N4 Building and Structural Construction

Gateways to Engineering Studies - Chris Brink

HYBRID LEARNING SOLUTIONS

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Building & Structural Construction N4

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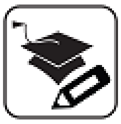
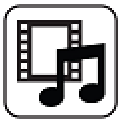
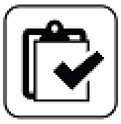
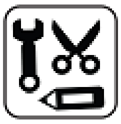
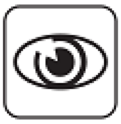
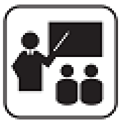
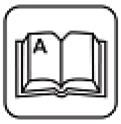
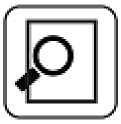
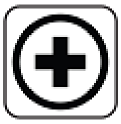
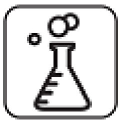
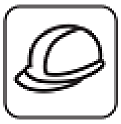
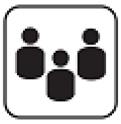
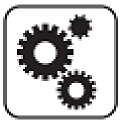
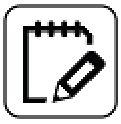
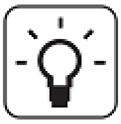
	Assessment / Activity		Multimedia
	Checklist		Practical
	Demonstration/ observation		Presentation/ Lecture
	Did you know?		Read
	Example		Safety
	Experiment		Site visit
	Group work/ discussions, role-play, etc.		Take note of
	In the workplace		Theoretical – questions, reports, case studies, etc.
	Keywords		Think about it

Module 1

Foundations

Learning Outcomes
On the completion of this module the student must be able to:

- Describe foundations for
  - solid walls up to two bricks thick
  - cavity walls up to double storey height (proportionate and to standard building regulations)
- Describe typical concrete mixes used in foundations

1.1 Introduction

There are many reasons for using foundations. Foundations serve as levelled bases for walling as the foundation spreads the weight of the wall and it's supporting parts over a wider area, preventing punching into ground or sagging of sections of building.

They prevent overturning in soft soils and provide a linked frame for the building to rest upon. This is particularly valuable when the site is water-logged. An indirect support for floors is provided.

1.2 Investigation of building site

Except where otherwise permitted in terms of the provisions of regulation 23, every building site shall be investigated from the point of view of soil conditions that will affect the foundations by a person who to the satisfaction of the Engineer is qualified by training and experience to do so, and if required by the engineer a copy of the report of the site investigation shall be lodged in his office.

Except where the engineer permits otherwise such investigation shall include one or more soil profiles recorded.

1.3 Provision of stable (firm) foundation

Every building, wall, or structure shall be supported on a stable foundation designed and constructed to transmit safely to the subsoil the total load to be carried by the foundation without undue differential settlement of the building or structure.

Provided that the engineer may permit the omission of such foundation where the building is supported directly on rock: the classification of a subsoil or to require or to dispense with the making of a site investigation or the recording of one or more soil profiles on the building site shall not involve the local authority in any responsibility for the safety of the proposed building or structure.

1.3 Made-up ground

No foundation shall bear on fill or other made-up ground except where special prior investigation has been made and a report (which includes the necessary precautions) lodged with the engineer. In such case the specified precautions shall be taken in full.

1.4 Foundations to be horizontal or horizontally stepped

All foundation bottom surfaces shall be horizontal or in the form of steps with-horizontal and vertical surfaces. Where such steps are made into the longitudinal section of the foundation, the portions of the foundation on adjacent levels shall overlap for a distance at least equal to the vertical thickness of the foundation or the difference between adjacent levels, whichever is greater.

1.5 Empirically constructed foundations

In any case where the engineer is satisfied from a knowledge of the subsoil conditions ill the locality within which a proposed building is to be situated or from experience of the behavior of building in such locality, that it would not endanger a proposed building to do so, he may permit the erection of such building without a site investigation.

1.6 Concrete

Concrete is one of the most important materials used in building construction.

Concrete is composed of a mixture of Portland cement, a fine aggregate (sand), a coarse aggregate (crushed stone) and water. After being mixed thoroughly the concrete mixture is very plastic and is therefore suitable for use in forms of various shapes or for casting on surfaces of soils. Hence its use for floors, foundations, beams, lintels, columns, stairs, retaining walls and many other items in building construction.

The hardening period for concrete, after mixing is completed, depends upon a great many factors, which also determine the strength of the concrete. Some of these are the:

- quantity of water used
- grading of the aggregates
- ratio of the materials

- time taken by mixing
- vibration after mixing
- weather conditions
- curing after casting

These are all important factors which determine a good concrete and the strength and life or durability of the concrete.

Concrete in its correct form or mixture hardens with age, which makes it one of the most ideal building materials available.

The following materials are used for making concrete.

1.6.1 Portland cement

Portland cement is manufactured by quarrying and crushing limestone and clay or shale, proportioning and grinding it into a raw mix and then processing it by burning it into a cement clinker and finally grinding the clinker into a finished Portland cement. This fine powder is packaged into 50 kilogram bags.

Did you know?

The development of Portland cement is credited to a brick mason of Leeds, England, a certain Joseph Aspdin, in the year 1824. He called his discovery Portland cement because it resembled a natural stone found on the Isle of Portland.

Portland cement is manufactured in various types, each to suit a particular purpose, namely:

- Ordinary Portland cement used for general purposes. It has a medium setting period.
- Rapid-hardening Portland cement used for special purposes where speed of setting is important.
- High alumina Portland cement ultra-rapid hardening cement which sets within 24 hours
- Blast-furnace Portland cement a cement and with a medium setting period.

1.6.2 Fine aggregate

Coarse sand is better than fine sand for concrete. Sand should be graded from coarse to fine size. This is preferable to a uniformly coarse or uniformly fine sand. Sand should be durable, hard and free from excessive amounts of clay, loam, silt, mica, shale or other organic matter.

The sand should be such that 90° of the particles will pass a sieve of 4,75 mm square openings.

The most popular sands used for the making of concrete are river sand and crusher sand. River sand is a washed sand from river beds and is of rounded particles of a variety of sizes up to 4,75 mm diameter.

Crusher sand is the remains of the crushed stone used in coarse aggregates. Crusher sand is a well graded cubical and angular particle shaped stone of maximum size 4,75 mm and is superior to river sand if properly graded. Crusher sand can withstand a high compressive loading and also contamination with impurities.

1.6.3 Coarse aggregate

This must be a stone of suitable hardness and strength, such as granite, dolerite, dolomite or quartzite. The stone used must not flake, expand or powder and must not contain impurities which will deteriorate with age or on contact with water or cement.

Note:
Impurities in the stone, such as coal, chalk and mica, should be avoided.

Coarse aggregate consists of stone of such a size that at least 90% of them will not pass through a sieve of 4,75 mm square openings 40 mm stone is suitable for foundations to walls and floor slabs over 152 mm thick.

For small floor areas or floor slabs of 152 mm and less, beams, lintels, columns, stairs and paving, 20 mm stone is suitable as an aggregate for use in the concrete. For very large volumes of concrete, stone of up to 76 mm may be used with graded aggregate (small stone) to fill the voids.

For concrete used in the construction of dams, crushed rocks of maximum size 150 mm are often used. For reinforced concrete work under normal conditions 20 mm aggregate is generally used.

1.6.4 Water

The water used for making concrete must be clean and free from clay and silt and such amounts of oil, acid, alkali and organic or other matter as could impair the required strength of the concrete.

Note:
The strength and workability of concrete depend to a great extent on the amount of water used in mixing.

Too small an amount of water decreases the strength of concrete and produces an unworkable concrete. An excessive amount of water produces low-strength concrete which tends to shrink excessively and is therefore not very dense or durable.

To ascertain the correct quantity of water to use in the mixture and *water:cement* ratio formula is used and test cubes of the mixture, 150 mrn x 150 mm x 150 mm are cast and tested after the lapse of a period of days.

The amount of water used can then be adjusted in order to produce a concrete of maximum strength.

1.7 Curing of concrete

This means the maintenance of a proper temperature · and moisture condition during the setting period of the concrete, to improve the chemical reaction between the cement and water.

This is done by either wetting or covering the concrete surface with wet bags, wet canvas or wet sand as soon as the concrete has set hard enough to receive this covering material' without damage to its surface.

The curing period will vary according to weather conditions but is usually seven days. for ordinary concrete, and three days for rapid hardening cement concrete.

1.8 Vibration of concrete

When using mechanical vibratory equipment to vibrate concrete, strict control of the period of vibration is necessary, since too long use of vibrations in one area will cause the heavier aggregates (stone) to settle at the bottom and will raise the fine cement and water to the concrete surface.

Furthermore, this mechanical equipment when used must NOT touch the outer edges of the concrete or the formwork, boxing or shuttering.

Activity 1.1

1. Describe the foundations required for solid walls up to two bricks thick.
2. Describe how to build foundations for cavity walls to double storey height according to building regulations.
3. Discuss the typical concrete mixes that are used in foundations.

Self-Check

I am able to:	**Yes**	**No**
• Describe foundations for		
o solid walls up to two bricks thick		
o cavity walls up to double storey height (proportionate and to standard building regulations)		
• Describe typical concrete mixes used in foundations		

If you have answered ‘no’ to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Module 2

Bonds in Brickwork

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the following wall bonds up to two bricks thick (solid)
  - English
  - Stretcher
  - Garden wall
- Describe cavity walls up to double storey
- Explain the use of concrete buildings blocks
- Explain quoins and T-junctions with stopped ends
- Explain wall binding for external facing

2.1 Introduction

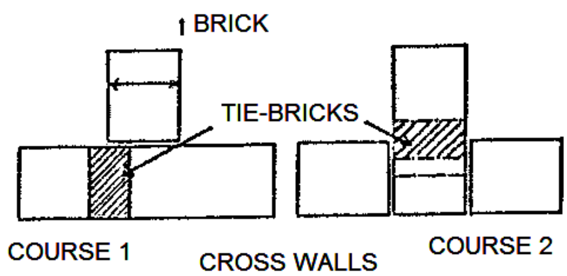
In this module you will learn about the bonds in brickwork. We will consider a number of different types of bonds used. As well as brick bonding in right-angled corners, tee and cross junctions

2.2 Bonding

Before attempting any bonding problems we shall discuss the six rules of bonding which, if studied, should enable you to solve any bonding problem that may crop up during your career.

2.2.1 Rules of Bonding

When applying the rules of bonding, consider the brickwork to be blocks laced together, each block consisting of units, the units being bricks as seen in **Figure 2.1**.



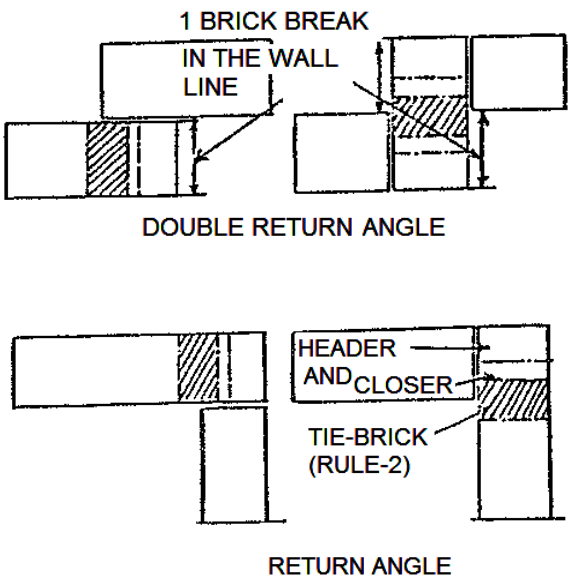


Figure 2.1 Rules of brick bonding

1. To maintain quarter-bond, a closer must follow the corner header as seen in **Figure 2.2**.

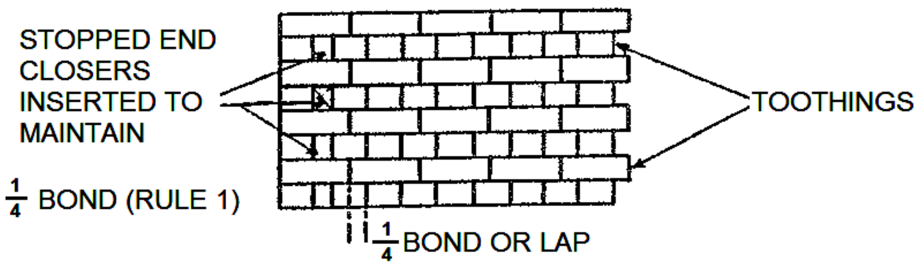


Figure 2.2 English bond

The exceptions to the rule are:

a) When maintaining “sectional bond”, a three-quarter bat is sometimes used as seen in **Figure 2.3**.

