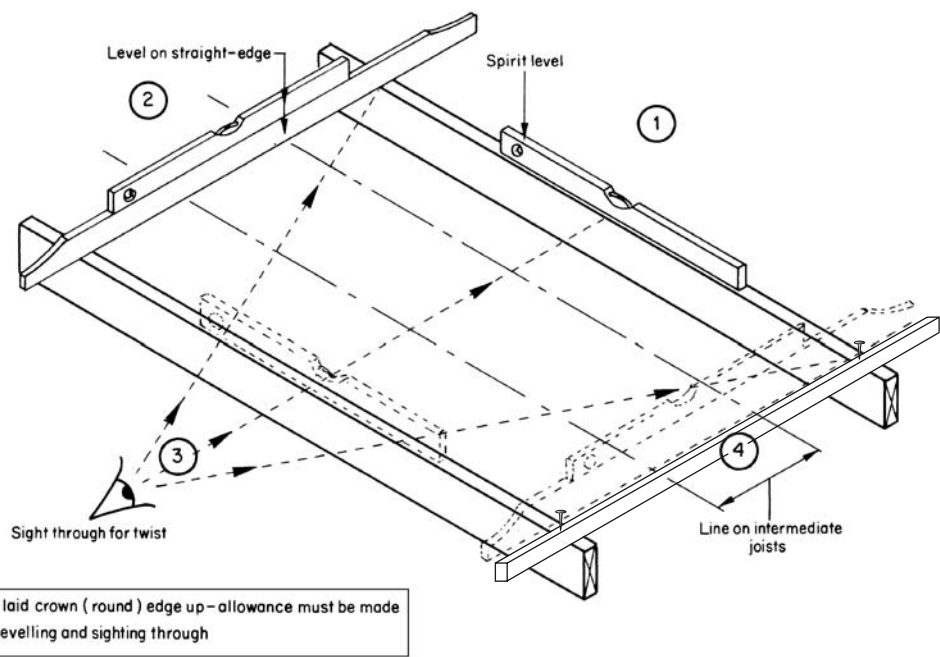
### 5.1.2 Levelling

The levelling process can be carried out by one or a combination of the following methods (see Section 1.7):

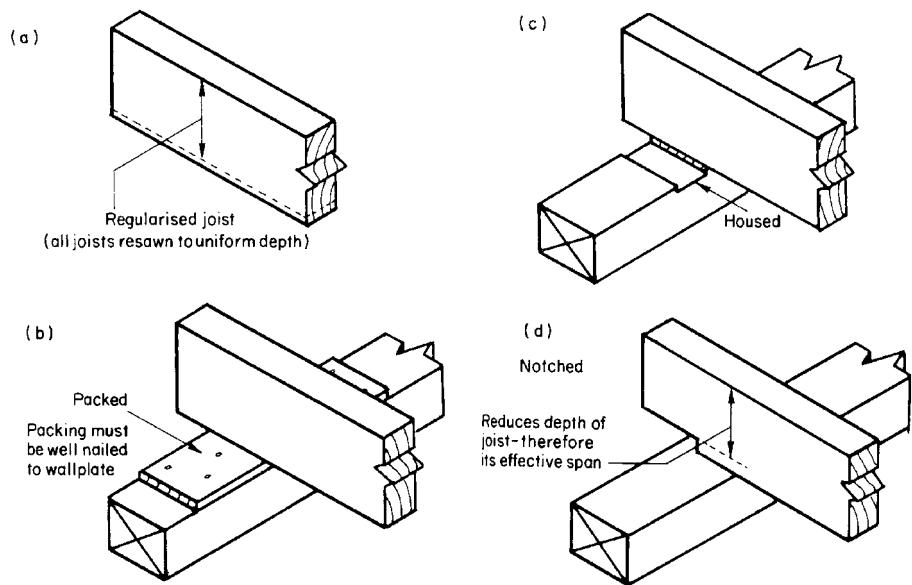
- spirit level and straight edge;
- water (aqua) level;
- Cowley automatic level (1.7);
- laser levels (1.7.6).

Figure 5.6 shows four simple stages that can be adopted with a spirit level and straight edge, provided there is sufficient room to work. If, however, restrictions prevent the joists from being sighted over, then use a spirit level at stage 3 and a straight edge to line through at stage 4. (A straight length of floor board will act as a suitable straight edge.)

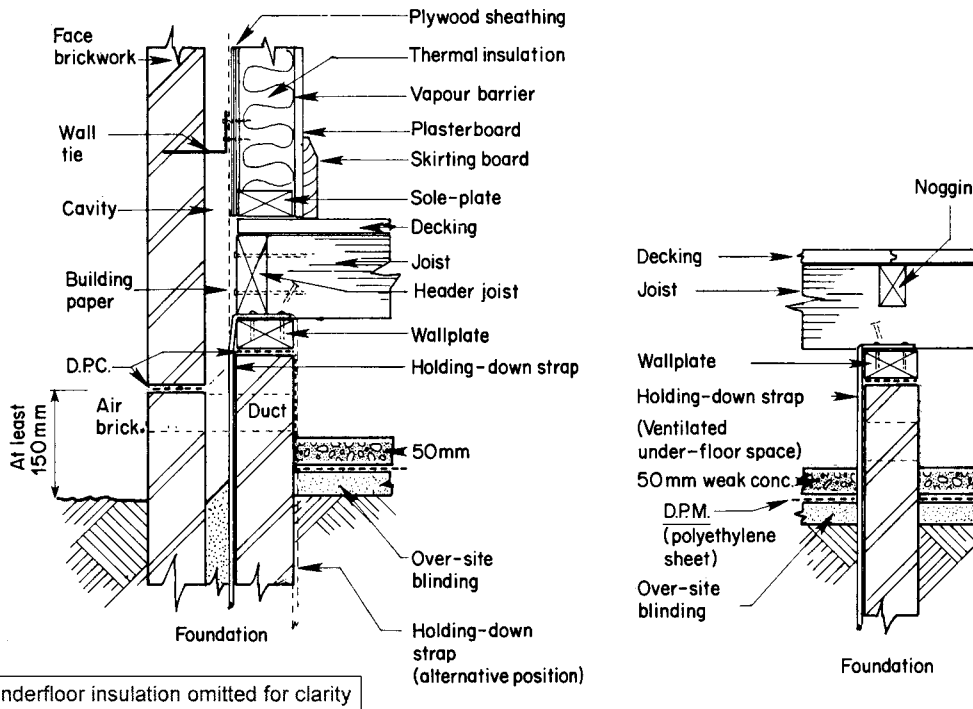
The accuracy of the whole process will depend very much on whether the wallplates (if used) were levelled correctly in the first instance. If the wallplates are level and the joists are all the same depth (regularised, Fig. 5.7(a)) the bearing of the joists should only require minor adjustment.



**Fig. 5.6**    *Laying and levelling floor joists*



**Fig. 5.7**    *Levelling and bearing adjustments*



**Fig. 5.8** Vertical sections through a floor to a timber-framed house

If, however, it is found that adjustments must be made, Figs 5.7(b) and 5.7(c) show acceptable methods. It should be noted that the method shown in Fig. 5.7(d) will reduce the depth of the joist and therefore its efficiency over its span (see Fig. 5.4).

The use of wallplates not only enables the floor's weight to be more evenly distributed over a wider area but also provides a means of securing the joists by nailing.

If the joist ends are to be built into the walls (Fig. 5.3) it is advisable to use slate not wood as a packing because the wood packing could shrink and eventually work loose. Alternatively, the method shown in Fig. 5.7(d) may be adopted, provided the joist is deep enough to allow this method to be used without it being weakened. However, when the joists are levelled and correctly spaced, they must be kept that way by *tacking a spacing lath on to the tops of the joists* (Fig. 5.6). This is removed after the joists have been walled in by the bricklayer.

Timber-framed houses often use an arrangement similar to that shown in Fig. 5.8. It should be noted that the floor forms part of the



**Fig. 5.9** *Positioning holding-down straps*

main structure – the walls rest upon it. Wallplates and structure must be anchored to the brick or concrete substructure.

This is done by using galvanised-steel straps like those shown in Fig. 5.9. In this case sleeper walls have their own foundations, which – provided a continuous over-site damp-proof membrane (DPM) or polythene sheeting is provided – will enable the traditional 100 mm thick over-site concrete to be reduced to a 50 mm layer of weak concrete.

### **5.1.3 Constructional hearths (solid fuel and oil-burning appliances)**

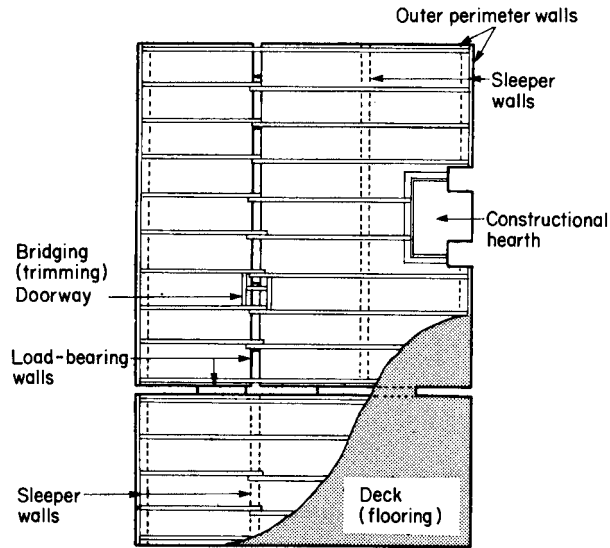
The floor layout in Fig. 5.10 has made full use of both sleeper wall and internal walls and has taken advantage of the resulting short spans.

Details of size requirements and the permissible proximity of timber to a fireplace opening, etc. are shown in Figs 5.11 and 6.3 – for further details regarding various fuels and gas-burning appliances refer to the Building Regulations 2002, approved document J.

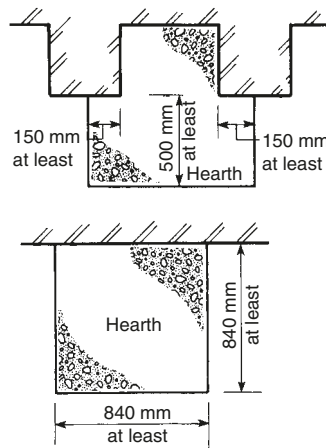
Two alternative joist arrangements to meet the above requirements are shown in Fig. 5.12.

### **5.1.4 Door openings**

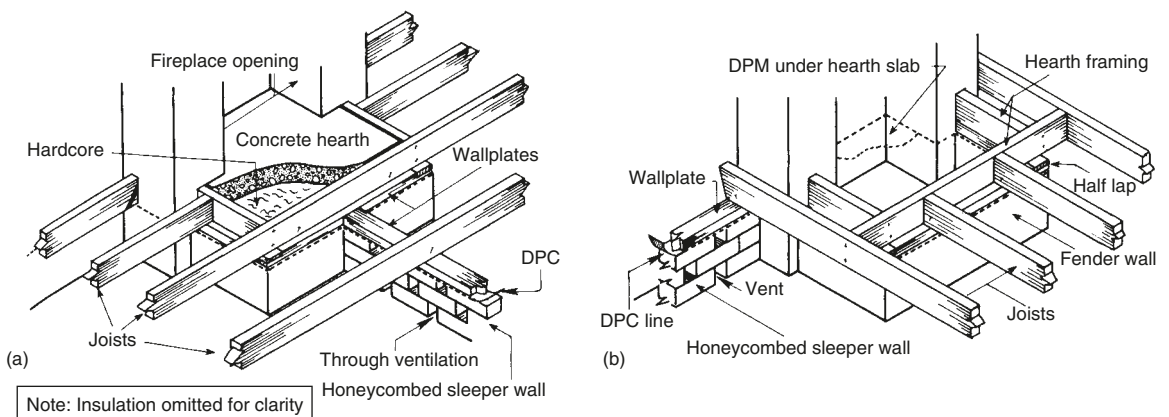
Keeping joists to their recommended centres often means that when a doorway is reached it is likely that the edges of sheet decking



**Fig. 5.10** Ground-floor joist layout

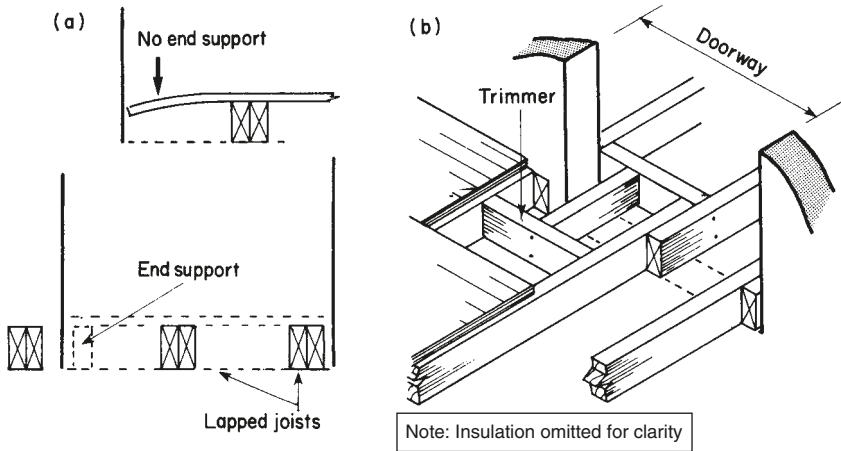


**Fig. 5.11** Constructional hearths (solid fuel and oil-burning appliances)

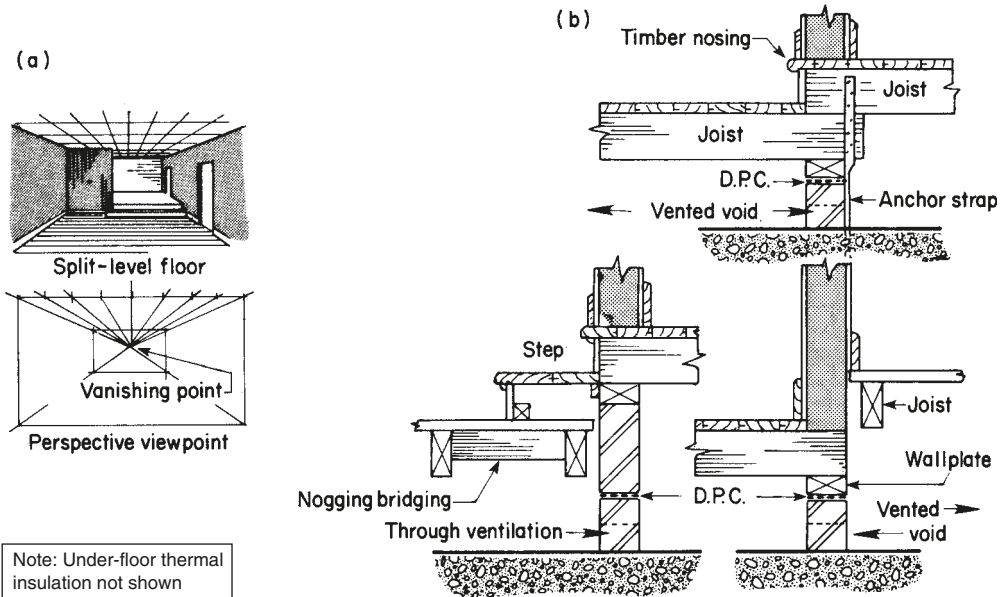


**Fig. 5.12** Alternative joist arrangement to a ground-floor construction hearth





**Fig. 5.13** Bridging openings



**Fig. 5.14** Vertical section through timber-to-timber split level floors

Note: For flooring (decking) details, see Section 5.4.

(flooring) or the ends of floor boards will be without support, as shown in Fig. 5.13(a). It is a simple matter to form a bridge by trimming out with short pieces of floor joist (Fig. 5.13(b)).

### 5.1.5 Split levels

Floors of this nature are usually constructed for reasons of appearance or as a means of dealing with sloping ground, etc. Figure 5.14(a) gives a perspective impression of how a split level may appear.

Construction will depend on which way the joists run and the amount of lift, as indicated in the vertical sections in Fig. 5.14(b). A concrete floor may have to serve as one of the floor levels, in which case ventilation can be provided to the space below the timber via a purpose-made duct or pipe (not less than 100-mm diameter) set in the concrete as shown in Fig. 5.15. Notice how the holding-down straps are bedded into the concrete, and the continuation of the DPM over the DPC.

## 5.2 Concrete floors incorporating timber

*Note: Preservative treatment is necessary in both cases.*

Concrete floors lack the resilience of wood. This problem can be overcome by:

- (a) attaching a timber floor on to the concrete using proprietary floor clips (Fig. 5.16);
- (b) attaching wood blocks to the surface of the concrete (Fig. 5.17).

Figure 5.16 shows how floor joists (bearers) are attached by steel clips, which have been bedded into the concrete before it set. The clips can be flattened (if designed to do so) until required – this reduces the danger of tripping and injuring feet.

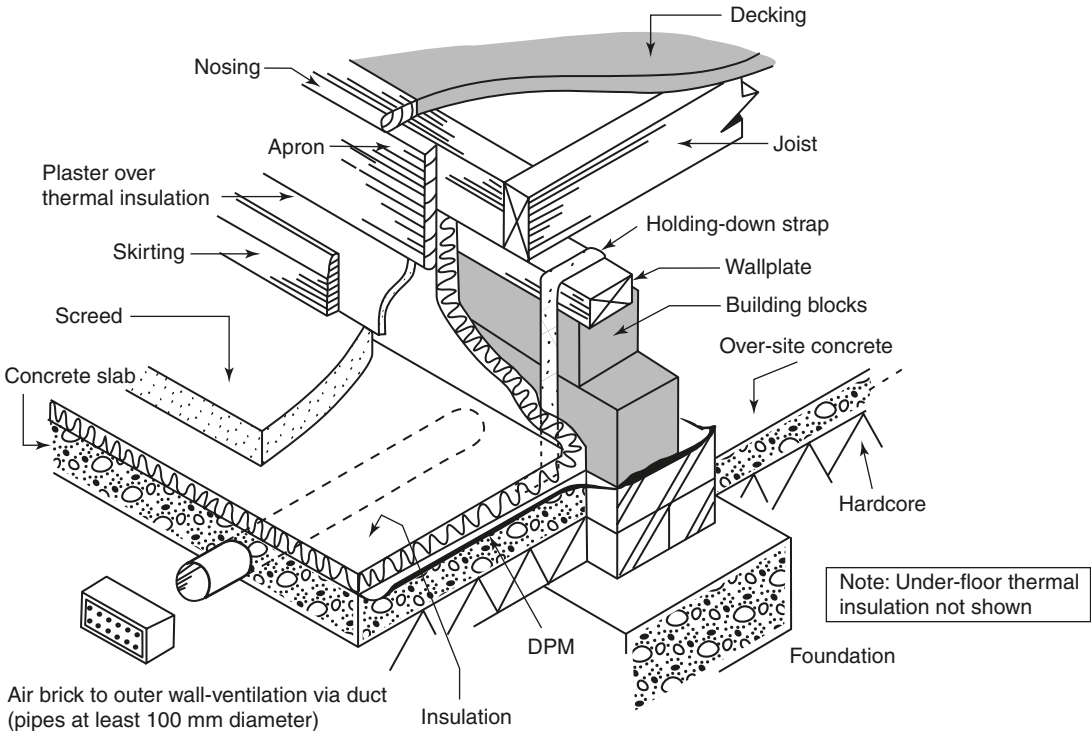
Timber floors built adjacent to concrete floors as shown in Figs 5.18–5.19 can be quite successful provided measures are taken to counteract any movement which may occur at doorways or openings due to moisture or loading – otherwise floor coverings, carpets, etc. will quickly become worn at these points.

### 5.2.1 Block floors

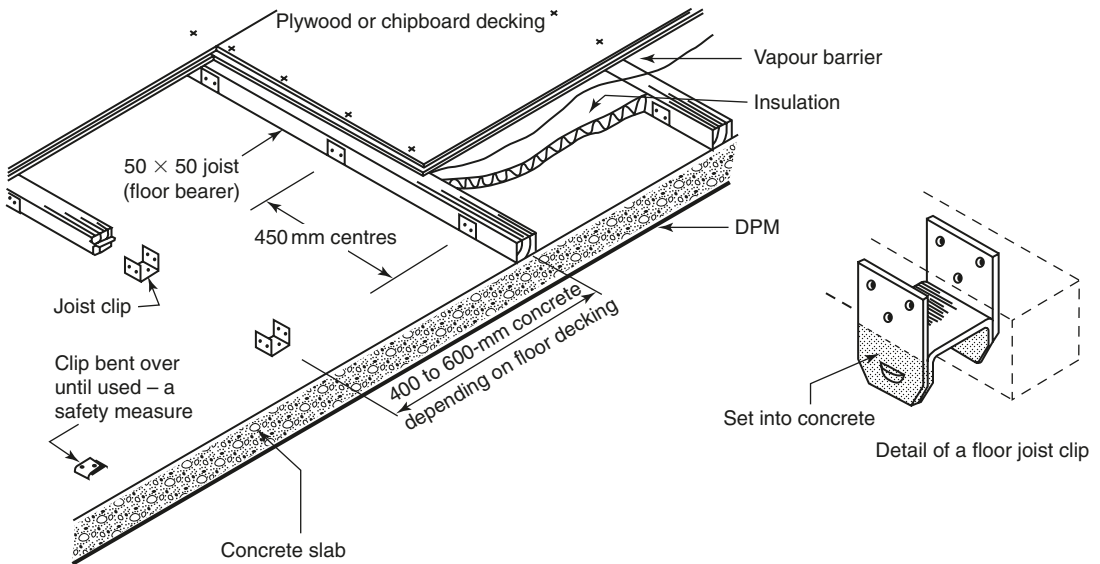
Fixing hardwood blocks or strips to a concrete floor is a specialised job. Blocks are usually stuck directly to the concrete surface with a mastic-type adhesive which may act as a DPM.

## 5.3 Thermal insulation (see also Section 6.6)

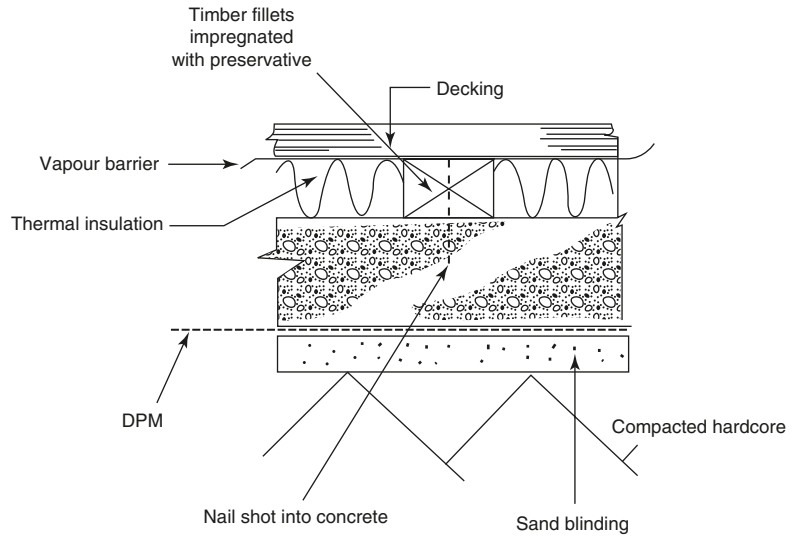
Thermal insulation is a means whereby insulation materials – usually in the form of lightweight highly cellular quilts made of fiberglass, mineral wool or granular products such as processed vermiculite (Micafil), etc. are positioned within walls, ground floors and roof, to help prevent warm air escaping from the building during cold weather thereby reducing heating costs. Conversely, thermal insulation materials help to keep the interior of the building cool during warm weather. Figure 5.20 shows how thermal insulation may be introduced into ground-floor construction.



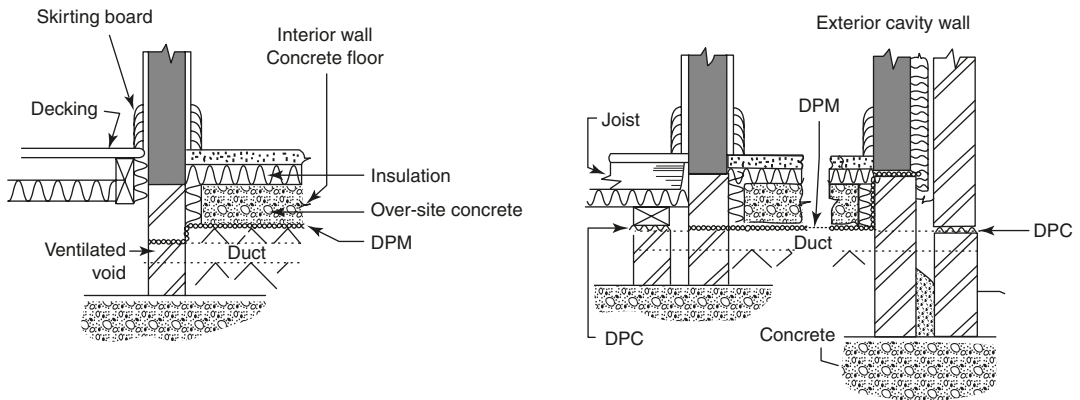
**Fig. 5.15** *Concrete-to-timber split-level floor*



**Fig. 5.16** *Joists (floor bearers) to a concrete floor*



**Fig. 5.17** Vertical section of floors which incorporate timber



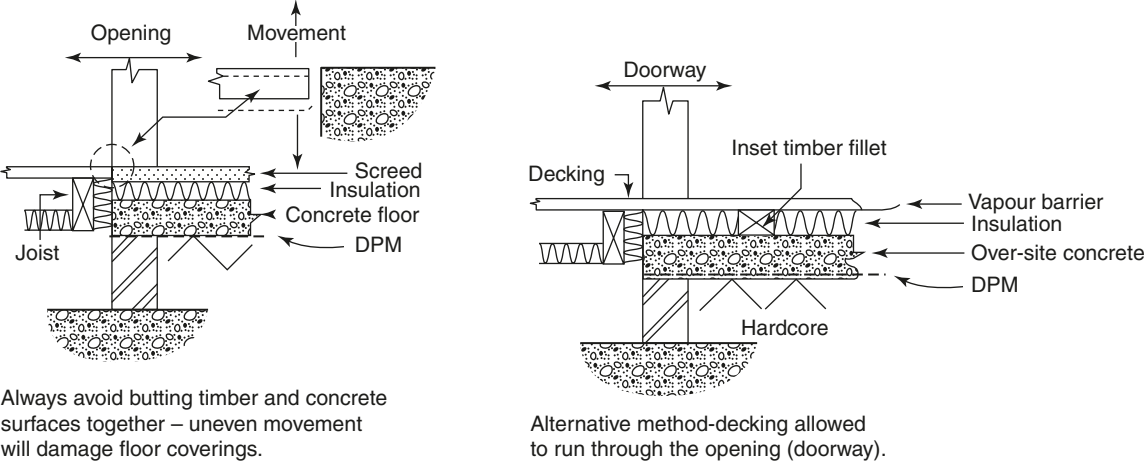
**Fig. 5.18** Vertical section through timber and concrete floors adjacent to one another

## 5.4 Flooring (decking)

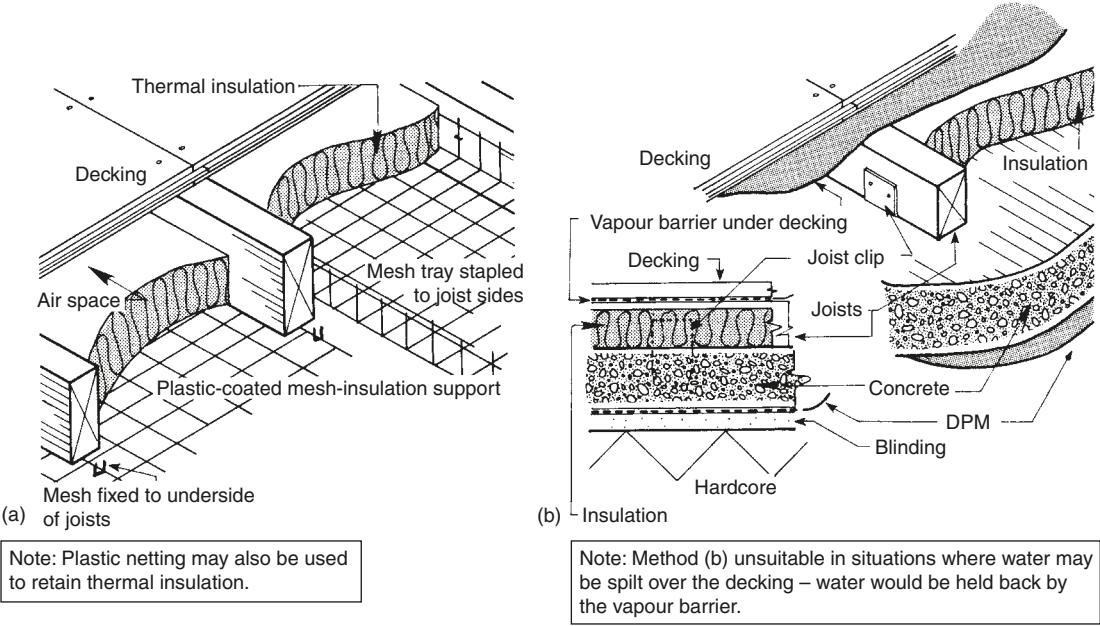
The flooring material will consist of either:

- (a) planed, tongued, and grooved (PTG) floor board;
- (b) flooring-grade chipboard – tongue and grooved or square edge (see Chapter 6.5.1);
- (c) flooring-grade plywood – tongue and grooved or square edge (see Chapter 6.5.3).

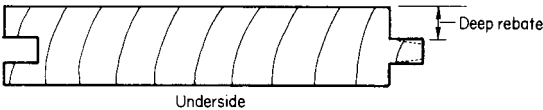
This section deals with floor boards, whereas sheet flooring materials is dealt with in *Chapter 6.5*. Figure 5.21 shows a typical section



**Fig. 5.19**    Vertical sections to show abutting timber to concrete floors



**Fig. 5.20**    Thermal insulation to ground floors



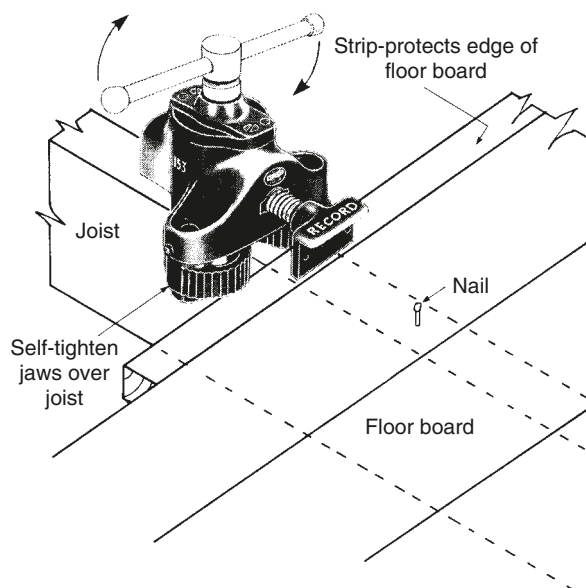
**Fig. 5.21**    Floor board section

of PTG. softwood board, with a deeper rebate cut from the upper face than from the underside. This deep rebate provides the joiner with a quick and useful guide to the board's face side. Also, before overall floor coverings (carpets, etc.) became fashionable and less expensive, it was commonplace, as it is becoming so today to walk directly on the floor boards – the only protection offered being a layer of varnish and/non-slip preparation. The story has it that the deeper rebate therefore allowed for more wear to take place before the tongue and grooves became exposed and the boards dangerously thin.

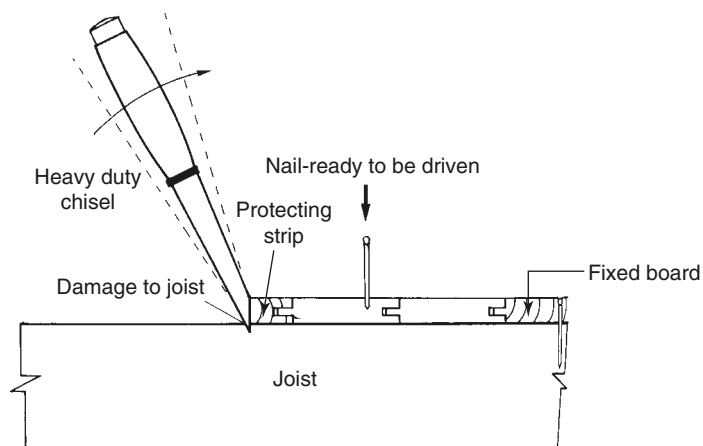
### 5.4.1 Laying floor boards

Boards are laid at right angles to the joists, and wherever they cross a joist they are eventually double nailed to it – using either lost-head nails or flooring brads (Volume 1, Section 12.1). Nails should be  $2\frac{1}{2}$  times the thickness of the floor board, whereas flooring brads are of standard cut length. The first board should be nailed approximately 15 mm away from one wall (the gap later being covered by skirting), then three to six boards are positioned edge to edge against it – the number of boards will depend on the method of clamping.

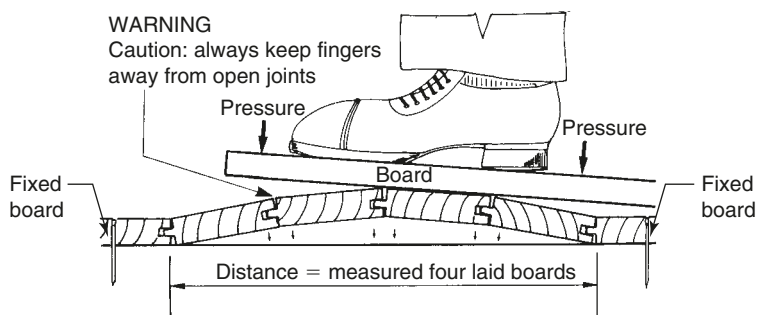
Figure 5.22 shows one of many types of flooring clamp (cramp) and its application. In the past, lever and folding methods have been used (Figs 5.23 and 5.24). Although not as efficient as the flooring clamps, these methods are still effective and are useful when dealing with small areas or working in confined spaces. However, the chisel does damage the top edge of the joist. Once the boards have been cramped tight (not overtightened), they should be nailed to the joist



**Fig. 5.22** *Record flooring clamp and its use*



**Fig. 5.23** Closing floor boards by leverage



**Fig. 5.24** Folding method of laying floor boards

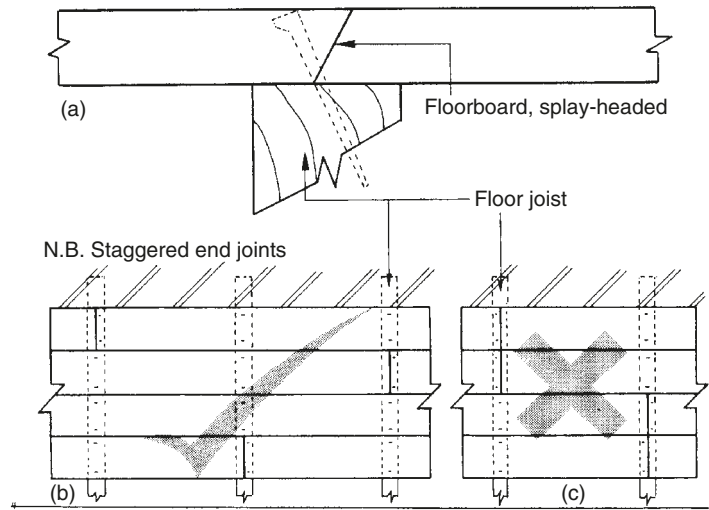
or be spot nailed sufficiently to hold the boards in position. Where the boards have to be end jointed, a splayed end joint can be used (Fig. 5.25(a)). This helps to prevent splitting.

*Note: If service pipes have been laid in close proximity to the floor joists, there is a danger of driving nails into them. It would therefore be advisable to nail that area fully as the floor boards are being laid, rather than trying to remember where the pipes were or forgetting to mark the danger area.*

These joints should always be staggered as shown in Fig. 5.25(b) – not as Fig. 5.25(c). Continue in this way across the room, where the last few boards can be cramped using the methods shown in Figs 5.23 and 5.24. The spot nailing should have been sufficient to indicate the centre position of all the joists, and this now enables the carpenter to mark a series of pencil or chalk marks across the room as a guide for the final nailing-down process, followed by punching the nail heads just below the surface. (The final nailing-down process is often termed *bumping*.) Using the spot nailing method releases the flooring clamps for use in other rooms.

## 5.4.2 Chipboard flooring

This type of floor covering is very common in new buildings as it is quick and easy to lay and must conform to BS EN 312 2003. The boards are available in sizes of  $2440 \times 600 \times 18$  mm or



**Fig. 5.25** *End jointing of floor boards*



Note: Under-floor thermal insulation not yet installed

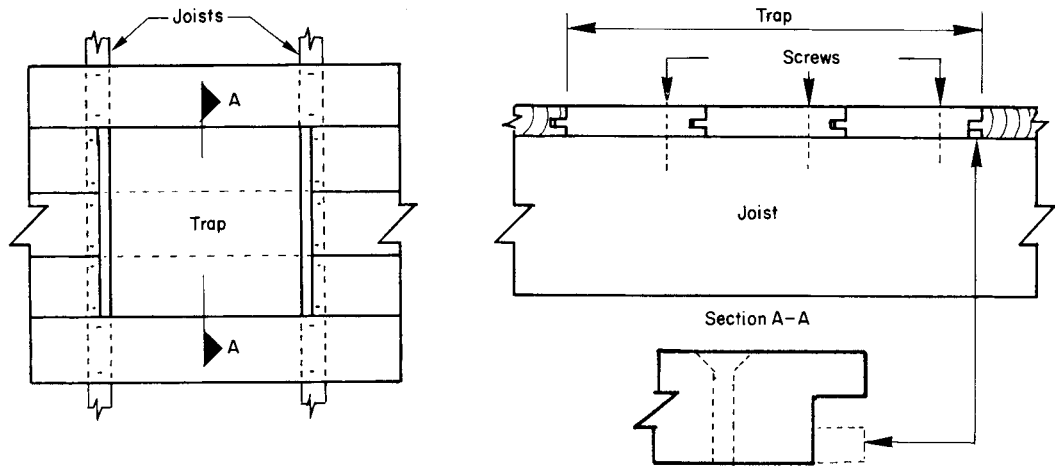
**Fig. 5.26** *Under-floor pipework*

1220 × 600 × 18 mm and generally fitted together using PVA-glued tongue-and-groove joints. The end joints must be seated on a joist, however the long edges, provided they have a tongue-and-groove joints, need no support (see Chapter 6).

### 5.4.3 Access to services

Under-floor space is used to run service pipes and cables, thereby avoiding exposure above the surface and the need for ducts and pipe boxes, etc. An example of how service pipes are run under a floor can be seen in Fig. 5.26. (Note that water pipes have been insulated.)





**Fig. 5.27** *Forming access and service traps*

Wherever services are concealed, provision should be made to allow access for servicing and maintenance (Fig. 5.27); therefore, unless the under-floor space is deep enough to allow a person to work from below, provision should be made from above by way of access traps in which case it should be sited in a non-traffic area, for example a cupboard under the stairs, etc. Laying services before the flooring is laid makes it possible to easily identify where traps are required. If, on the other hand, services are laid after the flooring due to alteration, etc., an insulating layer could make access difficult.

## 5.5 Skirting board

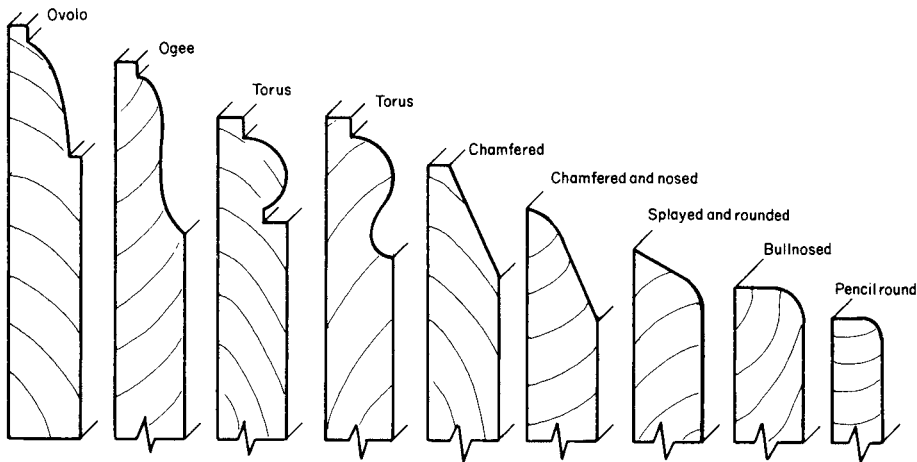
After the plastering is complete, a set of new operations takes place – known as *second fixing*. One of these operations is to fix the skirting board.