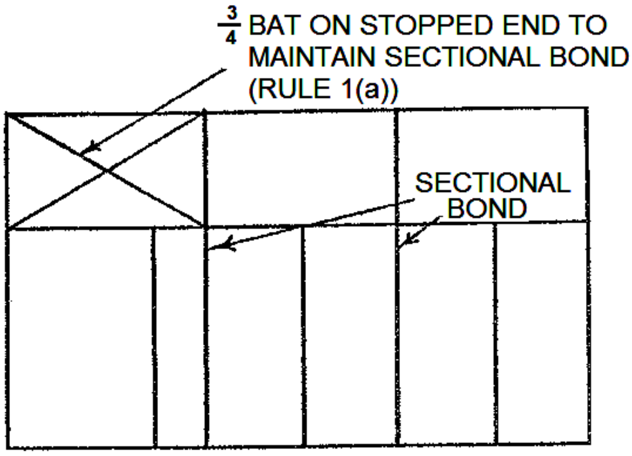


Figure 2.3 Diagram showing a ¾ bat

b) In some types of bond, a three-quarter bat is used on the corner.

2. At the junction of the two walls the "tie-brick", which can be either header or stretcher, Is always in the block that runs directly through to the face of the brick wall, and shows on the internal angle as either 1/4" or 3/4" bat.

   Contained in the same block are either the corner headers and closer or the corner three-quarter (see **Figure 2.4)**. It is often expressed as "the tie-brick is opposite the corner closer or three-quarter", as the case may be.

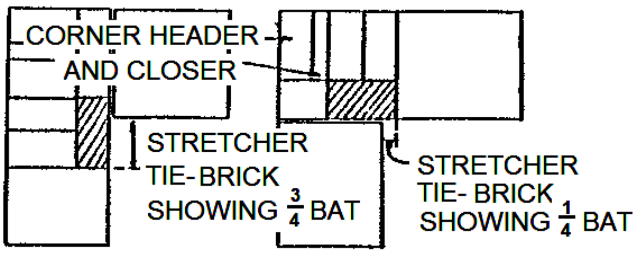


Figure 2.4 Tie-brick

3. All vertical joints going across the wall must go through direct, unless interrupted by a stretcher. This is termed "sectional bonding", and if sectional bonding is not adhered to, straight joints will occur (**Figure 2.5** and **Figure 2.6**).

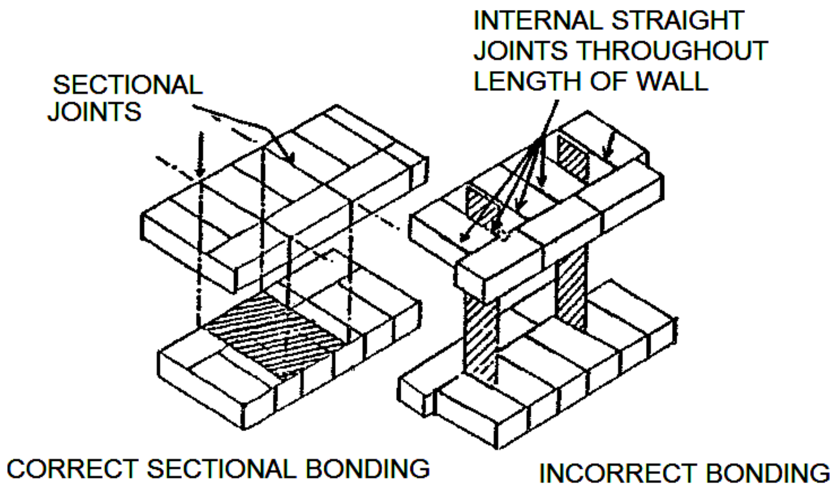


Figure 2.5 English bond

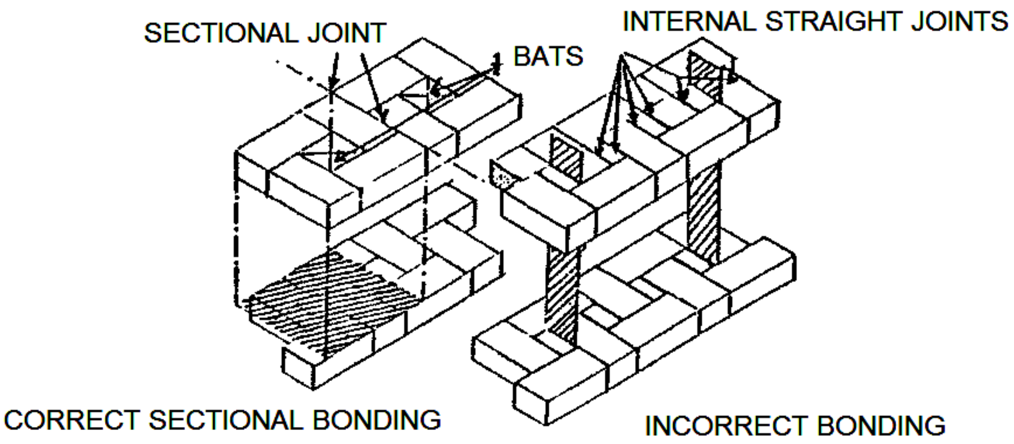


Figure 2.6 Flemish bond

4. The interior of a wall, looking from the face, must be of headers only. Thus, on cutting through a wall and showing its section it will be found to be in half-bond and any stretcher used on the interior would cause a straight joint, as seen in **Figure 2.7**.

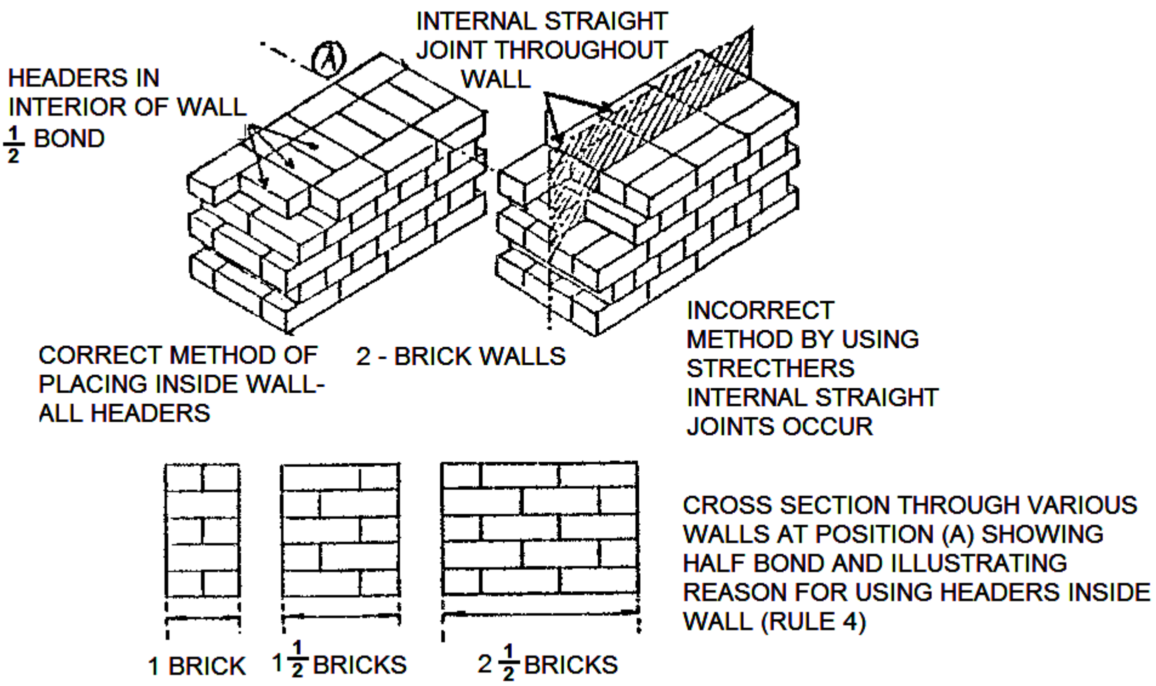


Figure 2.7 English bond

Exceptions to this rule are:

a) In Flemish bond it is sometimes necessary to use half-bats, as seen in **Figure 2.6**.

b) In the construction of footings and corbels.

In English bond, the following additional rules should be noted:

5. In every change of direction on the same course, the bond changes as seen in **Figure 2.8**).

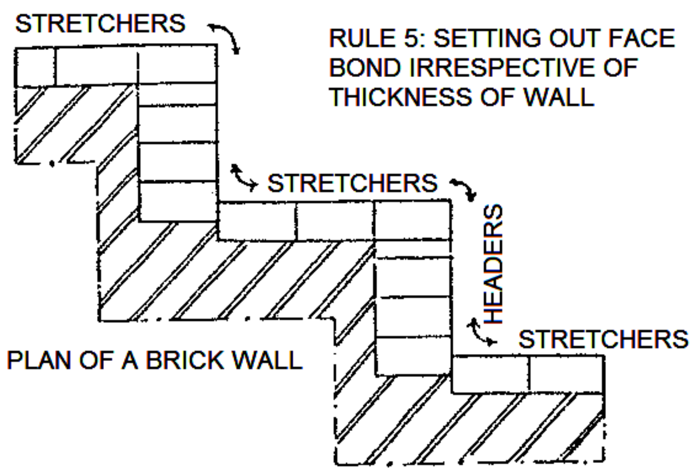


Figure 2.8 English bond

Exceptions to this rule are:

a) Certain circumstances, where two walls of differing thicknesses tie into each other, as seen in **Figure 2.9**.

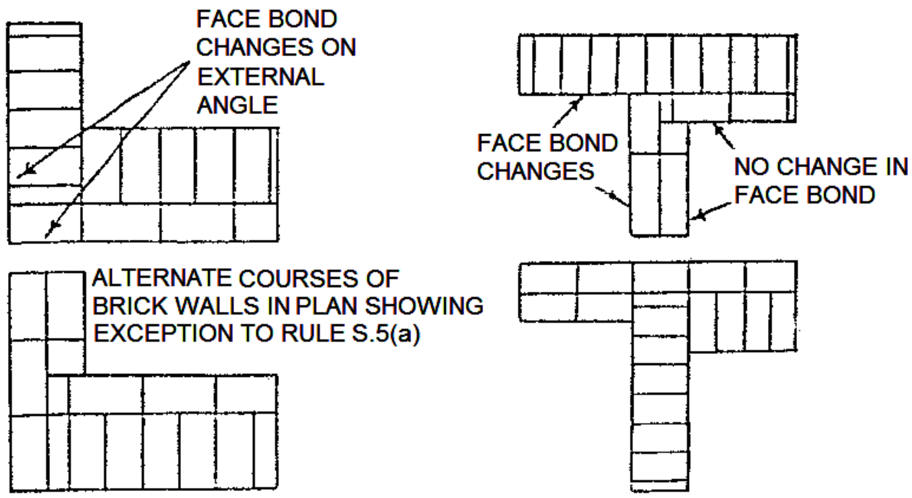


Figure 2.9 English bond

b) In "breaks" of less than a ½ brick the rule does not apply, unless instructions are received from the architect. See **Figure 2.10**.