Skirting boards are machined to many different profiles, some of which are illustrated in Fig. 5.28. The profile usually reflects the class of work being carried out.

The main function of a skirting board is to provide a finish between the wall and floor. It also acts as a seal against draughts from the sub-floor space and as a buffer to protect the wall covering from knocks that may occur during cleaning the floor covering – timber being much more resilient than plaster.

### 5.5.1 Fixing

Although skirting board is only a ‘trim’ (cover) – also see Vol. 3, Sec. 8, because of its frequent ill-treatment it does require to be



**Fig. 5.28** Skirting board sections

fixed firmly to the walls. This is usually achieved by one of the following methods (see Volume 1, Chapter 12):

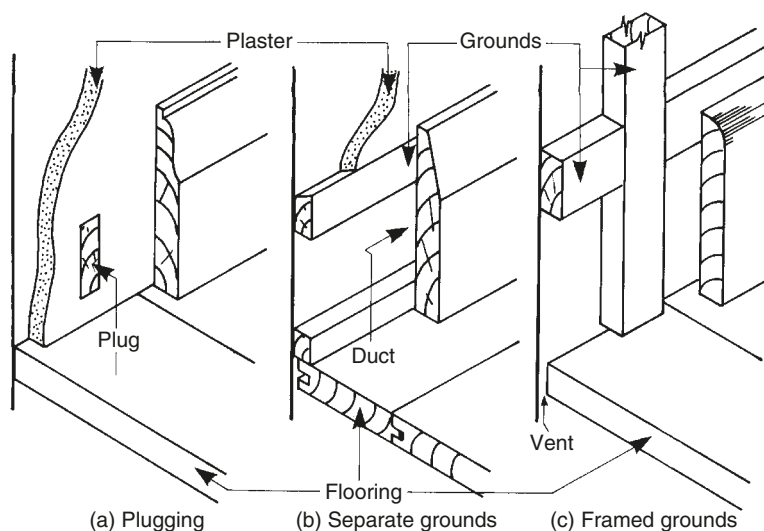
- plugging via a mortar seam (Fig. 5.29(a)) (not recommended);
- timber grounds (Fig. 5.29(b&c));
- direct nailing – cut clasp nails;
- masonry nails;
- plastic plugs;
- adhesives.

The use of wood plugs driven into mortar seams of brickwork was a traditional method of fixing to walls where brick or dense concrete blocks have been used. However, due to possible timber decay and disturbance of the structure, this is not recommended nowadays. (Volume 1, Figs 12.15 and 12.16 show the method of preparing and fixing such plugs.)

Plastics plugs or adhesive (if the wall is straight) could also be considered as a modern alternative where fixing by screws or screw nails is practicable or a permitted alternative (see Volume 1, Chapter 12).

Figure 5.29(b) and (c) shows the use of timber grounds as a fixing medium. The method of Fig. 5.29(b) provides a finish for the plasterwork and a continuous longitudinal fixing, while leaving a narrow service duct behind the skirting; whereas that in Fig. 5.29(c) is employed when used in conjunction with wall panelling. Certain modern types of building blocks will permit cut clasp nails to be driven directly into them, offering sufficient holding power for light-sectioned skirting board, thus speeding up the whole fixing process.

*Note: All timbers used as grounds must be treated with a suitable preservative (see Volume 1, Section 3.3).*



**Fig. 5.29** *Methods of fixing skirting boards to walls*

There are only three joints to consider here (see Volume 1, Chapter 10):

1. butt joint;
2. mitre joint;
3. scribed joint.

The layout of the floor will dictate the position and type of joint employed. For example, at doorway openings it is common practice to butt the skirting board up to the door-casing trim (known as the architrave); external corners are mitred; and internal corners are scribed (Fig. 5.1 and Volume 1, Section 10.22). However, where a piece of skirting board has to be joined in its length (a practice to be discouraged and it is not usually necessary), a cut of  $45^\circ$  is more desirable than a  $90^\circ$  butt joint. A cut of  $45^\circ$  enables the joint to be nailed more efficiently and provides a partial mask if or when shrinkage occurs (Volume 1, Section 1.7.1).

The methods of cutting these joints is dealt with in Volume 1, Section 10 and Volume 3, Section 8, together with the technique for scribing timber along its length and it is necessary where a skirting board has to be fitted to an uneven floor surface (Volume 1, Fig. 10.22).

## References

- Building Regulations 2002, approved document J.
- Building Regulations 2000 part A.
- TRADA. (Floor joist span details)
- BS EN 312. 2003.
- NHBC Standards

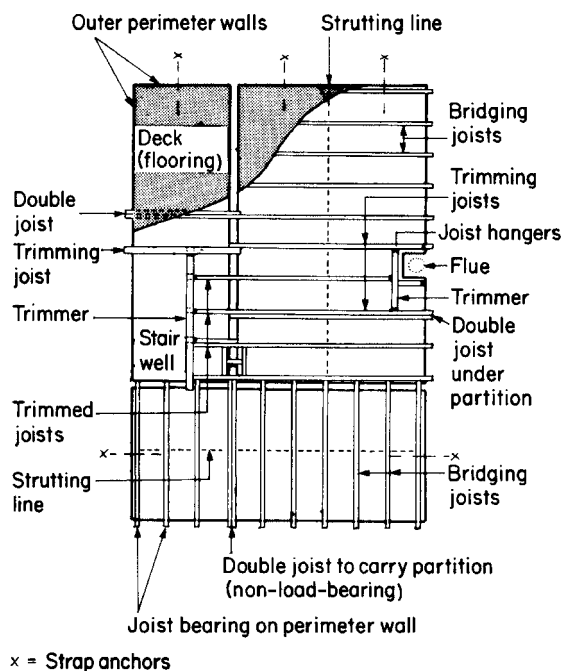
# 6

## Single upper floors

The main differences between the layout of a ground floor and an upper floor, as shown in Figs 5.1 and 6.1, are that for an upper floor:

- (a) the depth of the joist section is greater, to allow joists to span a greater distance (no sleeper walls);
- (b) an opening must be left to accommodate a staircase.

In Fig. 6.1, provision has also been made for the floor to fit around protruding blockwork.



**Fig. 6.1** *Upper-floor joist layout*

## 6.1 Floor joists

The determination of a suitable sectional size for an upper-floor joist will, as with all beams, be a matter of calculation, involving:

- the grade of timber,
- the load supported by the joist,
- the spacing of joists,
- the maximum span.

In the Building Regulations 2000, approved document A (1/2) and ‘Span tables for solid timber members in floors, ceilings, and roofs for dwellings’ published by TRADA, rules are set down to meet particular requirements. With regard to maximum span, it is advisable to keep well within the limits set if undue ceiling deflection (sag) is to be avoided.

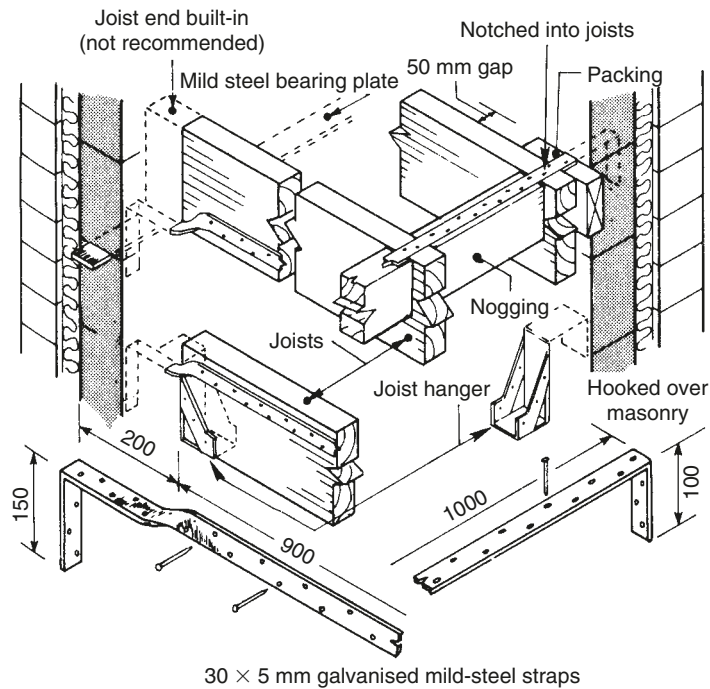
Unless a step in the floor or ceiling forms part of the floor design – which is highly unlikely in domestic dwellings – a sectional size of joist selected to span the greatest distance will generally mean that shorter spans will have to use over-sized joists if joist thickness is to remain uniform across the whole upper-floor area – which will be so in the majority of cases. Joist centres should correspond to the dimensions of the decking and ceiling material (plasterboard, etc.). Availability and cost are other factors; for example, European-redwood joists may only be available 200 mm wide – if suitably strength graded (structural graded) and sized at  $50 \times 200$  mm, these could span up to about 4 m in a domestic floor. Wider timber is available in spruce and hemlock. Douglas fir is available in sections up to  $50 \times 250$  mm but is more expensive.

*Note: All joists should be regularised in their depth (see Fig. 5.7) to produce a level floor and ceiling.*

### 6.1.1 Joist support

Joists, positioned ‘crown’ (curved edge) upwards, are supported usually by steel joist hangers. A traditional method, and not recommended (due to timber decay, shrinkage and loss of thermal insulation) was to build-in and support the joist on the inner leaf of the structure walls, and in some cases included a mild steel-bearing plate (Fig. 6.2). Where joists have to be joined over load-bearing walls, they should be lapped and nailed together.

Figure 6.2 shows different methods of supporting the joists, and how the floor framework is used to provide lateral support to walls. Building Regulations require that the whole of the floor framework be attached to the walls. Joists which are built-in should have a minimum bearing of 90 mm. When using joist hangers or when joists run parallel with the wall, they are required to be anchored with steel straps at intervals of not more than 2 m. Nogging should be at least 38 mm thick and over half the depth of the joist deep. For buildings over two storeys in height, see the Building Regulations 2000, approved document A (1/2).



Note: Joists strapped to walls at intervals of not more than 2 m

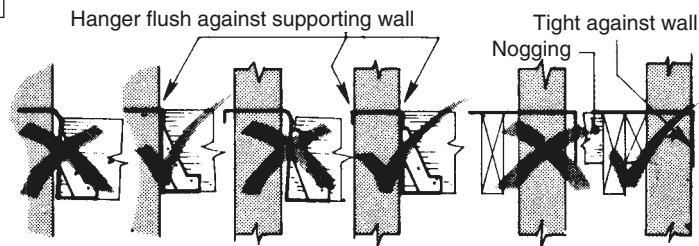


Fig. 6.2 Floor joist-bearing and lateral-wall support

## 6.2 Trimming openings

Trimming is an arrangement which enables support to be given to the ends of joists which have been cut short to provide an opening. Stair wells (Fig. 6.1), chimney breasts, and constructional hearths (proximity of combustible material in relation to solid fuel- and oil-burning appliances is shown in Fig. 6.3), ducts, traps, and manholes will all require some form of trimmed opening.

Examples of how these openings may be arranged are shown in Fig. 6.4. All the members in the arrangement have a specific function, namely:

- *trimmers (T)* are supported by a wall or trimming joist and provide a bearing for trimmed joists;
- *trimming joists (TG)* are supported by a wall and provide a bearing for trimmers;

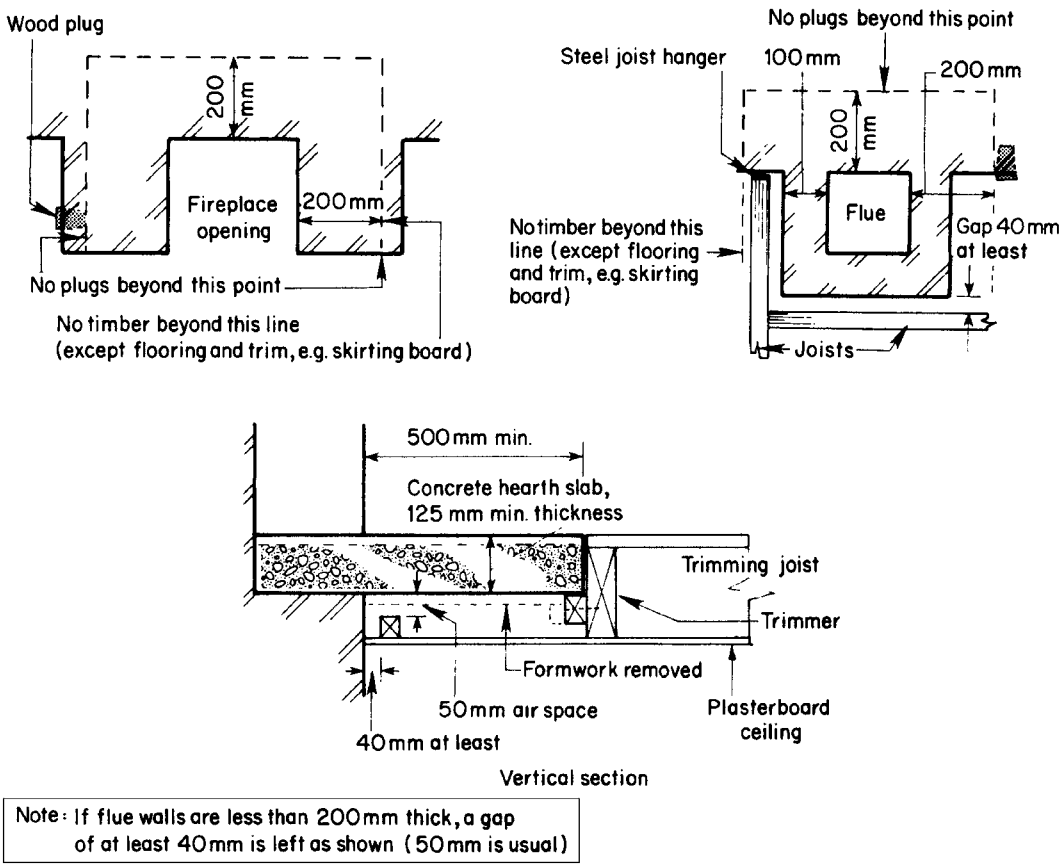


Fig. 6.3 Proximity of combustible materials (solid fuel- and oil-burning appliances)

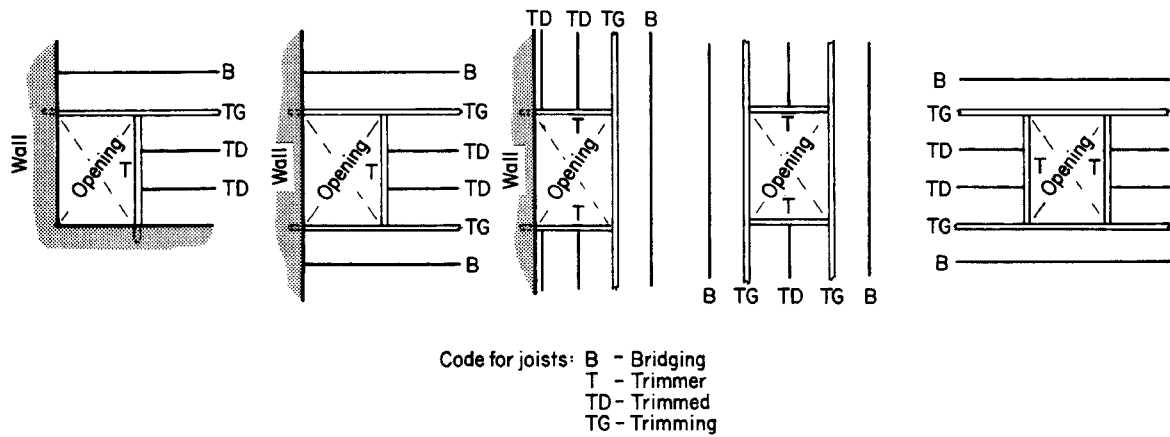
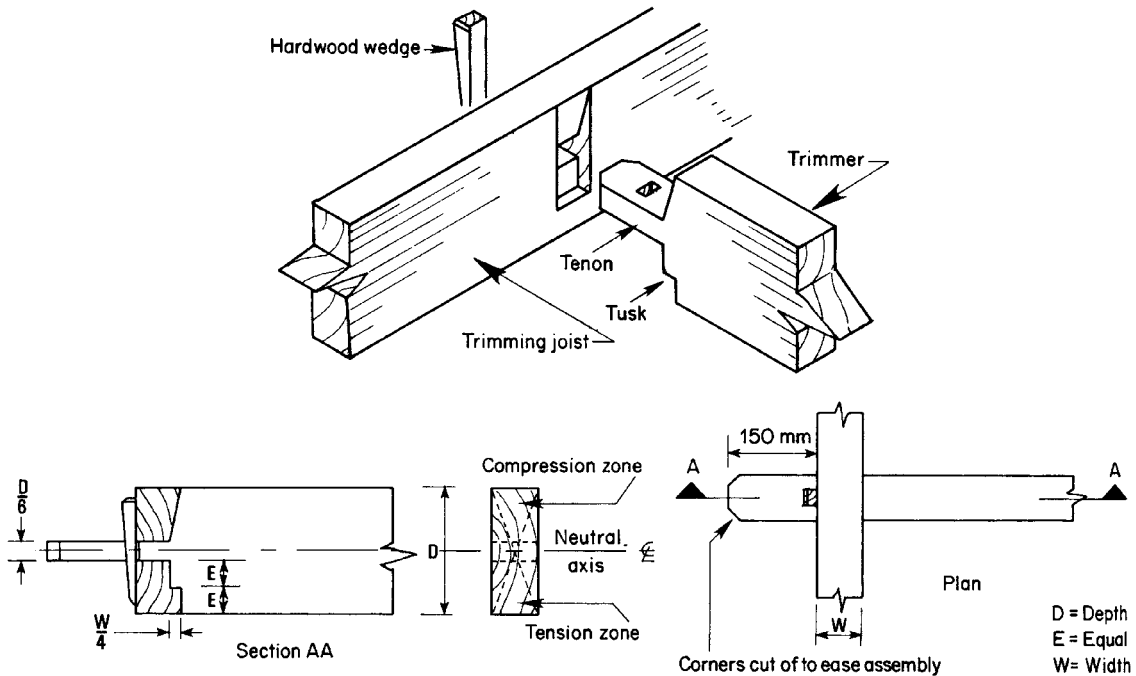


Fig. 6.4 Trimming floor openings – chimney breasts, wall protrusions, service traps, etc.



**Fig. 6.5** Tusk tenon joint – joining trimmer to trimming joist

- *trimmed joists (TD)* are supported by trimmers, or by a trimmer and a wall, and provide joist filling between trimming joists or between a wall and a trimming joist.

Trimmers and trimming joists will be more heavily stressed than trimmed or bridging joists, due to load transference between members; therefore both trimmers and trimming joists must either be thicker (usually by 25 mm) than the rest of the joists or be formed from two or more joists nailed together side by side. If the floor is to be heavily loaded, structural calculations will be necessary.

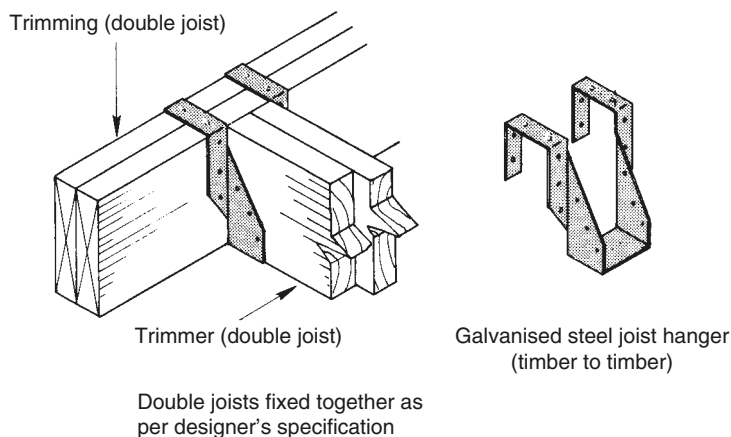
### 6.2.1 Trimming joists

Traditionally the joint between a trimmer and a trimming joist was made with a 'tusk tenon' (Fig. 6.5), and in certain situations this is still used today. However, steel joist hangers have in recent years become very popular, and they are also suited to situations where joists have been doubled-up as shown in Fig. 6.6. Several examples of joining trimmed joists to a trimmer can be seen in Fig. 6.7.

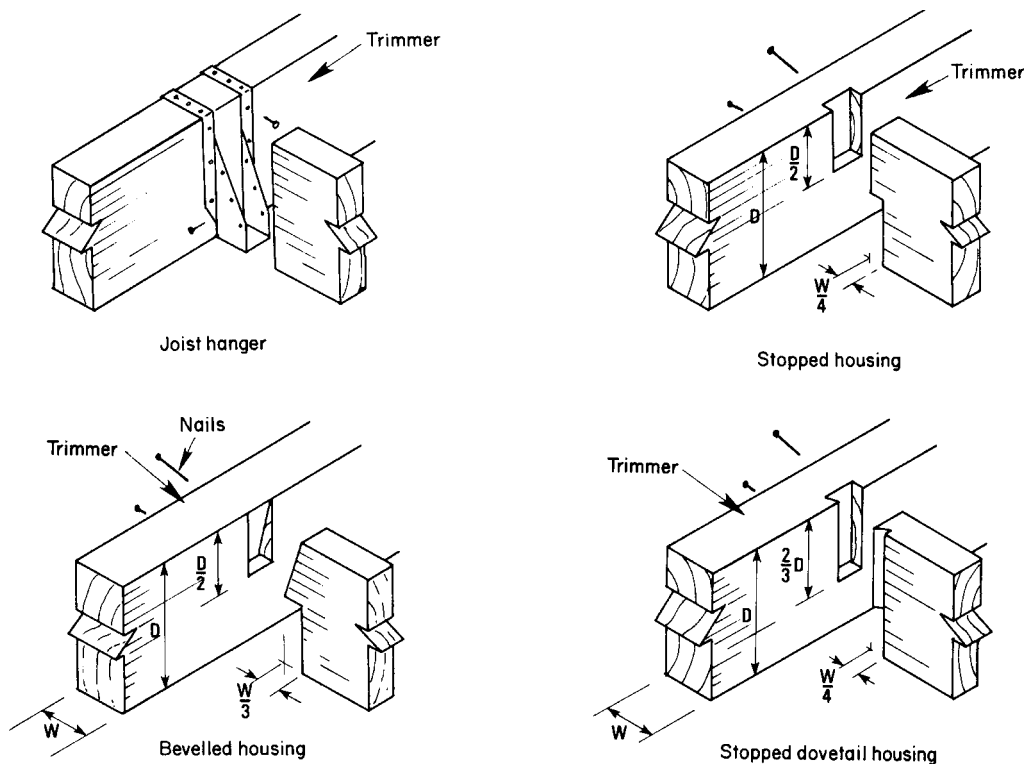
## 6.3 Strutting

Strutting is used to stiffen the whole floor – long, deep, narrow joists will tend to bow and/or buckle unless restrained along their



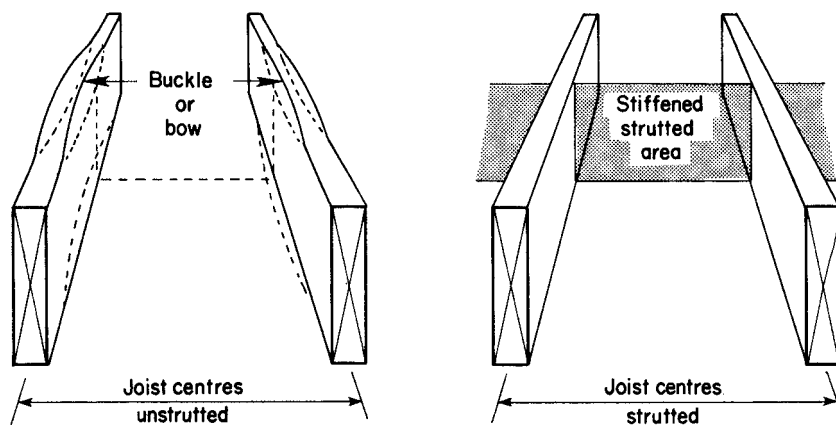


**Fig. 6.6** Joist hanger: type of hanger, and method of fixing (size and type of nails/bolts) should be as specified by the designer and/or manufacturer



**Fig. 6.7** Joints – trimmed joist to trimmer

length (Fig. 6.8). Stiffening (strutting) is carried out at intervals according to the joist depth-to-breadth ratio and span (British Standard (BS) 5268: Part 2:2002 'Structural use of timber' Section 2, part 14.8), for example, strutting should be provided at intervals not exceeding 6 times the depth of the joist, when the depth-to-breadth



Note: Deep thin beams are inclined to buckle under load

Fig. 6.8 Lateral support to joist

ratio is greater than 5. Thus a  $38 \times 200$  joist would have a depth-to-breadth ratio of  $200/38 = 5.26$ . Therefore strutting will be required at intervals not exceeding  $6 \times 200 = 1.2$  m.

There are three methods of strutting currently employed:

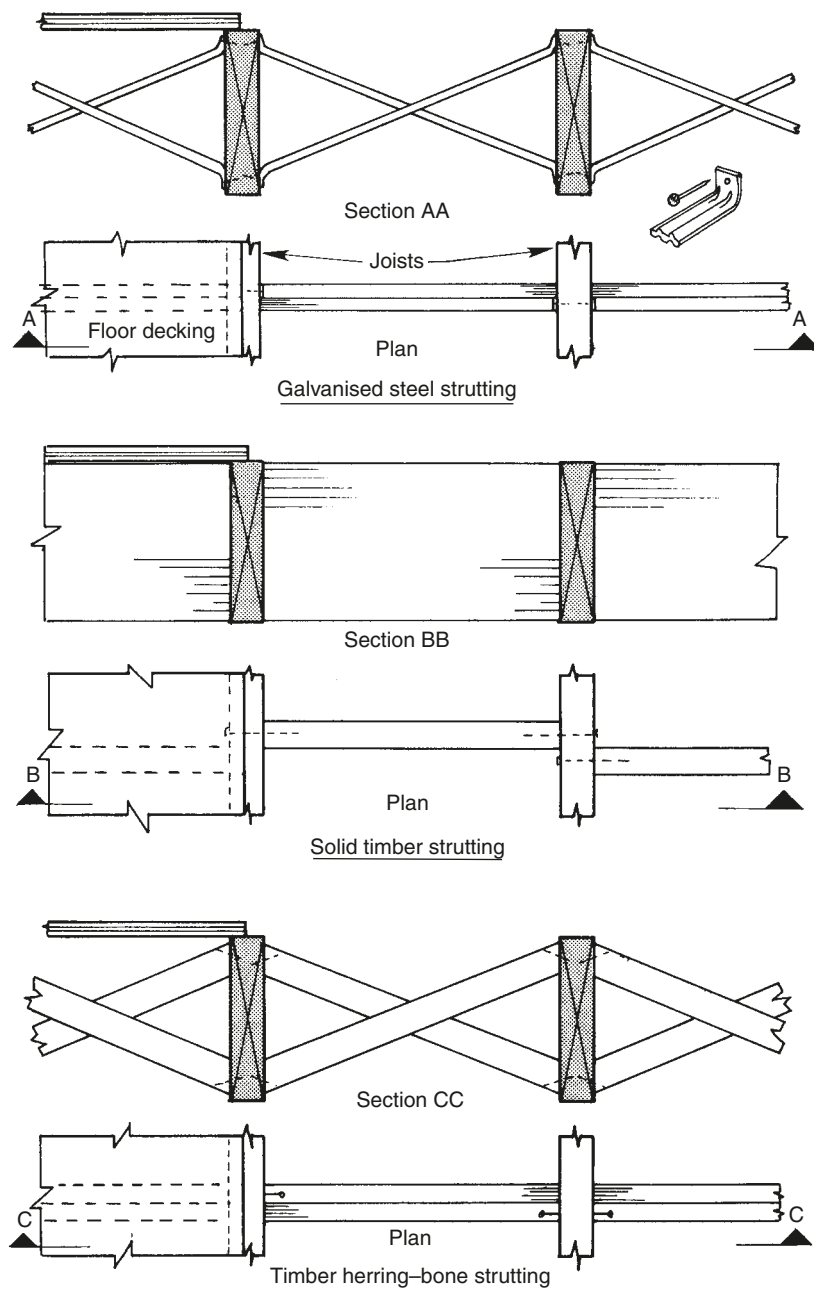
- (i) steel strutting,
- (ii) solid strutting (solid bridging),
- (iii) herring-bone strutting.

All three, together with their relevant positions, are shown in Fig. 6.9. Probably the most effective – although expensive in labour costs – is herring-bone strutting. Figure 6.10 shows how it is cut and fixed.

It should be noted that, no matter which type of strutting is used, the end of the line will need a packing between the last joist and the wall. Care must be taken if folding wedges are used for this purpose, as overtightening could dislodge the blockwork.

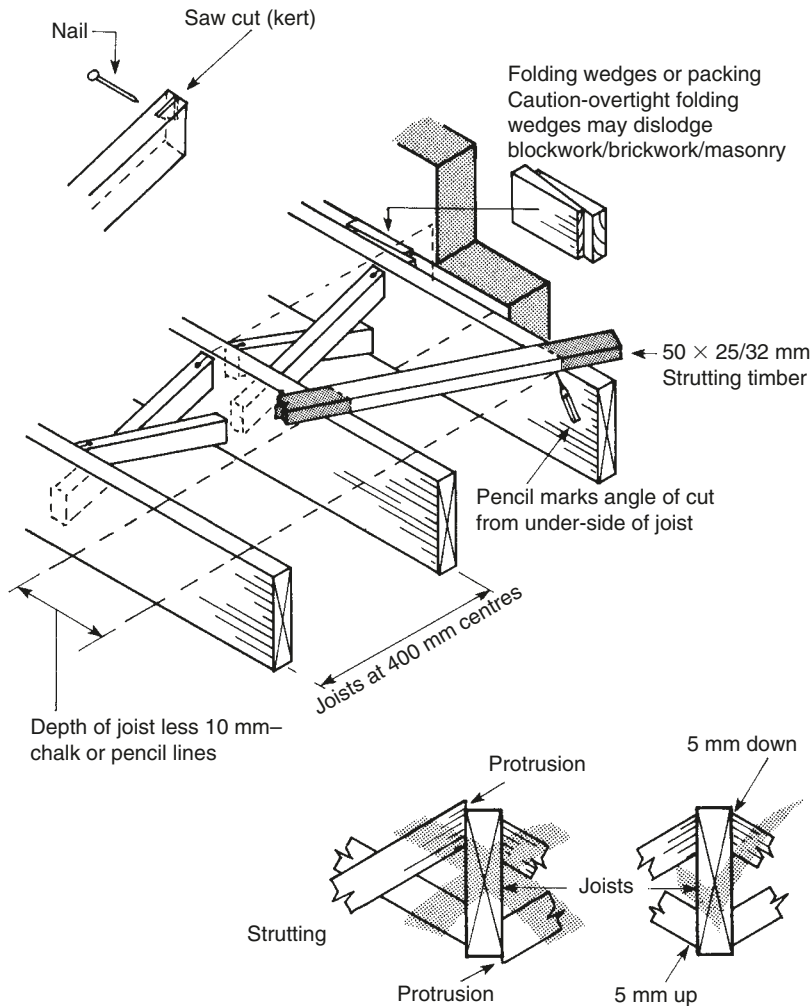
## 6.4 Notching joists

Unlike timber ground floors, where services can be run under the joists, upper-floor services must run either parallel with the joists or, when this is not possible, through them. The only alternative is to run them above the floor on the walls – doorways and openings are then a problem. Where holes or notches have to be made through joists, the reduced depth should be allowed for in the floor's design, for example by increasing the depth of the joist by 25 mm (depending on the depth of notch) and/or adding an extra joist, thereby reducing the



**Fig. 6.9** *Types of strutting*

distance apart. Holes for cables should be drilled mid-depth of the joist through the neutral axis (Fig. 6.5). Guidelines with regard to drilling holes and cutting notches are shown in Fig. 6.11; further reference should be made to BS 5268: Part 2:2002 'The structural use of timber', NHBC, and TRADA.



**Fig. 6.10** *Marking, positioning, and fixing herring-bone strutting*

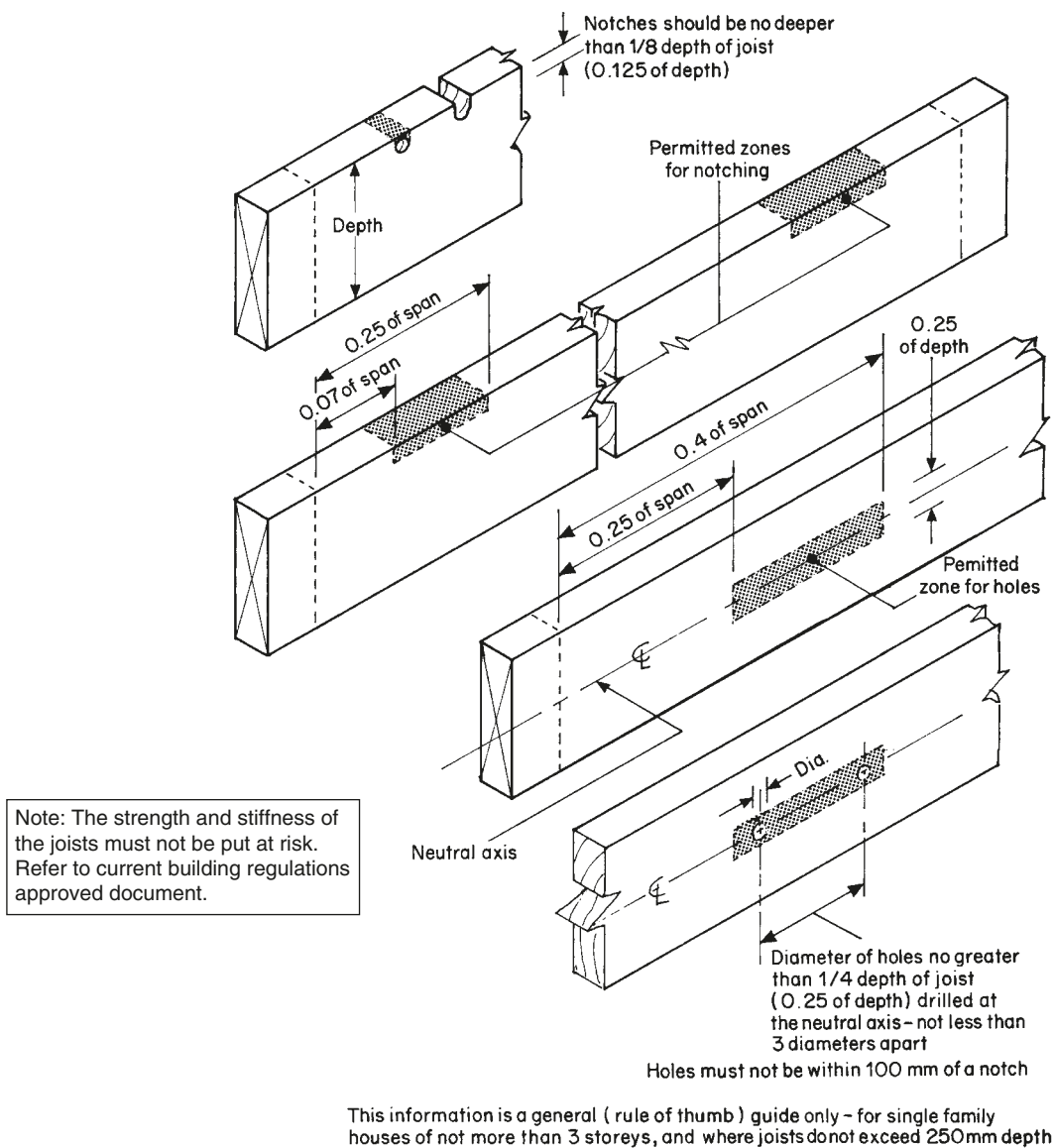
Holes should be drilled in the neutral axis with a diameter not exceeding 0.25 ( $\frac{1}{4}$ ) of the depth of the joist, should not be less than 3 diameters (centre to centre) apart and should be located between 0.25 and 0.4 times the span from the support.

## 6.5 Flooring

As stated in 5.4, materials used as decking are:

- planed, tongued, and grooved (PTG) floor board (see Fig. 5.21);
- flooring-grade chipboard – tongued and grooved or square edged;
- flooring-grade plywood – tongued and grooved or square edged.

The processes which follow are common to both ground and upper floors – laying floor board was dealt with in 5.4.1.



**Fig. 6.11** Drilling holes and cutting notches in joists

### 6.5.1 Flooring-grade chipboard

All chipboard used as floor decking must conform to BS EN 312 2003 (also see 5.4.2). Board thickness in relation to span is shown in Table 6.1.

### 6.5.2 Laying

Tongued-and-grooved boards are laid across the joists as shown in Fig. 6.12 – their ends must meet on a joist. Long edges do not require noggings (horizontal members fixed between joists to support board

**Table 6.1** Guide to decking-material thickness

Decking material	Finished thickness (mm)	Maximum joist centres* (mm)	Reference
PTG softwood	16 19	450 600	Building Regulations approved document A
Flooring-grade chipboard	18/19 22	450 600	National House Building Council (NHBC)
Flooring-grade chipboard	18/20 22	450 610	BS EN 312 2003
Decking plywoods	16 19	400 600	

\* Joists should also be spaced to accommodate the surface dimensions of the decking and ceiling material (plasterboard).

**Table 6.2** Nailing guide

Material	Edge treatment	*Maximum distance between nails (mm)	
		Edges	Intermediate supports
Flooring-grade chipboard	Tongued and grooved (all round)	200–300	Four nails to each joist
	Square edged (all round)	200–300	400–500
Decking plywoods		150	300

\*As per manufacturer instructions.

edges), but the tongues and grooves should be glued together with a PVA adhesive, to help stiffen the floor and prevent joint movement. For nailing details, see Table 6.2.

The laying of square-edged boards is shown in Fig. 6.13 – long edges meet on a joist; short edges must be supported by noggings. Nailing details are given in Table 6.2.

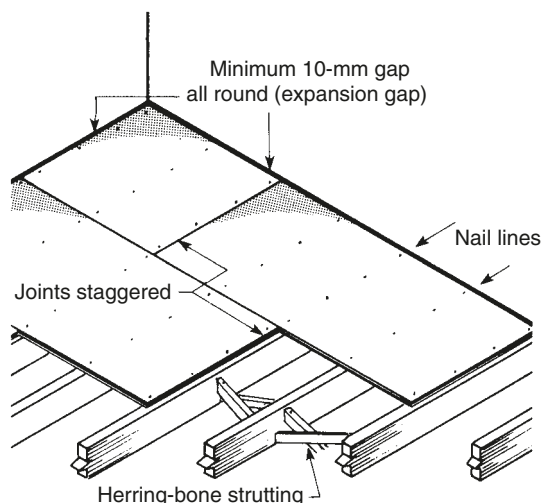
It is important to stagger short joints, to help stiffen the floor and to distribute floor load more evenly. Depending on floor width, a gap of not less than 10 mm should be left around the perimeter of the floor to allow for moisture movement, the actual gap will depend on the dimensions of the room – gaps will be covered by skirting board.

Where cuts are to be made for traps, etc. that portion of board which remains should be not less than 150 mm wide. All free edges should be supported by noggings.

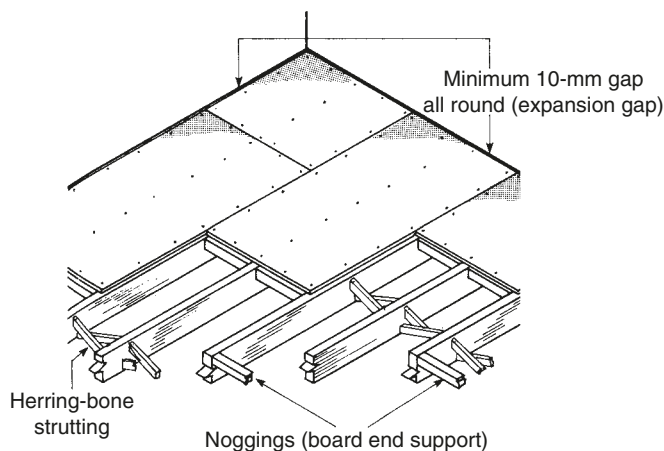
Boards are fixed to joists with nails or screws (Table 6.2), the length of which should be  $2\frac{1}{2}$  times the board's thickness. Lost-head nails can be used, but annular-ring nails (improved nails) are recommended because of their resistance to 'popping' or lifting (see Volume 1, pages 250–251).