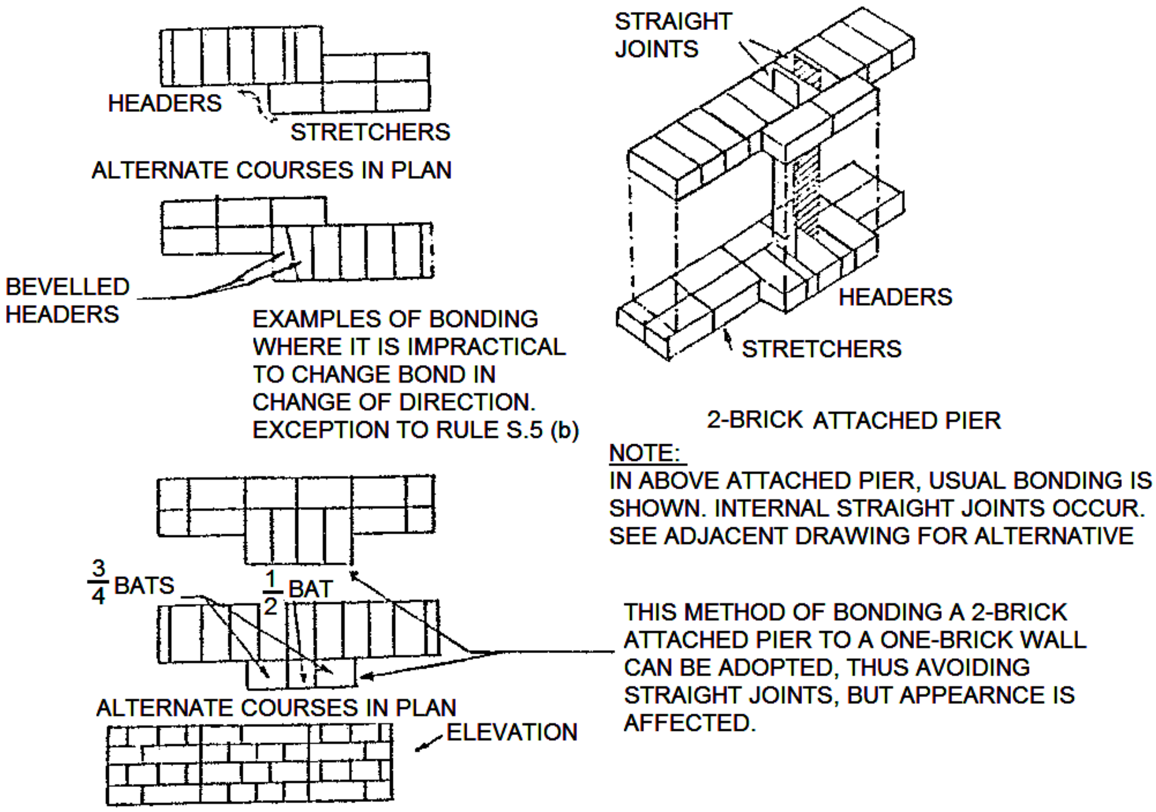


Figure 2.10 ½ Brick bonding

Where there is an even number of bricks in the thickness of the wall, headers show on both sides of the wall. Where there is an odd number of bricks in the thickness of the wall, headers show on one side of the wall and stretchers on the other, as seen in **Figure 2.7**.

Use whole bricks wherever possible; if the first two courses have been set out correctly they will repeat themselves and the perpends, or vertical joints, in every other course will be upright or "plumb".

The bricklayer checks this by plumbing perpends at every three feet or so along the wall, course by course.

Having considered the rules, we can now apply them in order to set out some bonding problems.

2.3 English bond

2.3.1 Two brick walling in English bond

Figure 2.11 to **Figure 2.13** illustrates the bonding between two two-brick walls both built in English bond.

- **Quoin**

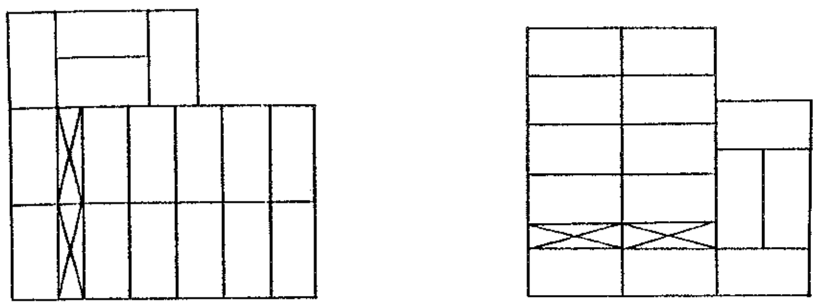


Figure 2.11 Quoin

- **Stopped intersection (T-junction)**

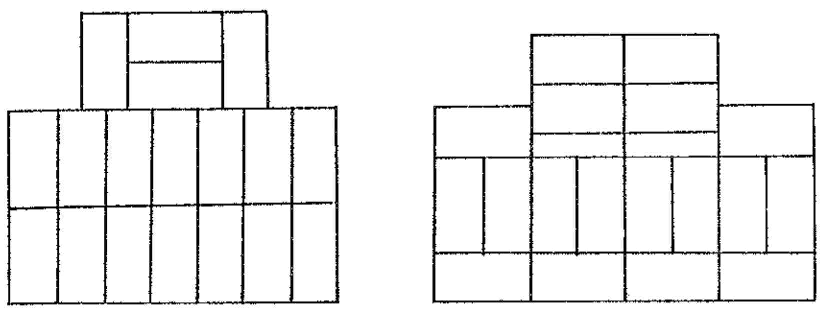


Figure 2.12 Stopped intersection (T-junction)

- **Crossed intersection**

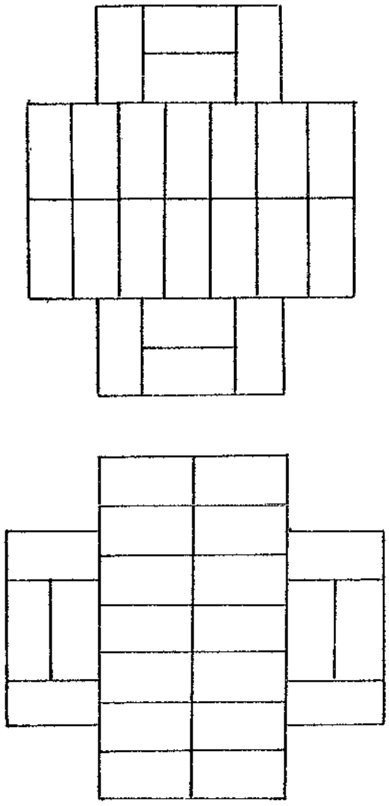


Figure 2.13 Crossed intersection

2.3.2 Stopped intersection (T-junction) between two-and-a-half brick and two-brick wall

Figure 2.14 illustrates the above.

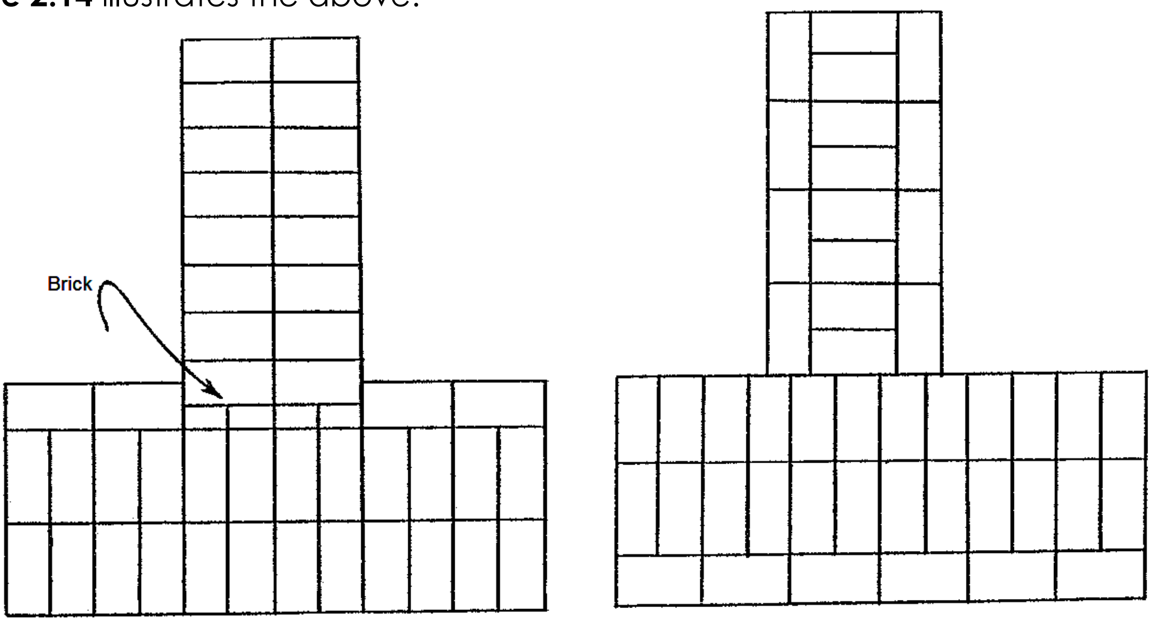


Figure 2.14 T-junction between a two-and-a-half brick and a two-brick wall both in English bond.

2.3.3 Two-and-a-half brick walling in English bond

Figure 2.15 to **2.17** illustrates the bonding between two-and-a-half walls, built in English bond.