### 6.5.3 Plywood

Like chipboard, flooring grades of plywood are available with tongued-and-grooved or square edges. Boards must always be fixed with their face grain at right angles to the joists. Board ends should rest on joists, and all edges of square-edged boards must be supported either by joists or by noggings. Board joints should be staggered, to stiffen the floor.



**Fig. 6.12** *Laying tongued-and-grooved chipboard decking*



**Fig. 6.13** *Laying square-edged chipboard decking*

Board thickness is related to span (Table 6.1). 45 mm long 'improved nails' are recommended for boards 12.5 mm, 16 mm, and 19 mm thick, and 50 mm nails for boards 20.5 mm thick. For spacing of nails, see Table 6.2.

## 6.6 Insulation

Thermal insulation (see 9.3.1) will be necessary only where the floor intervenes between the dwelling and the external air or a ventilated space; for example, if it forms part of an overhang or acts as a ceiling to a porch (Fig. 6.14) it will be required to comply with the Building Regulations 2002, approved document L – in which case a similar arrangement to Fig. 6.14 (with the addition of a suitable ceiling) should be considered.

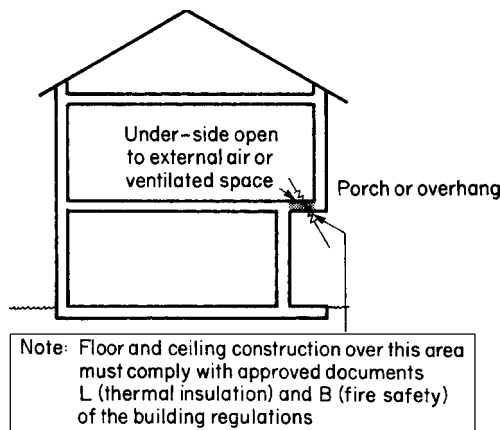
Sound insulation (see 9.3.2) need only be provided if the floor separates the dwelling from another or as stated in the Building Regulations 2003, approved document E – in which case it must offer resistance to the transmission of both 'airborne' and 'impact' noise. A suitable arrangement is shown in Fig. 6.15, where the decking floats on a resilient insulating quilt draped over the joists to reduce impact noise (e.g. footsteps). In the past floor mass has been increased by using dry sand as pugging to reduce airborne noise (e.g. from a record player).

*Note: Allowance must be made in the design of the floor to accommodate the extra loading put on the floor by the weight of the pugging.*

## 6.7 Safety

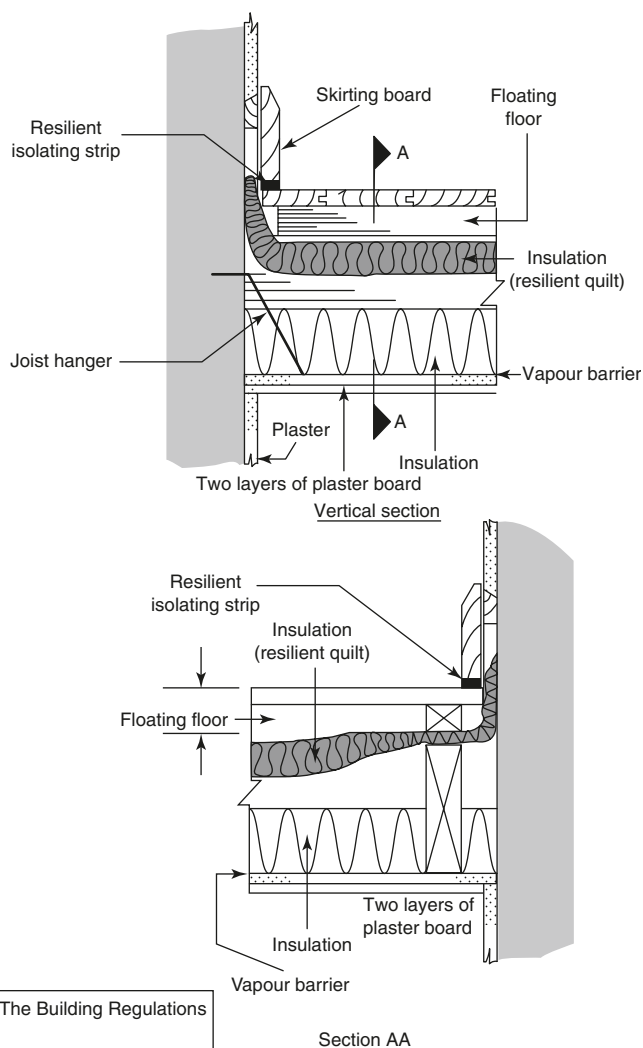
*Note: Before any work starts, a risk assessment must be carried out.*

The height of a habitable room is not generally less than 2.3 m – with the possible exception of the underside of beams – which means that initially operatives will be working above open joists, which are over 2 m above the ground. Therefore, according to the The Construction (Health, Safety and Welfare) Regulations 1996, where persons are working on or above 'open joisting' through which a person could fall and injure themselves, the joisting must be securely boarded over to provide safe access and/or a safe working place.



**Fig. 6.14** Floors requiring thermal insulation





**Fig. 6.15** *Sound insulation to an upper floor*

## References

The Construction (Health, Safety and Welfare) Regulations 1996.  
 The Building Regulations 2000, approved document A (1/2).  
 The Building Regulations 2003, approved document E.  
 The Building Regulations 2002, approved document L.  
 BS 5268: Part 2:2002 'Structural use of timber' Section 2, part 14.8.  
 BS EN 312 2003.  
 TRADA. (Floor joist span tables)  
 NHBC Standards.

# 7

## Single timber flat roofs

Although the underside of a 'flat' roof may be flat (horizontal), the upper surface will slope in order to disperse roof water. The amount of fall (slope) should not exceed  $10^\circ$  (otherwise the roof would be classed as a pitched roof) and may depend upon:

- (a) the type of building and its appearance and location,
- (b) the type of decking,
- (c) the type of weather-proof covering.

Direction of fall may be affected by the position of:

- (i) joists in relation to decking,
- (ii) the nearest surface-water drain into which roof water will discharge.

With regard to the laying of roof joists, providing support, anchorage, strutting, and decking, the construction of the roof can generally be likened to that of an intermediate timber upper floor.

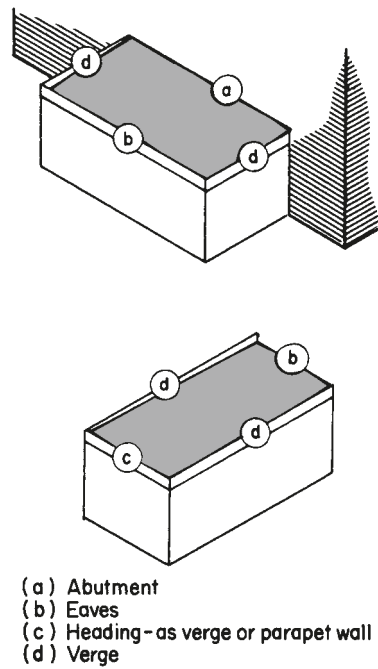
Figure 7.1 shows diagrammatically how attached and detached flat roofs may appear in relation to their fall (slope) with a key showing the whereabouts of different edge treatments. Figure 7.2 shows a means of constructing a flat roof that abuts a house wall. Stages of assembly are detailed in Section 7.7.

### 7.1 Roof joists

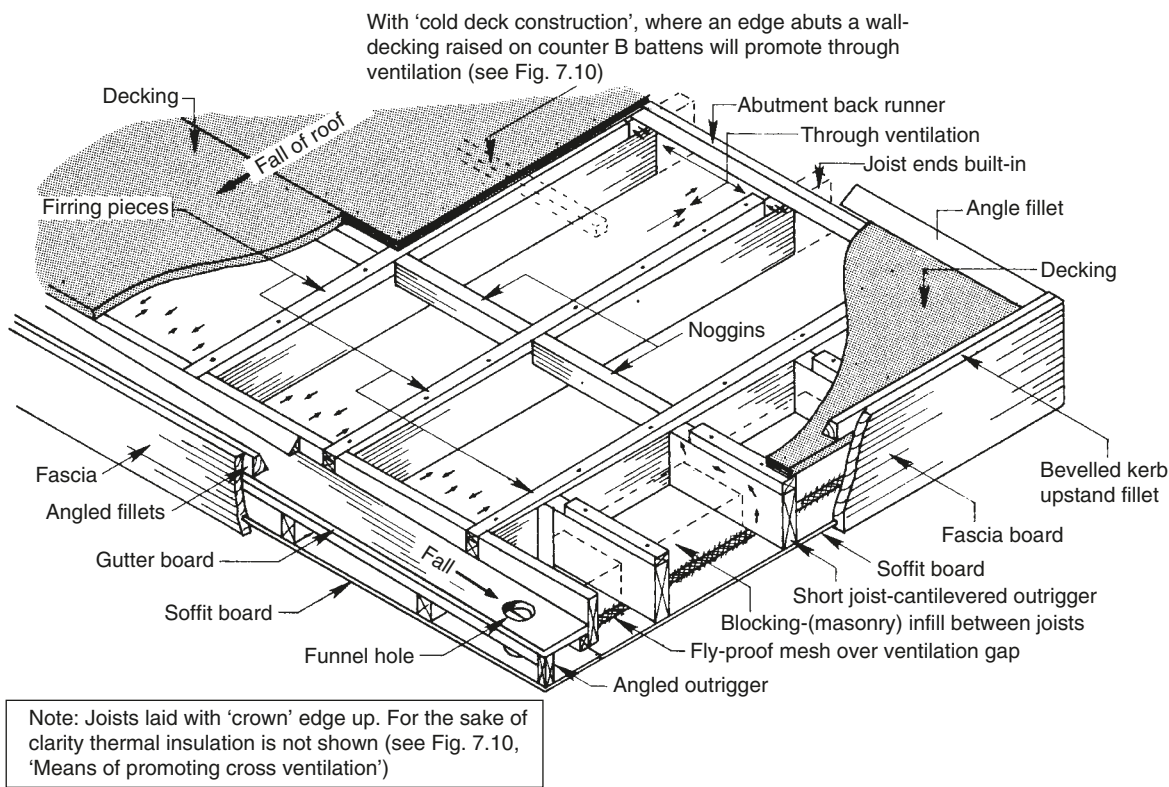
The Building Regulations 2000, approved document A, relates to roof and floor constructions. However, Timber Research and Development Association (TRADA) now publishes tables concerning joist sectional size to grade of timber, loading, span, and centres. Joist centres should be submultiples of the dimensions – length and width – of both decking and ceiling material (plasterboard, etc.), to avoid unnecessary noggings.

Fall can be achieved by one or a combination of the following methods:

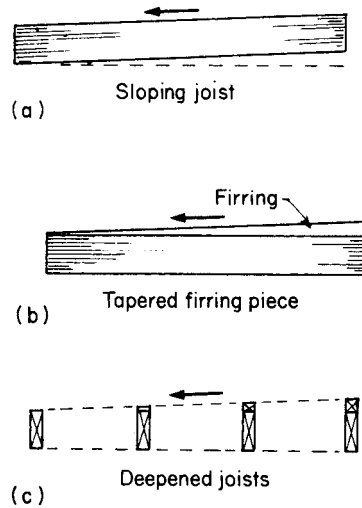
- (a) *Sloping joists* (Fig. 7.3(a)): decking and ceiling run parallel. This is suitable for garages, outbuildings, or where there is to be no ceiling or a level ceiling is not required.



**Fig. 7.1** *Key to roof edge details*



**Fig. 7.2** *Flat-roof construction (exposed isometric projection)*



**Fig. 7.3** *Alternative joist arrangements*

- (b) *Tapered furring pieces* (Fig. 7.3(b)): tapered pieces of timber (firrings) nailed along the top edge of horizontal joists.
- (c) *Deepened joists* (Fig. 7.3(c)): lengths of timber of decreasing section which are positioned at right angles to the fall of the roof and nailed to the top edges of the joists.

If a flat under-ceiling is required, regularised joists (see Fig. 5.7(a)) should be used for sloping joists. Regularised joists should also be used where tapered firrings are used, to avoid furring adjustments.

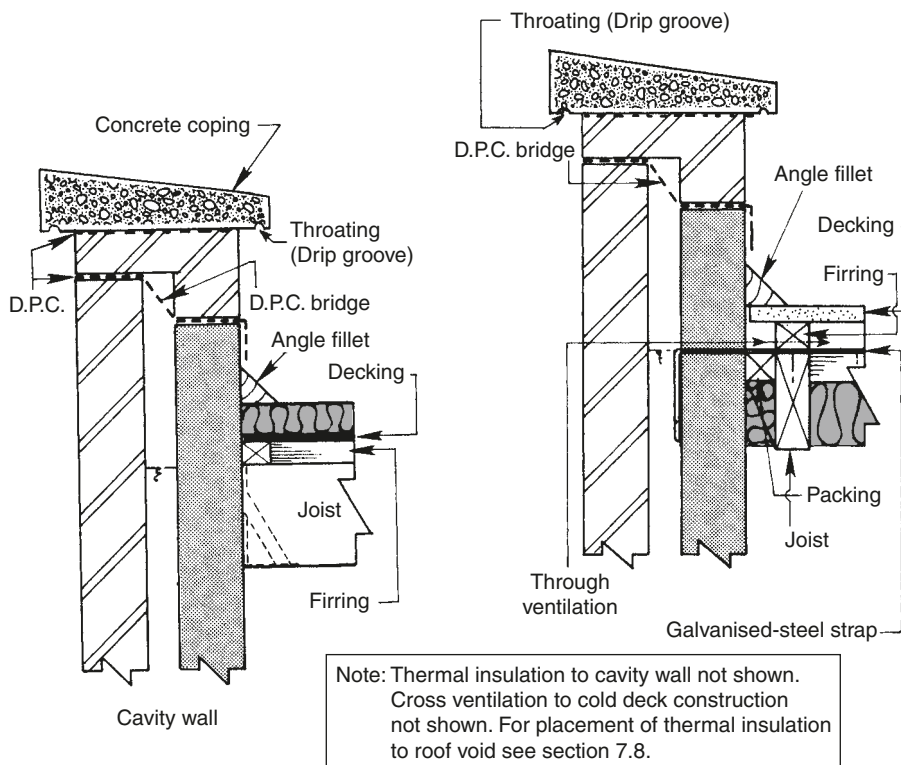
Stiffening of joists by strutting can be carried out as for floors (see Section 6.3). It would be advisable to use packing as opposed to folding wedges at the eaves and verges.

## 7.2 Abutment to walls

Figure 7.1 shows typical abutment locations, for example, against a face wall (Fig. 7.1(a)) and possible parapet wall (Fig. 7.1(c&d)). A parapet wall is a wall which protrudes above either the verge or eaves, as shown in greater detail in Fig. 7.4, and is terminated by a weathered coping.

Several methods of providing a joist bearing are shown in Fig. 7.5. They are:

- (a) *Built-in* (not recommended) (Fig. 7.5(a)): joist ends should be treated with preservative.
- (b) *Flange of a steel beam or joist* (Fig. 7.5(b)): where the roof adjoins an opening in the abutting wall.
- (c) *Steel joist hanger* (Fig. 7.5(c)): built into and *tight up* against the wall face (see Fig. 6.2).
- (d) *Timber wall piece* (Fig. 7.5(d)): supported by steel corbel brackets built into the wall. The joist bearing should be reinforced with steel framing anchor plates.



**Fig. 7.4** *Flat roof abutting a parapet wall (vertical section)*

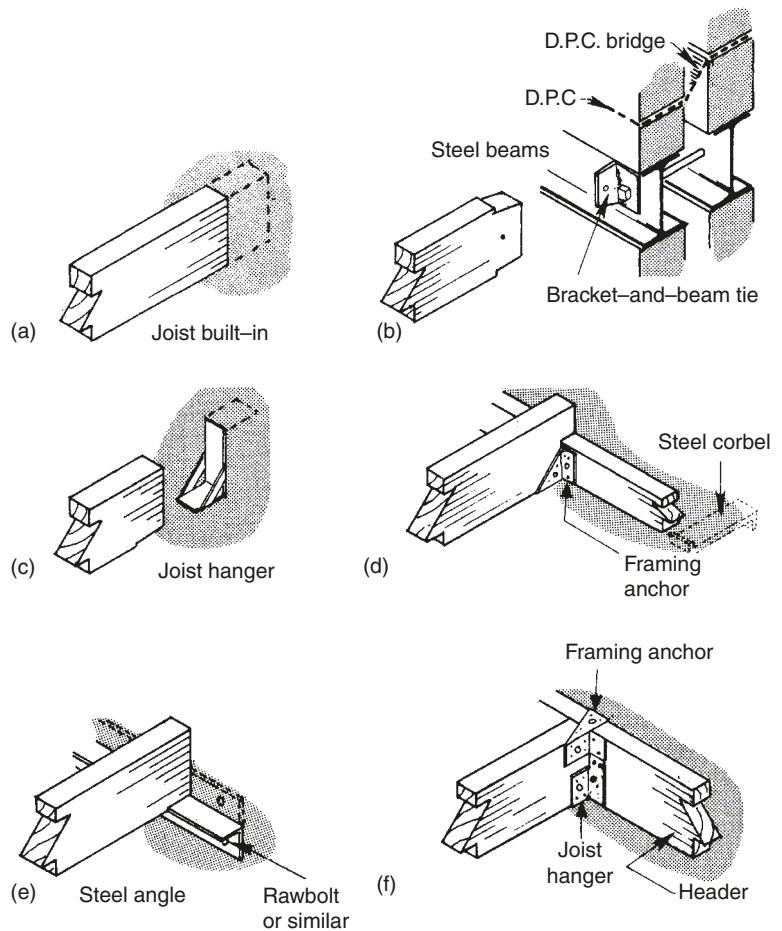
- (e) *Steel angle* (Fig. 7.5(e)): bolted to the wall with rawbolts or similar fixing, depending on the wall material.
- (f) *Framed* (Fig. 7.5(f)): headers bear on steel corbel brackets or angle. The whole roof framework can be constructed at ground level then hoisted into position, with or without roof decking. This method is suitable for roofs, or roof sections, of a small surface area.

## 7.3 Eaves treatment

At the eaves, roof water will be discharged into a gutter. Figure 7.6 shows how this area may be treated. Two methods of providing thermal insulation to roof void have been shown (see Section 7.8), but whether thermal insulation is required will depend upon the type and purpose of the building.

The fascia board of flush eaves (Fig. 7.6(a)) stands just proud of the face wall – this will allow for any face-wall unevenness and provide a ‘drip’. Figures 7.6(b) and (c) both show closed (although vented) overhanging eaves, but Fig. 7.6(c) shows a timber-framed substructure.

The ‘boxed gutter’ (gutter with parallel sides) shown in Fig. 7.6(d) forms an integral part of the roof structure and it is expensive to construct compared to an external gutter, but it is very efficient and



**Fig. 7.5** Joist bearings – abutting a wall (furring pieces not shown)

Note: Not recommended

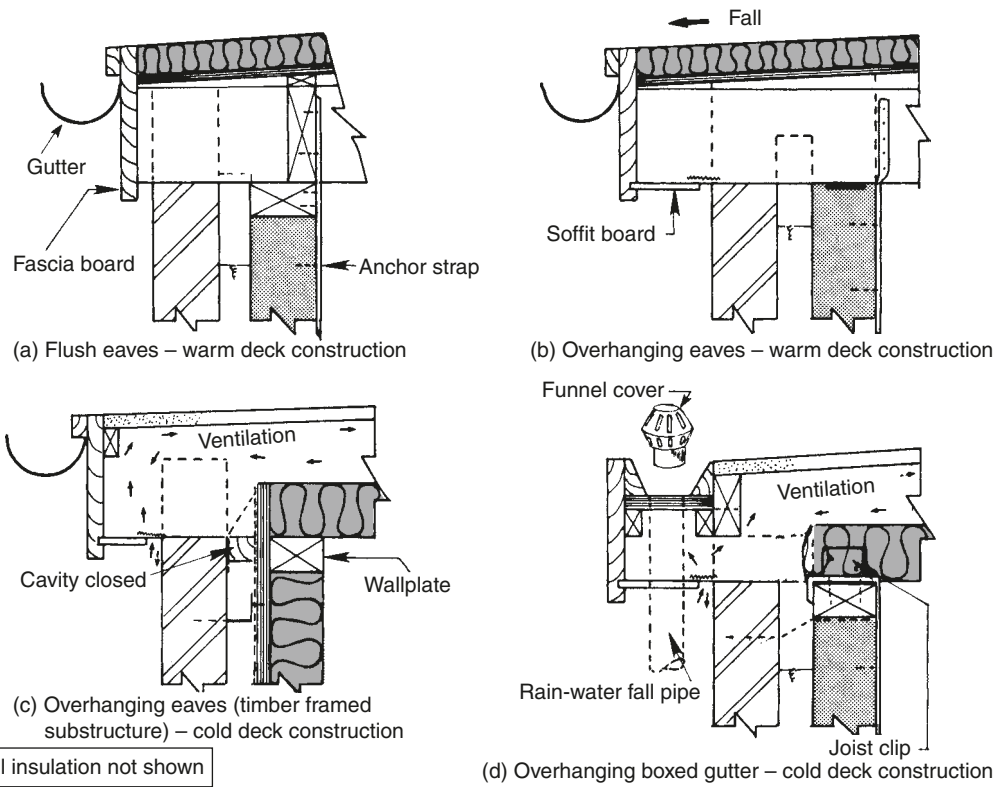
Note: The position of the surface-water drain can influence the whole design of the roof.

gives a neater finish to the eaves. Boxed gutters are best constructed within the overhang and should have a minimum fall of 1:60. The gutter outlet (funnel) can be sited either at the ends or at mid-length of the gutter, and a balloon of galvanised wire or plastics should be fitted over the outlet to help prevent the rainwater fallpipe becoming choked with silt, leaves, or the stone chippings used on some roof coverings. (White stone chippings help keep the roof's surface cool by reflecting solar heat, and they also add to fire resistance.)

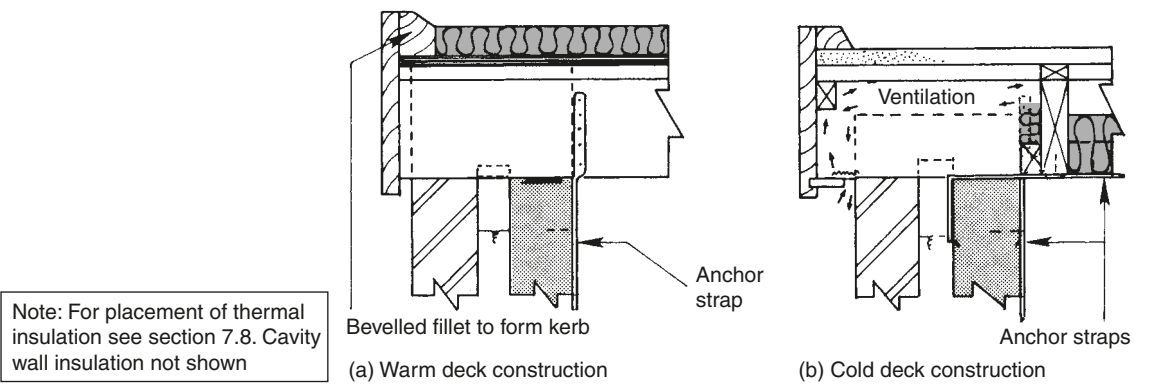
## 7.4 Verge treatment

A verge is an edge of the roof that lies parallel to the fall of the roof.

Figure 7.7(a) shows a method of providing a kerb edge (an upstand which prevents roof water running off the edge) which abuts the decking material. Joists run at right angles to the fall of the roof.

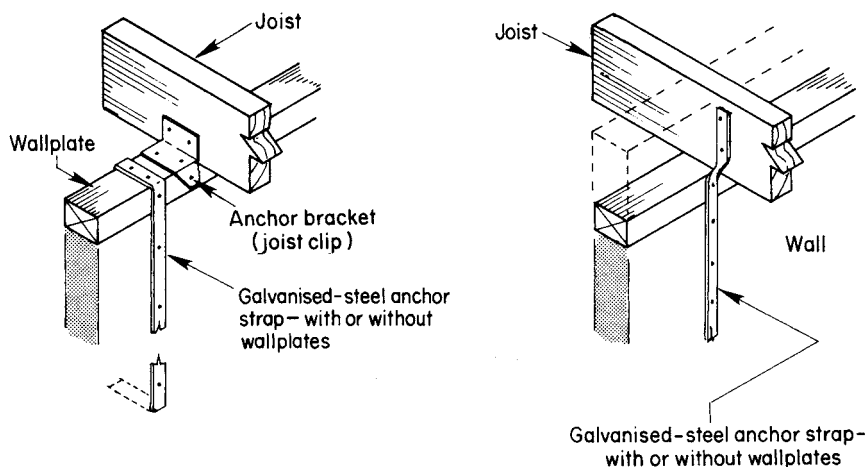


**Fig. 7.6** *Alternative eaves details to a thermal-insulated roof (vertical section). Cavity wall insulation not shown*



**Fig. 7.7** *Alternative verge details to a thermal-insulated roof (vertical section)*

In Fig. 7.7(b) the kerb is planted on to the decking. The joists now run with the fall of the roof, therefore short joists (outriggers) are used to carry the roof over the end walls and provide a means of fixing the fascia and decking material. With short roof runs, the fascia can be



**Fig. 7.8** *Joist and wallplate anchorage*

fixed level (but need not be), in which case the inner upstand is tapered to suit the fall. This is achieved by using a tapered angle fillet or by leaving a tapered margin between the angle fillet and the fascia top. An example of angle-fillet application is shown in Fig. 7.2.

## 7.5 Roof anchorage

Except when joists are fully built into a wall (Fig. 7.5(a)), this type of roof will only be held down by its own weight, which provides insufficient anchorage to prevent it lifting in strong winds. A suitable anchorage can be achieved by using steel holding-down straps (galvanised), which can also offer lateral (against side movement) support to the walls. Examples are shown in Fig. 7.8 (see also Figs 6.2 and 8.26 for lateral wall support).

## 7.6 Roof decking

Any of the following materials may be specified as a decking.

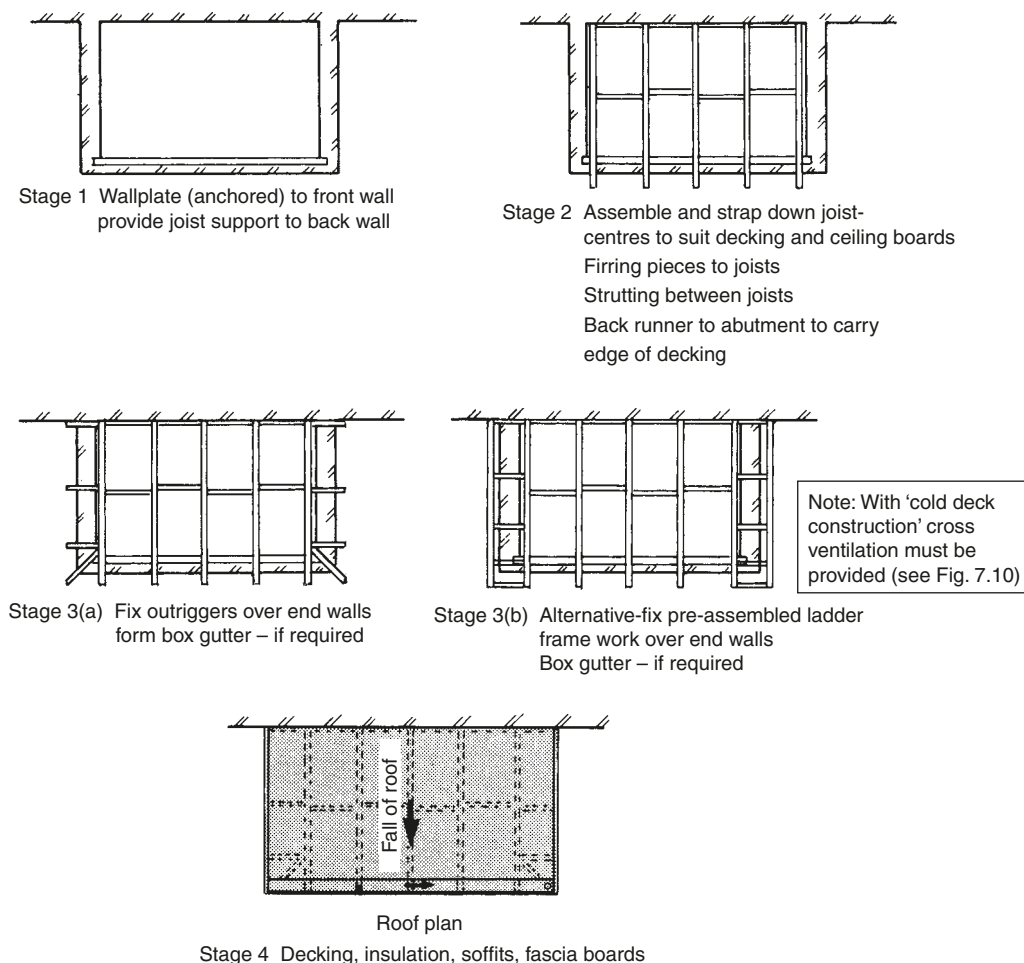
### ***Tongued-and-grooved floor boards, or square-edged boards***

These are laid either with, or diagonal to, the fall of the roof. 'Cupping' of tangential-sawn boards laid across the fall could cause the roof's covering to form hollows of sufficient depth to partially hold back the flow of water off the roof and leave pools. The method of laying and fixing are the same as for floors.

### ***Chipboard***

Only types recommended for roofing should be used BS EN 312 2003 (see Volume 1, Table 4.4) – these possess moisture-repelling qualities. Boards are available which have a covering of bituminous felt bonded to





**Fig. 7.9** *Stages of constructing a flat roof that abuts a vertical wall*

one surface – this gives the board temporary protection against wet weather once it has been laid and the edges and joints have been sealed.

Edge support, laying, and fixing are similar to floors.

### **Plywood**

Only weather and boil proof (WBP) roofing grades should be used (see Volume 1, Table 4.1 & 4.2), fixed in the same manner as for floor decking.

## **7.7 Stages of construction**

Figure 7.9 illustrates in plan view how a flat roof which abuts a wall can be erected. The drawings should be studied in conjunction with Fig. 7.2 which, although thermal insulation has been omitted, shows how through ventilation to the whole roof space can be provided if required.

## 7.8 Thermal insulation

Unless it serves only as a shelter to a shed, garage, or porch, etc. one of the main functions of a roof is to help conserve heat within the structure it covers or, conversely, to offer resistance against heat entering it.

Materials possessing good thermal-insulation qualities are cellular in their make-up and, with the exception of solid wood, are generally of a non- or semi-rigid nature such as quilts of glass or mineral wool and expanded polystyrene. Rigid slabs are usually in a composite form (cored within a laminated board). To totally satisfy current (Building Regulations L1 2000, conservation of fuel and power), insulation requirements, the use of timber alone would be both impracticable and uneconomical, therefore lightweight inexpensive materials like those mentioned are introduced within the roof. Where these materials are positioned will depend on whether the roof is of a 'cold-deck', or 'warm-deck' construction.

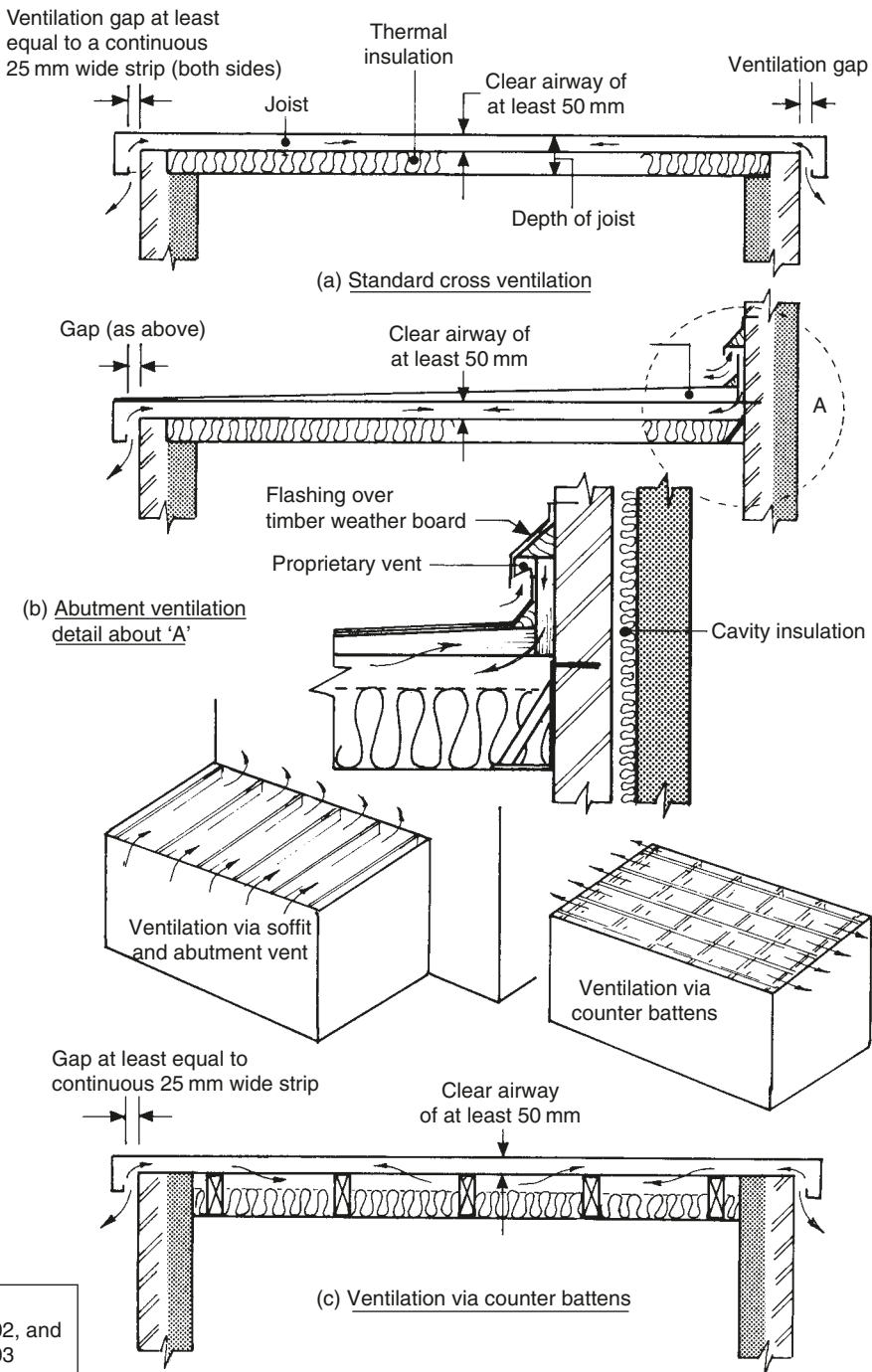
### 7.8.1 Cold-deck construction

*Note: 'Through' ventilation can be improved by fixing decking to cross battens set at right angles to the joists (Fig. 7.2).*

By placing the insulation material at ceiling level, as shown in Fig. 7.11(a), heat is retained at this point. However, unless a vapour barrier (an impervious membrane such as polythene sheeting) is positioned at the warm side of the insulation, water vapour will pass through the insulation and, on contact with the cold impervious decking, will turn into droplets of water (condensation). Dampness in this void can mean that there is a danger from fungal attack and that the insulation will become wet and eventually compacted, and therefore less effective – not to mention the presence of damp patches on the ceiling below. To prevent the risk of condensation, voids between joists must be thoroughly ventilated. A gap of at least 50 mm should be left between the decking and the thermal insulation to allow for free air space.

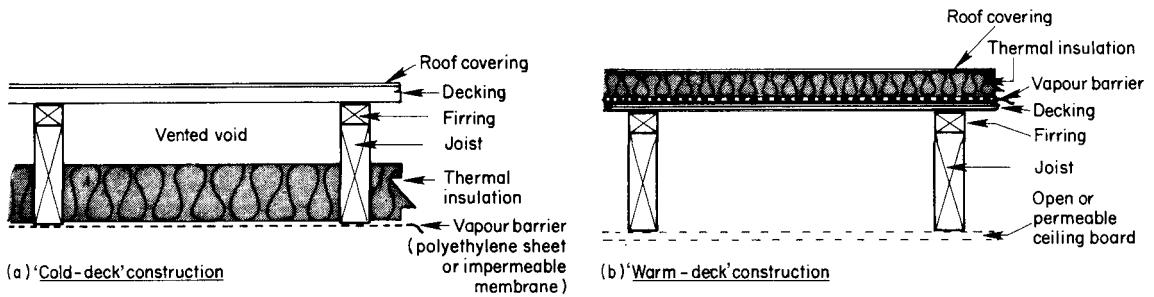
As shown in Fig. 7.10 options include:

- (i) *Figure 7.10(a)*: Cross ventilation is provided by leaving gaps equivalent to a 25 mm wide continuous strip along each of two opposite sides. Inner void should be such that a 50 mm gap between the underside of the roof decking and upper side of the insulation is left open to allow free movement of air.
- (ii) *Figure 7.10(b)*: Where cross-ventilation is not possible (due to an abutting wall), a proprietary head venting system may be installed such as the one shown.
- (iii) *Figure 7.10(c)*: An alternative to Fig. 7.10(b), is to use counter battens – these must be strong enough to support the decking and be securely anchored to the substructure.



Note: See also  
BS 5250: 2002, and  
BS 6229: 2003

**Fig. 7.10**     *Means of promoting cross-ventilation*



**Fig. 7.11** Methods of providing thermal insulation

### 7.8.2 Warm-deck construction

*Note: Reference should be made to the Building Regulations with regard to insulation type and relevant thickness for cold-deck and warm-deck construction.*

As shown in Fig. 7.11(b), thermal insulation in this case is positioned at decking level, with a vapour barrier to its warm underside. Ceiling voids will not need ventilating. One advantage of this method is that, if access to the roof void is required for services (electric cables, etc.), this can be achieved without damaging the vapour barrier.

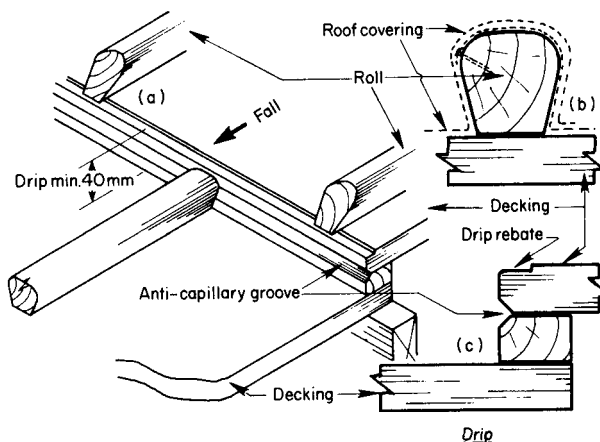
## 7.9 Roof coverage

Layers of bitumen roofing felt stuck to the decking and to each other, with a top layer of bitumen bedded stone chippings; mastic asphalt; or metals such as aluminium, copper, or lead may be used as a weather-proof covering. Roofing felt can be applied directly to the flat surface of the decking.

With metals there is the problem of thermal movement (expansion and contraction according to environmental temperature change), and provision must be made on the decking to allow movement to take place. This is achieved by the introduction of timber upstands known as 'rolls'. These rolls are positioned at intervals along the fall of the roof (Fig. 7.12(a)), the distance apart varying with the type of metal. A roll suitable for lead covering is shown in Fig. 7.12 (b), only one edge of the sheet is fixed. These rolls take care of the longitudinal joint. Due to the thickness of the material – lead, for example – joints across the fall of the roof (width of sheet covering) could form a water check, in which case a step in the decking, known as a 'drip', would be formed as part of the roof's construction as shown in Fig. 7.12(c).

### 7.9.1 Disposal of water

Falls of not less than 1:60 should be maintained across the whole roof area and the gutters associated with it. Otherwise any slight rise in



**Fig. 7.12** *Provision for thermal movement of a lead-covered roof*

Note: See Section 8.11 'Eaves, gutters, and down pipes'.

the roof's covering at joints, etc. could cause water to pool and become a catchment area for enough silt to encourage and support plant life, which could have a harmful effect on the roof covering and become powerful enough to break open water seals.

## References

- The Building Regulations 2000, approved document A.
- The Building Regulations 2000, approved document L1.
- The Construction (Health, Safety and Welfare) Regulations 1996.
- BS 5268: Part: 2 2002.
- BS 5268: Part: 3 1998.
- BS 8103: Part: 3 1996.
- BS EN 312: 2003.
- TRADA. (Floor joist span tables)
- BS 5250: 2002.
- BS 6229: 2003.

# 8

## Roofs of equal pitch

The roof must be included in the design of a building as a whole, be it a factory, a house, or a garage. Just as its substructure depends on the roof for cover, so must the roof rely on the walls for support. Therefore the roof and walls must complement each other. Size, shape, location, use, and appearance are all factors which influence the choice of roof.

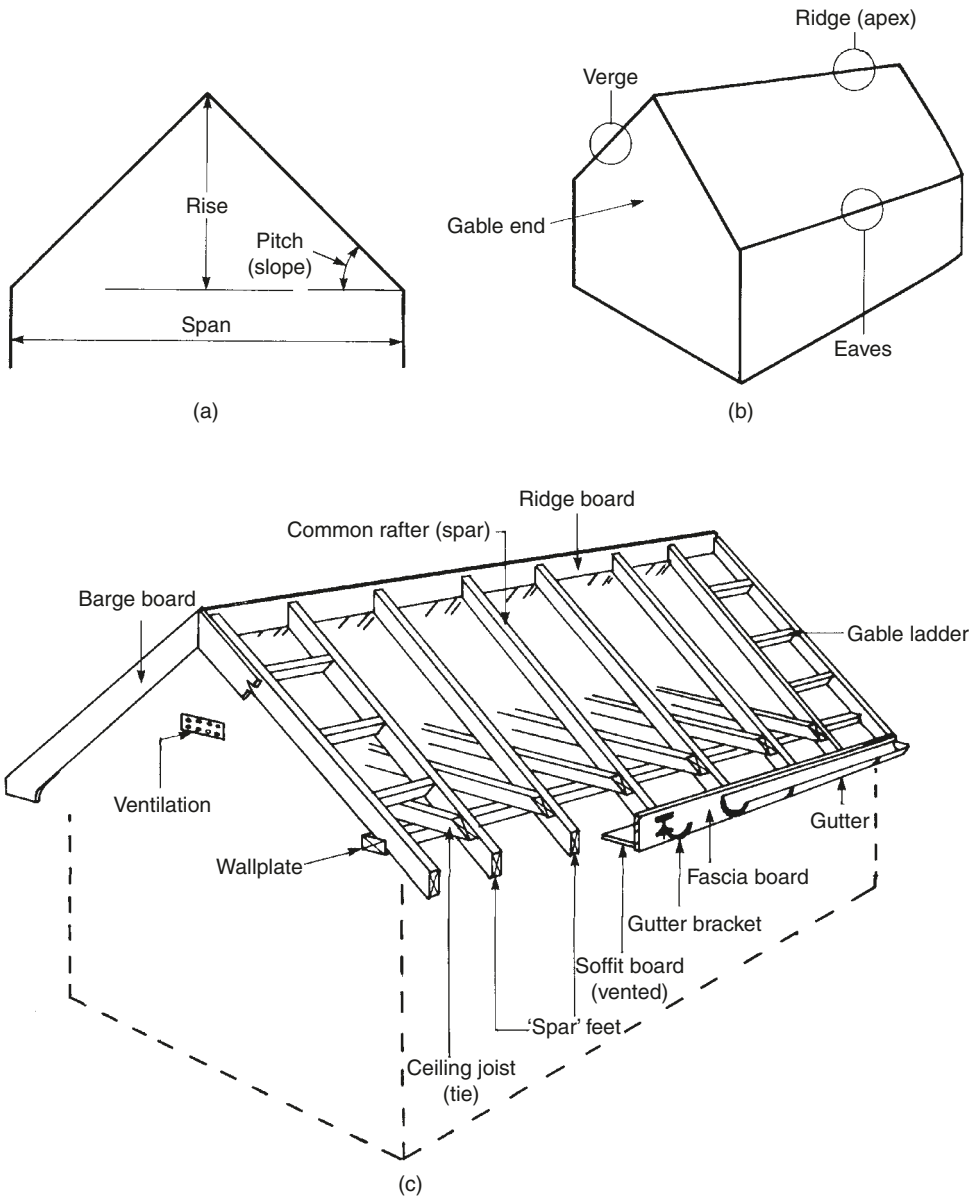
This section is concerned with roofs which span up to 4 m, have surfaces steeper than 10° to the horizontal – known as *pitched* roofs – and have their length terminated by end walls (gable walls).

### 8.1 Roof terminology

- *Single roof*: common rafters span from wallplate to ridge board without intermediate support as shown in Fig. 8.1 and Fig. 8.2.
- *Double roof*: common rafters have their effective span halved by mid-support of a beam (purlin). Also known as a *purlin* roof (see Section 8.4).
- *Roof span*: Usually taken as the distance between the outer edges of the wallplates (Fig. 8.1(a) & 8.5).
- *Roof rise*: the vertical distance from a line level with the upper surfaces of the wallplates to the intersection of the inclined slopes (Fig. 8.1(a)).
- *Roof pitch*: the slope of the roof (Fig. 8.1(a)) expressed either in degrees or as the fraction rise/span, that is, rise divided by the span. For example, for a rise of 1 m and a span of 2 m,

$$\text{Roof pitch} = \frac{\text{Rise (1 m)}}{\text{Span (2 m)}} = \frac{1}{2} \text{ pitch or } 45^\circ$$

Figure 8.1(b) names those parts (elements) of a pitched roof to which the various members (components) shown in Fig. 8.1(c) relate.



**Fig. 8.1** *Roof terminology (traditional roof)*

### 8.1.1 Roof elements (Fig. 8.1(b))

- **Ridge:** (apex) the uppermost part of the roof.
- **Gable:** the triangular upper part of the end walls.
- **Verge:** the overhanging edge at the gable ends.
- **Eaves:** the area about the lower edge of the roof surface at the top of the outer face walls.

### 8.1.2 Roof components (Fig. 8.1(c))

- *Ridge board*: receives the ends of the rafters.
- *Common rafter* (spar): rafter spanning from wallplate to ridge board.
- *Gable ladder*: framework taking the roof over the gable end.
- *Ceiling joists*: carrying ceiling material and act as rafter ties.
- *Wallplate*: provides a fixing for rafters and ceiling joists, and distributes the roof load.
- *Barge board* (*verge*): cover (trim) for the ends of the horizontal members, that is, wallplate, gable ladder, and ridge board.
- *Fascia board*: vertical facing to rafter ends (spar feet).
- *Soffit board*: horizontal board closing the underside of the spar feet.
- *Gutter*: channel section in metal, plastics, or wood fixed slightly off level to the spars to allow roof water to drain away to a fall pipe (downpipe). Wooden gutters are sometimes called *eaves spouting*.

## 8.2 Types of single-pitched roofs

Figure 8.2 identifies common methods of forming pitched roofs and offers a guide to their maximum span. Size of members will depend on pitch, span, and form. Where a tie acting as a ceiling joist (couple close roof) exceeds 2.5 m, it will, for reasons of the most economical sectional size (see Fig. 5.5), need to be restrained from sagging by using hangers and binders (Fig. 8.2(f)); otherwise the sag will put undue stress on the joints and unbalance the framework.

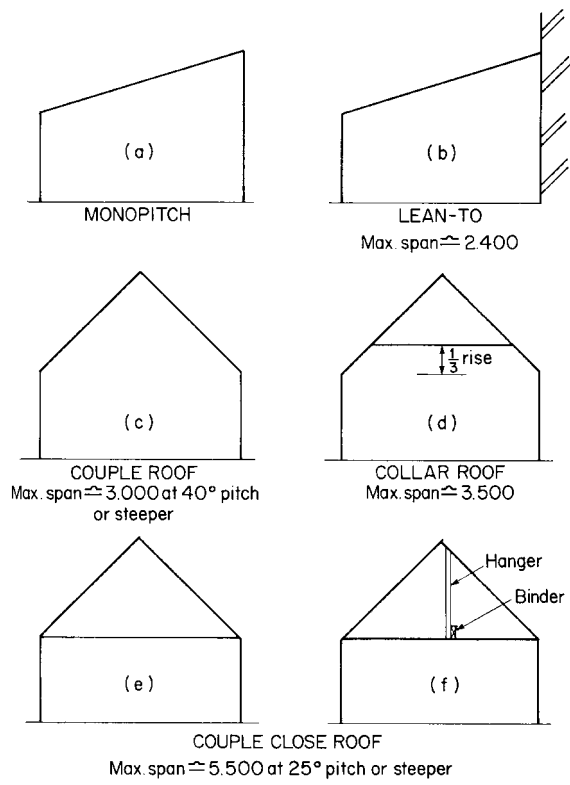
### 8.2.1 Forming a pitched roof

If a length of timber were reared against a wall, like a rafter in a lean-to roof (Fig. 8.2(b)), or leant against a similar inclined length to form the ridged effect of a couple roof (Fig. 8.2(c)), it would become apparent that the slope, length, and weight, together with the smoothness of the surfaces in contact, would lead to the sliding effect shown in Fig. 8.3(a).

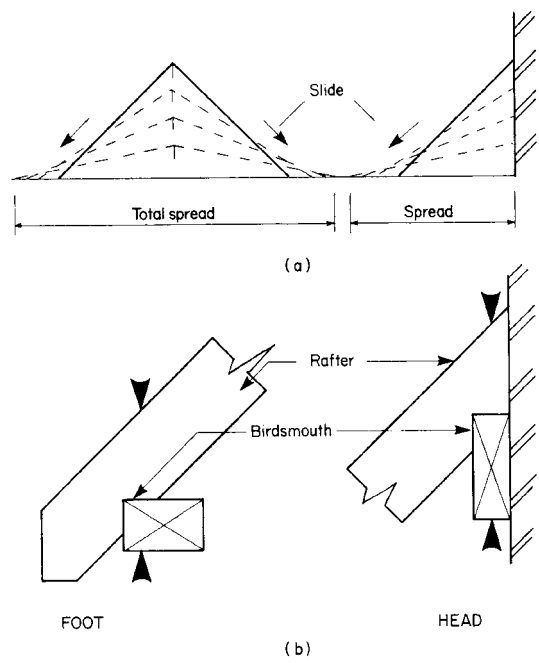
Provided the rafters have bearings at the top and bottom of the roof which are capable of transmitting loads vertically, like those offered by monopitch and lean-to roofs (Fig. 8.2(a) and (b)), slide can be restrained by cutting a *birdsmouth* into the rafter at these points, as shown in Fig. 8.3(b). However, deflection (due to loading) of the rafters and the hinging effect at the apex of a couple roof could produce enough horizontal thrust to push the supporting walls outwards; therefore the walls must be strengthened or a tie be introduced into the roof structure.

These principles can be more fully understood by using a model similar to that shown in Fig. 8.4(a). The component parts consists of four narrow strips of plywood – two rafters, one tie, and a strut – with holes bored to suit either dowel or nuts and bolts (free to move).

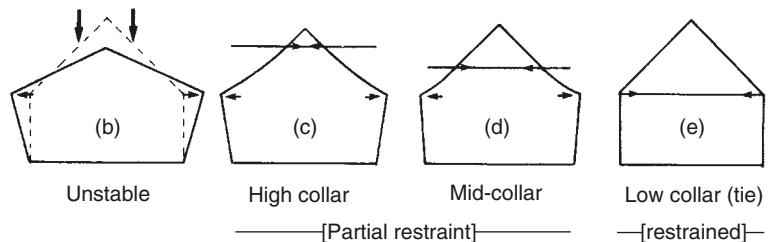
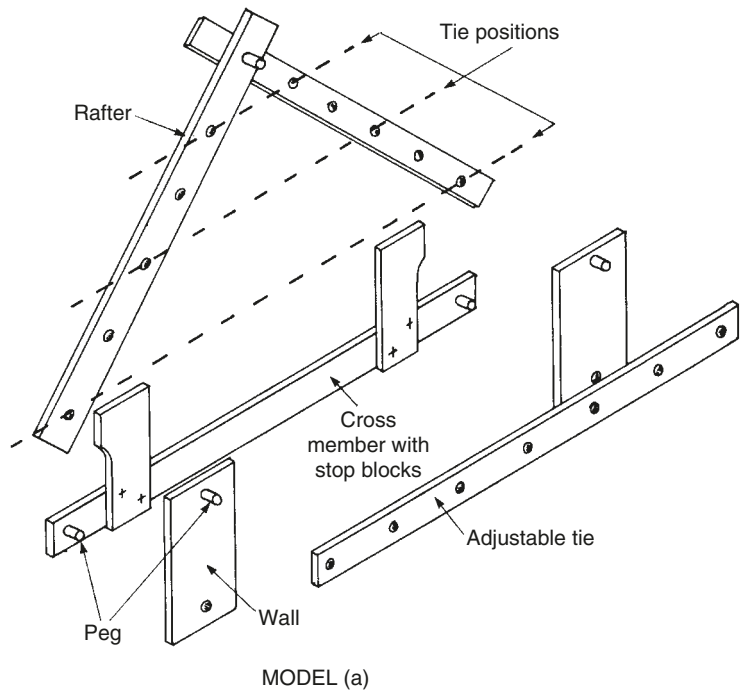




**Fig. 8.2** *Types of single (pitched) roofs*



**Fig. 8.3** *The effect and restraint of an inclined rafter*



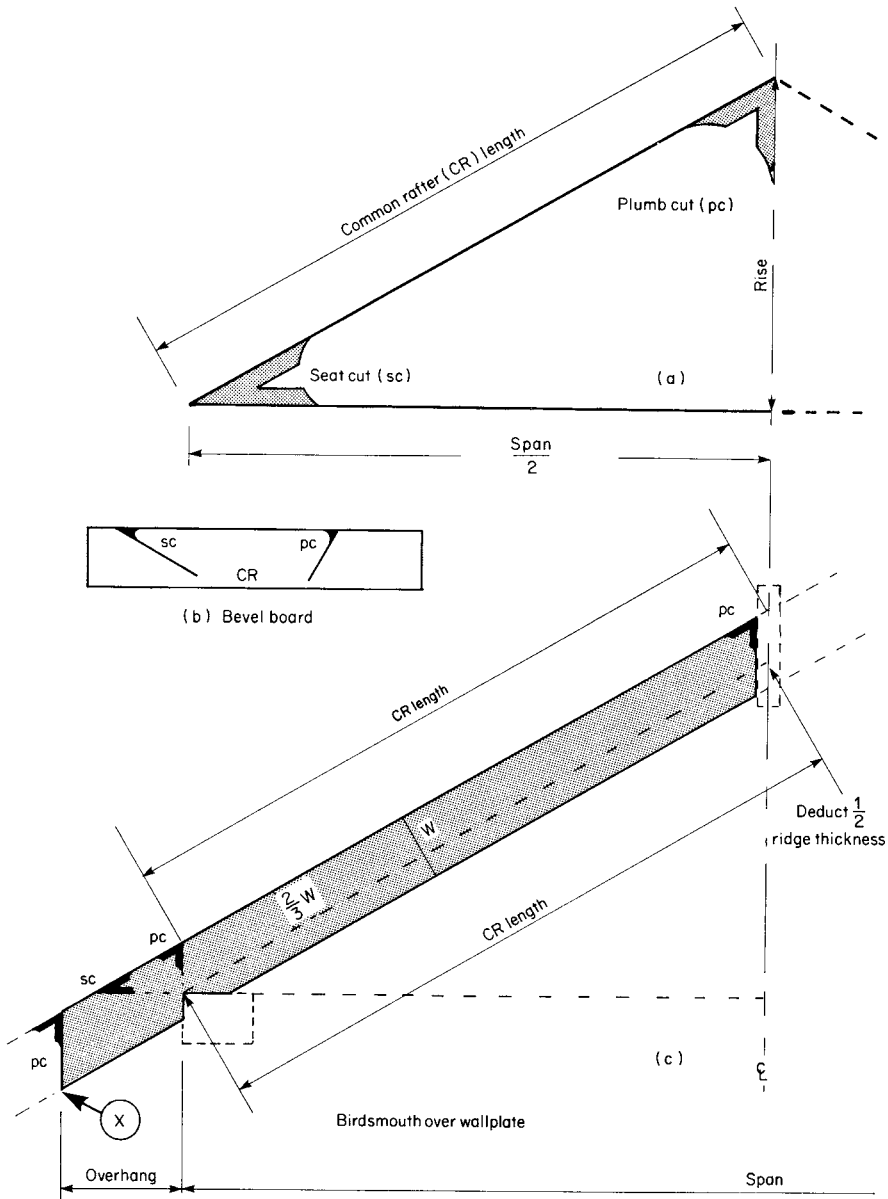
**Fig. 8.4** Roof model, showing horizontal thrust

The walls are represented by short wide strips. The arrangement from 'unstable' to 'restrained' is listed below:

1. Fig. 8.4(b): when the pitch is varied, instability is very noticeable as the walls move way.
2. Fig. 8.4(c): the introduction of a high collar (tie) produces severe bending of the rafters at this point. The walls still move outward.
3. Fig. 8.4(d): when the collar (tie) is lowered, the roof slope becomes more stable (Fig. 8.2(d)).
4. Fig. 8.4(e): wall movement is prevented by fully lowering the tie (see also Fig. 8.2(e)).

## 8.2.2 Common rafters

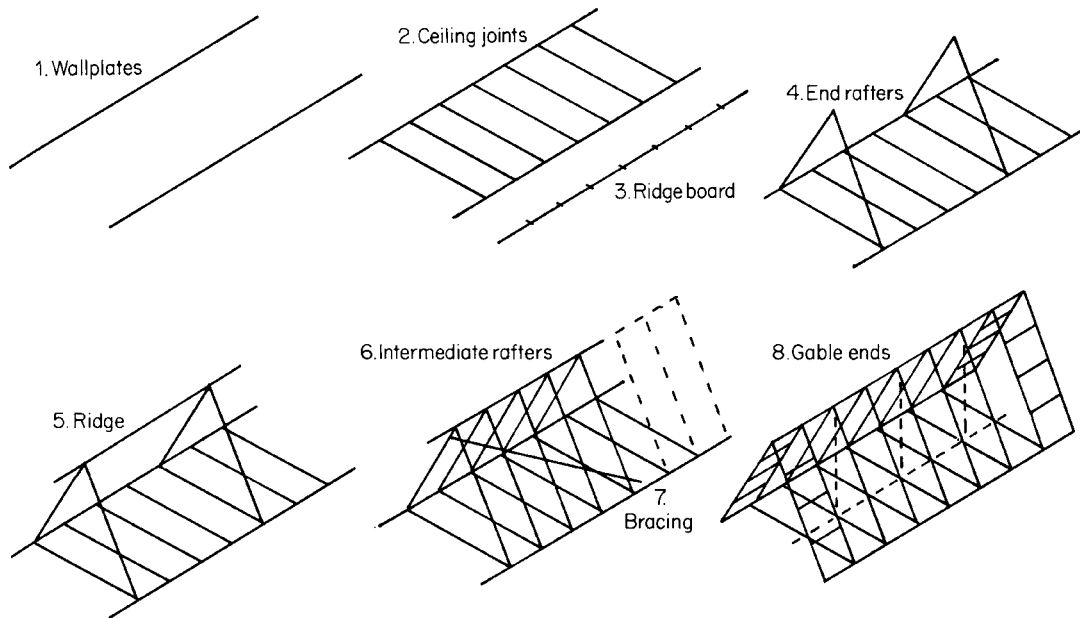
Figure 8.5 shows a method of obtaining the bevels for common rafter *plumb cut* and *seat (foot) cut*. A triangle is drawn to a suitable scale (the larger the better) to represent the roof's rise and half its span



**Fig. 8.5** *Setting out for pattern rafter*

*Note: In practice, the cut at X is made in situ after the rafters are all assembled. This gives a certain amount of leeway if any adjustments have to be made.*

(to the outer edges of the wallplates), Fig. 8.5(a). The two angles formed by the common rafter (CR) are measured or transferred to a short end of timber by laying it over the drawing. The angles PC (plumb cut for common rafter) and SC (seat cut for common rafter) are clearly marked as shown on the 'bevel board' (Fig. 8.5(b)). Rafter length



**Fig. 8.6** *Roof assembly. Note: Roof will require bracing, and tying down to gable ends, also anchoring down to the walls*

is also determined from the drawing and can be checked by using Pythagoras' theorem. Using a sliding bevel, the angles are transferred to a full-size rafter (Fig. 8.5(c)) which, when cut, is used as a pattern for all the other rafters – ensuring uniformity across the whole roof.

### 8.2.3 Roof assembly

Listed below is a sequential guide to the assembly of a short-span gable-ended single roof (traditional pitched roof) – to be used in conjunction with Fig. 8.6.

1. *Wallplates*
  - (a) Assist the bricklayer to bed the wallplates and fix them (anchored down to the substructure) straight, level, and parallel.
  - (b) Couple close roof – mark the positions of ceiling joists, taking into account that their centres should relate to the size of ceiling material (if used).
  - (c) Couple and collar roof: mark the positions of rafters.
2. *Ceiling joists*: Position and nail the ceiling joists to the wallplates; check that they are parallel.

*Note: Roofs require bracing, tying to gable (end) walls, and anchoring down to their substructure (see Fig. 8.29 and Section 7, Fig. 7.8).*

3. *Ridge board*: Mark the position of rafters from the ceiling joists or rafters.
4. *End rafters*: Position and nail two end pairs of rafters to suit the length of the ridge (scaffolding must be used to suit the situation).
5. *Ridge*: Position the ridge board (from underneath). Nail the ridge to the rafters and the rafters to the ridge board at both ends.
6. *Intermediate rafters*: Fix enough rafters to enable the roof framework to be plumbed and squared (the number required usually depends on the ridge-board length).
7. *Bracing*: Plumb the roof from one gable wall and strap with a diagonal brace. Fix the remaining rafters to suit the ridge-board length.
8. *Gable ends*: Mark the position and fix the gable ladder. Mark and fix binders and hangers if required.

If at any stage during the construction of a roof a person is liable to fall more than 2 metres, a guarded working platform with a suitable means of access must be provided and used, in accordance with 'The Construction (Health, Safety and Welfare) Regulations 1996'.

The first part of this chapter dealt with single gable roofs of short span. If the span of such a roof is increased beyond the limits stated, roof failure may occur as a result of either excessive rafter deflection (sag) or substructure spread (Fig. 8.4). Rafter deflection can be reduced by one of three ways:

- (i) increasing the sectional size,
- (ii) introducing a beam (purlin) midway between the ridge and the wallplate,
- (iii) substituting a trussed framework (trussed rafter) in place of each adjoining pair of rafters.

The first method (i) could prove expensive and impracticable. The latter (ii) & (iii) form the basis of this section, namely the 'purlin' or 'double' roof (Section 8.4) and the 'trussed-rafter' roof (Section 8.7).

## **8.2.4 The hipped roof**

Unlike the gable roof, the end walls of a hipped roof finish at the eaves level above which the roof is sloped to meet up with other inclined roof surfaces.

Figure 8.7 shows a skeletal pictorial view of a gable roof meeting a hipped roof. The intersection of the roof surfaces produces either a 'valley' or a 'hip'. Hip rafters form a spine to interconnect rafters which have been reduced in length called '*jack rafters*'. Valley rafters are similarly used to connect shortened rafters called '*cripple rafters*'.

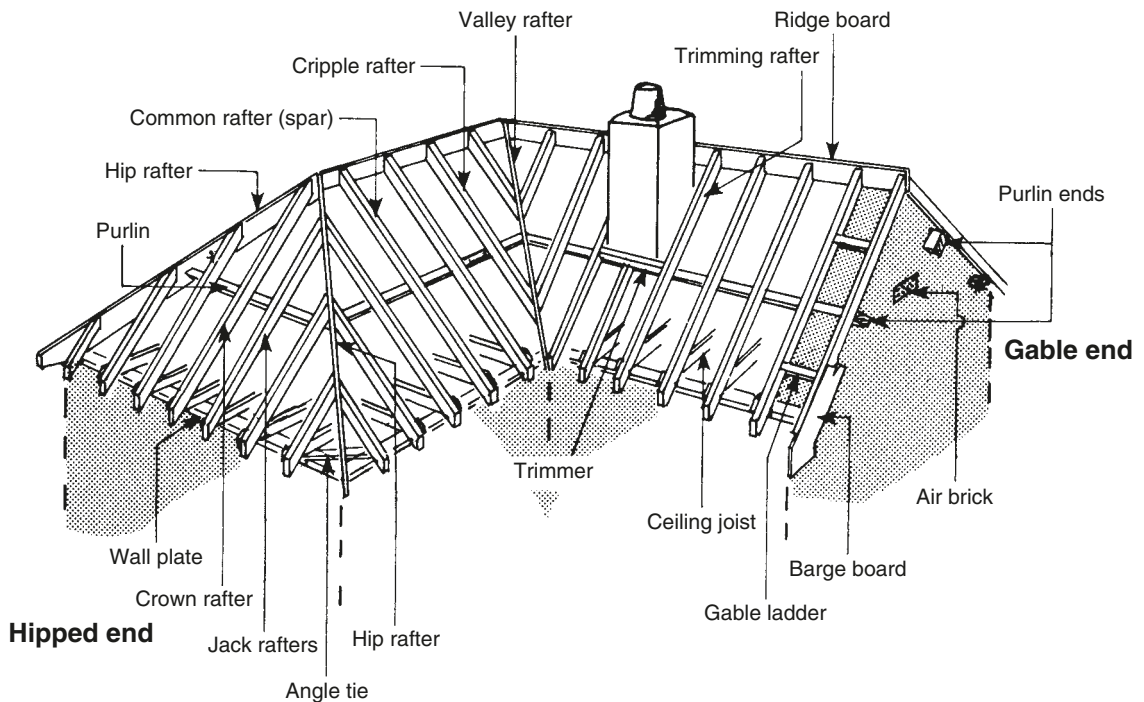


Fig. 8.7 Hip-and-gable roof

## 8.3 Roof geometry

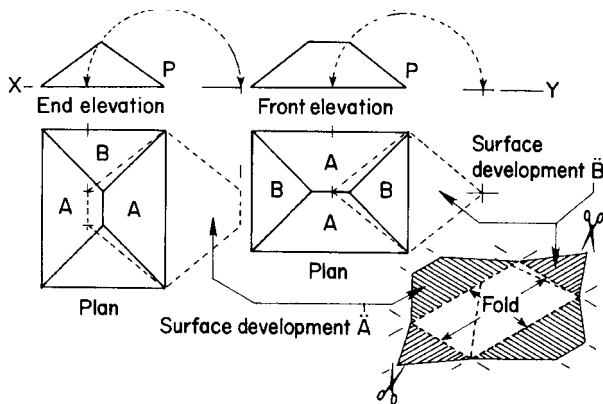
*Note: If Fig. 8.8 is to be used as a basis for a model, enough room should be left between the elevations and the plan to allow all four surfaces to be developed around the plan, as shown in the pictorial view.*

An understanding of basic roof geometry is needed to ensure that all the members meet up correctly, but before dealing with individual members it is advisable to make a small card or paper model of the developed roof surfaces. This should help to explain how:

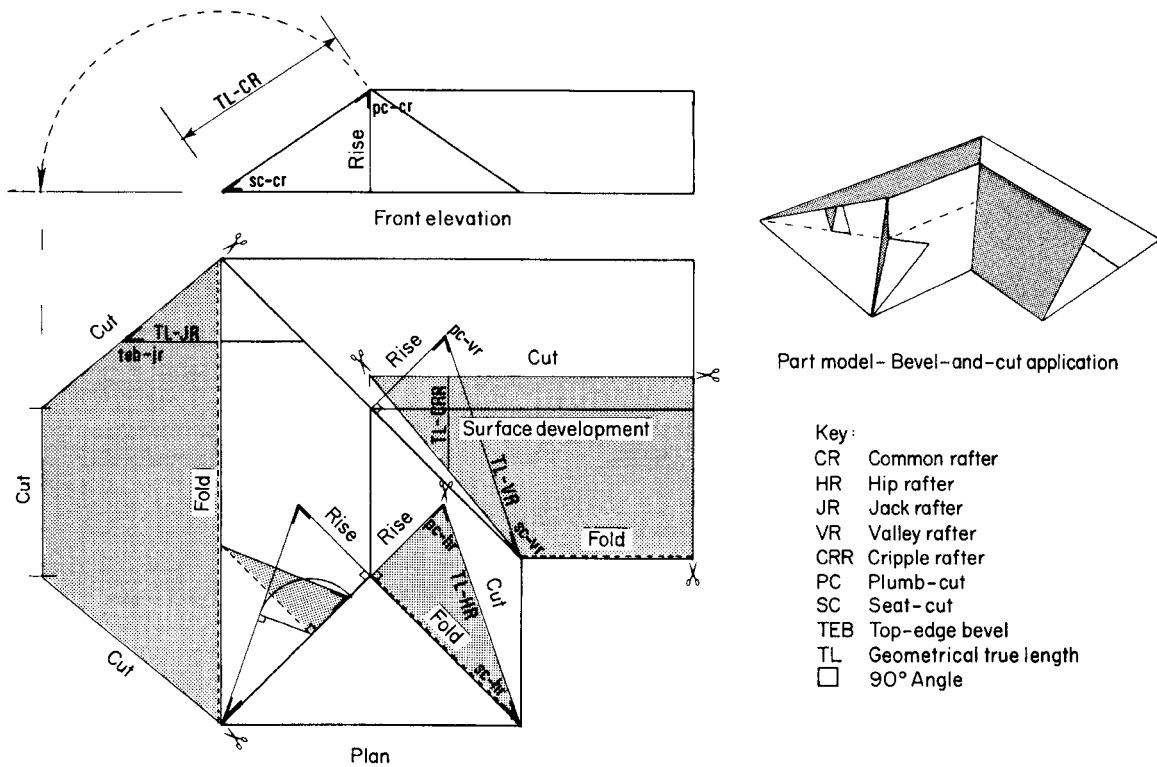
- (a) roof surfaces meet up,
- (b) the plan of a roof can give a false impression of the roof's true size and shape,
- (c) the true length of a roof's surface and hip can be determined.

To develop the roof surfaces shown in Fig. 8.8, set compasses to the common-rafter length and scribe a semicircle from point P (on the end or front elevation) to meet the XY line. At the points of intersection, drop perpendicular lines over the plans. The hip-to-ridge intersection points are then extended horizontally until they meet the perpendicular lines, and lines are then drawn to the appropriate corner.

Figure 8.9 shows how the various roof bevels are produced. To obtain the true length of a hip rafter, draw a  $90^\circ$  line of a length equal to the roof rise from one end of the hip's plan (run) to produce a triangle. The longest side (hypotenuse) of the triangle is then the hip's geometrical true length, and the top and bottom angles are used as hip plumb and seat cuts. Valley-rafter true lengths and bevels are similarly produced.



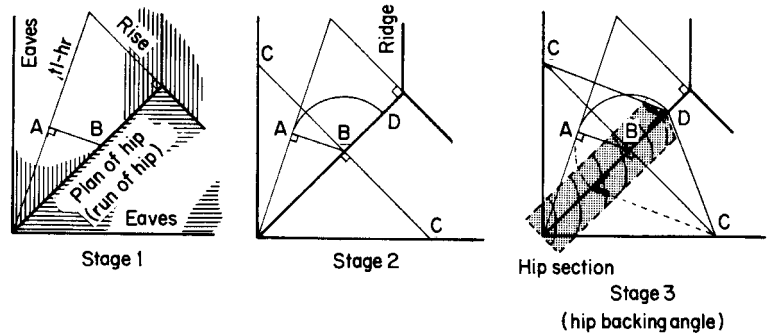
**Fig. 8.8** *Roof surface development*



**Fig. 8.9** *Roof geometry*

The hip-rafter backing angle (dihedral angle) is formed as a result of two inclined roof surfaces meeting on a hip. This angle is probably the most difficult of all the angles to produce, and for this reason it has been dealt with in three stages (Fig. 8.10):

- (i) Draw a  $90^\circ$  line from A on the true length of the hip line to meet the plan (run) of the hip line to meet the plan (run) of the hip at B.



**Fig. 8.10** Hip-rafter backing  
(half-dihedral) angle

- (ii) Draw line CC through B at right angles to the plan (run) of the hip. From B with compasses set to AB, scribe an arc to produce D.
- (iii) Join point D to C. The resulting angle will be the hip-backing angle, as shown by the hip section.

### 8.3.1 Positioning the hip rafter (Fig. 8.11)

The pair of common rafters which are to receive the hip rafters will have been assembled as an 'A' frame, joined together at the top with a 'saddle board' (plywood or timber) of sufficient depth to allow the plumb cuts of both hip rafters to rest squarely against each other and provide a fixing. It should be noted that, for the hip mitre to meet on the geometrical centre lines, the first pair of common rafters ('A' frame) will have to set back at a distance equal to the saddle-board thickness – otherwise the hip rafters would be too long. The hip-edge bevel at this point is shown separately.

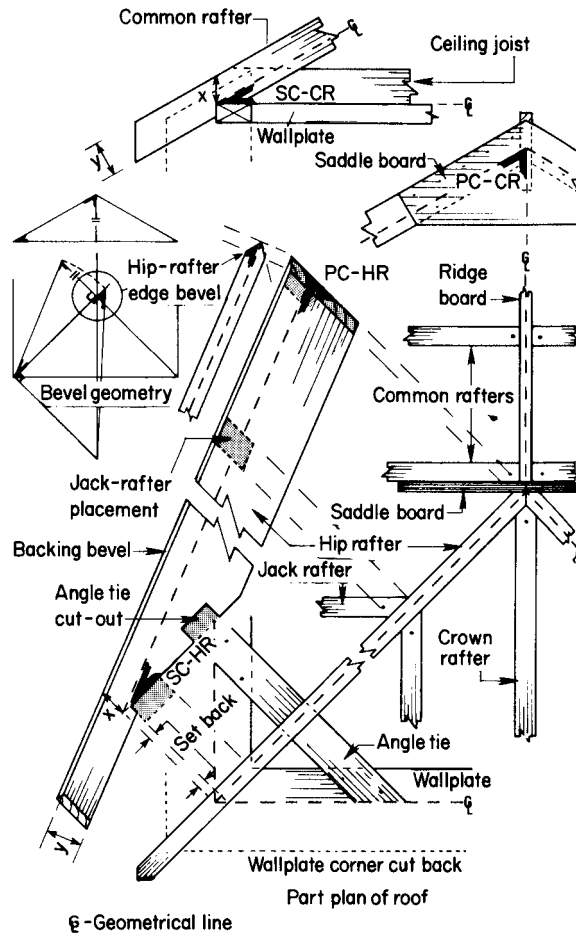
The corner wallplate is cut back as shown to allow the birdsmouth to fit square. An allowance equivalent to the amount removed must be made to the birdsmouth ( $x$ ), otherwise the rafter will be too long. Hip-rafter overhang is reduced to suit the depth of the common rafters ( $y$ ). An angle tie has been fixed across the corner to help prevent outward thrust and to provide extra bearing to the rafter seat cut. Angle ties can be positioned after the rafter is in place.

## 8.4 Double roof or purlin roof

Purlins are introduced into the roof as a means of mid-rafter support, thereby reducing rafter span by half. Purlins may be fixed vertically or at right angles to the slope of the roof, depending on the type of bearing, for example, built-in (preservative treated), gable walls, or supported by internal (load-bearing) walls either directly or indirectly via corbels, steel hangers, or struts. Roof trusses also offer strutted support.

Where an inclined purlin meets a hip rafter, the intersecting face angles will produce top-edge and side-edge bevels as shown in Fig. 8.12. To find the top-edge bevel, use distance AB to scribe an arc to meet the horizontal line from A to produce C. Drop a perpendicular line from A on to the plan of the hip to obtain A'. Repeat with B to





**Fig. 8.11** *Hip-rafter application*

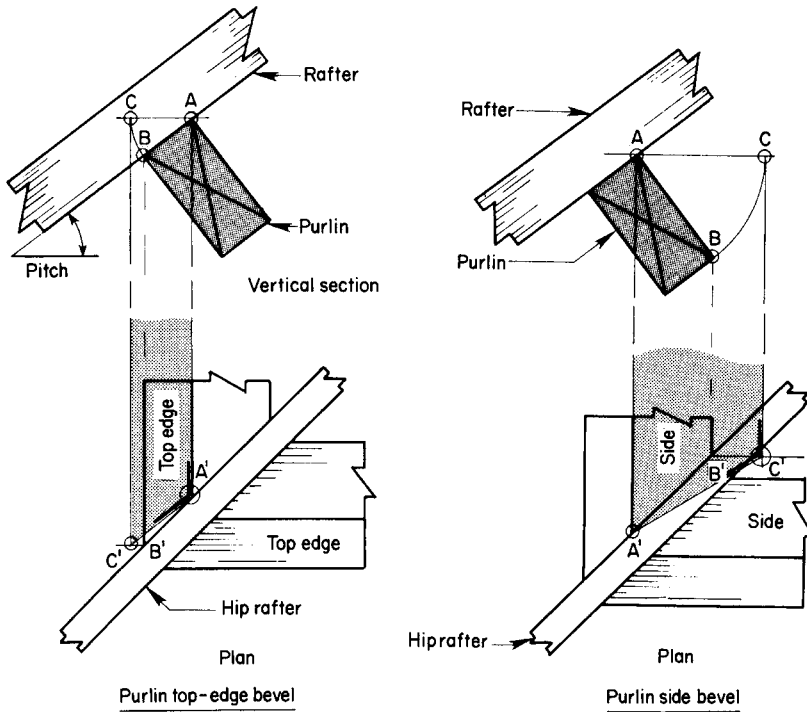
obtain  $B^1$ . Draw a horizontal line from  $B^1$  to meet a perpendicular line drawn from  $C$  to produce  $C'$ . The angle between  $AA'$  and  $A'C'$  is the 'purlin top-edge bevel'. Side-edge bevel is found in a similar manner, as shown on the right-hand side of Fig. 8.12.

*Note: To produce the above bevels it would normally only be necessary to use single lines to represent:*

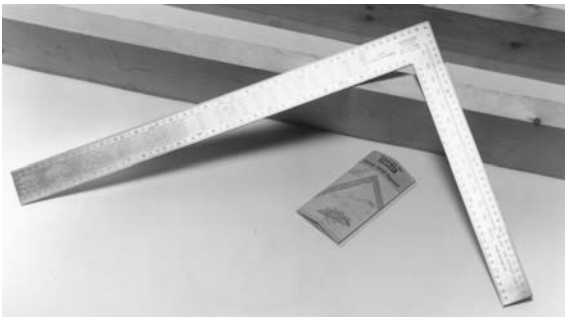
- the pitch of the roof,
- a top-edge distance of the pitch line,
- a line at right angles to the pitch of a length equal to the purlin side,
- the plan of the hip ( $45^\circ$ ).

## 8.5 Steel roofing square

The steel squares shown in Fig. 8.13 consists of two arms set at  $90^\circ$  to one another. The 'body' or 'blade' (longest arm) is 600 mm long, the 'tongue' 400 mm. The 'heel' of the square is the corner of the



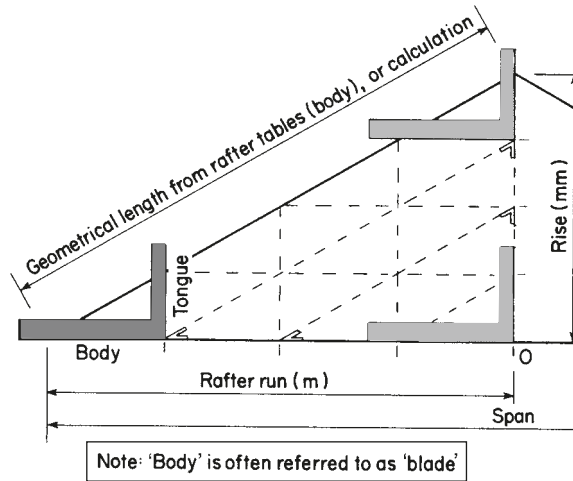
**Fig. 8.12** *Purlin geometry*



**Fig. 8.13** *Stanley and Smallwood steel roofing squares*

outer edges. Both outer edges are graduated at 2 mm intervals, reading off in millimetres. Rafter tables are printed on one face, with cuts on the other. (The type of tabulation varies between makes of square.)