- **Quoin**

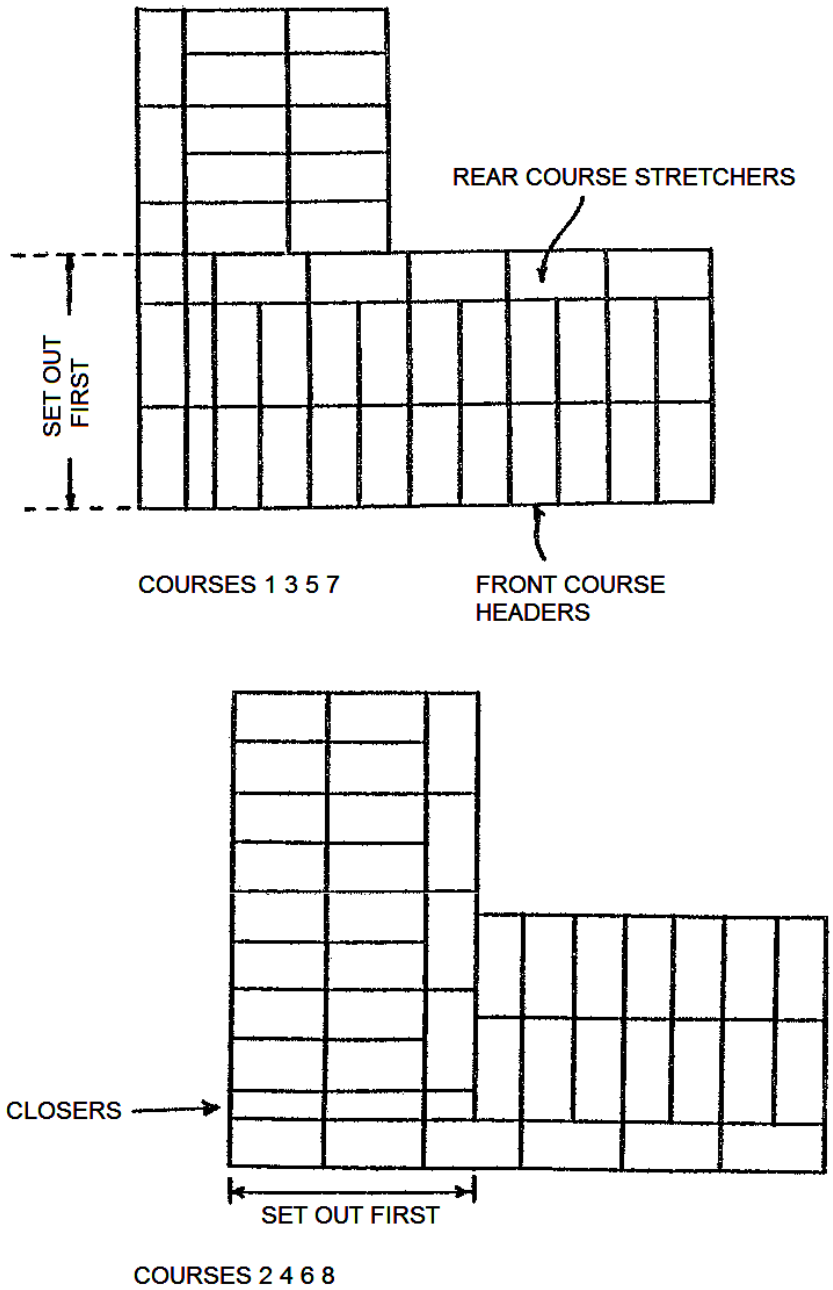


Figure 2.15 Quoin

- **Stopped intersection (T-junction)**

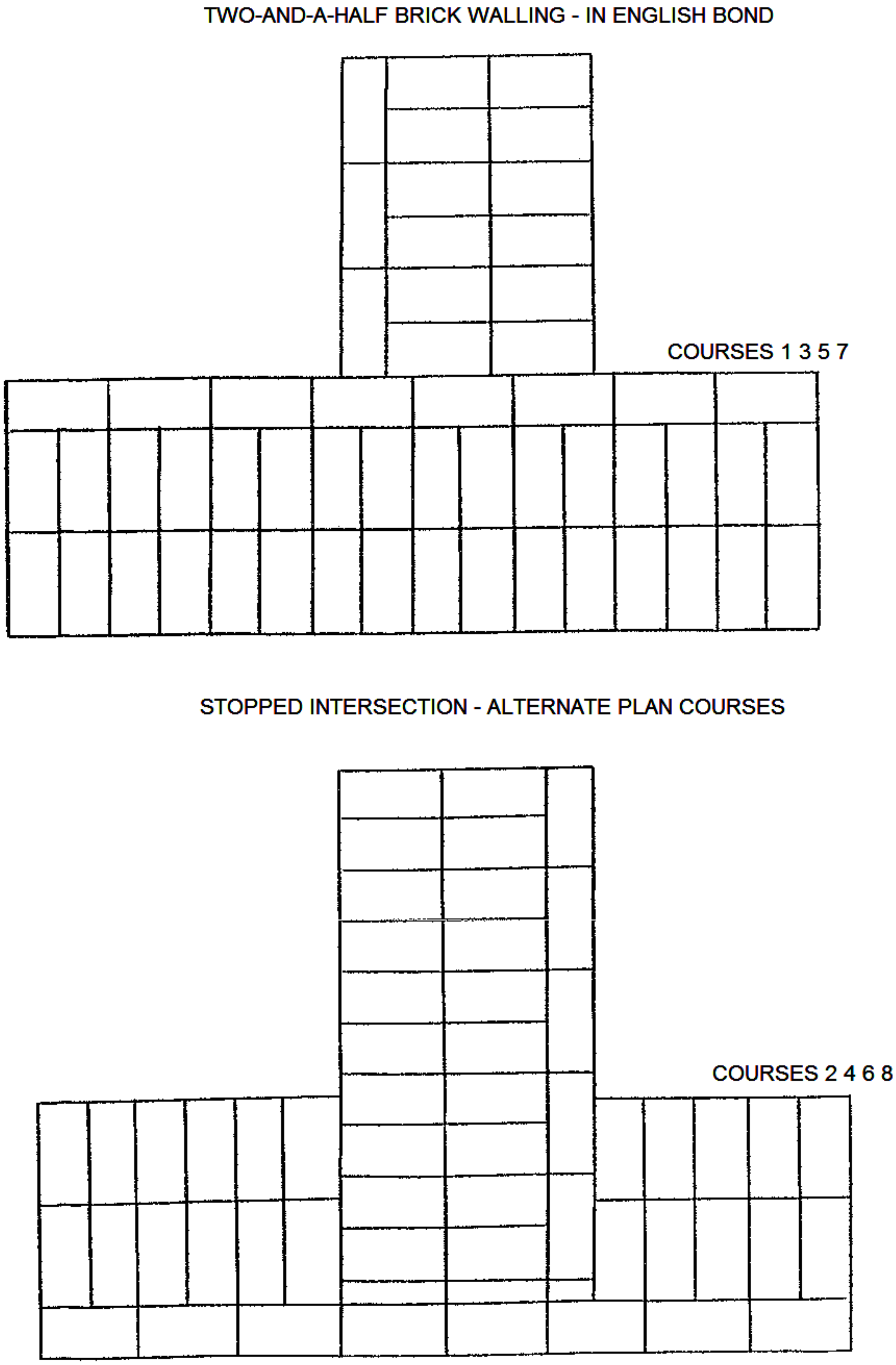


Figure 2.16 The alternate plan courses of a stopped intersection in English bond between two two-and-a-half brick walls.

- **Crossed intersection**

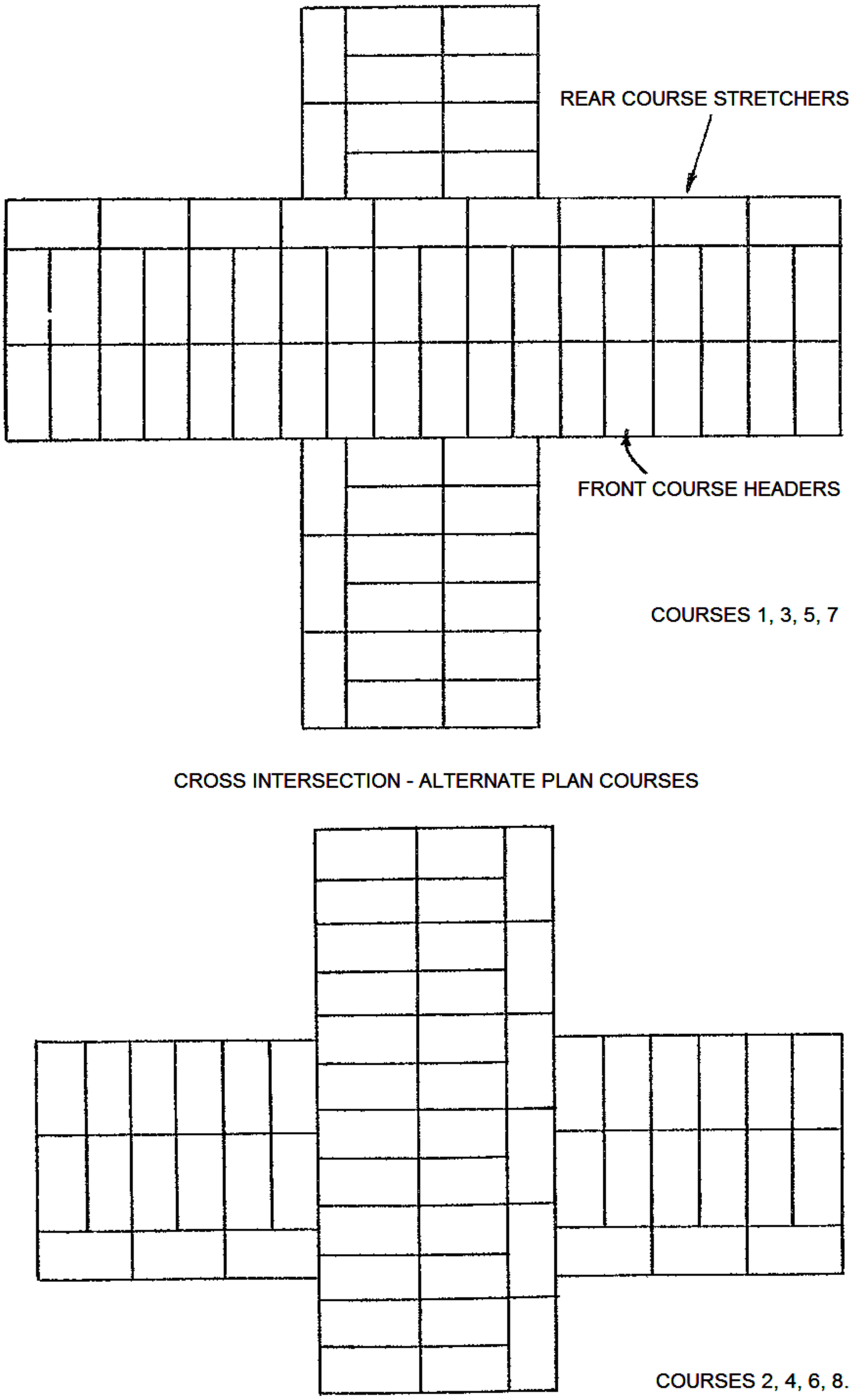


Figure 2.17 The alternate plan courses of a crossed intersection between two two-and-a-half brick walls

2.3.4 Stopped intersection between two-and-a-half brick wall in English bond and three-brick wall in Flemish bond

Figure 2.18 illustrates the above

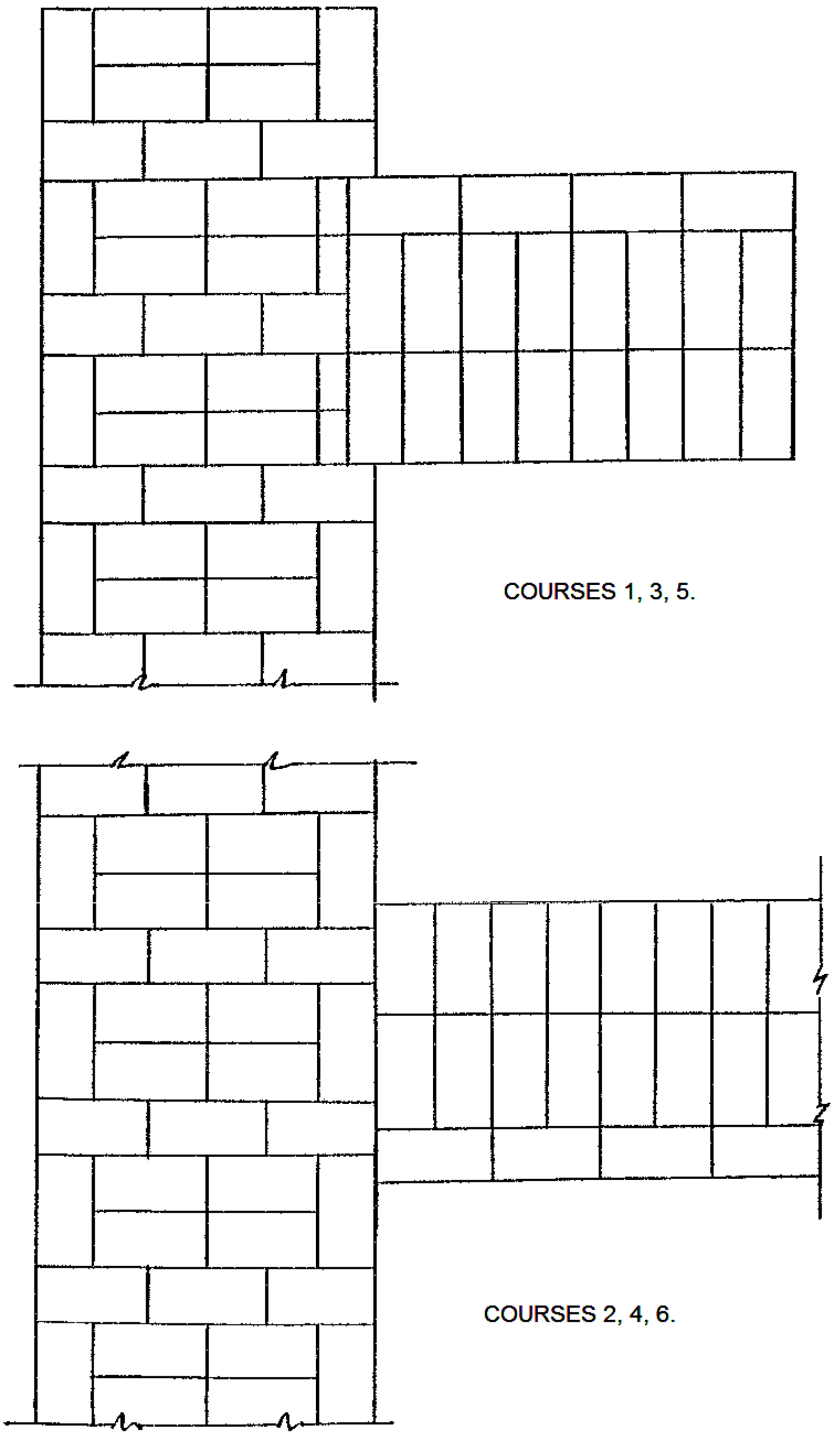
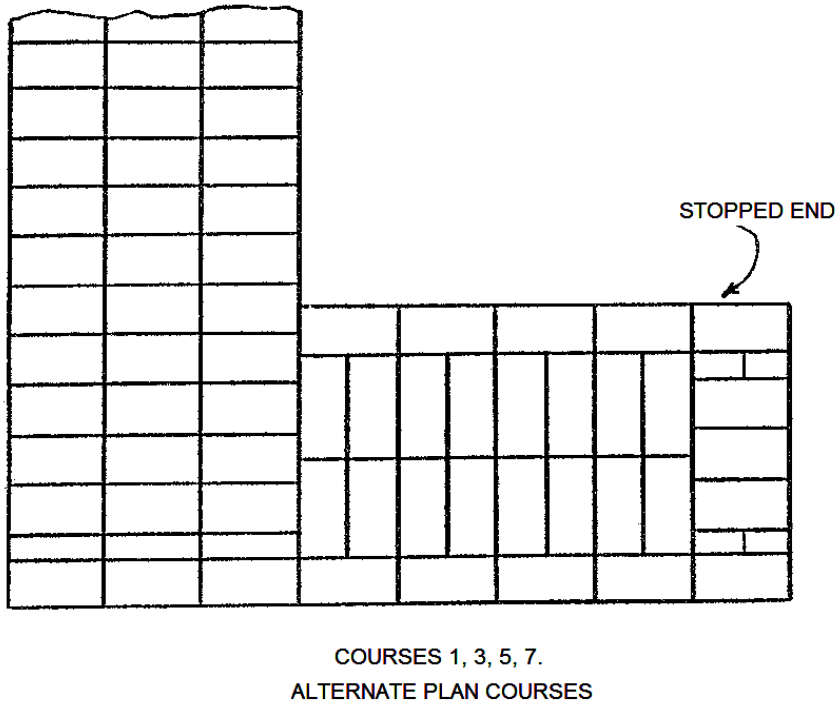


Figure 2.18 T-junction between a three-brick wall in Flemish bond, and two-and-a-half brick wall in English bond.