Steel squares can be used to obtain both the angle of cut and the length of all the roof members. Different makes vary in their method of application – manufacturer's instructions are supplied with each square. 'Buttons' (stair guides) featured in photo may be purchased to hold the square against the edge of the timber to act as a fence. A purpose made movable fence is shown in Fig. 8.17.



**Fig. 8.14** *Proportional millimetre rise to metre run of rafter*

The geometrical means by which roof bevels and member lengths are obtained may require that roof sizes be scaled down. Scaling down is necessary with the steel square, but only to the extent of determining the number of millimetres the roof rises for every metre run of common rafter (for an equally pitched roof,  $\text{run} = \frac{1}{2} \times \text{span}$ ).

Figure 8.14 shows that, providing the ratio of millimetre rise to metre run is kept constant, the angles set against the hypotenuse will always be the same. It also follows that the distances along the body (rafter run), tongue (roof rise), and hypotenuse (rafter length) must be proportional to those in the full-sized roof.

### 8.5.1 Rafter length

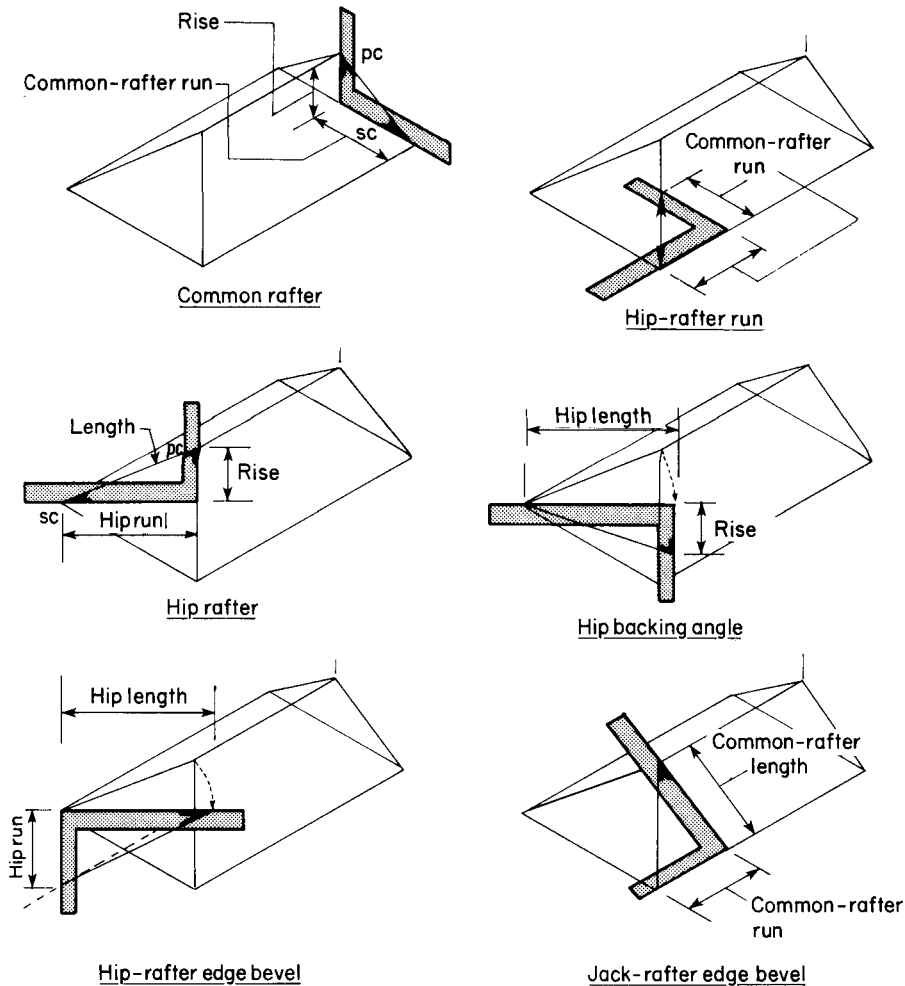
Reference is made to the tables printed on the body of the square, which are calibrated according to roof rise (mm) per run (m) of common rafter. To obtain this figure, the following calculation will be necessary:

$$\text{millimetre rise per metre run} = \frac{\text{rise (mm)}}{\text{run (m)}}$$

For example, if a double-pitched roof has a rise of 1.5 m and a span of 6 m, its millimetre rise per metre run is:

$$\begin{aligned} \text{millimetre rise per metre run} &= \frac{\text{rise (mm)}}{\frac{1}{2} \times \text{span (m)}} \\ &= \frac{1500}{3} = 500 \text{ mm/m} \end{aligned}$$

In other words, for every metre run the roof rises 500 mm. Once this figure is found, it can be applied to all the roof members listed on the body to obtain their geometrical lengths.



**Fig. 8.15** *Roof bevels being related to the steel roofing square*

Alternative methods of finding rafter lengths include:

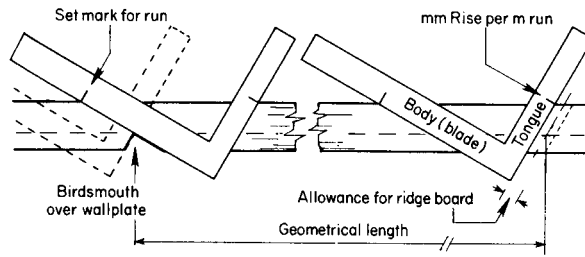
- (a) calculation, using Pythagoras' theorem (see Section 1.3.1) or trigonometry;
- (b) measuring across the hypotenuse of the square and scaling up;
- (c) physically stepping the square along the rafter 10 times (assuming that both the run had initially been divided by 10 to proportionally reduce the size).

Method (a), although accurate, demands mathematical knowledge. Method (b) and (c) may prove inaccurate, particularly (c), which is prone to error accumulation.

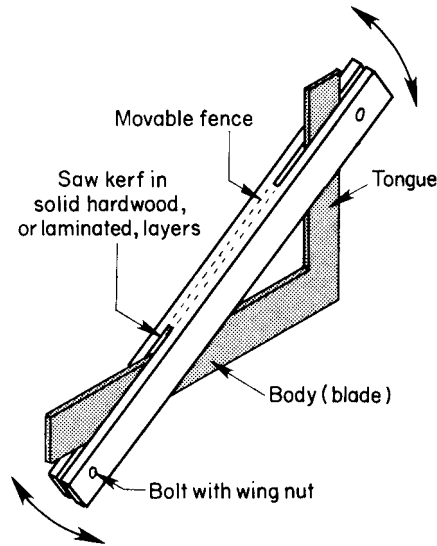
## 8.5.2 Roof bevels

Figure 8.15 shows theoretically how the diagonal members of the roof relate to the angles shown on the square. However, in practical

**Fig. 8.16** *Applying a steel roofing square to produce a pattern rafter*



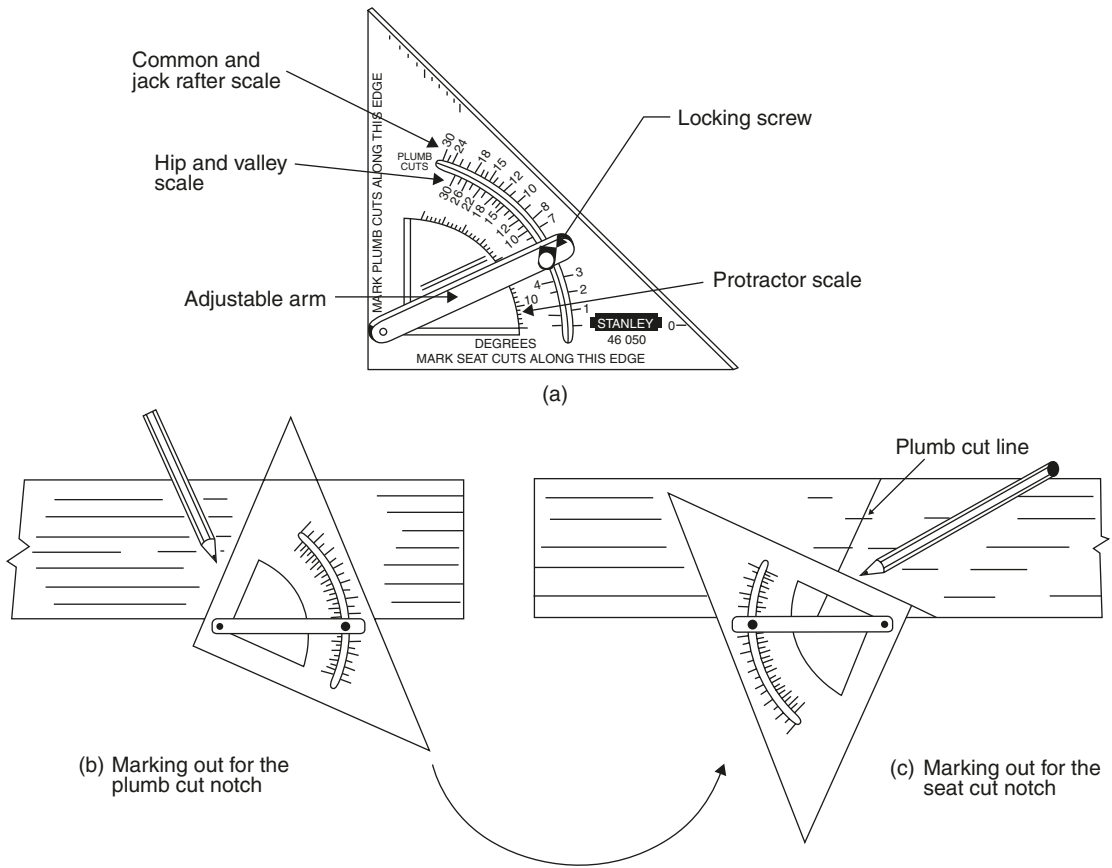
**Fig. 8.17** *Steel roofing square with movable fence*



terms the square has been designed to cope with all the necessary roof bevels simply by using the roof's millimetre rise per metre run marking on the tongue and off-setting this against a 'set mark' (marked by an arrow) on the body to ascertain both the plumb and seat cuts as shown in Fig. 8.16. A purpose-made movable fence (Fig. 8.17) can make setting-up and angle transfers much easier. Proprietary 'buttons' are shown in Fig. 8.13.

With all its tables and figures, the appearance of the steel square can be a little off-putting but, once the makers' instruction booklet has been thoroughly read, and after a little practice, it should become much easier to use than first imagined – perhaps then it may have a use other than that of a large try-square.

Other types of roofing squares are available which are triangular in shape and made from durable aluminum. Figure 8.18 shows the 'Stanley Quicksquare' that has an adjustable lockable arm which is set and held against the timber to be marked and cut. Using the instruction



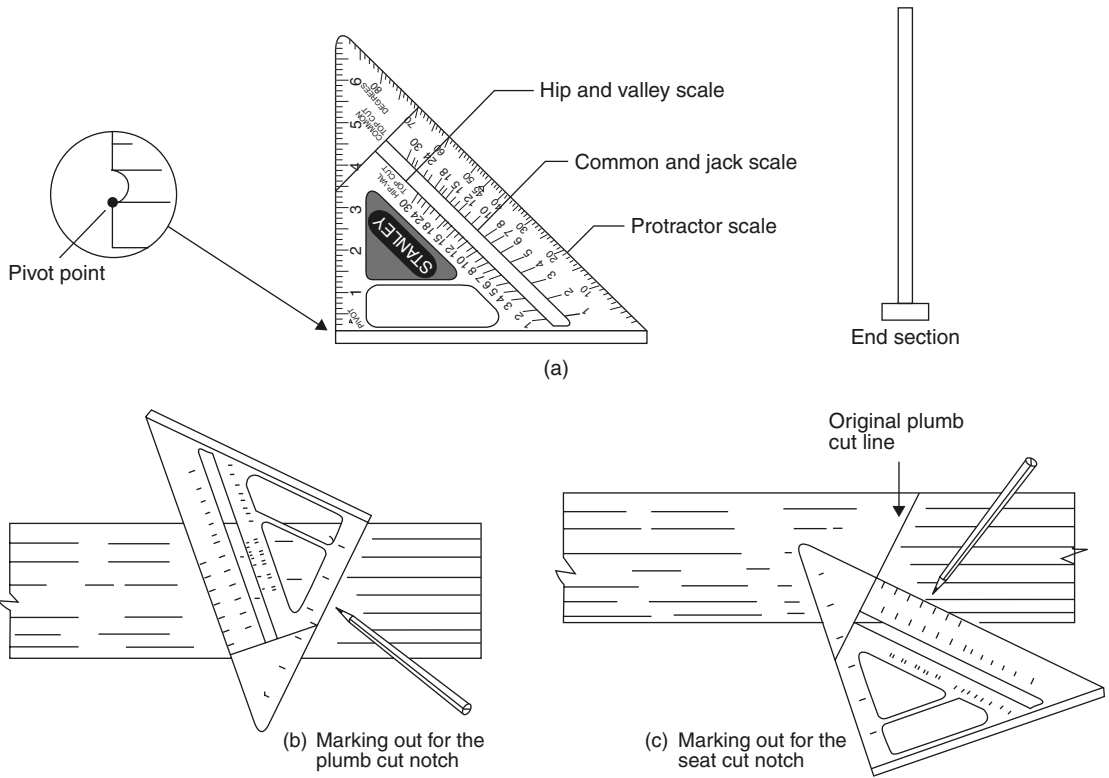
**Fig. 8.18** *Stanley Quicksquare and applications*

booklet supplied, the laying out and cutting of the various lengths and bevels for common, hip, valley and jack rafters can be achieved.

Figure 8.19 represents a Stanley 'pocketsquare' and its application. Although smaller than the 'quicksquare', it is similar in shape and calibration – one obvious exception is the swinging arm that the 'quicksquare' uses as a fence when marking various bevels. The 'pocketsquare' on the other hand uses an indentation set to one end of a key sectioned fence (or stock) known as its 'pivot' point. As shown in the lower diagram this 'pivot' point is used as a datum point for marking out different bevels onto timber roof members such as the pattern rafter for common rafters or various bevels required for the hip, valley and jack rafters.

## 8.6 Trussed roofs

Where suitable purlin supports cannot be achieved from load-bearing walls, or where a clear uninterrupted roof span is required, a roof



**Fig. 8.19** *Stanley Pocketsquare and applications*

*Note: Due to the pressure required to drive the teeth of the connectors fully into the wood, a special high-tensile drawing bolt is used to avoid stripping the teeth off a standard bolt. When the joint is drawn-up tight, the high-tensile bolt is removed and replaced by a permanent bolt. No provision is made in the initial design of these trusses for any extra loading such as water-storage tanks, etc. – if these are to be installed, provision must be made to strengthen the truss and/or to take support from load-bearing internal walls. Due to more modern methods of roof design a truss roof is rarely required.*

truss may provide the answer. Trusses are positioned along the length of the roof at intervals of up to 1.800 m centres to support the purlins which the infilling common rafters, at 450 mm centers, will use as a mid-support. Hipped ends can be formed by using a half-truss in place of the crown rafter. Hip rafters are constructed in a similar manner as previously described. Figure 8.20 shows the construction and assembly of a previous Timber Research and Development Association (TRADA) domestic-type roof truss. Truss joints in the main require members to be lapped and bolted together with 50 mm double-sided toothed-plate connectors with square washers on the outer sides (Fig. 8.21). The number of connectors between each joint will depend on the number of members being joined; for example, the single lap between rafter and ceiling joist (not shown in detail) will require one connector whereas the joint in Fig. 8.20(A) will require three, that in Fig. 8.20(B) two, that in Fig. 8.20(C) – a nailed joint, and that in Fig. 8.20(D) three.

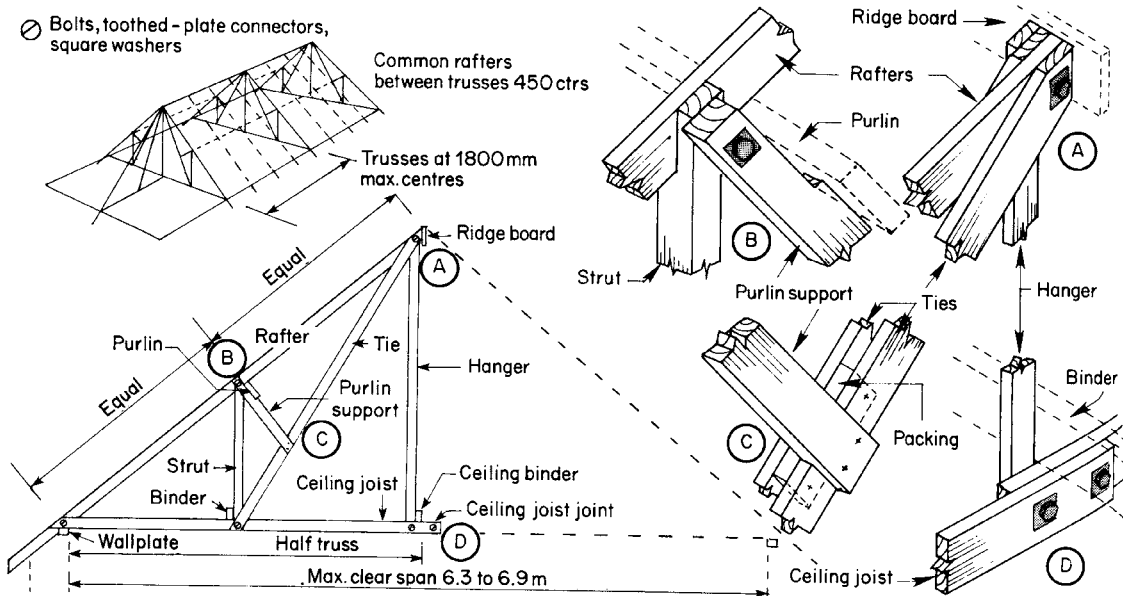


Fig. 8.20 TRADA domestic roof truss

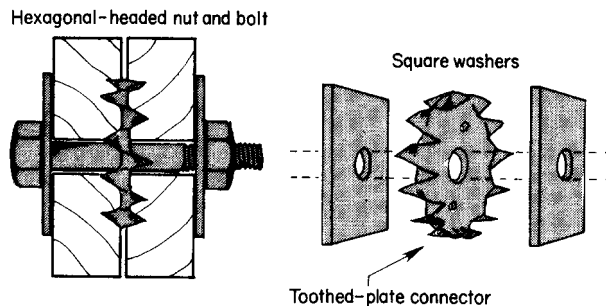


Fig. 8.21 Toothed-plate connection (double-sided connector)

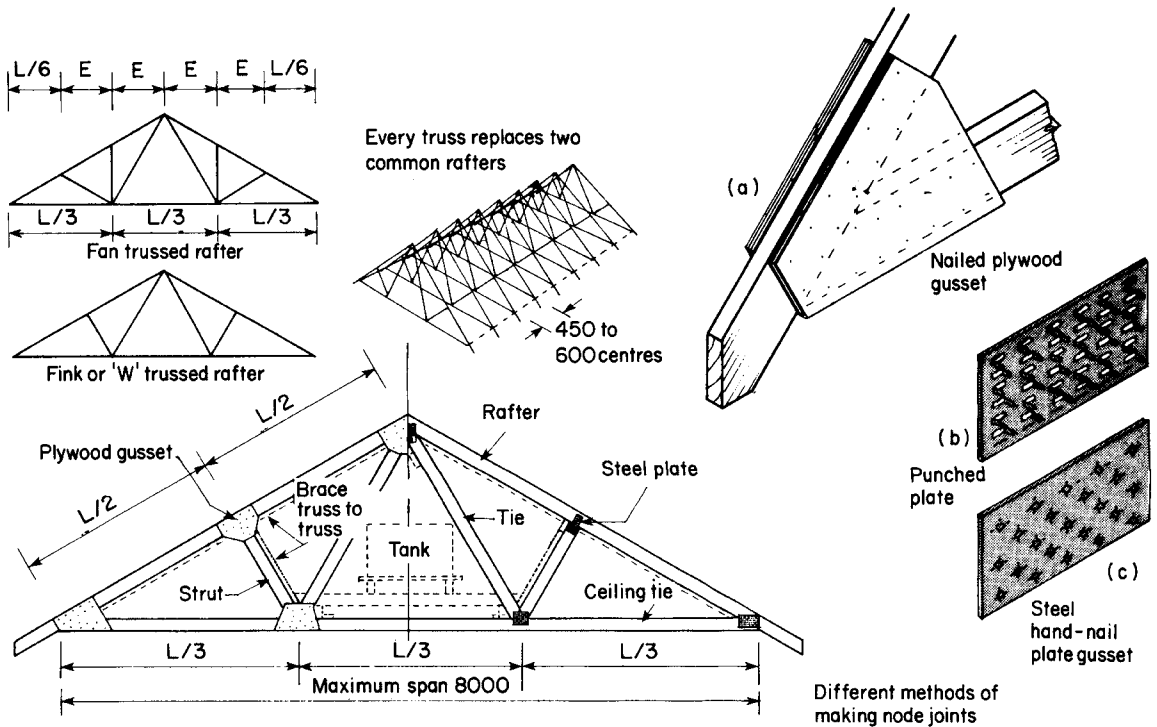
## 8.7 Trussed-rafter roofs

Trussed rafters have been used in the UK for well over 30 years and have now become one of the most acceptable means of providing the roof framework over domestic dwellings.

As shown in Fig. 8.22, each trussed-rafter type (fan and fink) consists of a complete stable framework of struts and ties. The trusses are positioned at 450–600 mm centres, thereby replacing each pair of adjoining common rafters and their interconnecting ceiling joist. Purlins are dispensed with.

The design of the trussed rafter (responsibility of 'The Trussed Rafter Designer') will depend upon the span, pitch, and loading.





**Fig. 8.22** *Trussed rafters*



**Fig. 8.23** *Unloading trussed rafters*

One great advantage over traditional methods of construction is that trussed rafters are pre-made under factory-controlled conditions and delivered on site ready to be erected over the wallplates. Fig. 8.23 shows a method that is not recommended when receiving a delivery of truss rafters. They should be taken off the lorry either by mechanical

means, or carefully lifted and supported. Site geometry is unnecessary unless hips or valleys form part of the roof plan, in which case traditional means of setting out, as mentioned earlier, will be integrated into the roof.

### 8.7.1 Construction

Over the years, members have been either butted together with plywood gussets nailed to both sides (Fig. 8.22(a)), or butted with proprietary steel plates fixed over the joints. These could have been nailed through punched holes in the plate (Fig. 8.22(c)), or as with the modern trussed rafter a toothed plate connector (Fig. 8.22(b)) is pressed over the joints whilst the rafter members are held in a jig.

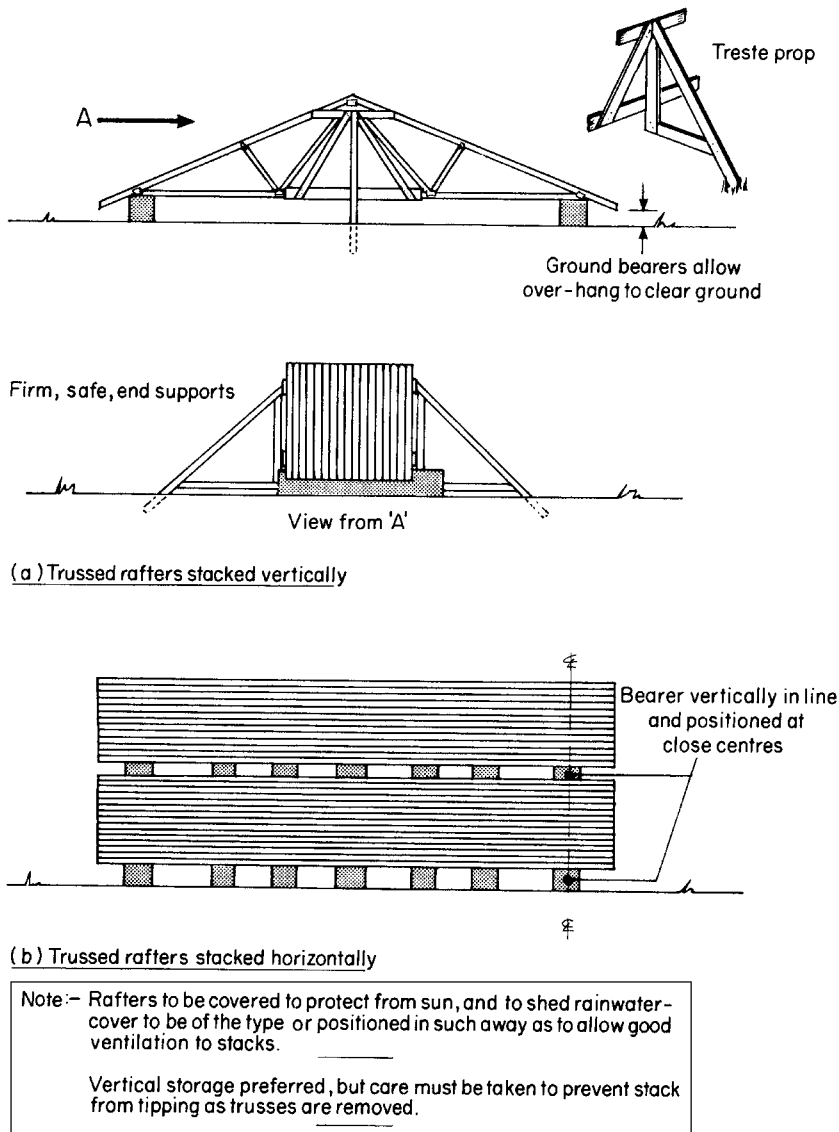
### 8.7.2 Site storage (Fig. 8.24)

Correct stacking of rafters is essential if they are to remain distortion free, and if their moisture content is not to rise above 22%.

Distortion can be the result of supporting bearers not being level – one with another (twisted), or being wrongly positioned (not in-line above another). Trusses banded together too tightly can also result in distortion.

High moisture content is usually due to the stack not being adequately protected against inclement weather, or by not ventilating the cover and thereby encouraging condensation to develop on the underside of the cover. Ground protection is also necessary to prevent rising damp reaching the trusses or their supports.

Figure 8.24 shows two methods of storage. When trussed rafters have to be stored on site, provision must be made to ensure that they do not become distorted or strained in any way. They should be stored on the ground on raised bearers set parallel with one another. The preferred method is the vertical storing method (Fig. 8.24(a)) where at one end of the supporting framework, the trusses are positioned against a firm and safe support in the form of a trestle prop anchored to the ground, a similar propping arrangement is securely fixed at the other end. Raised bearer supports are provided at each end of the truss (to ensure that the rafter overhang clears the ground) which are positioned at points of support assumed in the design, for example, where the wallplates would be. With horizontal storage (Fig. 8.24(b)) where trusses are stacked flat the bearers must be positioned at every joint to give level support at close centres. Stored trusses should be protected from the weather by a water-proof cover, which must be



**Fig. 8.24** *Site storage of trussed rafters*

arranged in such a way to safely allow for the circulation of air - thereby reducing the risk of condensation forming on the underside of the sheeting.

A typical example of a specification for bracing and binders used in the construction of a domestic dual-pitched roof of up to 30°, is described and illustrated in the 'Defect Action Booklet', produced by 'Building Research Establishment'. Fig. 8.25 (a-d) is an example of a typical specification for fixing braces and binders.

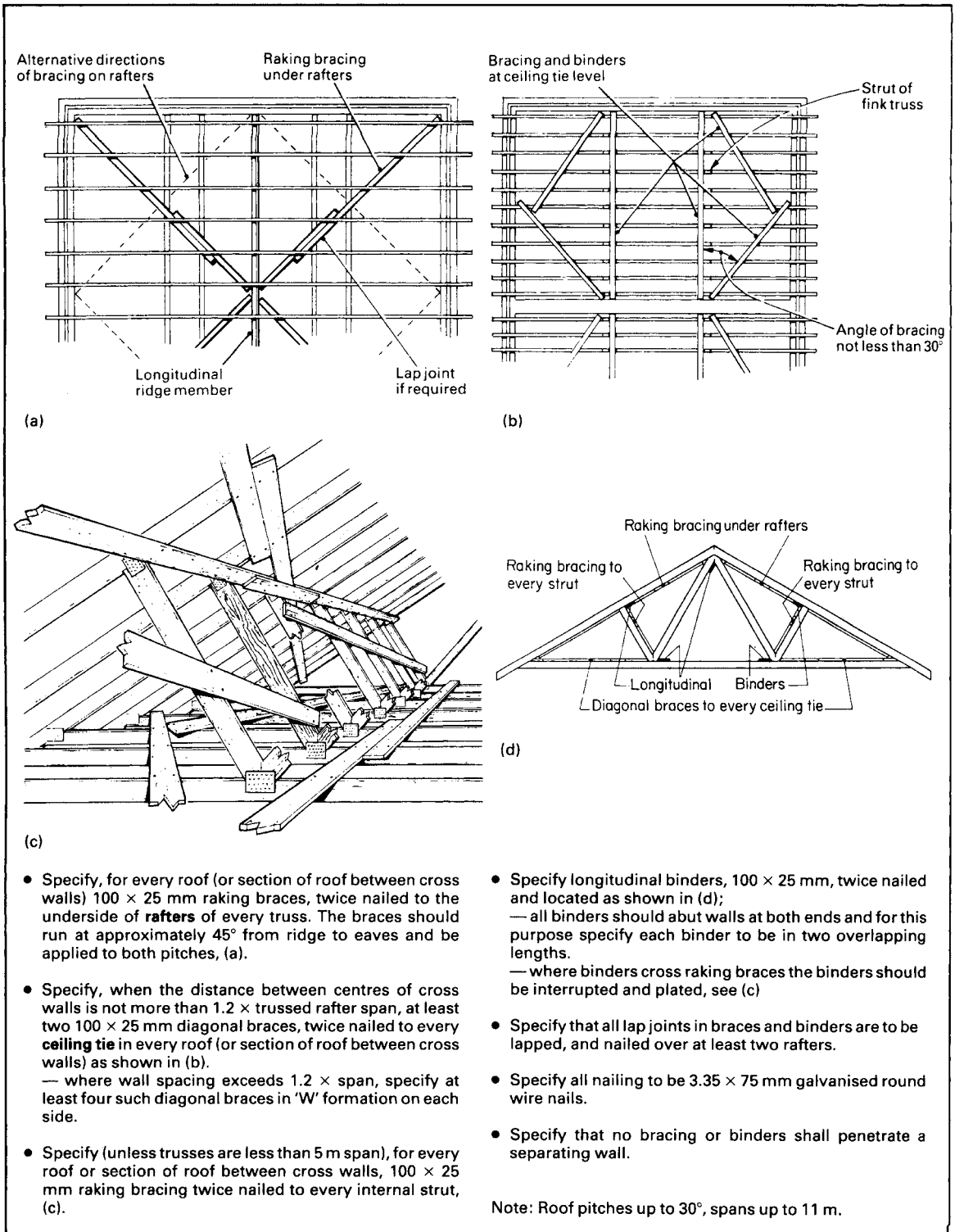
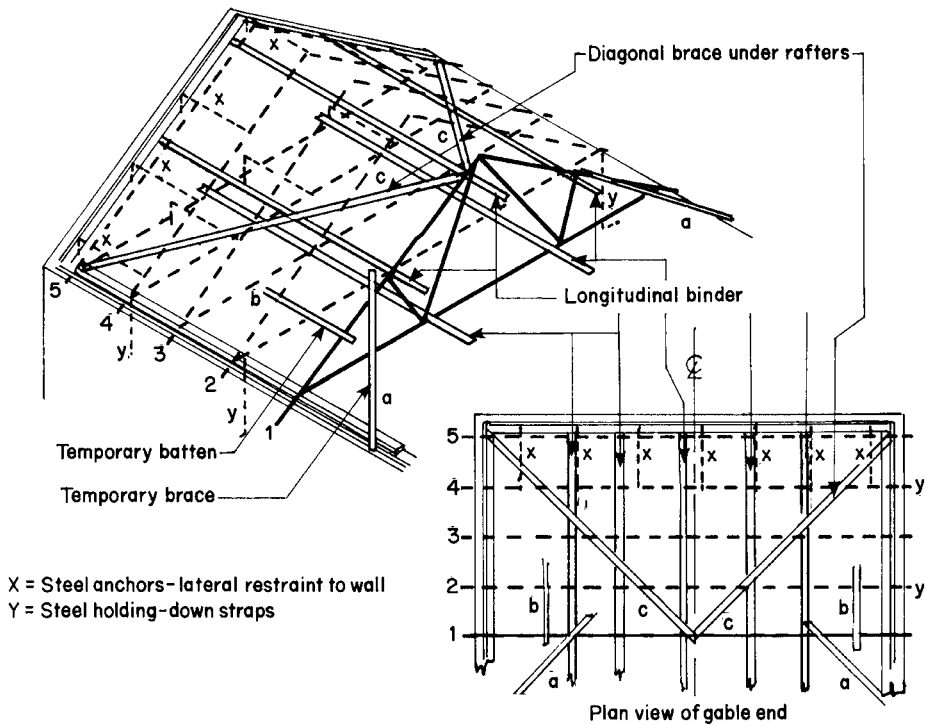
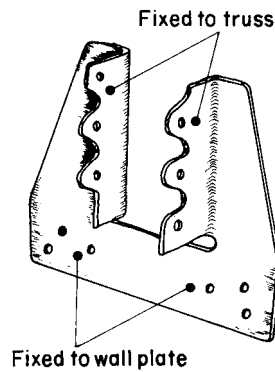


Fig. 8.25 Typical specification details for fixing braces and binders to a trussed-rafter roof



**Fig. 8.26** *Trussed-rafter-roof erection*



**Fig. 8.27** *Truss clip*

### 8.7.3 Stages in erection (Fig. 8.26) (spans up to 8 m)

Details should be provided by the 'Building Designer' to suit each particular roof. The following stages in conjunction with Fig. 8.26 should be regarded only as a general guide for domestic roofs:

1. Mark truss-rafter position on the wallplate and fix truss clips (Fig. 8.27) as and when required.



**Fig. 8.28** *Trussed-rafter roof being erected*

2. Position the first truss rafter to the gable side of where the diagonal (c) would reach the ridge.
3. Once the truss has been plumbed, fix temporary stays (a) to the rafter.
4. Fix the second trussed rafter to the first with temporary batten (b) to the rafters and ceiling ties.
5. Fix the remaining trussed rafters in the same manner.
6. Fix diagonal braces (c) to the underside of the rafters and wallplates.
7. Securely fix all longitudinal members.
8. Fix all remaining longitudinal, diagonal and chevron bracing required on the internal members of the trussed rafters as specified.
9. Fix all lateral restraining anchors, and holding down straps as and where required by the Building Designer and current Building Regulations.

Note: (a) All work to be carried out in accordance with the procedure stipulated by the 'Building Designer'.

(b) Consult British Standard (BS) 5268: Part 3: 1998 'Structural use of timber' – 'Code of Practice for trussed-rafter roofs'.

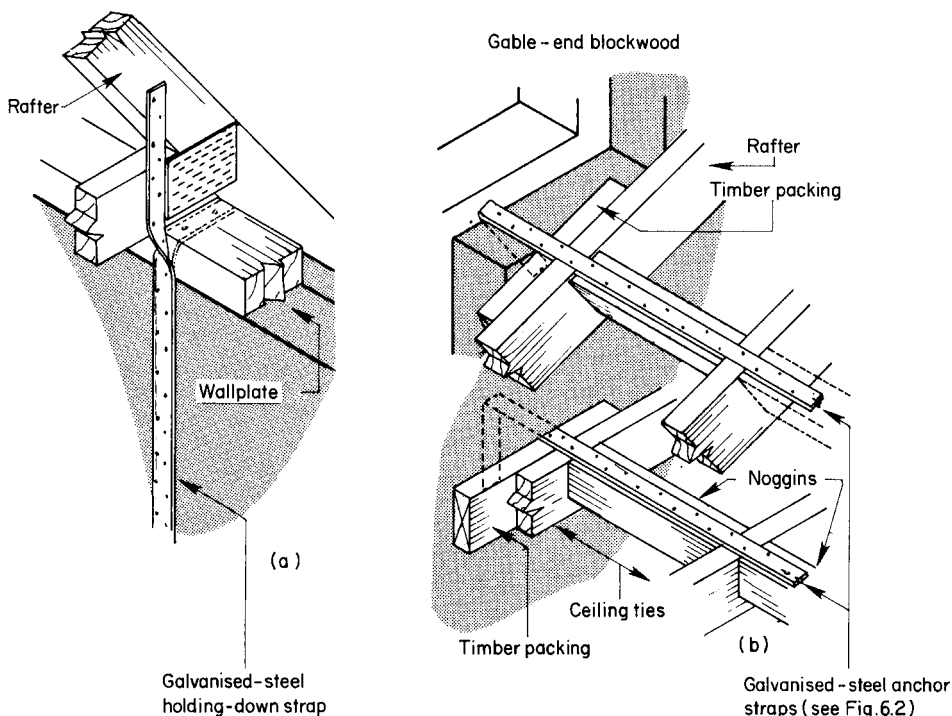
Note: With regard to construction, handling, erection, and tank support, etc. reference should be made to British Standard Code of Practice BS 5268: Part 3: 1998, and the Truss Rafter Association Technical Handbook.

Figure 8.28 shows a trussed-rafter roof being erected. Where water-storage tanks are to be sited in the roof void (Fig. 8.22) and the only means of support are the ceiling ties of the trussed rafters, then two cross-bearers can be laid as close as possible to the one-third (node) point, long enough to span a minimum of three trusses (depending on the size of the tank), with two more bearers over these, then a further two to form the platform. This will ensure that the load is distributed over a wide area. Whenever possible supports for water tanks should be independent of the trussed rafters.

## 8.8 Roof anchorage

Rafters, ceiling joists, and trussed rafters will be fixed to wallplates by skew nailing or truss clips. Where lightweight roof coverings are used – or if the roof is to be subjected to strong winds – anchor straps (Fig. 8.29(a)) and framing anchors, and/or truss clips can be used. Wallplates will in all cases need anchoring to the substructure. Roofs of less than  $15^\circ$  pitch require strap anchorage at intervals of not more than 2 m.

*Note: Monopitch roofs – particularly those of a lightweight nature – will require good anchorage because of their high risk of displacement due to wind suction. Lateral support must be given to masonry gable walls via the roof structure. This is achieved by positioning galvanised-steel anchor straps (minimum cross-section  $30\text{ mm} \times 5\text{ mm}$ ) against the outer face of the inner masonry leaf and nailing them over the rafters and ceiling ties at intervals of not more than 2 m. Fixings are shown in Fig. 8.29(b). For position and location of anchorage and lateral support consult the current part of the Building Regulations, for example, 'The Building Regulations 2000: approved document A' 1/2, as well as TRADA (see floor joist span tables).*



**Fig. 8.29** *Lateral support to a gable wall, and roof anchorage*

*Note: Large-span roofs may be required to provide lateral wall support along the eaves of the roof.*

*If gable ends consist of a framework of timber, the roof as a whole must be diagonally braced against the effects of wind.*

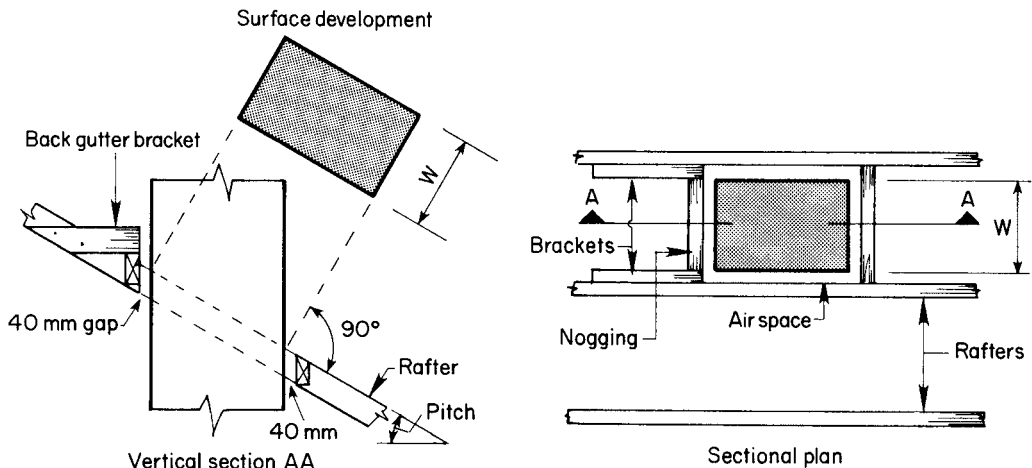
## 8.9 Roof openings

Openings may be required for a chimney stack, ventilators, or roof lights (windows).