2.3.5 Three-brick walling in English bond

Figure 2.19 to **2.22** illustrates the bonding between three-brick walls, built in English bond.

- **Quoin**



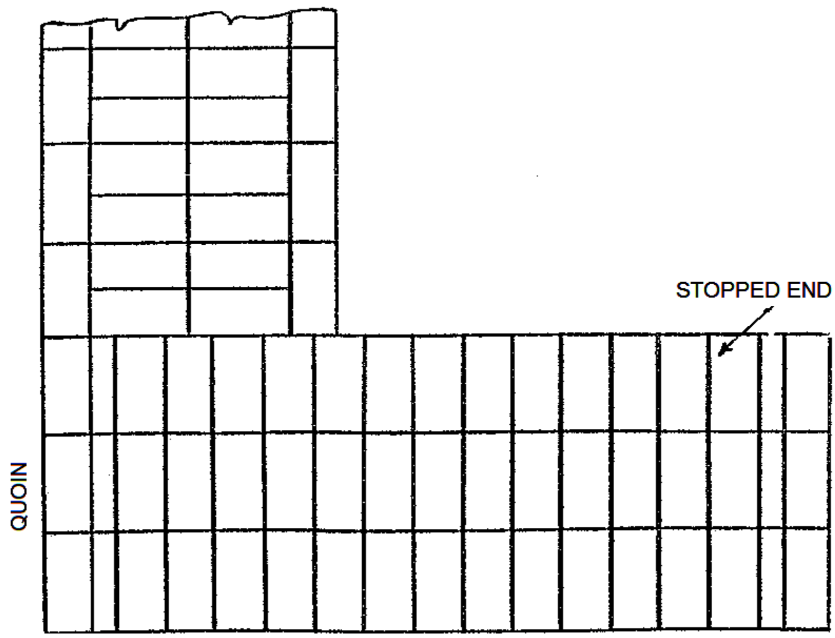


Figure 2.19 The alternate plan course of a quoin in English bond between two three-brick walls.

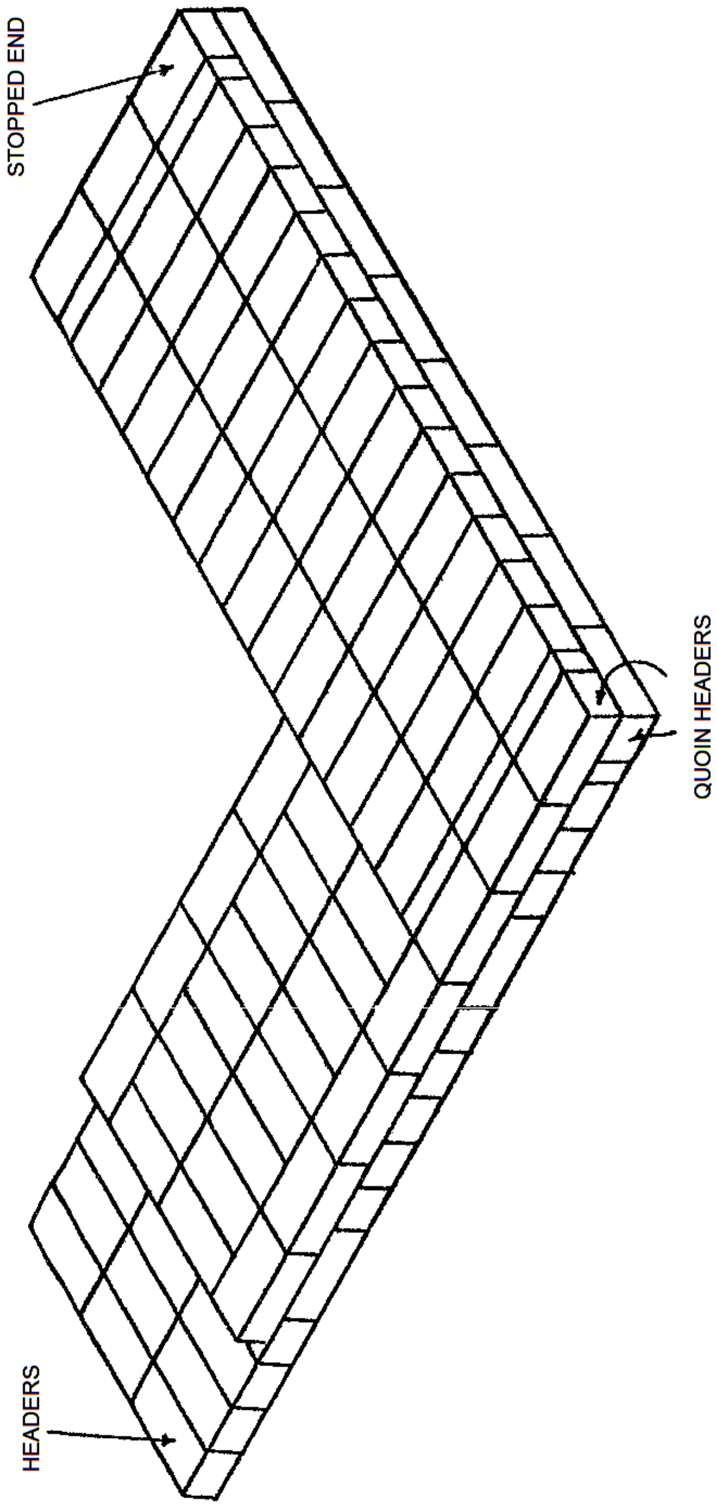


Figure 2.20 Isometric view of a Quoin in three-brick walling - English bond

- **Stopped intersection (T-junction)**

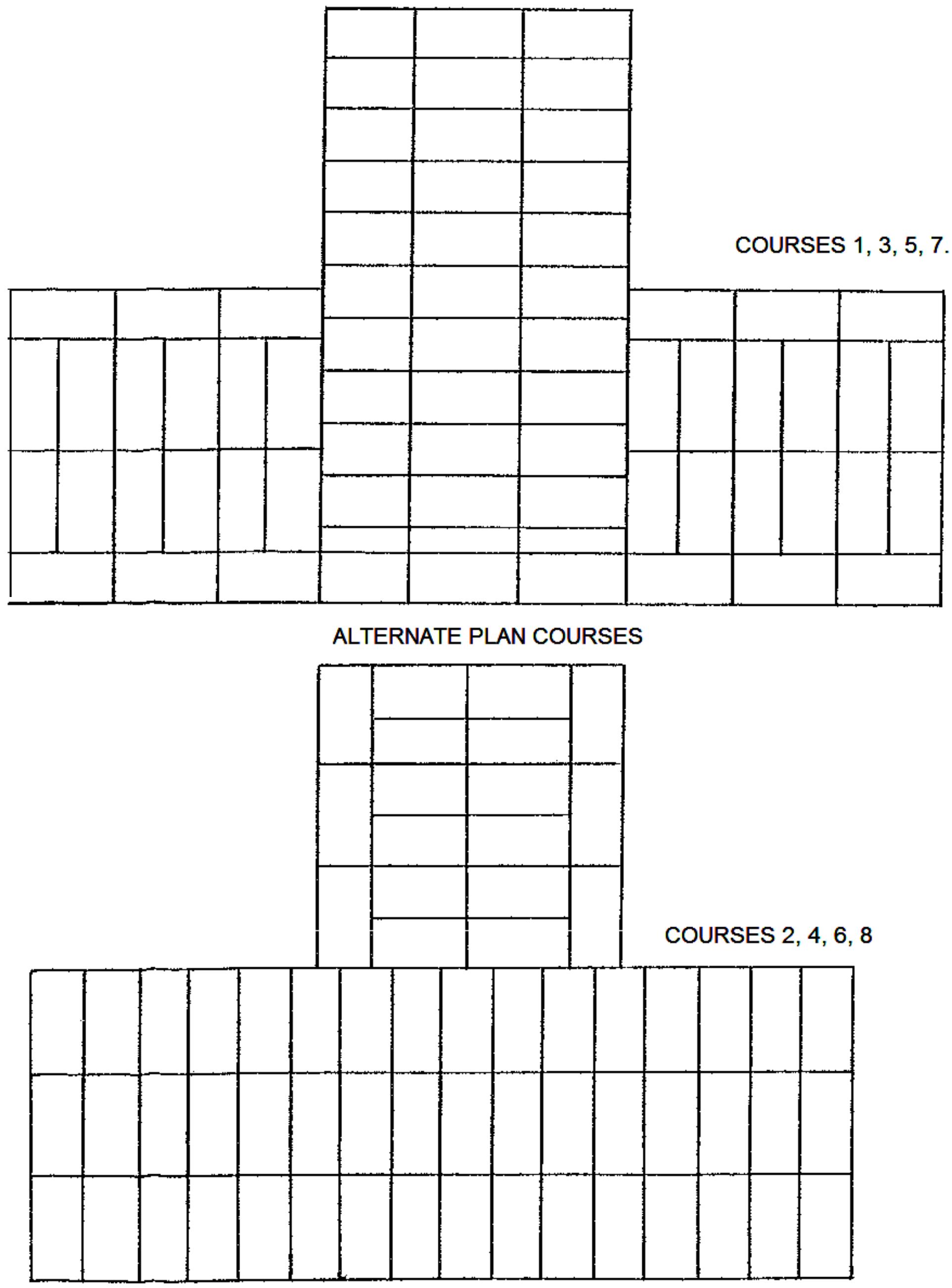


Figure 2.21 The alternate plan courses of a stopped intersection between two three-brick walls laid in English bond