Figure 8.30 shows how provision can be made to take the roof around a rectangular chimney stack; if the opening is wider than the space between the rafters, two trimmers should be used in place of the noggings to carry trimmed rafters. The surface development of the opening (excluding the perimeter gap) is produced by projecting two lines at right angles to the slope of the roof with a distance apart equal to the sloping length of the opening, the width of the development is equal to  $W$  on the sectional plan.

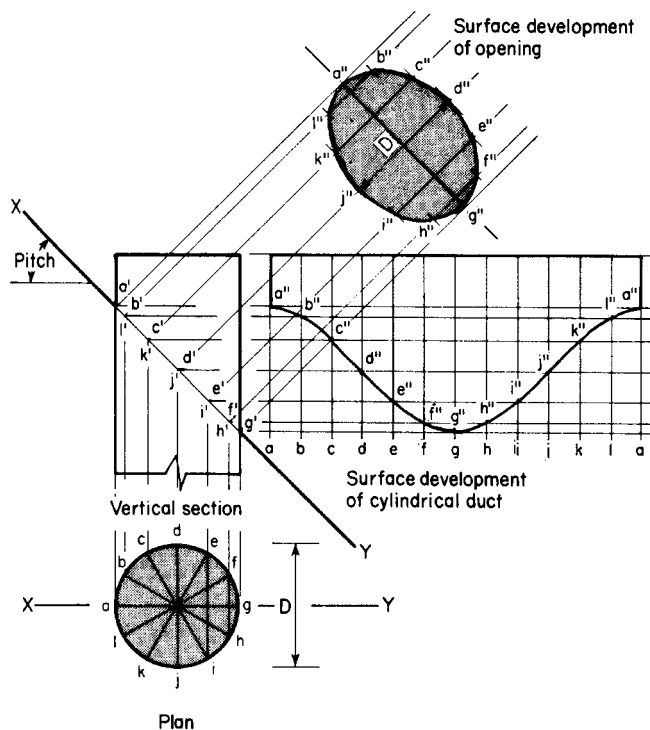
Figure 8.31 shows how the true shape (surface development) of an opening produced by a cylinder piercing a sloping roof is obtained and how that portion of the cylinder protruding above the roof would look if it were opened out 'flat'.

To develop the opening, mark points  $a$  to  $g$  equally spaced around the circumference (plan) of the cylinder and project them up to the pitch line (vertical section  $XY$ ), to obtain  $a'$ ,  $b'$ ,  $c'$ , etc. Project lines from points  $a'$  to  $g'$  at right angles to the pitch line and, at a convenient point, draw a line  $a''g''$  at right angles across them. From centre line  $ag$  on the plan, transfer vertical distances  $bl$ ,  $ck$ ,  $dj$ ,  $ei$ ,  $fh$ , to the



**Fig. 8.30** Rectangular chimney stack or duct piercing a pitched roof





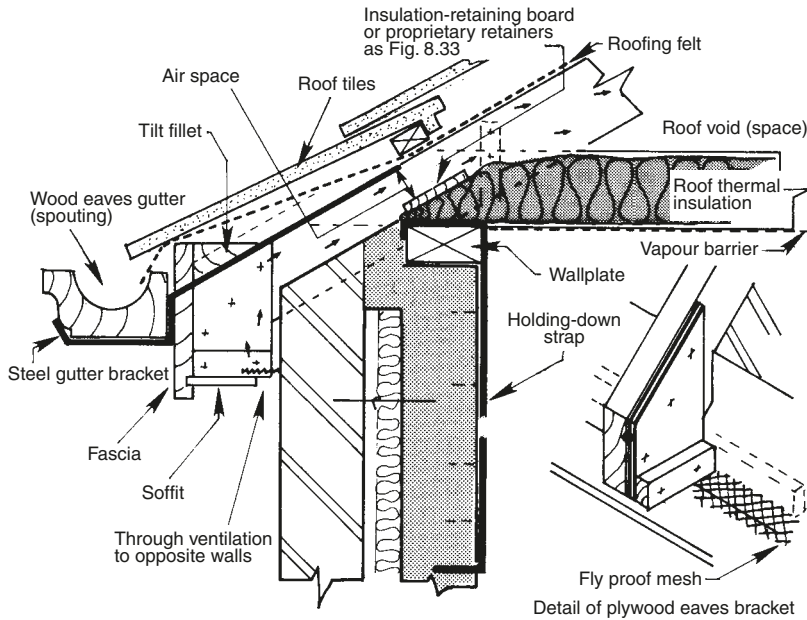
**Fig. 8.31** Cylindrical duct  
piercing a pitched roof

surface development to produce  $b''l''$ ,  $c''k''$ , ..., and so on. The points are then joined together freehand to produce the elliptical-shaped development. To develop the cylindrical projection, project  $a'$  to  $g'$  horizontally. Vertical lines which form part of the grid are spaced at intervals equal to the arc lengths  $ab$ ,  $bc$ ,  $cd$ , ..., and so on. Where these lines meet, they give points  $a''$ ,  $b''$ ,  $c''$ , ..., and so on. Join these points together freehand to produce the development.

*Note: Openings to be formed around flues, whether at roof or ceiling level, must comply with current Building Regulations with regard to proximity of combustible materials. An opening in a ceiling used as a manhole for access to services, etc. may, depending on its size and joist centers, require trimming (use of joist hangers, etc.). Its edges should be lined out to accommodate a hinged trap door which, for safety reasons, is made to open into the 'loft' (roof void), the joint between the lining and plasterboard being covered with a 'trim' (architrave). If a loft ladder is to be installed then the trap door usually forms part of the arrangement and is therefore hinged to open into the room or landing below.*

## 8.10 Thermal insulation and ventilation

As stated in Section 7.8, thermal insulation must be provided to satisfy current Building Regulations. In the case of a pitched roof with a ceiling, insulation is usually in the form of a quilt sited in between ceiling joists. A vapour barrier can be positioned on the underside of

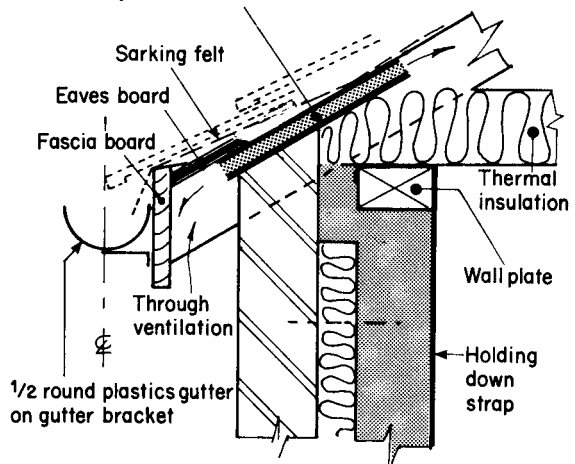


**Fig. 8.32** *Insulation and eaves detail (traditional roof construction)*

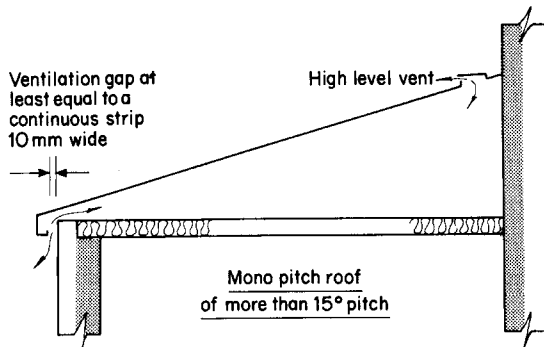
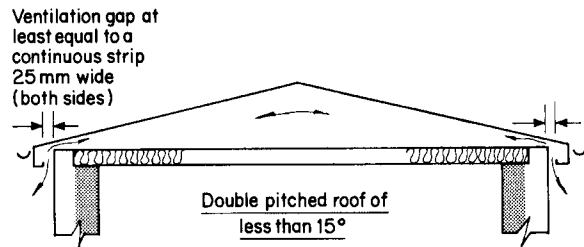
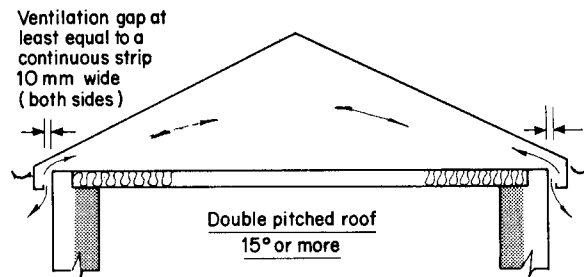
the insulation – foil or polythene-backed plasterboard may be suitable, provided the joints are sealed – this barrier can help reduce the amount of water vapour which would normally pass through the ceiling into the roof void.

Figure 8.32 shows how the insulation within the eaves of this traditionally constructed roof is taken on to the inner leaf of the wall at eaves level – a board prevents the insulation from blocking air flow conducted via a vented soffit. Ventilation is vitally important in the roof void if condensation is to be avoided. Means of providing ventilation include a continuous insect screened eaves opening along two opposite sides of the roof (Fig. 8.33 shows a proprietary type of eaves ventilator used with a roof with ‘Open Eaves’). Gable vents may accompany eaves ventilation (air bricks), and ridge vents. For roofs of  $15^\circ$  pitch and above, ventilation openings should be of a size equivalent to a continuous 10 mm gap along two opposite sides of the roof; below  $15^\circ$  pitch the gap should be increased to 25 mm. Examples of promoting cross-ventilation are shown in Figure 8.34. If ventilation is inadequate and/or the vapour barrier becomes inoperative due to damage or gaps left around the edges of access traps, etc. warm moist air from the dwelling below may reach and make contact with the cold outer shell of the roof, condensing into droplets of water – possibly of sufficient volume to cause continuous wetting to timber, which could result in loss of timber strength, fungal decay, and the corrosion of metal components such as truss plate connectors, etc.

Proprietary through ventilating panel fits between rafters—prevents roof space thermal insulation from blocking the airway



**Fig. 8.33** *Proprietary roof ventilator used in conjunction with open eaves*



**Fig. 8.34** *Method of promoting cross-ventilation to a roof space*

## 8.11 Eaves details (see Section 8.1.1)

At the eaves, rain water from the roof is allowed to flow into a gutter. This is usually a separate component (metal, wood, or plastic) secured to the fascia board. The design of the eaves can be constructed in four ways, all of which must provide an aesthetic finish to the final roof construction:

- *Flush eaves* (Fig. 8.35(a)): Spar feet are cut about 25 mm longer than the outer face wall, to allow for roof-space ventilation. Fascia boards are then nailed to them to form a trim and provide a bearing for gutter brackets.
- *Open eaves* (Fig. 8.35(b)): Spar feet are allowed to project well beyond the outer face wall. Fascia boards are often omitted, the gutter being supported by brackets fixed on the top or side of the spar ends. Eaves boards mask the underside of the roof covering.
- *Closed eaves* (Fig. 8.35(c)): Spar feet overhang but are completely boxed-in (provision must be made for ventilation to roof space). Purpose-made brackets will be required to support the soffit at the wall edge. The front edge can be tongued into the fascia.
- *Sprocketed eaves* (Fig. 8.35(d)): This shows two methods of reducing the roof pitch at the eaves of a steep roof, thus reducing the risk of water flowing over the gutter under storm conditions, or the tiles lifting under high winds. The sprocket piece may be fixed on to or to the side of the rafter.

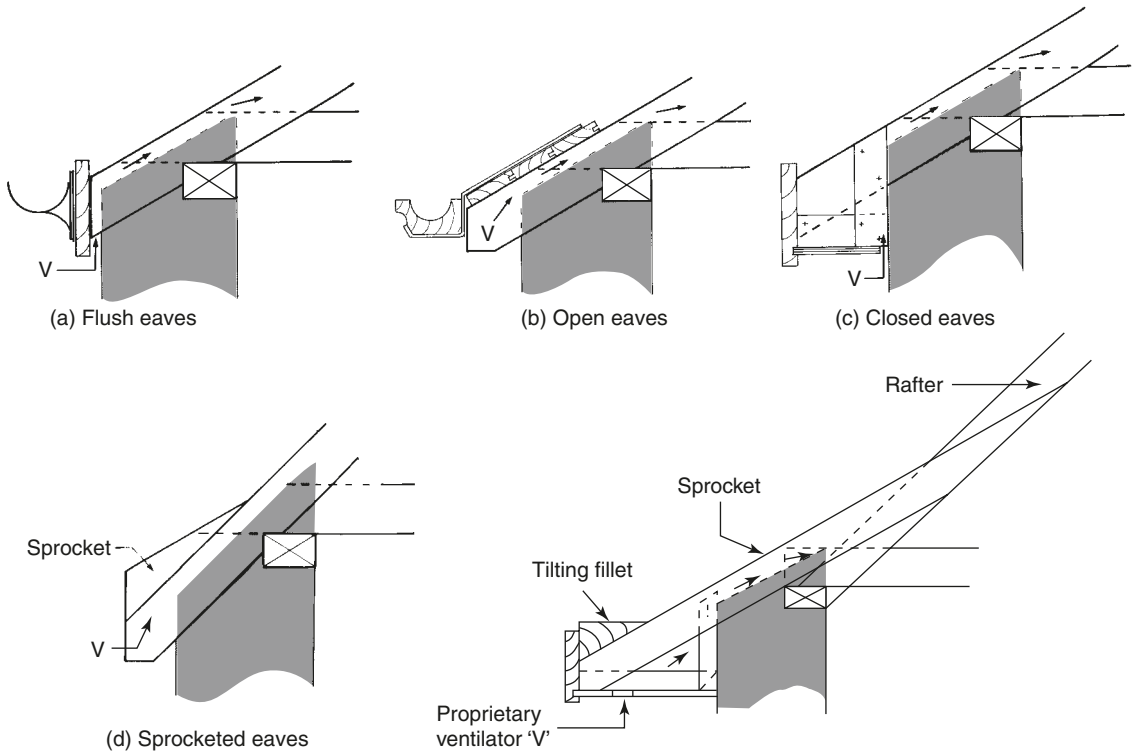
Note: Roof ventilation is dealt with in Section 8.10.

### 8.11.1 Fascias and soffits

As previously discussed, these components form part of the eaves details. The materials used are such that they must be durable to all weather conditions. For example, weather and boil proof (WBP) exterior ply (weather and boil proof see Volume 1, Section 4.1.2) is a common material. This type of plywood does not generally need any form of preservative treatment except a paint finish. Timber, however, requires some form of treatment as well as regular painting to avoid decay.

### 8.11.2 Eaves gutters

As mentioned and shown in Figure 8.32 wood eaves gutters are still quite popular in some areas. Butt and mitre joints (Fig. 8.36) usually incorporate a half-lap, this not only strengthens the joint but ensures alignment between adjoining lengths. Joints are usually sealed with a bituminous mastic compound, then covered with a strip of lead which should be recessed flush with the channel surface. After the lead has been secured to the gutter with closely spaced copper tacks the heads are covered with a thin film of mastic – lead funnels (Fig. 8.36) which act as water outlets are pushed through holes cut through the channel of the gutter – an expansive bit (Volume 1, Fig. 5.52) is used to bore the hole through the gutter. Holes should be bored from the outer face of the gutter. Using a scribing gouge and mallet funnel, flanges are recessed and then fixed in the same manner



**Fig. 8.35** Eaves details, V = ventilation to roof space, mesh covered to deter insects and birds, etc.

*Note: Lead joints may be the job of the plumber.*

as above. Traditionally the whole of the inner surface of the gutter was treated with a water repellent (bituminous type) paint.

Plastics are now the most common gutter material available in a variety of section sizes and lengths. Plastics gutter must be well supported by using the appropriate fascia or rafter bracket fixed at centres not less than those specified by the manufacturer. Joints must be sealed in accordance to the manufacturer's instructions.

Gaps between joints are left to allow for thermal movement, for example, a gutter length of up to 2 m which is to be assembled during the winter months should have a joint gap of 7 mm, if the same job was carried out during the summer months than a joint gap of 5 mm should be left. Gutter lengths between 2 and 4 m will require gaps of 10 mm in winter and 7 mm in summer. Failure to leave expansion gaps could result in the gutter becoming distorted or buckled. Plastics components such as guttering are usually fixed by the plumber. Metal gutters for domestic property are generally supplied and fixed by firms who specialise in that type of work.

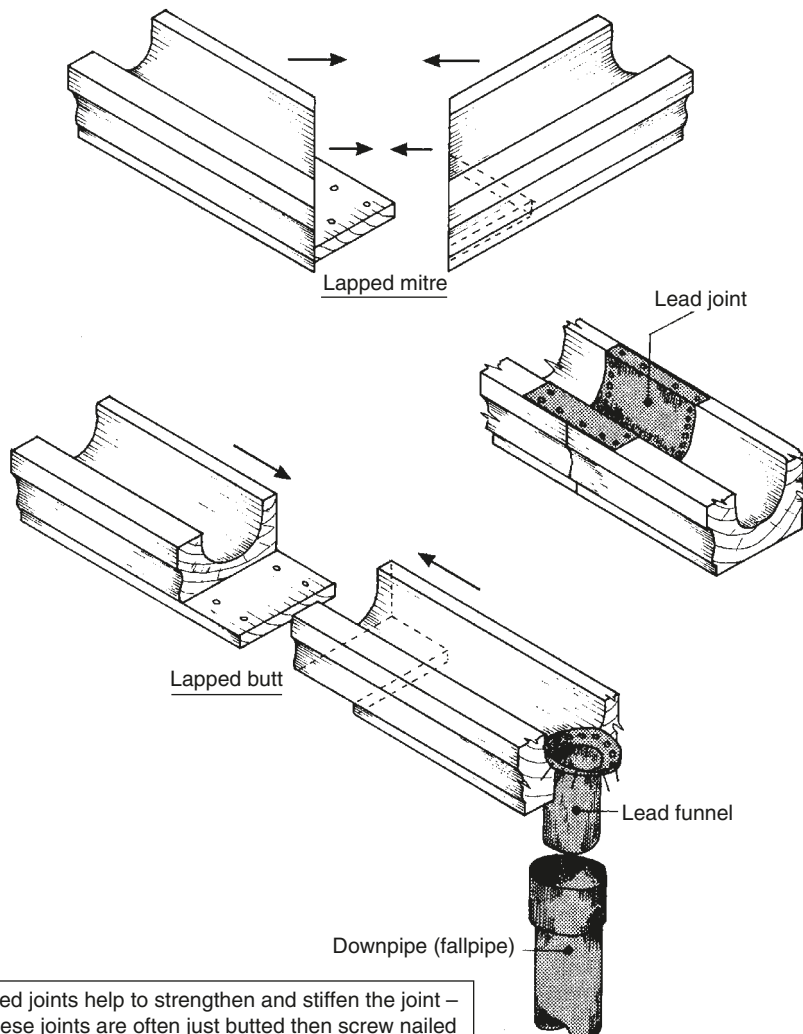
All eaves gutters should have sufficient slope to ensure that all the water likely to be discharged into them from the roof should run away

without leaving any puddles. The direction of fall will depend upon the location of the nearest down pipe (fall pipe). Domestic eaves gutters should have a minimum fall of 1 in 350 or about 10 mm in 3 m.

Alignment of the eaves tiles/slates with the gutter (channel) centre line as shown in Fig. 8.33 is important as this not only ensures that roof water enters the gutter correctly, it makes adequate provision for the eaves sarking felt to enter the gutter back, and provides for reasonable access to gutter channels for cleaning and maintenance purposes.

### 8.11.3 Down pipes (fall pipes)

Plastic is now the most common material for down pipes. Adequate wall fixings are important, distances between fixing should be specified



Note: Lapped joints help to strengthen and stiffen the joint – although these joints are often just butted then screw nailed

**Fig. 8.36** Traditional wooden gutter joints and connections

by the manufacturers and these distances should never be exceeded. As with gutters, provision for thermal movement must be made; this can be achieved by pushing home the joint, then slightly withdrawing the spigot from the socket by the amounts previously stated for gutters.

### References

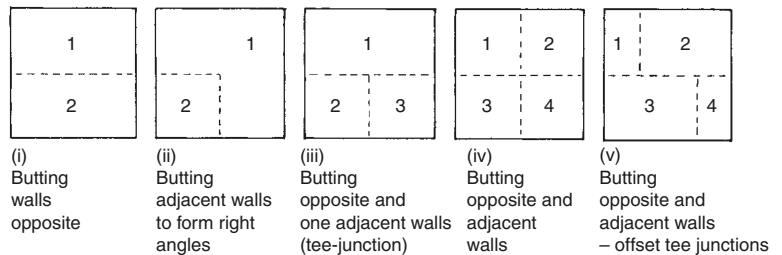
The Construction (Health, Safety and Welfare) Regulations 1996.  
'Building Research Establishment'.  
BS 5268: Part 3: 1998 'Structural use of timber' – 'Code of Practice for  
trussed-rafter roofs'.  
Truss Rafter Association.  
The Building Regulations 2000, approved document A' 1/2.  
TRADA. (Floor joist span tables)

# 9

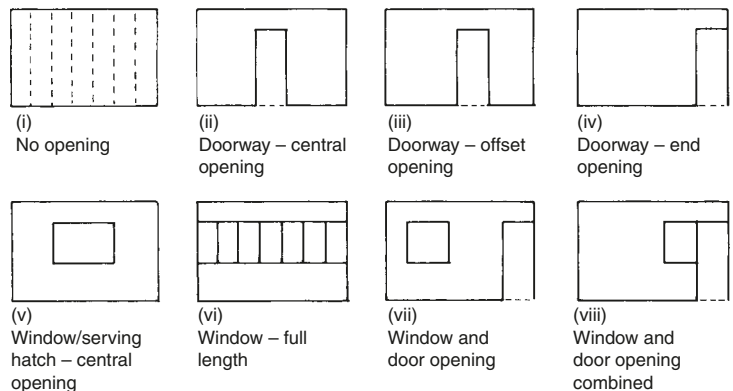
## Partitions (non-load bearing)

Partitioning provides a means of dividing interior floor space into two or more smaller areas (Fig. 9.1(a)). The dividing walls may incorporate a door, window, hatch opening, etc. or a combination of these (Fig. 9.1(b)).

This chapter is concerned with those partitions which are non-load bearing (not to be used as a means of structural support). Compared to masonry walls, these are lightweight in their construction; however,



(a) Plan view of floor, showing possible division by partition(s)



(b) Elevations, showing possible window/hatch and door openings

**Fig. 9.1** Possible partition placements



adequate provision must be made at floor level to carry the partition's weight. Furthermore, the Building Regulation, approved document E: 2000, specifies conditions of soundproofing within buildings.

These partitions may be divided into two types:

- (i) timber stud partitions,
- (ii) proprietary partitions of panel construction.

The former are based on traditional timber-framed construction, whereas the latter include many modern proprietary systems.

## 9.1 Timber stud partitions

This type of partitioning consists of a series of vertical members called 'studs' (from which the partition takes its name), framed by a sole-plate or sill, two end studs, and a head-plate (Fig. 9.2(a)). Intermediate studs are spaced at centres to suit both the overall size and the permitted span of the lining material (Fig. 9.2(b)). Studs are stiffened by using one or more rows of noggings (Fig. 9.2(c)); the number and location of rows will depend on the sheet size and the position of trims such as deep skirting board, dado rails, and chair-back rails, etc. (Fig. 9.2(d)).

### 9.1.1 Construction

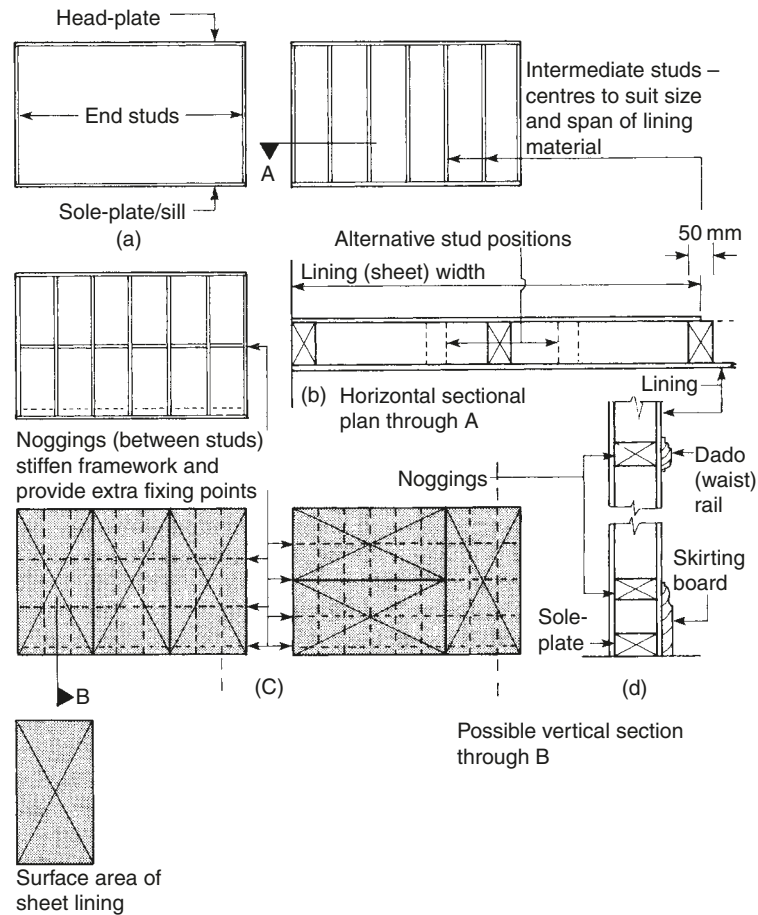
The framework (carcase) can be made up of  $75 \times 38$  mm or  $75 \times 50$  mm section. Where sheets abut,  $75 \times 50$  mm should be used, to ensure adequate bearing (Fig. 9.2(b)).

Pre-fabrication of partitions or their framework is generally not practicable for reasons of transportation and access through doorways etc., but if access is possible, – perhaps to a single-storey warehouse or an industrial development with large loading-bay doors, etc. – then pre-fabrication should be considered. Partitions within ready-built domestic dwellings are therefore erected either by building them *in situ* or, if the situation allows, the framework may be built-up on or off the floor, then reared into position and then fixed. (This latter method would, of course, mean making the framework smaller than the opening and fixing packing between the framework and the wall at all the fixing points.) Both methods of construction are shown in Figs 9.3 and 9.4.

### 9.1.2 Built-in framework (Fig. 9.3) between walls

The following lists explain the built-in framework between walls

1. Cut the sole-plate and head-plate to length from straight stock. If the walls are plumb, stud positions may be marked while both plates are placed together as shown. If the plate lengths differ, the length of the head-plate must be adjusted accordingly; if it is longer than the sole-plate, marking-off can be carried out with the timber laid across or down the room's length. The joints between

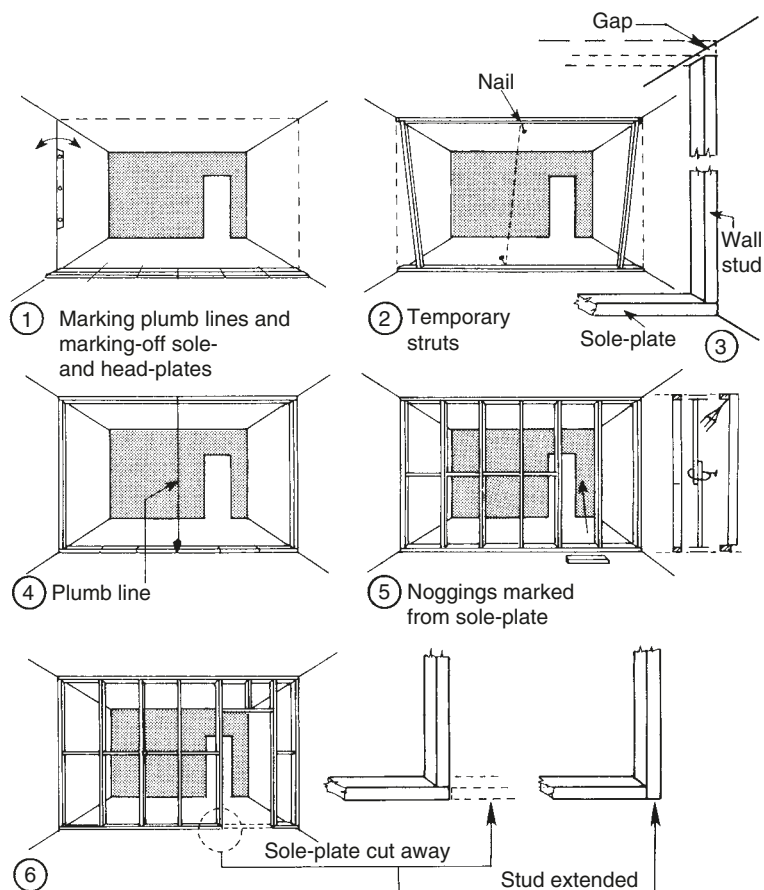


Note: Positions of studs and noggings will vary according to the size of lining sheets, amount of stiffening required, and fixing points for trims etc.

**Fig. 9.2** *Timber stud partitioning*

the plates and the studding should be prepared at this stage. The sole-plate may now be fixed to the floor (Fig. 9.7) and plumb lines be marked on the walls at each end.

2. The head-plate can now be fixed to the ceiling (Fig. 9.7). Temporary struts may be used until fixings are made, if a mid-strut is required, use a nail driven into the head-plate to steady the strut.
3. Alternatively, and perhaps the safer method, the end studs may be fixed first, leaving a gap at the top to accommodate the head-plate. Provided there is no cornice (moulded fillet, usually plaster between the wall and ceiling), the head-plate can then be pushed into position from one side, then fixed to the ceiling.



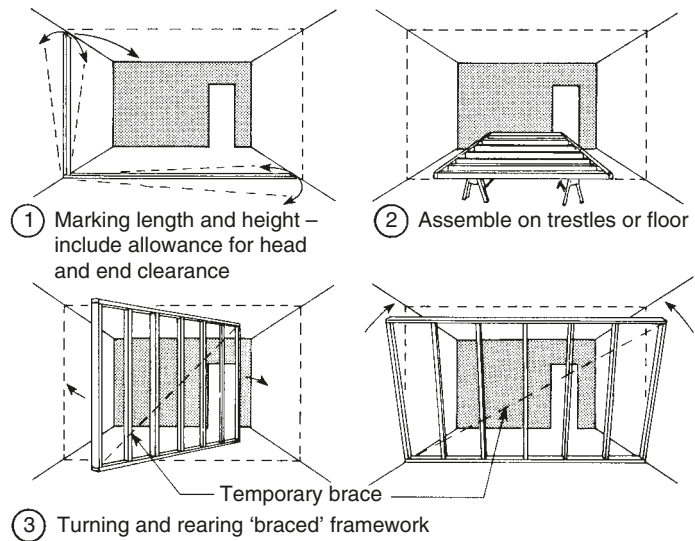
**Fig. 9.3** Built-in framework

*Note: Each stud should be marked separately, as the floor-to-ceiling heights will vary slightly across the room. After the studs have been fixed to the plates (Fig. 9.5(a) and (b)), noggling heights are levelled across the partition. Noggling lengths are taken at sole-plate level – in this way, bent studs will be straightened as the noggings are nailed between them (Fig. 9.5(c)).*

4. Once the outer framework is complete, check that the intermediate stud marks are plumb. If satisfactory, complete fixing to the floor and ceiling.
5. Mark the length of each stud by sitting one end on the sole-plate and marking the underside of the head-plate or housing. Alternatively, use a pinch rod (see Chapter 1, Fig. 1.7).
6. If a door or other opening is required, studs will be left out or cut short and, in the case of door openings, the sole-plate will be cut away. Alternatively, if the studs run through to floor level, the appropriate allowance will be made as shown in Fig. 9.5. (see also Fig. 9.9.).

### 9.1.3 Pre-assembled framework (Fig. 9.4) for fixing between walls

1. The lengths of the sole-plate, head-plate, and end studs should be shorter than the lengths required to fit between the floor, ceiling, and walls, so that the completed framework can be turned or reared into its final position; otherwise the arc it would follow would cause the ends or top to bind on the ceiling and/or walls as shown.



**Fig. 9.4** *Pre-assembled framework*

*Note: Door openings will be dealt with as stated for built-in frameworks.*

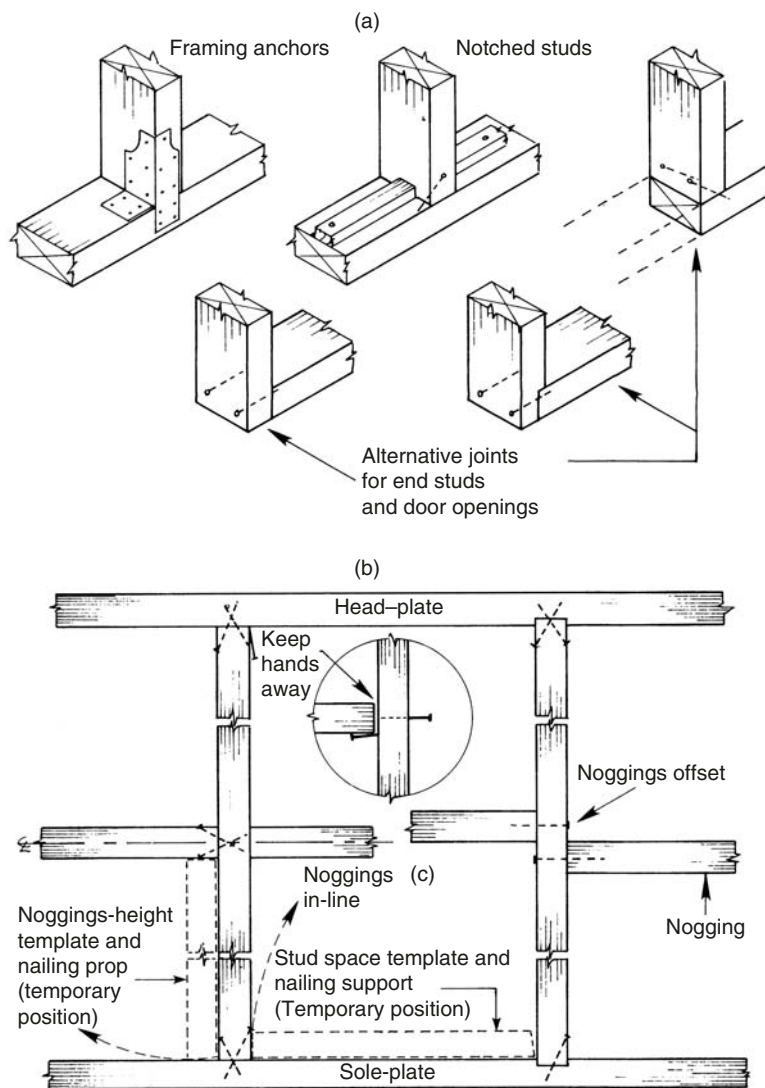
2. Once the required lengths and height are known, the whole framework can be assembled either on the floor or on a trestle staging (the latter method being less troublesome to one's back and knees).
3. Once assembled, the framework can be reared and swung into its final position – either on the turn or, where floor space is not a problem, by rearing straight up. A temporary brace may be used to keep the framework rigid during this operation. End fixings are shown in Fig. 9.8. Floor and ceiling fixings are shown in Fig. 9.7.

#### 9.1.4 Joints (Fig. 9.5)

Members are butted, housed, or notched and nailed together, or joined with the aid of framing anchors. With the exception of pre-framed structures, partitions which do not reach full storey height, and certain situations shown in the illustrations, joints will be skew nailed. To prevent members from moving while nails are being driven at an angle, temporary support and placement can be achieved by using either a partly driven nail at the back of the member or a short length of timber as shown.

##### **Studs to sole-plate (Fig. 9.5(a))**

Direct nailing is not possible except where frames are pre-assembled and at door openings, where studs may be cut long to allow them to run over the ends of the sole-plate. Although time consuming, stud placement can be more easily achieved by nailing a batten along the middle of the sole-plate and notching the studs over it, or by housing the sole-plate to receive stud ends.



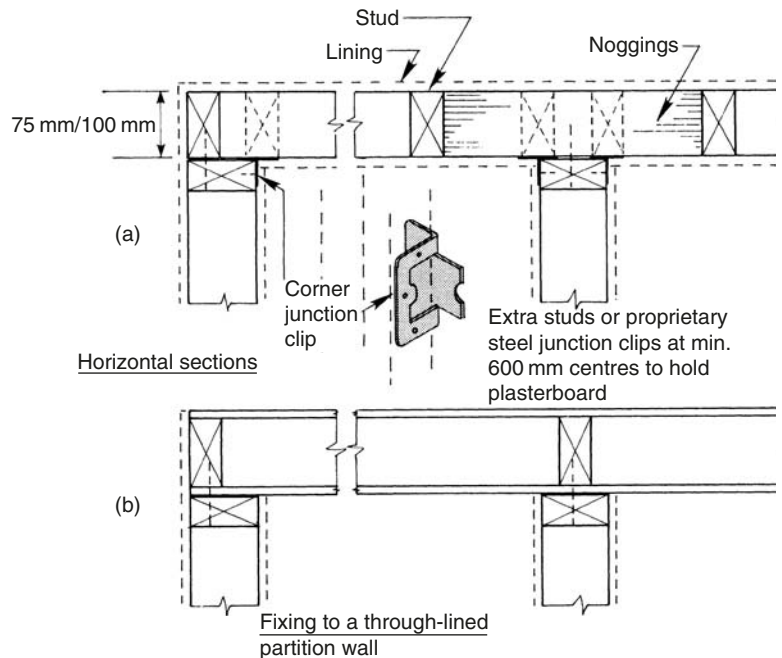
**Fig. 9.5** *Joints and built-in framework*

### **Studs to head-plate (Fig. 9.5(b))**

Except where the partition is not full-storey height, or above or below openings, similar fixing arrangements can be made as for the sole-plate. Overhead nailing can be difficult if the stud is not held in position by temporary means, as shown.

### **Noggings to studs (Fig. 9.5(c))**

Where noggings are used for stiffening purposes only, they can be offset, in which case, with the exception of end (wall) studs, through-stud nailing is possible. If, on the other hand, noggings are to provide



**Fig. 9.6** Corner and junction details. (a) Horizontal sections and (b) fixing to a through-lined partition wall

an edge bearing for the lining material at some point, nails will have to be driven at an angle or skew nailed into the studs as shown.

**Warning** never clasp a nogging and stud together while nailing them together keep hands away from the joint, as due to the ‘springing’ of the members, the chances are that the insides of fingers and palm could become trapped.