- **Crossed intersection**

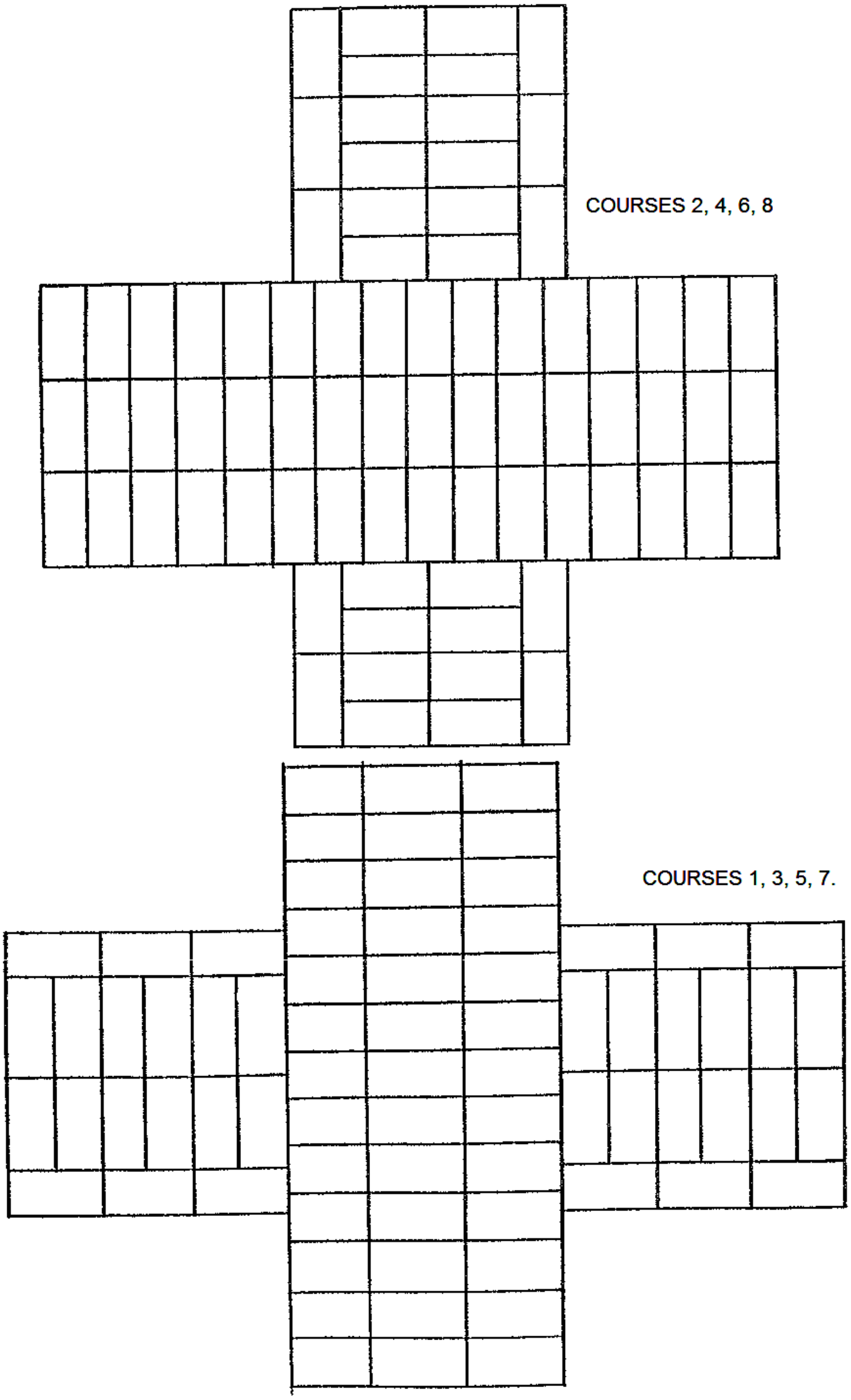


Figure 2.22 Alternate plan courses of a crossed intersection between two three-brick walls laid in English bond

2.3.6 Crossed intersection between three and two brick wall

Figure 2.23 illustrates the above.

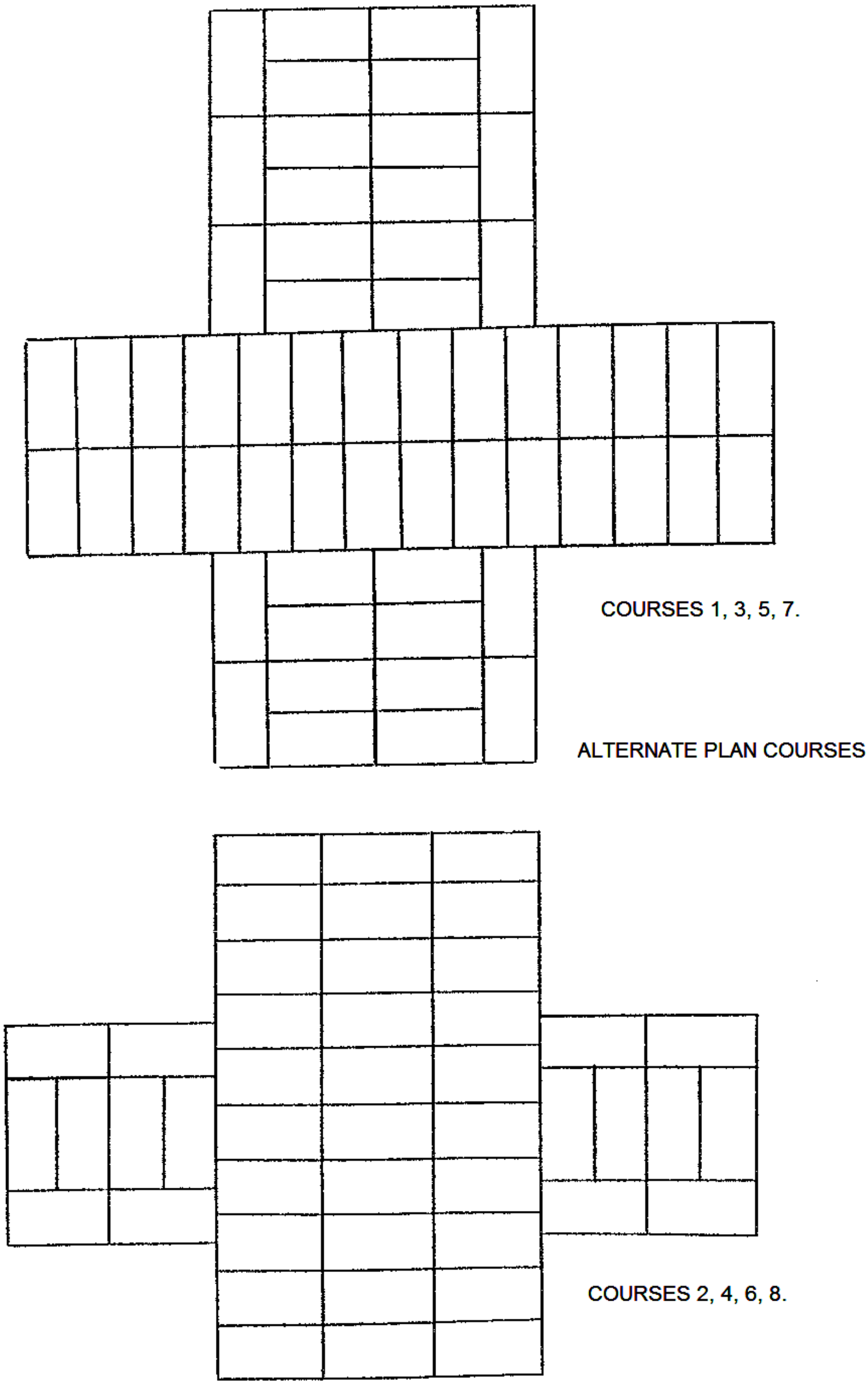


Figure 2.23 Crossed junction between three brick main wall, and a two brick wall

2.3.7 Isolated piers in English bond

Figure 2.24 to **Figure 2.27** illustrates the bonding for isolated piers.

- **Two-brick square**

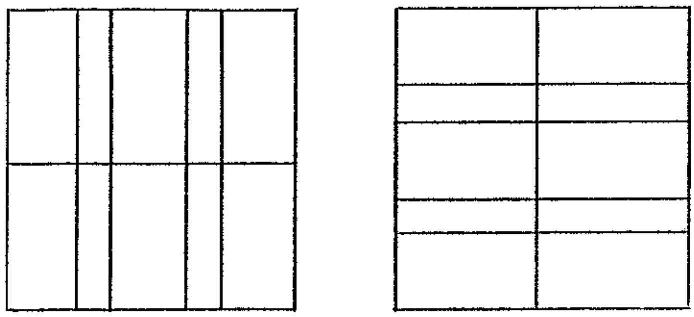


Figure 2.24 The orthographic plan course of an isolated pier two bricks thick drawn in English bond.

- **Two-and-a-half brick square**

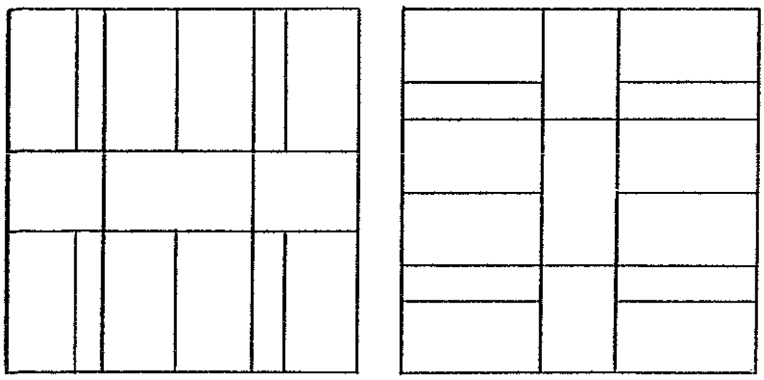
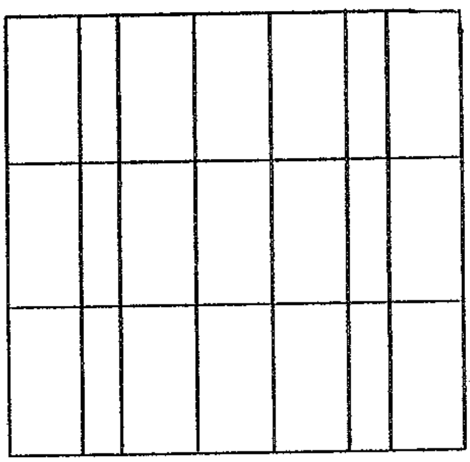


Figure 2.25 The orthographic plan course of an isolated pier two-and-a-half bricks thick dawn in English bond

- **Three-brick square**



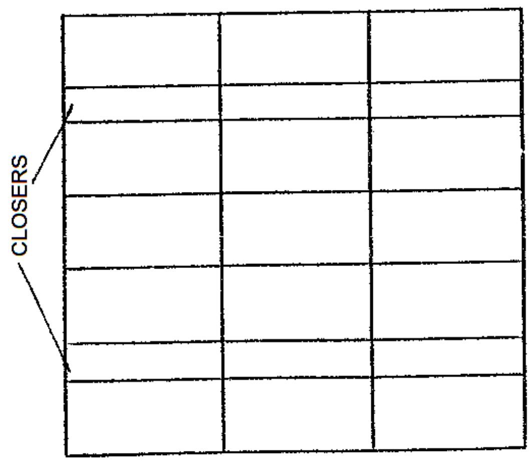
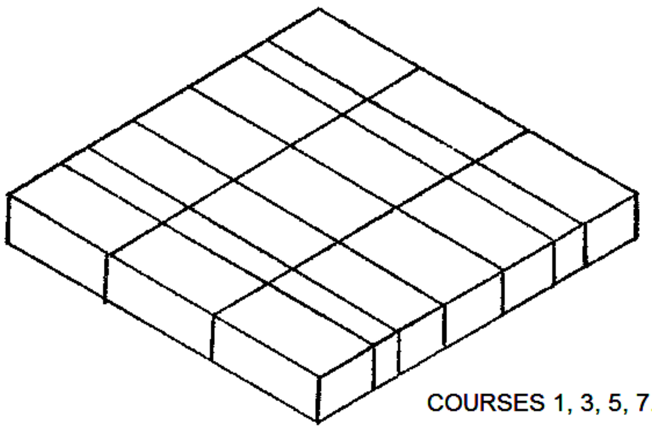


Figure 2.26 The orthographic drawing of a three-brick isolated pier drawn in English bond



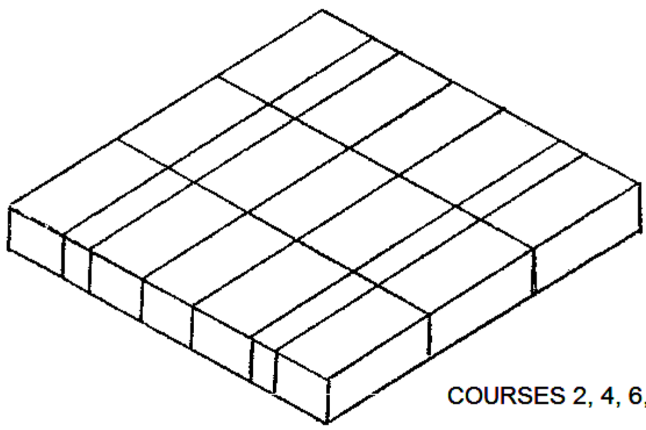


Figure 2.27 The isometric drawing of a three-brick isolated pier drawn in English bond

2.4 Flemish bond

2.4.1 Two brick walling in Flemish bond

Figure 2.28 to **Figure 2.31** illustrates the bonding for two brick walls, in Flemish bond.