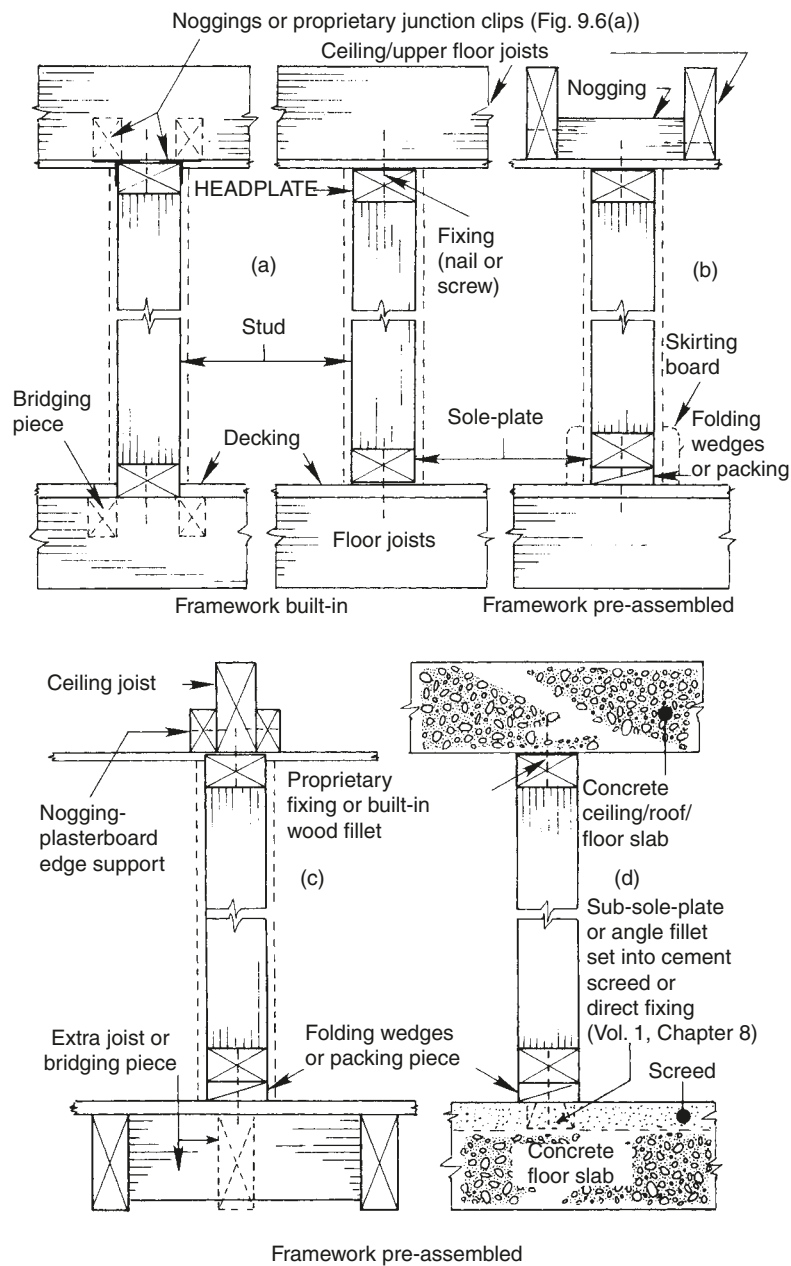
### **Fixing framework at corners and junctions (Fig. 9.6)**

Nailing or screwing a stud to a stud, or a stud to a nogging, should present little difficulty (Fig. 9.6(a)), but providing edge support for lining materials at internal corners might. There are two possible solutions: either extra studs or proprietary steel junction clips as shown.

On the other hand, if one side of the framework is lined before abutment takes place, as shown in Fig. 9.6(b), then edge support is not necessary.

### **Fixing framework to floors and ceilings (Fig. 9.7)**

If the partition forms part of the original building design, provision for fixing may be made during the building’s construction. If the partition is being added to an existing building, joist centres must be located. This can be done by gently tapping the ceiling lining – the joists will make a solid sound, compared with the hollow sound of the areas



**Fig. 9.7** Vertical sections through built-in and pre-framed partitions

between joists, and their location is confirmed by inserting a bradawl at these points.

Figure 9.7(a) shows how the plates of a built-in framework are positioned at right angles to joists and fixed before or after the decking and ceiling linings are in place.

**Fig. 9.8** *Horizontal section through a partition*

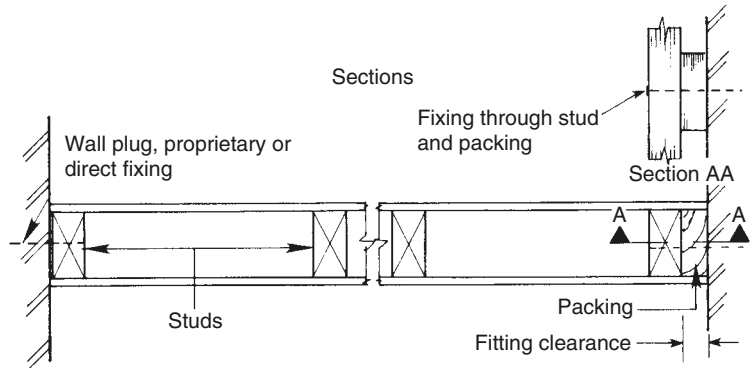


Figure 9.7(b) shows how a pre-assembled framework is wedged and packed-up off the floor before fixing. Where the head-plate falls between two ceiling joists, noggings are used as restraints and fixings.

In Fig. 9.7(c), a pre-assembled framework falls within two floor joists; therefore cross-bridging or an extra floor joist positioned directly under the partition could be used as support. At the head, lining material will need support, and this can be offered either by battens nailed to the sides of the ceiling joist or by junction clips nailed to the head-plate.

Figure 9.7(d) shows how a pre-assembled framework meets up to concrete floor and ceiling slabs. Various types of proprietary fixing device are available for making satisfactory fixings here; alternatively, preservative treated wood fillets or timber runners may be inset into the concrete or its screed (top finishing layer).

### **Fixing framework to walls (Fig. 9.8)**

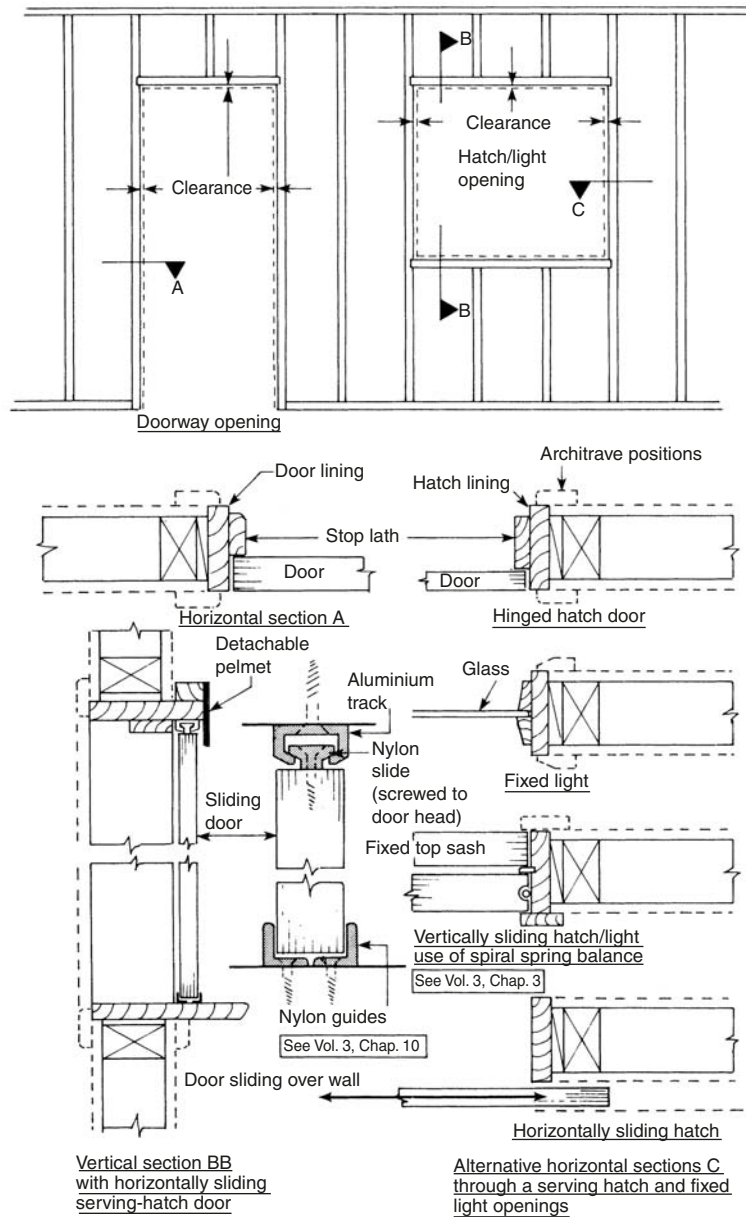
Many types of building blocks permit direct nailing; whereas brick and concrete will require plugging for nails or screws, unless timber pallets (wood blocks) have been built into the structure. Where packings are required between the framework and wall, they should be positioned at the point of fixing as shown.

### **Provision for openings (Fig. 9.9)**

Openings such as doorways, windows (to provide borrowed light from another room), serving hatches, etc. should where practicable fall within the run of studwork and within a single sheet of lining material. Openings should be made oversize; minor adjustments can then be made at the time of fixing a door or window frame. Adjustments are made with the aid of folding wedges and packings at fixing points, and gaps are made good with trim (architrave).

Figure 9.9 shows typical horizontal and vertical sections through door and hatch-lining arrangements. Closing a hatch can be dealt with



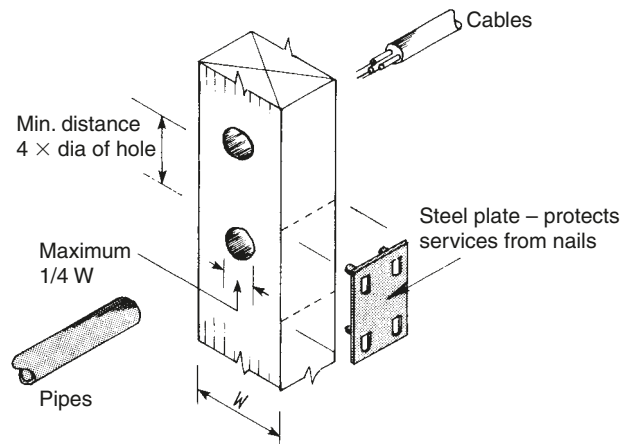


**Fig. 9.9** *Forming openings and their treatment*

in several ways as shown, namely, single or double hinged doors, or a horizontally or vertically sliding door or doors. A beaded fixed light is also shown.

### 9.1.5 Provision for services (Fig. 9.10)

Services may be provided in the form of electric cables, water pipes, etc. If these services pass vertically or longitudinally through a partition, the holes which are to receive them should be central to the



**Fig. 9.10** Positioning holes in framework for service pipes and cables (non-load-bearing partitions)

**Table 9.1** Typical sheet dimensions of plasterboard used for partitioning

Plasterboards	Thickness (mm)	Width (mm)	Length (mm)
'Gyproc' wallboard (tapered and square edge) (Fig. 9.11(a) and (b))	9.5, 12.5, 15	900, 1200	1800, 2400, 2500, 2700, 3000, 3600
'Gyproc' wallboard (bevelled edge) (Fig. 9.11(c))	12.5, 15	1200	2700, 3000
'Gyproc' plank	19	600	2400, 3000

member's width, of a diameter not exceeding one-third of that member's width or thickness, and not closer one to another than three times the diameter of the hole. Steel cover plates are available which help protect service pipes or cables from indiscriminate nailing.

### 9.1.6 Lining materials

In appropriate circumstances, most wood-based manufactured boards may be used as lining materials, for example:

- (a) plywoods;
- (b) particle boards;
- (c) fibreboards
  - soft board (insulation board),
  - medium board,
  - hardboard.

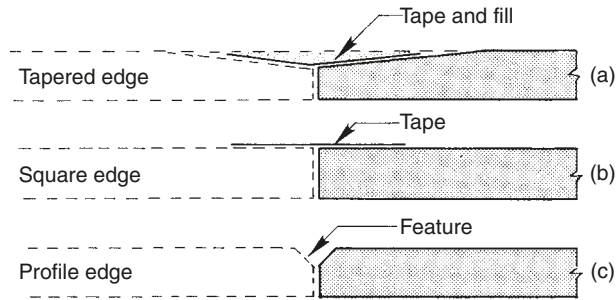
Some indication of the many boards and sheet sizes available at timber merchants can be found in Volume 1, Appendix 2. It may be found, however, future sheet sizes could follow a pattern of co-ordinating a few standard sizes; for example:

---

*Width (mm):* 600, 900, 1200  
*Length (mm):* 1800, 2400, 3000

---

Probably the most common lining to a timber stud partition is plasterboard. Types and sizes are given in Table 9.1.



**Fig. 9.11** *Plasterboard-edge profiles*

## 9.2 Proprietary partitions of panel construction

### 9.2.1 Demountable systems

These systems can be divided into two groups:

- (i) demountable (capable of being dismantled and reassembled elsewhere with little or no disturbance between interconnecting components);
- (ii) non-demountable.

These are ideally suited to dividing up large floor areas for commercial or industrial use, etc.

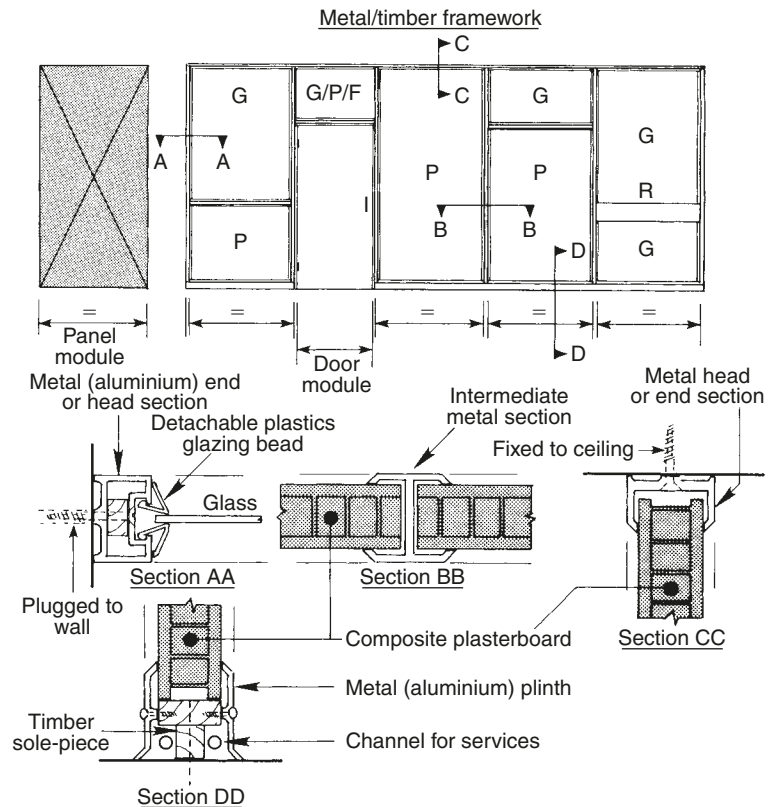
A modular framework of steel, aluminium, or timber is purpose-built to house composite plasterboard panels, compressed strawboard, particle board, glass, etc. or their combination. Panels may also be surfaced fixed or hung, possibly with an insulation material behind both faces. As shown in Fig. 9.12, panel modules are made to suit various linings, openings, and other combinations; for example:

- (a) solid,
- (b) solid and glass,
- (c) door and solid,
- (d) door and glass (fanlight),
- (e) glass.

Door storey frames with or without window (fanlight) over the door may be of a narrower module. Possible sectional details combining metal and timber are also shown.

### 9.2.2 Non-demountable systems

These are mainly used for housing, to provide a lightweight partition system with either plastered finish or a dry decorated finish. Due to the rigidity of the panels used in these systems, framing is usually only necessary as an anchorage and fixing medium at floors, walls, and ceilings; purpose-made clips or insets wood blocks are generally all that are required to fasten panel to panel.



**Fig. 9.12** Typical demountable partition system, using metal section, composite plasterboard panels, and glass

F = Fanlight  
G = Glazed area  
P = Panel of composite plasterboard, compressed straw board, or similar  
R = Dado rail

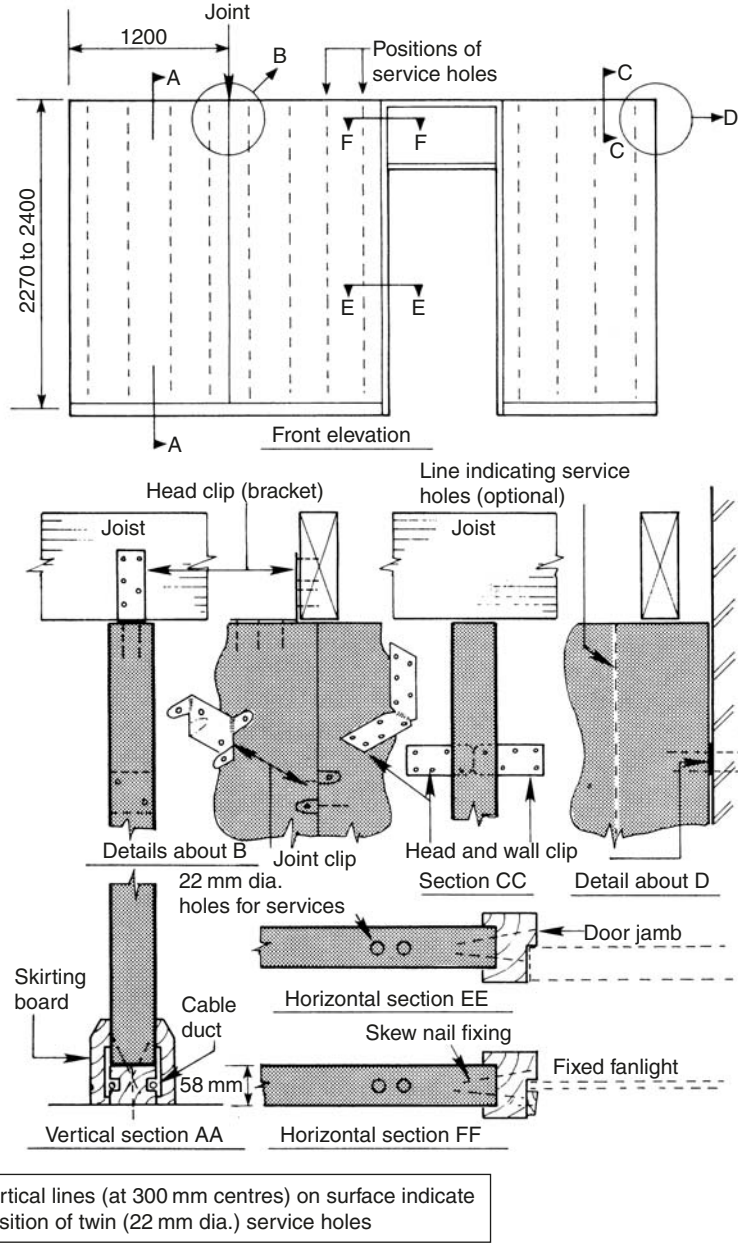
Figures 9.13 and 9.14 show a partition and storey-frame arrangement suitable for compressed-straw-board panels.

Figures 9.15 and 9.16 shows a more recent system produced by British Gypsum which is non-load bearing incorporating a special light gauge metal framework covered both sides with 15 mm 'Gyproc sound block rapid'. Soundproofing qualities may be improved by the introduction of insulation within the partition.

## 9.3 Insulation

### 9.3.1 Thermal insulation

Unless a partition is used to separate a heated room or area from one which is not, thermal insulation will not be necessary. However, if it is, requirements such as those described for timber-framed construction in Chapter 1, Volume 3 may apply.



Note: Vertical lines (at 300 mm centres) on surface indicate position of twin (22 mm dia.) service holes

**Fig. 9.13** Possible partition arrangement using the 'Karphos' non-demountable system

**9.3.2 Sound insulation**

What we are really trying to insulate against is *unwanted* sound, that is, noise! Sound travels in waves through the air (air-borne sound) as a result of conversation, etc. Noise is very often the result of amplified sound from a radio, television (TV), or audio equipment. It may travel by a direct route through the structure or by an indirect route



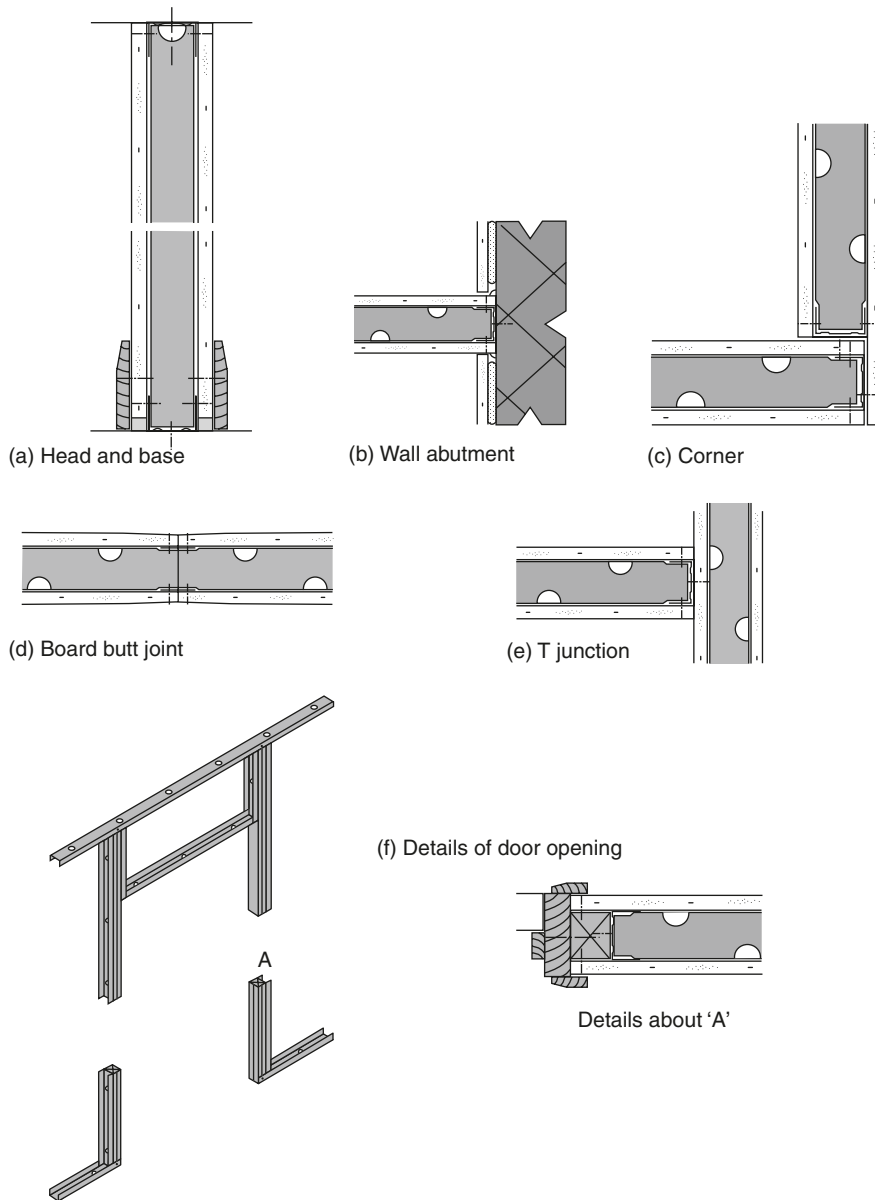
**Fig. 9.14** *Installing a 'Karphos' partitioning system*

via gaps around the edges of the partition, its doors, or similar openings, in which case, the gaps should be sealed with a sound-absorbent material or mastic. Flanking may be another route by which sound may travel to adjoining rooms, as shown in Fig. 9.17.

Noise may also materialise as a result of impact (impact sound), when the building structure is used as a vehicle to transmit noise which may have originated from a door closing (slamming), a striking object, vibrating water pipes, etc. as shown in Fig. 9.18. Such noise is also known as 'structure-borne' noise.

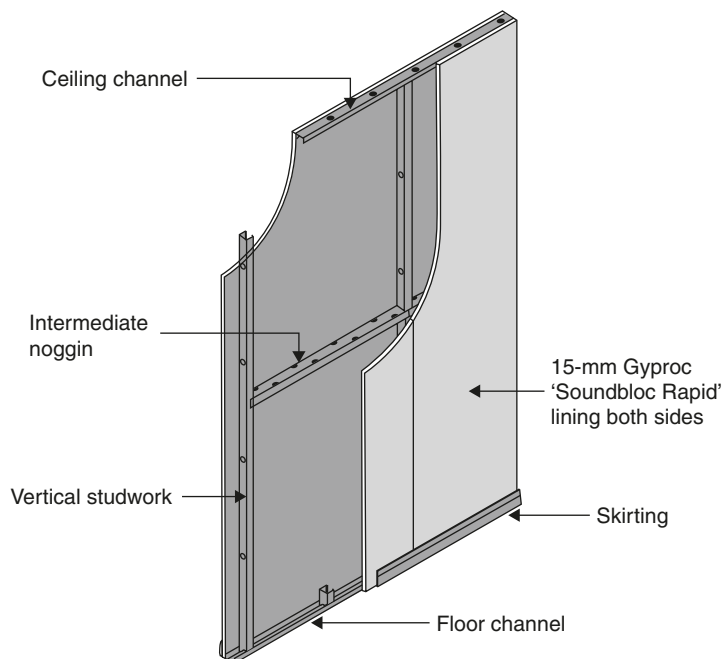
When air-borne and impact (structure-borne) sound waves strike a partition, their vibration will be lessened only according to the amount of sound insulation offered by the partition.

A partition separating a w.c. from a living room or bedroom within a house under the control of the National House Building Council

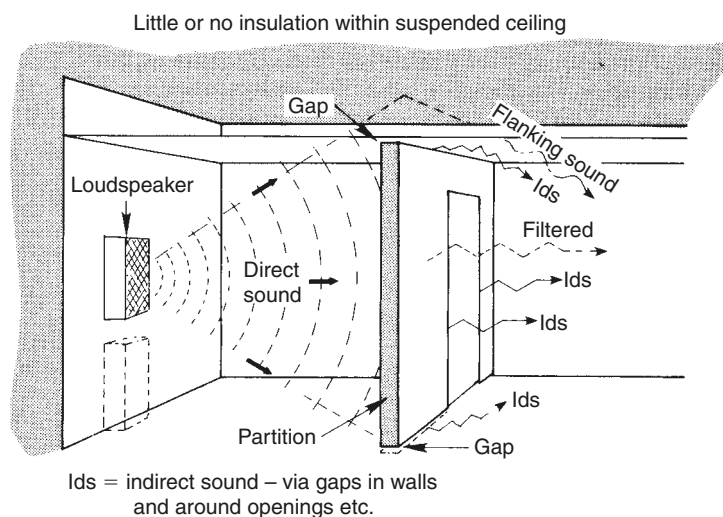


**Fig. 9.15** 'Gypwall Rapid' Non-demountable system

(NHBC) must be built to satisfy a minimum sound-reduction index of 40 dB (the higher the decibel (dB) value, the better the insulation). The Building Regulations, approved document E 2000, resistance to the passage of sound, specifies minimum requirements to provide sufficient soundproofing within buildings. Examples of how these levels of insulation may be achieved are illustrated in Fig. 9.19. Some proprietary systems can meet these requirements.



**Fig. 9.16** Exposed view of British Gypsum 'Gypwall Rapid' panel and fixing details



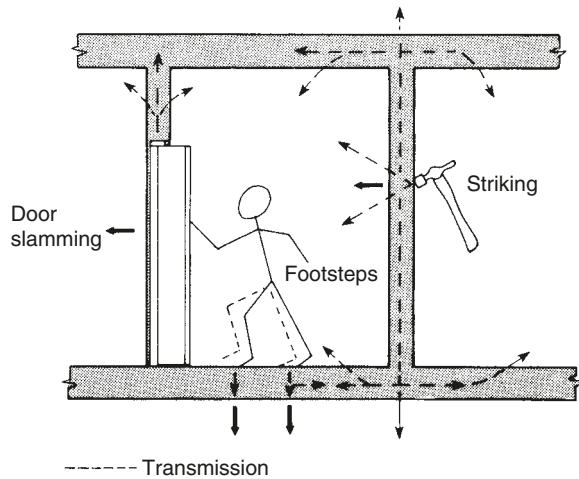
**Fig. 9.17** Air-borne sound. Ids through gaps in walls and around openings, etc.

Transmission of sound may be reduced by 50 dB or more by:

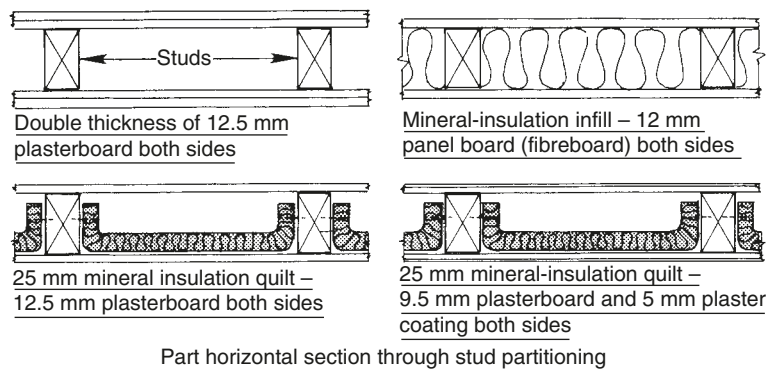
- having alternate studs set proud to leave a staggered gap,
- incorporating insulation board within or as part of the lining,
- increasing the mass of insulation material,
- using a resilient backing to linings and the joints between the partition and the floor, walls, and ceiling as shown in Fig. 9.20.

Note: Further reference should be made to Building Regulations, approved document E 2000.



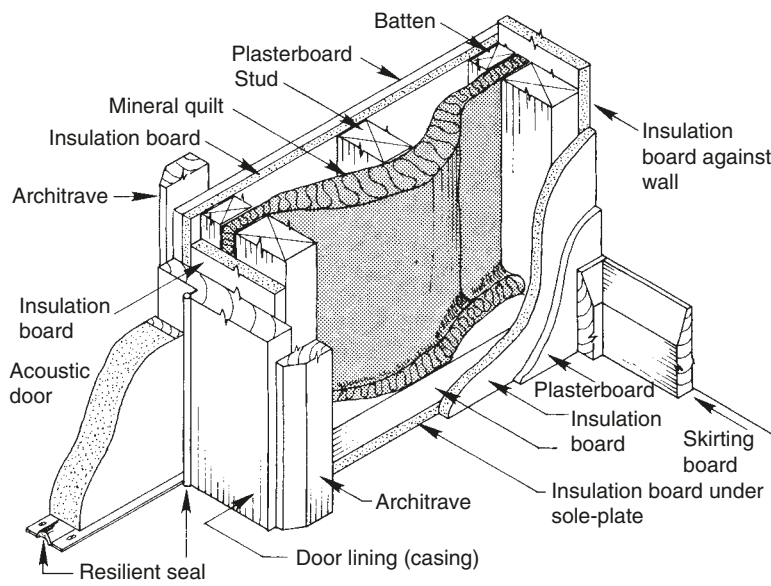


**Fig. 9.18** *Impact sound (structure borne)*

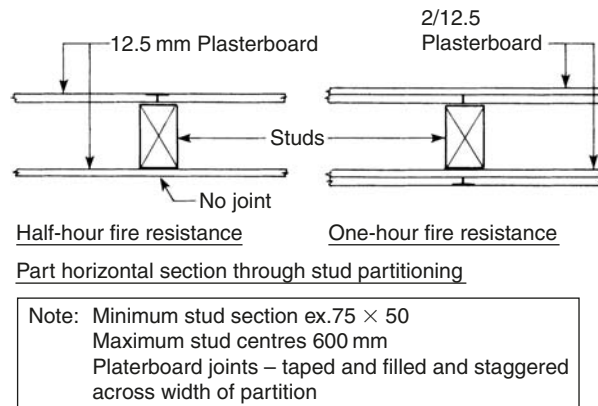


**Fig. 9.19** *Alternative arrangements for sound insulation to satisfy the NHBC*

Part horizontal section through stud partitioning



**Fig. 9.20** *Improving sound insulation*



**Fig. 9.21** *Examples of how fire resistance is achieved*

## 9.4 Protection from fire

### 9.4.1 Fire resistance

Broadly, this means the ability of a partition (as an element in a building) to resist collapse, passage of flame, or heat liable to ignite material on its opposite side, for a set period of time in hours (for example  $\frac{1}{2}$ , 1 (see Fig. 9.21),  $1\frac{1}{2}$ , and 2 hr, etc.) when under attack by fire from one side. Depending on the location and purpose of the partition, it may be legally required to provide fire resistance for a particular period of time.

### 9.4.2 Surface spread of flame

Surface finishes of lining materials are usually required to be classified as to the extent and rate at which flame would spread across them. Materials are tested according to the methods described in British Standard (BS) 476:part 7:1997 and BS 476:parts 20 to 23:1987 and given a number from 1 to 4. The higher the number, the greater the risk of flame spread. Class '0' may be regarded as non-combustible. The Building Regulations stipulate what classification will be required for a given situation such as the building type and the floor area which the partition or partitions will enclose.

### References

- Building Regulations, approved document E 2000. Resistance to the passage of sound.
- BS 476: Part 7: 1997. Fire tests on building materials and structures.
- BS 476: Parts 20 to 23: 1987. Fire tests on building materials and structures.
- NHBC Standards.

# Scaffolding

A scaffold can be regarded as a temporary structure which provides a safe working platform for operatives and their materials. It may consist of or be made up of ladders, trestles, or tubular metal (steel or aluminium) with a platform of wood or metal. The more common forms of scaffold broadly fall into the following groups:

- ladder scaffold, *not acceptable* (see Section 10.1.1);
- trestle scaffold;
- putlog-tied scaffold (often called a bricklayer's scaffold);
- independent-tied scaffold;
- system scaffold;
- mobile scaffold.

All scaffolding and the means of getting on and off it must be constructed and maintained in accordance with the provisions laid down in the Statutory Instrument 1996 No.1592, The Construction (Health, Safety and Welfare) Regulations 1996; together with the Health and Safety at Work Act 1974, require that those persons involved in erecting scaffolding are 'competent' to do so. A competent person could be regarded as one who possesses sufficient practical and theoretical knowledge, together with enough actual work experience, to be capable of carrying out the job in question safely and efficiently, which would include being familiar with all *relevant* statutory requirements and the contents of the following British Standards; and guidance notes from the Health and Safety Executive:

BS 5973: 1993	Code of practice for access and working scaffolds and special scaffold structures in steel.
BS EN 39:	Metal scaffolding.
BS EN 39: 2001	Specification for tubes for use in scaffolding.
BS 1139-2.1: 1991	Specification for couplers and fittings for use in tubular scaffolding.
BS 1139-3: 1994	Specification for pre-fabricated access and working towers.
BS 1139-4: 1982	Specification for prefabricated steel splitheads and trestles.

BS 1129: 1990	Timber ladders, steps, trestles, and light-weight stagings.
BS 2037: 1994	Aluminium ladders, steps, and trestles for the building and civil engineering industries.
BS 2482: 1981	Specification for timber scaffold boards.
HSE Information sheet	General access, Scaffolds and ladders Information Sheet 49.

## 10.1 Ladders

(see: Health and Safety Information Sheet 49)

A ladder is either used independently to reach a job of work or, as part of a scaffold, is used to allow operatives to reach or leave the working platform. It may in some cases offer support to a platform (ladder scaffold). There are three classes of ladder as stated in BS 1129 and BS 2037: 1994.

- Class 1 *Industrial (heavy duty)*: High frequency and onerous conditions of use. Carriage and storage suitable for industrial use.
- Class 2 *Light trades*: Medium duty, low frequency, and good conditions of use, carriage, and storage. Suitable for light-trade purposes.
- Class 3 *Domestic*: Light duty. Suitable for domestic and household use only.

The class and duty must be clearly marked on the equipment. Many accidents happen due to the wrong class of ladder being used. Figure 10.1 shows four different types of timber ladders (with the exception of the 'pole' ladder, these may also be constructed of aluminium alloy). Minimum recommended overlaps for timber extending ladders are as shown in Fig. 10.2. Suitable timber species for use in ladder construction are listed in Table 10.1.

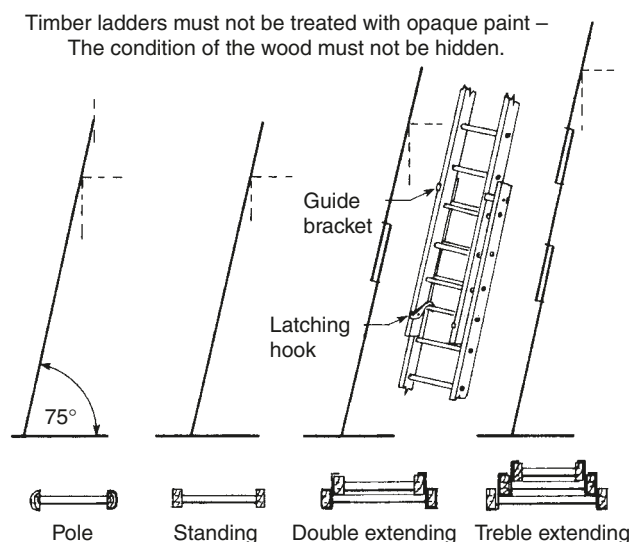
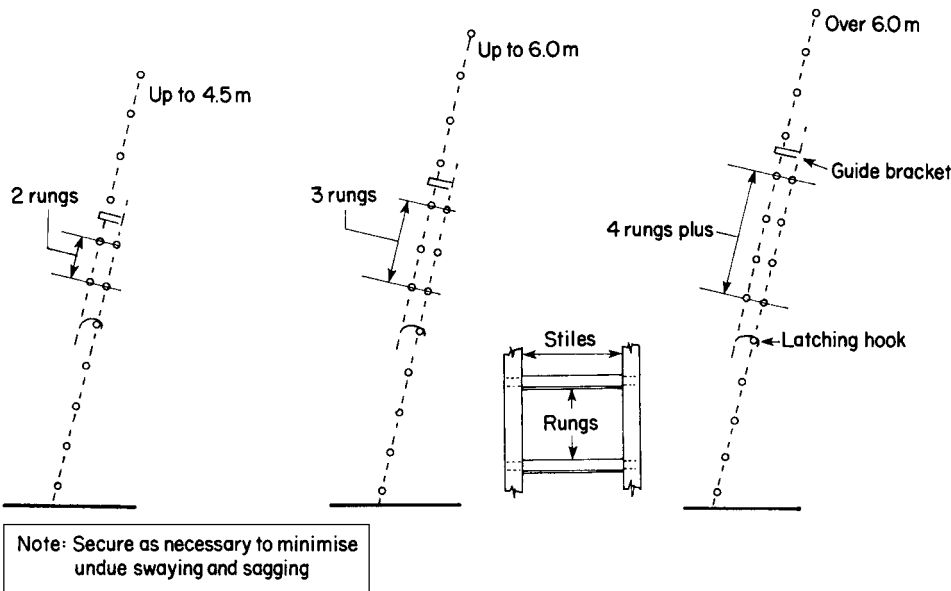


Fig. 10.1 Ladder types

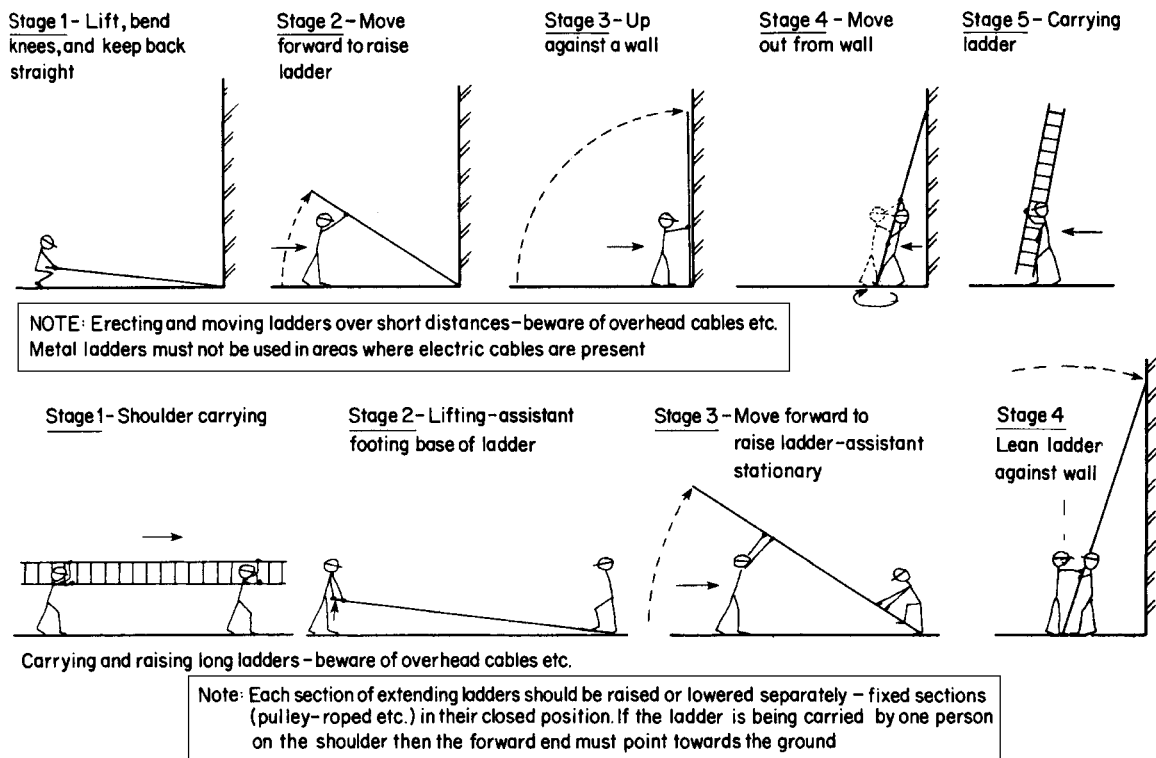


**Fig. 10.2** Minimum rung-over-rung overlap for extending ladders (guide only)

**Table 10.1** Suitable timber species (indicated by a '✓') for ladders, steps, trestles, and lightweight staging

Item	Component	Timber species															
		Hardwoods										Soft woods					
		European oak*	American white oak*	European ash*	American white ash*	Hornbeam	Yellow birch	Hickory*	Robinia	Keruing	Ramin	European whitewood	European redwood	Douglas fir	Sitka spruce	Western hemlock	Parana pine
Pole ladder	Stiles											✓	✓				
	Rungs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						
Standing and extending ladders	Stiles											✓	✓	✓	✓	✓	
	Rungs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						
Step ladder	Stiles											✓	✓	✓	✓	✓	
	Tread									✓	✓	✓	✓	✓	✓		✓
Trestles	Stiles											✓	✓	✓	✓	✓	
	Cross-bearers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Lightweight staging	Stiles											✓	✓	✓	✓	✓	
	Cross-bearers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Decking											✓	✓	✓	✓	✓	✓

*Note:* The same timber species must be used for all components of any one item.  
\* Check growth rate.