- **Quoin**

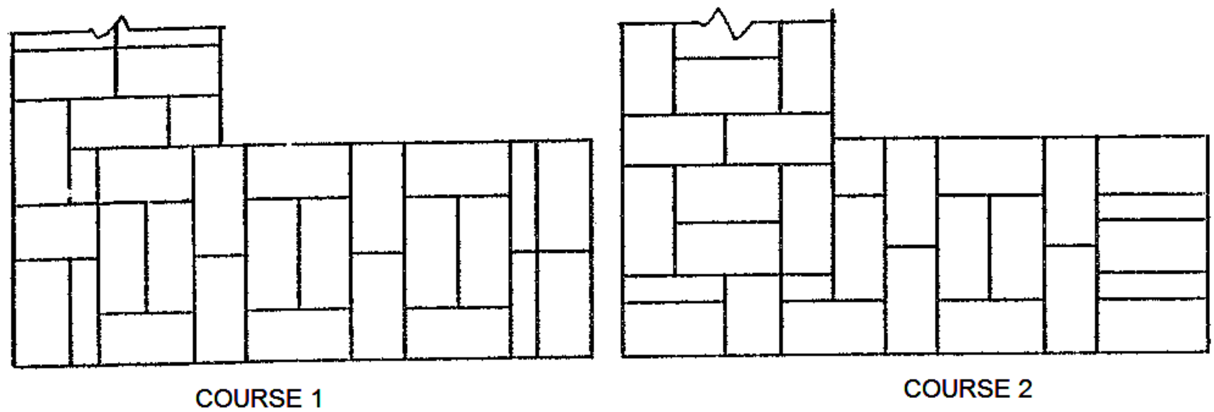


Figure 2.28 Alternate plan course of a quoin in two-brick walling

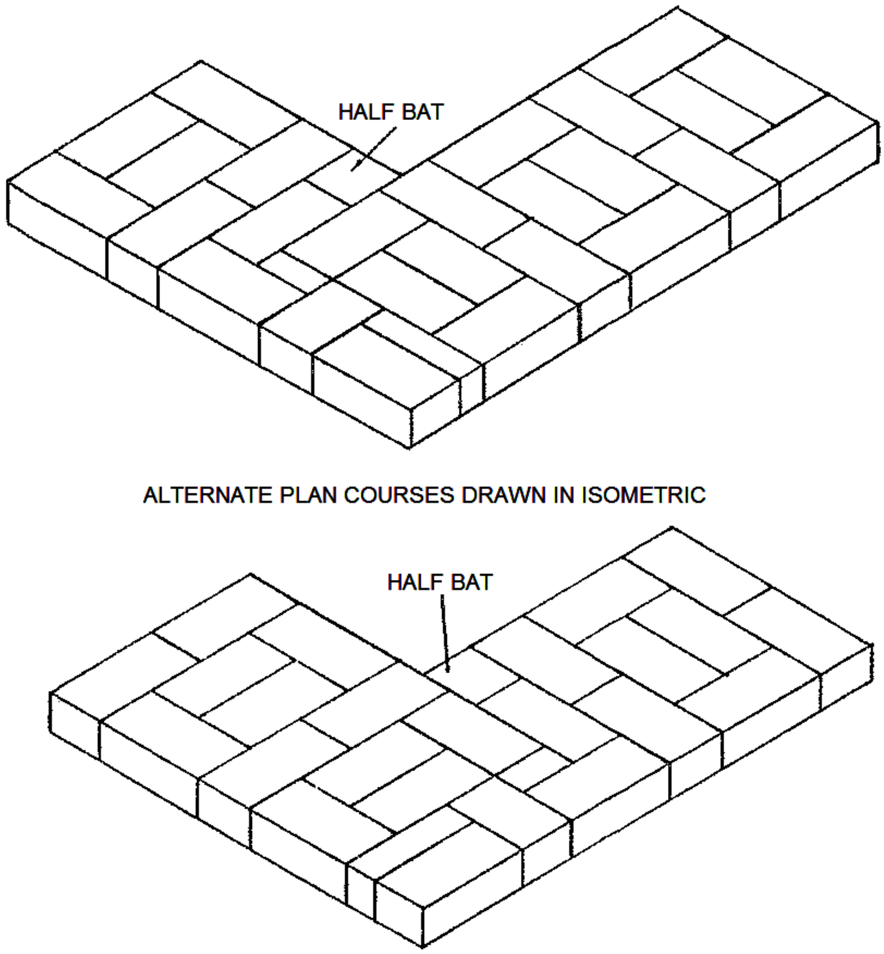


Figure 2.29 The alternate plan courses of a double Flemish bond quoin in two-brick walling. The drawing is done in isometric projection.

- **Stopped intersection (T-junction)**

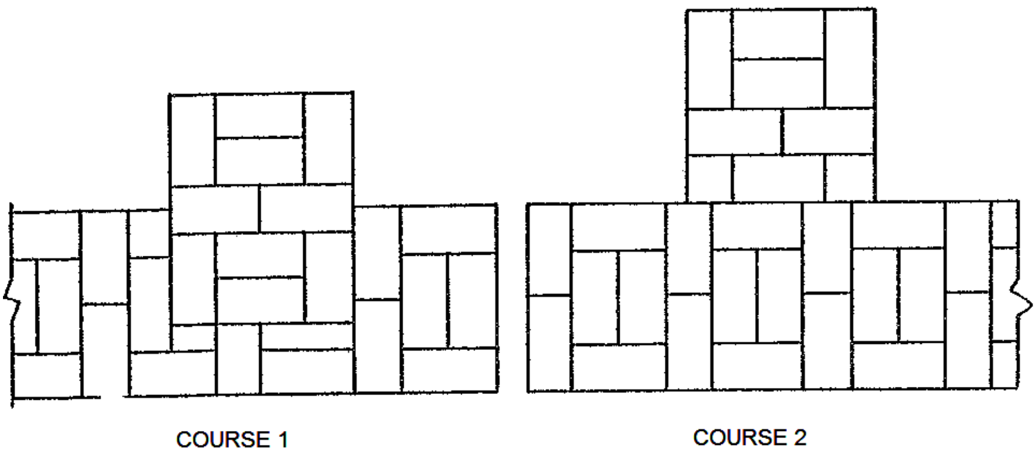


Figure 2.30 Alternate plan courses of a stopped intersection in two-brick walling

- **Crossed intersection**

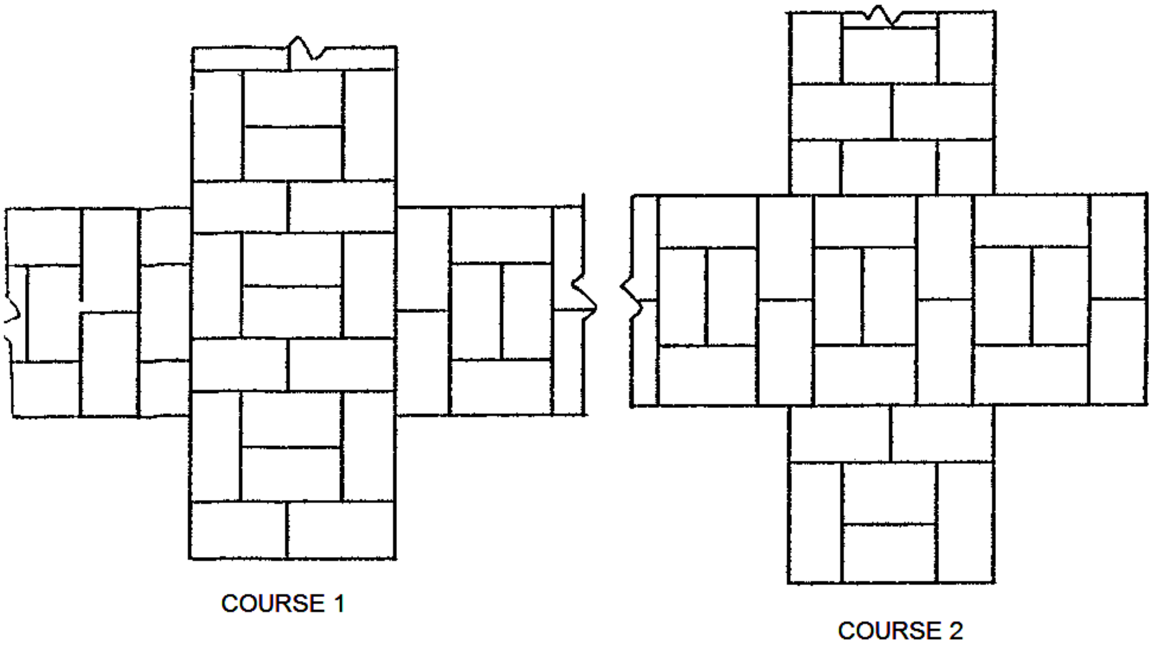


Figure 2.31 Alternate plan courses of a cross intersection in two-brick walling

2.4.2 Two-and-a-half brick walling in double Flemish bond

Figure 2.32 to **Figure 2.35** illustrates the bonding for two-and-a-half brick walls, in Flemish bond.

- **Quoin**

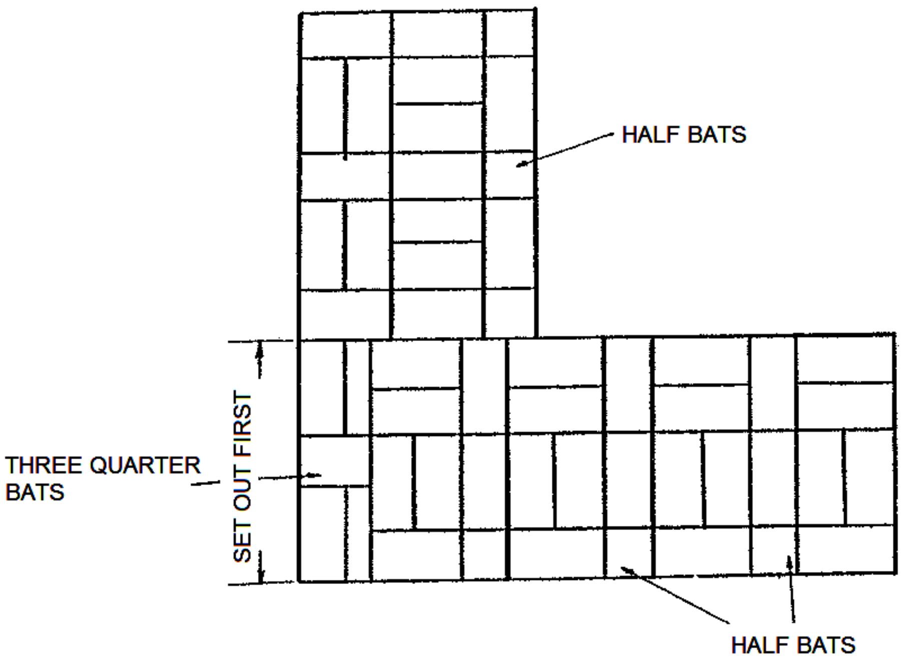


Figure 2.32 The alternate plan courses in double Flemish bond of a quoin

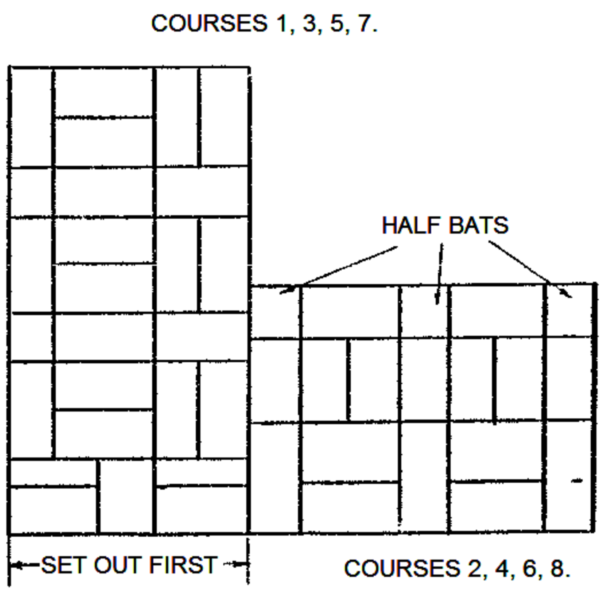


Figure 2.32 The alternate plan courses in double Flemish bond of a quoin (continued)