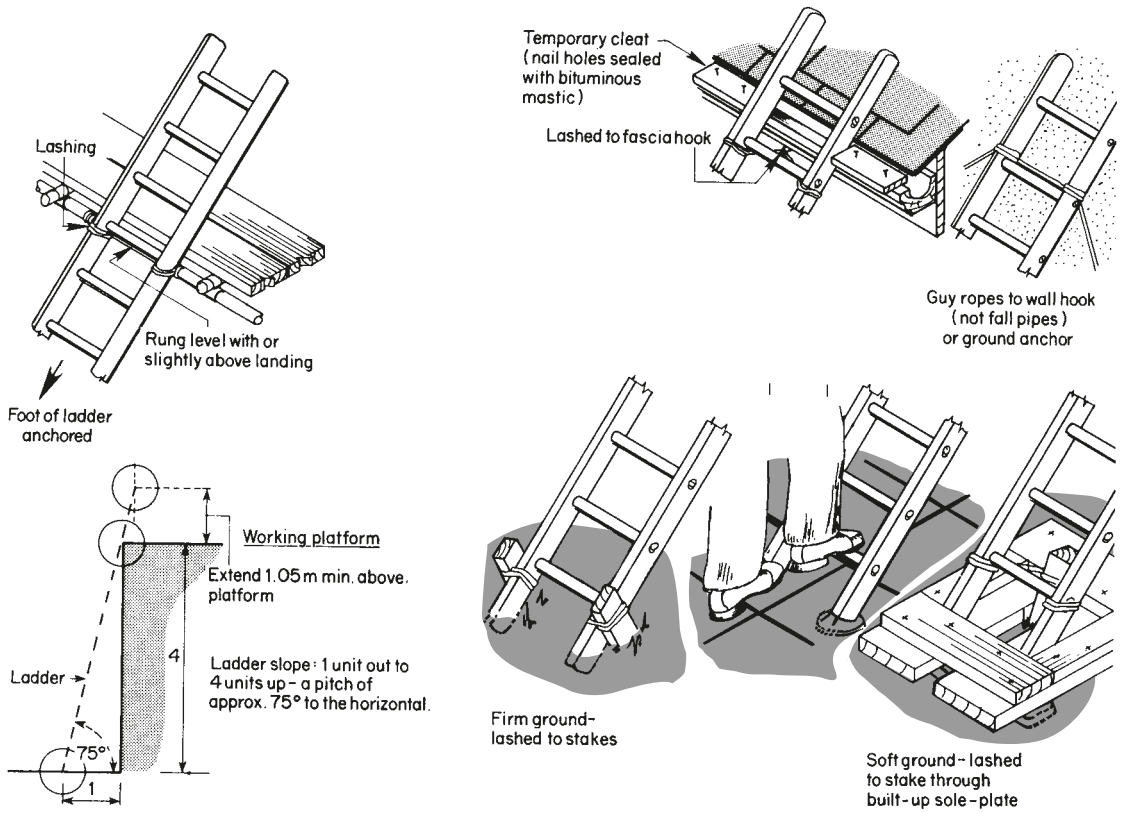
**Fig. 10.3** *Manipulating and manoeuvring ladders*

Methods of raising, lowering, and carrying ladders are shown in Fig. 10.3. Unless only short ladders are involved, all these operations require two operatives: one to act as anchor, the other to raise or lower the ladder. By employing two persons to carry the ladder, the load is halved and manoeuvring around corners and obstacles is made safer and simpler.

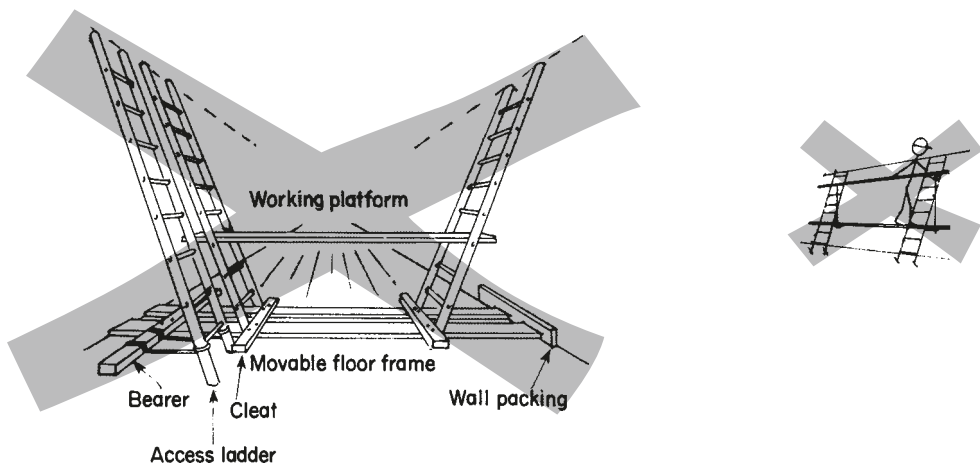
Figure 10.4 shows various means by which the top and bottom of a ladder can be prevented from slipping. Where a ladder is used to reach a landing (working platform), it must extend above it by not less than 1.05 m, to provide a handhold when stepping on to and off the landing. The slope of the ladder should be at an angle of about 75° to the horizontal: set one unit out to every four units up.

### 10.1.1 Ladder scaffold: not acceptable as a working platform

Not acceptable as a structural component for a working platform (see Fig. 10.5).



**Fig. 10.4** Means of securing ladders



**Fig. 10.5** Ladder scaffold – not to be used as a means of a working platform

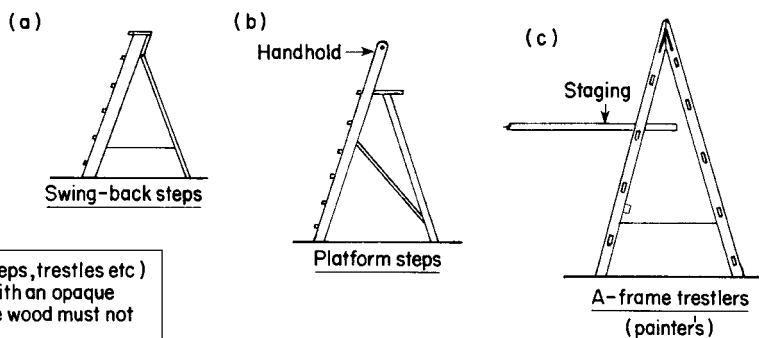
## 10.2 Trestle scaffold

A trestle scaffold consists of a working platform (staging) supported by two or more trestles. Folding steps (Figs 10.6(a) and (b)) are often suitable as a means of access to trestles for low-rise work. 'A-frame' trestles (Fig. 10.6(c)) which may be used to operate at higher levels are often called 'painter's' or 'shopfitter's' trestles. A scaffold arrangement, together with its limitations, is shown in Fig. 10.7. The need for check blocks, which prevent the hinges from becoming strained when the trestles are being carried or stored, is also illustrated. In the open position ropes may be used to prevent strain on hinges.

Rigid trestles (Fig. 10.8) are available either as fixed-width units or as individual legs (splitheads) with stirrup heads designed to receive a single (as shown) or double beam which allows two platforms to butt together. By using multiples of these trestles, and providing adequate bracing or end restraint is used to prevent sideways movement large flat platformed areas can be constructed. Toe boards and guard rails are required at all heights exceeding 2 m.

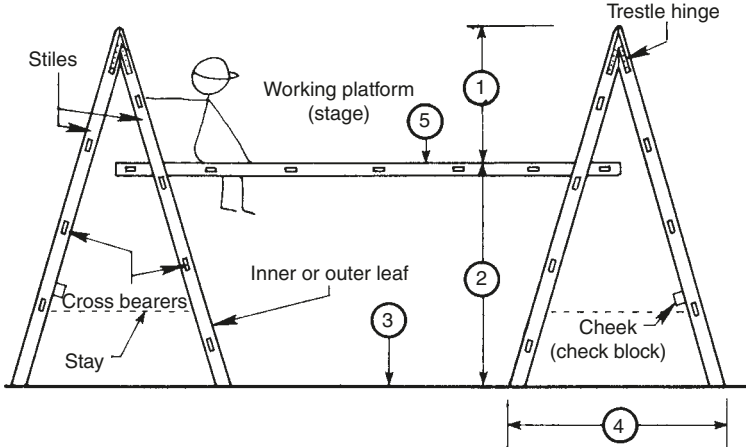
No trestle scaffold should be used without first carrying out a risk assessment with regard to the height of its working platform. Folding supports should never accommodate more than one working platform. The platform (not less than 600 mm wide) may be made up of either scaffold boards or a proprietary type of staging similar to that shown in Fig. 10.9. On completion of a risk assessment, it may be advisable for a separate ladder or pair of steps to be used for access to the platform.

Suitable timber species for the construction of folding step ladders, trestles, and lightweight staging, are listed in Table 10.1.



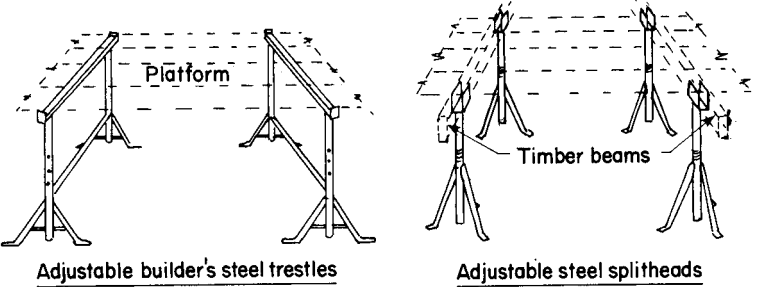
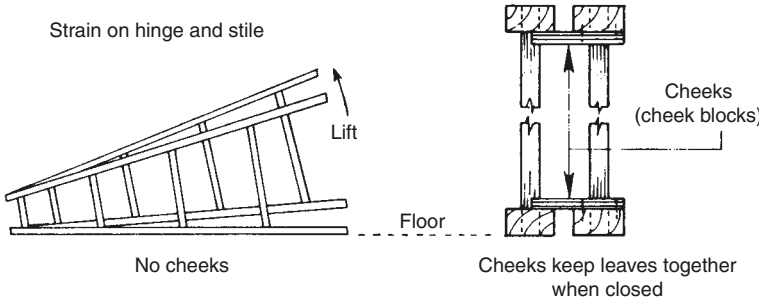
**Fig. 10.6** *Folding steps and trestles*



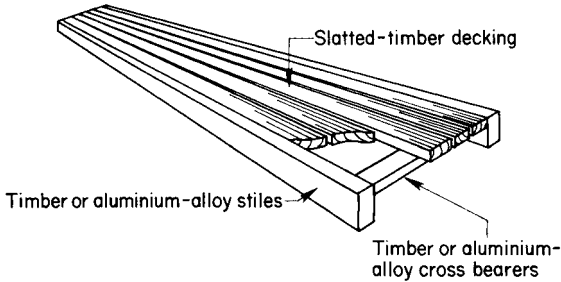


**Fig. 10.7** *Folding-trestle scaffold.*

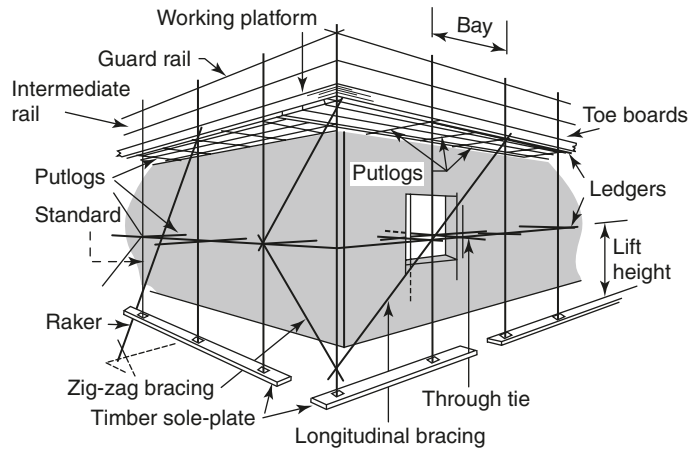
- 1. Upper third of the trestle above working platform;
- 2. Must not be used where a person could fall without a risk assessment being carried out;
- 3. Firm level ground;
- 4. Trestles fully opened;
- 5. Proprietary staging recommended (Fig. 10.9)



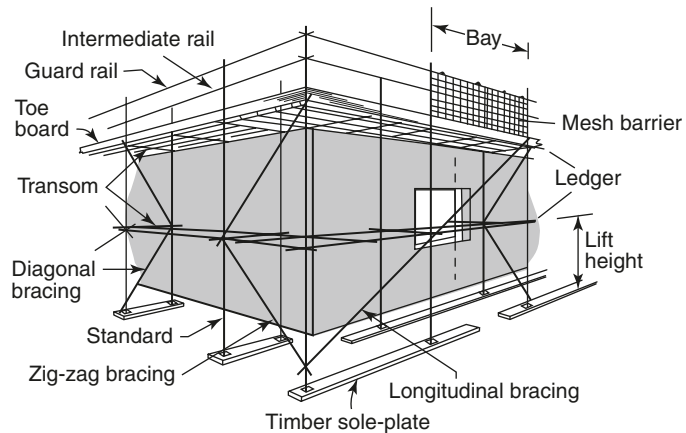
**Fig. 10.8** *Rigid trestles*



**Fig. 10.9** *Proprietary staging*



**Fig. 10.10** Putlog-scaffold arrangement



**Fig. 10.11** Independent-tied-scaffold arrangement

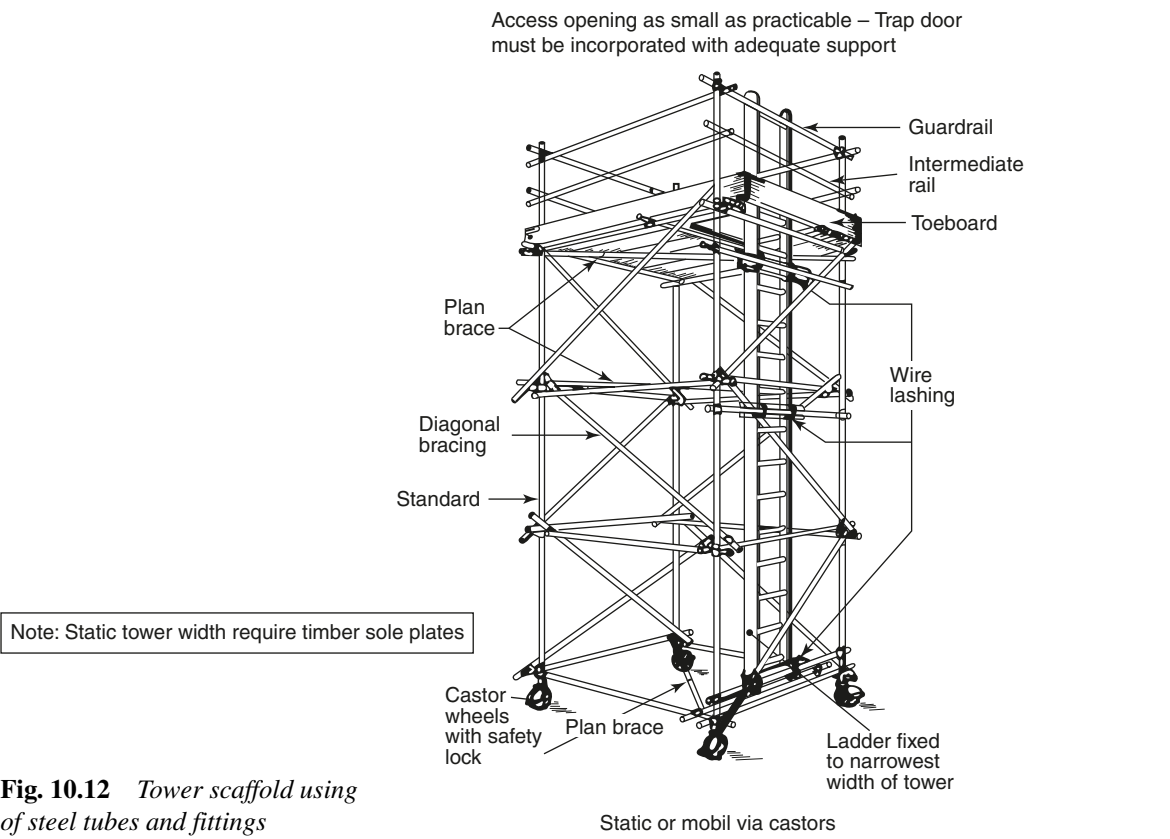
## 10.3 Tubular scaffold

Tubular metal 'components' together with a variety of 'couplers and fittings' can be used to assemble various scaffolding forms. Three of the most common are:

- (i) putlog scaffolding (Fig. 10.10);
- (ii) independent-tied scaffolding (Fig. 10.11);
- (iii) access towers (Fig. 10.12), which as shown may be mounted on castors for mobility.

*Note: Steel and aluminium alloy tubes should not be used in the same scaffold structure, because of their different strength qualities.*

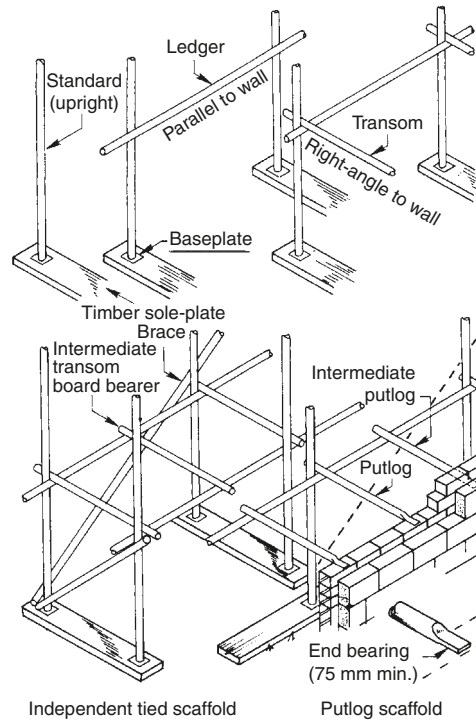
Each form is designed and constructed to suit individual job requirements. The function of each tubular component is stated in Table 10.2, and Fig. 10.13 locates some of them. Table 10.3 lists and



**Fig. 10.12**
Tower scaffold using of steel tubes and fittings

**Table 10.2**
Tubular scaffold components

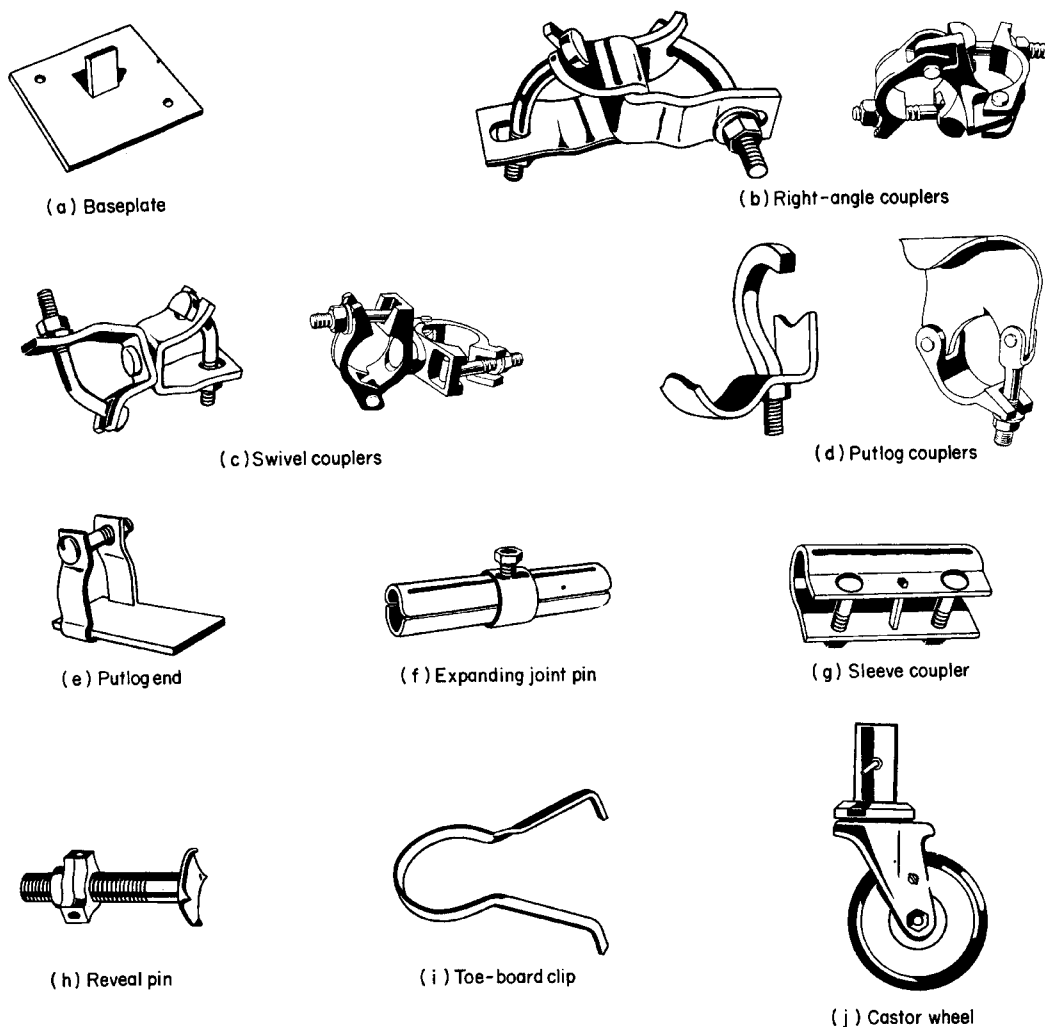
Components	Definition and/or function
Standards (or uprights)	Vertical tubes which support the weight of the scaffold and its load.
Puncheons	Vertical tubes not based on the ground but starting from within the scaffold.
Ledgers	Horizontal tubes which connect standards longitudinally and may support putlogs and transoms.
Transoms	Horizontal tubes which span ledgers to lie the scaffold transversely. Together with intermediate transoms (board bearers), they may support a working platform.
Putlogs	Horizontal tubes, one end of which is flattened or connected with a putlog end to bear on or be built into a supporting wall. The other end is fixed to a ledger or a standard. Together with intermediate putlogs, they may support a working platform.
Raker	An inclined load-bearing tube with its baseplate bearing against a suitable foundation.
Braces	Tubes fixed diagonally across the face and width and through a scaffold to give stability to the whole scaffold.
Ties	Tubes attached to standards or ledgers (by right-angle couplers) to secure the scaffold to the building.
Bridles	Horizontal tubes fixed (by right-angle couplers) across wall openings to provide support for a putlog transom or tie tube.



**Fig. 10.13** Location of tubular components

**Table 10.3** Scaffold couplers and fittings

Couplers and fittings	Fig. 10.14	Definition and/or function
Baseplate	(a)	A square metal plate with a spigot over which a standard or raker is positioned to distribute the load over a greater area.
Adjustable baseplate	–	A baseplate capable of height adjustment via a threaded shaft and collar.
Right-angle coupler (90° coupler)	(b)	For joining scaffold tube at right angles – used for fixing ledgers, transoms, or putlogs to standards, and for securing ties and braces, etc.
Swivel coupler	(c)	Used for joining scaffold tubes at any angle where a right-angle coupler cannot be used.
Putlog coupler	(d)	Used for joining intermediate putlogs and transoms to ledgers.
Putlog end	(e)	A fitting to convert a scaffold tube into a putlog.
Joint pin	(f)	Used for joining scaffold tube end-to-end – it fits internally, expanding to grip the tube. Joint pins may only be used for standards or puncheons – although a sleeve coupler is preferred.
Sleeve coupler	(g)	Joins scaffold tubes end-to-end, externally. Used to join ledgers, braces, all tower-scaffold members, and recommended for standards.
Reveal pin	(h)	An adjustable screw fitting used for tightening a tube serving as part of a reveal tie.
Toe-board clip	(i)	For fixing toe boards to scaffold members.
Castor wheels	(j)	Lockable swivelling wheels which are secured to the base of vertical members (e.g. standards) used in conjunction with a mobile scaffold.



**Fig. 10.14** Couplers and fittings

*Note: With all types of scaffolding, an intermediate guard rail must be included, situated between the guard rail and the toe board (see HSE Information sheet General access, scaffolds and ladders Information Sheet 49).*

describes the location and/or function of those couplers and fittings which are commonly available, most of which are illustrated in Fig. 10.14.

### 10.3.1 Putlog scaffold (Fig. 10.10)

This has on its outer side a single row of standards normally set at between 1.8 m and 2.4 m apart (depending on the load) which stand off solid or compacted ground via baseplates and a timber sole-plate. Inner support is provided by the wall of the building into which the

**Table 10.4** Scaffold-board span in relation to its thickness

Nominal thickness of board (mm)	Maximum span (m)	Minimum overhang (mm)	Maximum overhang (mm)
38	1.5	50	150
50	2.6	50	200
63	3.25	50	250

*Note:* See Fig. 10.16.

blade end of the putlogs (or adaptors) are built-in. The distance between putlogs will depend on whether they support a working platform and the thickness of the scaffold board; for example, under a platform decked with 38 mm thick boards, they should be set about 1.2 m apart (see Table 10.4). Where boards abut, putlogs are doubled (as shown in Fig. 10.16). Putlogs are connected to horizontal ledgers. Ledgers which are fixed to the standards are positioned at vertical intervals of about 1.35 m (for bricklayers) to 2.0 m which would provide for headroom between lifts if under platforms were to be used. Longitudinal or facade braces at about 45° are required over the whole height of the scaffold to form either a vee or a zig-zag pattern.

All ties should preferably be the 'through' type similar to that shown in Fig. 10.15(a) or the cast-in anchor type such as the one shown in Fig. 10.15(f), but until the walls are stable enough to hold the scaffold, temporary raking struts should be set-up from the ground (Fig. 10.15(b)). Working platforms (Fig. 10.16) should not be more than five boards wide. An arrangement for a toe board and guard rail, which must be provided where a person is liable to fall more than 2.0 m, is shown in Fig. 10.16.

### 10.3.2 Independent tied scaffold (Fig. 10.11)

This consists of a double row of standards which stand-off solid or compacted ground via baseplates and a timber sole-plate. The inner row may be set not more than 300 mm away from the building. For use as a general-purpose scaffold, the distance between rows should not normally exceed the width of five boards. Pairs of standards may be set between 2.0 and 2.4 m apart, depending upon loading. Transoms are spaced as for putlogs, and transom ends are connected to ledgers. The first pair of ledgers is positioned not more than 2.0 m above the ground; further pairs at intervals of 2.0 m.

Diagonal bracing between alternate pairs of standards and 45° longitudinal and/or zig-zag bracing should extend to the full height of the scaffold. The whole scaffold structure must be tied to the building in accordance with BS 5973:1993. Ideally at least half of the ties used should be of the through type similar to that in Fig. 10.15(c). Reveal ties (Fig. 10.15(d)) provide a less reliable anchor and need constant checking for tightness. Timber 'pads', used to protect the reveals,

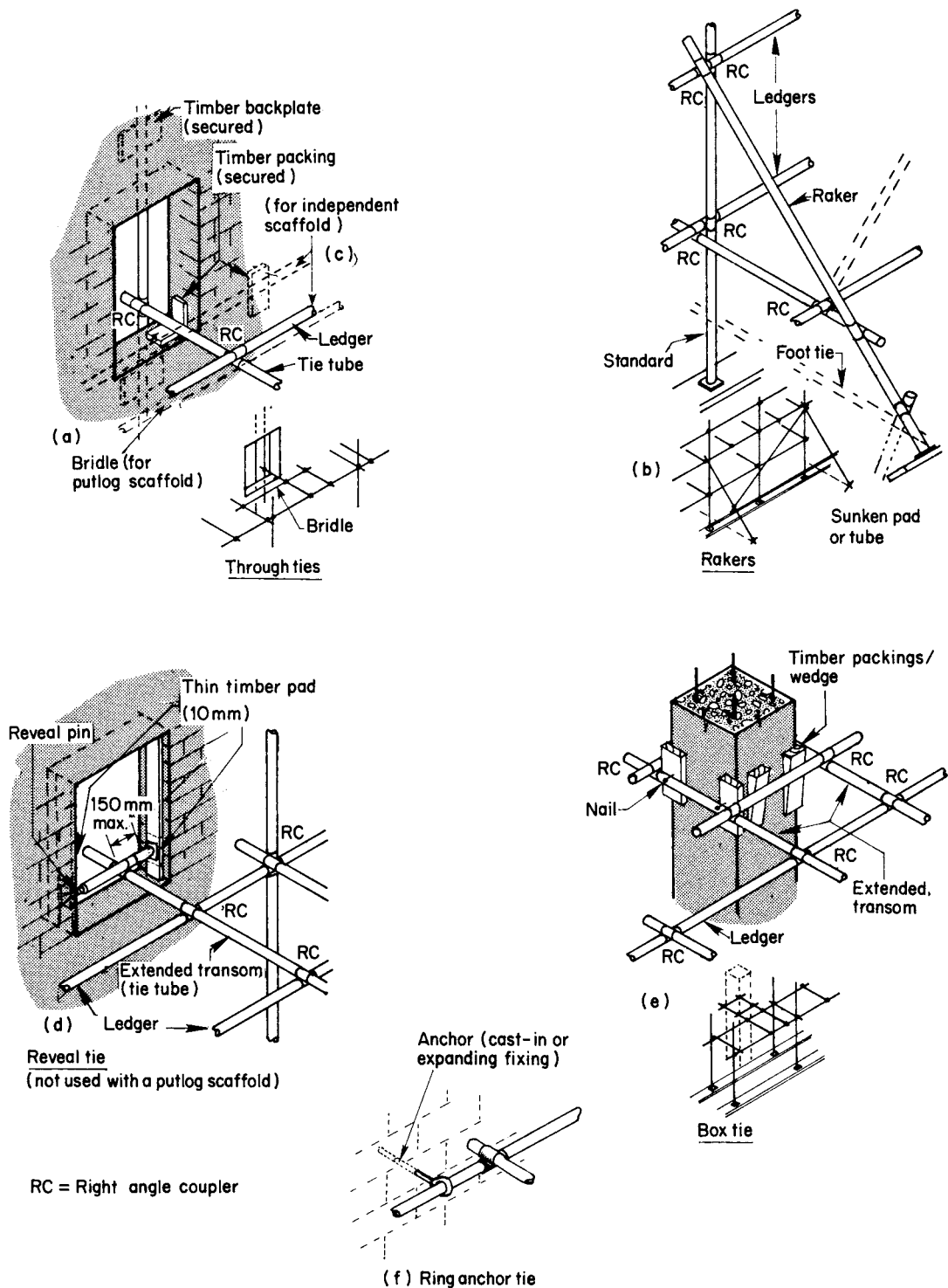
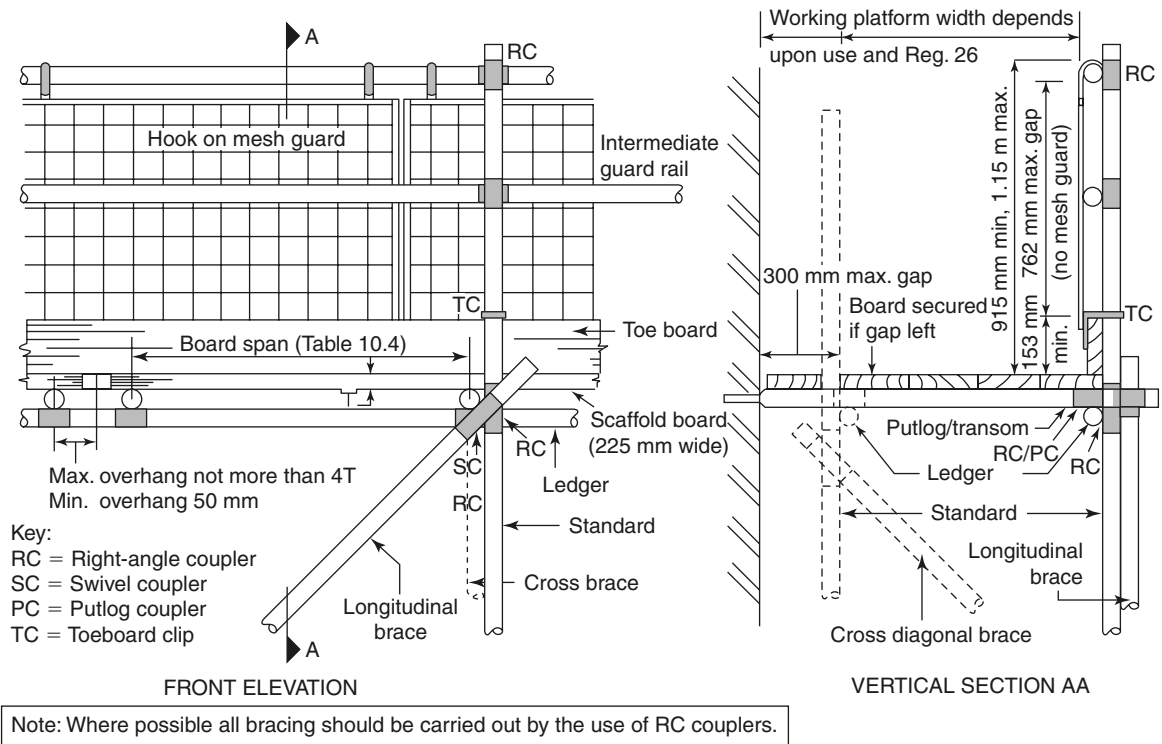


Fig. 10.15     Ties and rakers



**Fig. 10.16** Working platform for a tubular scaffold

should be of a thin material to reduce the effect of any shrinkage. There are many other forms of ties used, such as the 'box' tie (Fig. 10.15(e)) and anchor ties (Fig. 10.15(f)) which may have been cast or drilled into the structure. A working platform together with a toe board, guard rails, and brick guard are shown in Fig. 10.16. Toe boards and guard rails must be provided where a person is liable to fall more than 2 m.

## 10.4 Ties

Both putlog and independent forms of scaffold should be tied to the walls in accordance with the recommendations set down by BS 5973: 1993, Section 9, tying scaffolding to building facades.

## 10.5 Access towers

(Fig. 10.12) (Also see Section 10.6)

An access tower can be either stationary – in which case it stands on timber sole-plates – or mobile, with castors at each corner. The structure is made up of normal steel tubing and couplers. Corner standards should be not less than 1.2 m apart, and each lift should not exceed the width of the shortest side to a maximum lift height of 2.7 m. Diagonal bracing is carried out in zig-zag style at each side, over the full height of the tower. Plan bracing is introduced across the base and alternate lifts.



Height limits will depend on the type (static or mobile) and the situation (exterior or interior use). For example, mobile access towers used externally should not be higher than 3 times the width of the narrowest base side; for interior use, the height could be extended to  $3\frac{1}{2}$  times that width. In situations where operatives are to apply horizontal forces, for example drilling operations, provision must be made to prevent the tower overturning.

Toe boards and guard rails should be provided to all sides as shown in Fig. 10.12. The ground under a mobile scaffold must be level and firm. While static, the castors should be facing outwards from the tower and be locked (brake on). No attempt should be made to move a mobile tower until the platform is totally clear of operatives and their equipment. Movement pressure should then only be applied from the base.

## 10.6 System scaffold (proprietary systems)

These systems (Figs 10.17 and 10.18), which can be adapted to suit all types of scaffolding situations, are either fully or partly standardised.

A fully standardised system consists of a number of interlocking components, each with its own built-in fixing device (slot, or pin and wedge) to simplify assembly.

Partly standardised systems may, for example, use a series of 'H'-frames in place of standards and main transoms, the rest of the scaffold being made up of traditional tubes, couplers, and fittings. Frame system



**Fig. 10.17** *Frame system scaffold*

scaffold uses fixed-length transoms and putlogs with couplers permanently attached to them and the rest of the scaffold is traditional. Partly standardised systems therefore offer the flexibility of traditional scaffolding plus some of the advantages of a full system.

### 10.6.1 Tower systems

*Note: All tower scaffolds should be tied to the building in the case of strong winds, blasting of the wall or where heavy materials are to be lifted. Ties should be checked on a regular basis.*

Figure 10.19 shows an assembled aluminium mobile tower. Access to the working platform is via a built-in integral ladder. Both Figs 10.19 and 10.20(a) show access towers with outriggers to provide greater stability, thereby allowing the working platform height to be increased (as stated by the manufacturers). Static towers can in some cases be linked together as shown in Fig. 10.20(b). Access to the working platform is in this case via a hinged trap door, which forms part of the working platform. All tower access systems must only be climbed from within the inside of the tower, using the built-in stair or ladder. There is a code of practice for the erection of aluminium scaffold produced by the Prefabricated Access Suppliers and Manufacturers Association (PASMA). This is available from all leading scaffold hirers.



**Fig. 10.18** RMD 'Kwikstage' scaffold system



**Fig. 10.19**    *SGB mobile tower*



(a)



(b)

**Fig. 10.20**    (a) *Static tower with stabilising outriggers; and (b) two static towers linked together*

## General

Erection and dismantling procedures for systems scaffolds should be carried out according to the maker's instructions and statutory legislation.

## 10.7 Inspection of scaffolding

*Note: Every employer must ensure that any scaffold used by their employees is safe and complies with the regulations.*

Scaffolds should be inspected by the constructor before they are handed over for use. Thereafter all types of scaffolding must be inspected at least once every week by a competent person, to ensure that all couplers are tight, braces and ties are secure, and platforms, their toe boards, guard rails, and access ladders are in good condition and held secure. Scaffold foundations should likewise be checked. Particular attention should be paid to checking the whole structure, or system, after inclement weather, for example, after strong winds, changes in temperature, or frost as this may have affected its safety or stability.

All inspections, except those of scaffolds under 2 m in height and trestle scaffolds, should be clearly assigned to a suitably experienced and qualified person whose duty should include the completion of reports required by The Construction (Health, Safety and Welfare) Regulations. All such reports must be made available to the Health and Safety Inspectorate.

## References

- HSE Information sheet General access, Scaffolds and ladders Information Sheet 49.
- The Construction (Health, Safety and Welfare) Regulations 1996.
- BS 5973: 1993, Section 9 – tying to buildings.
- BS 5973: 1993 Code of practice for access and working scaffolds and special scaffold structures in steel.
- BS EN 39: Metal scaffolding.
- BS EN 39: 2001 Specification for tubes for use in scaffolding.
- BS 1139-2.1: 1991 Specification for couplers and fittings for use in tubular scaffolding.
- BS 1139-3: 1994 Specification for pre-fabricated access and working towers.
- BS 1139-4: 1982 Specification for prefabricated steel splitheads and trestles.
- BS 1129: 1990 Timber ladders, steps, trestles, and lightweight stagings.
- BS 2037: 1994 Aluminium ladders, steps, and trestles for the building and civil engineering industries.
- BS 2482: 1981 Specification for timber scaffold boards.

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