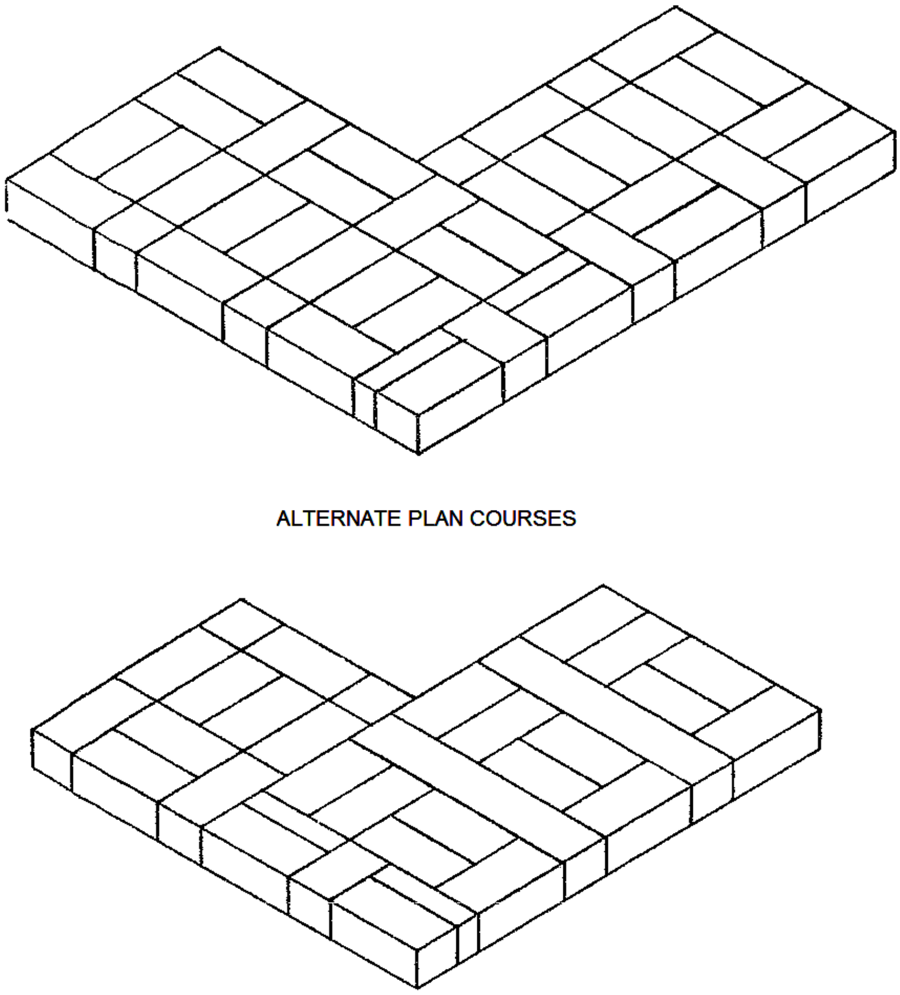


Figure 2.33 The alternate plan courses of a quoin two-and-a-half brick double Flemish bond. The drawing is in done in Isometric projection.

- **Stopped intersection (T-junction)**

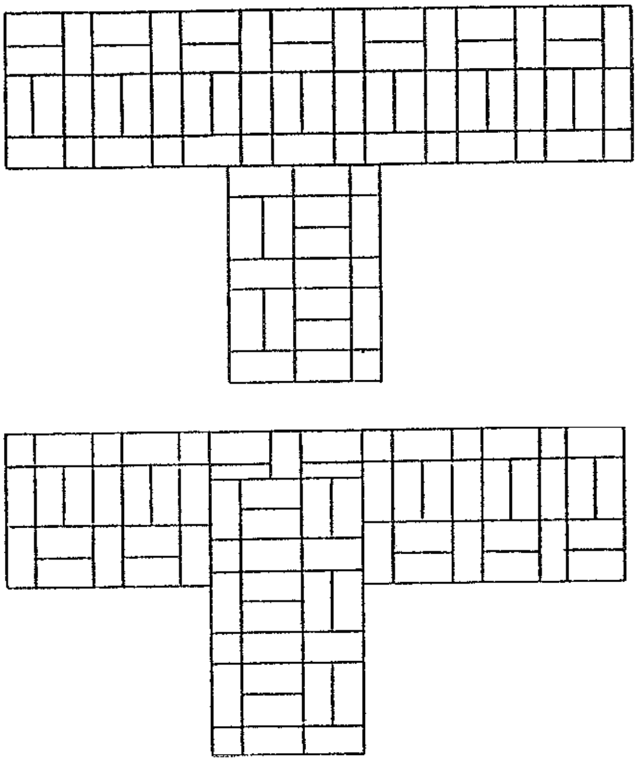


Figure 2.34 The alternate plan courses of a stopped intersection between two-two and a half brick thick walls built in double Flemish bond.

- **Crossed intersection**

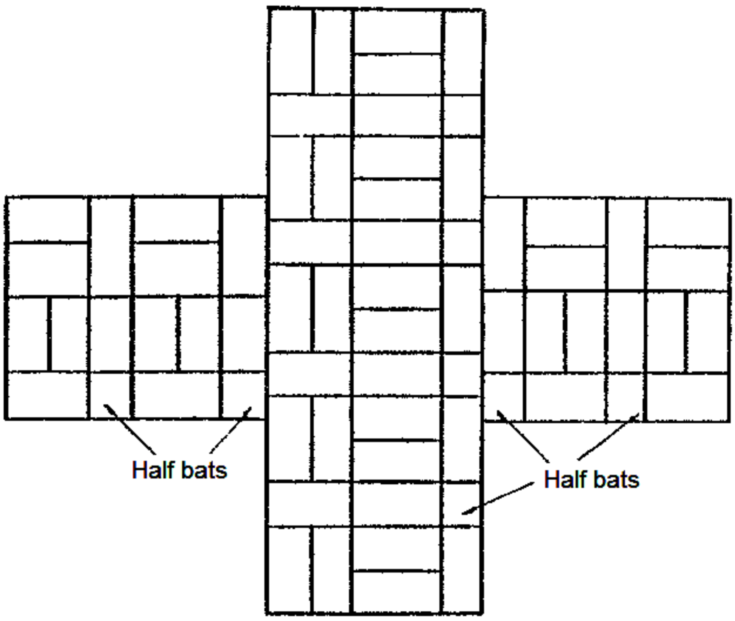


Figure 2.35 Two alternate plan courses of a cross intersection built in double Flemish bond, two-and-a-half bricks thick

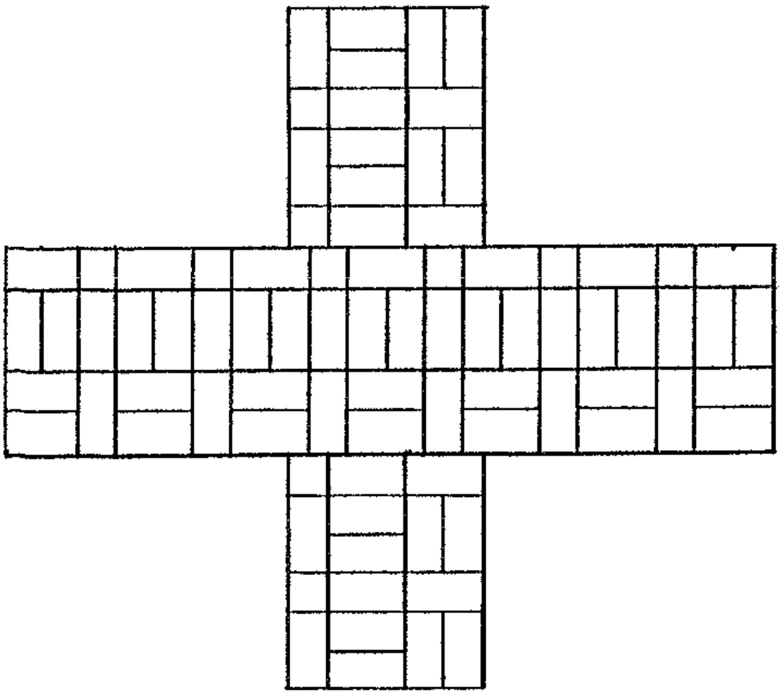


Figure 2.35 Two alternate plan courses of a cross intersection built in double Flemish bond, two-and-a-half bricks thick (continued)

2.4.3 Three-brick walling in double Flemish bond

Figure 2.36 to **2.38** illustrates the bonding for three- brick walls, in Flemish bond.

- **Quoin**

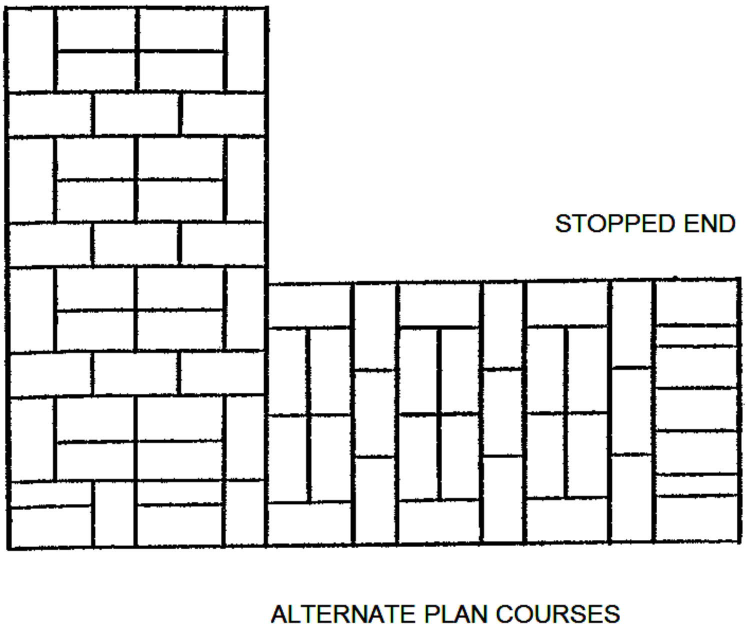


Figure 2.36 The alternate plan courses of a quoin built in three-brick double Flemish bond. The drawing is done in orthographic projection.

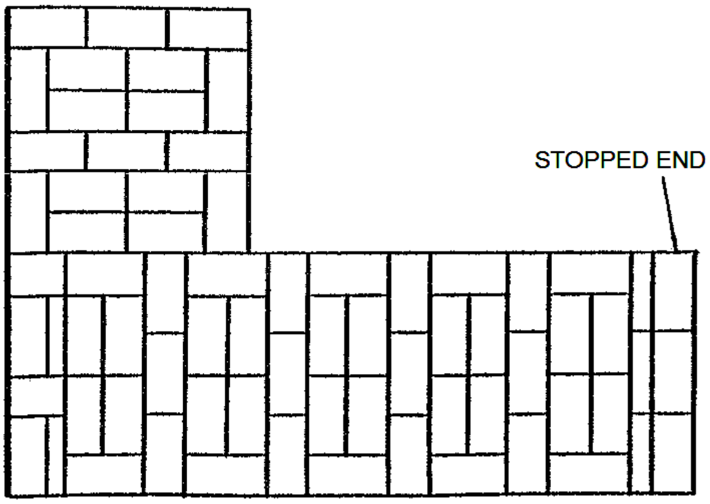


Figure 2.36 The alternate plan courses of a quoin built in three-brick double Flemish bond. The drawing is done in orthographic projection (continued)

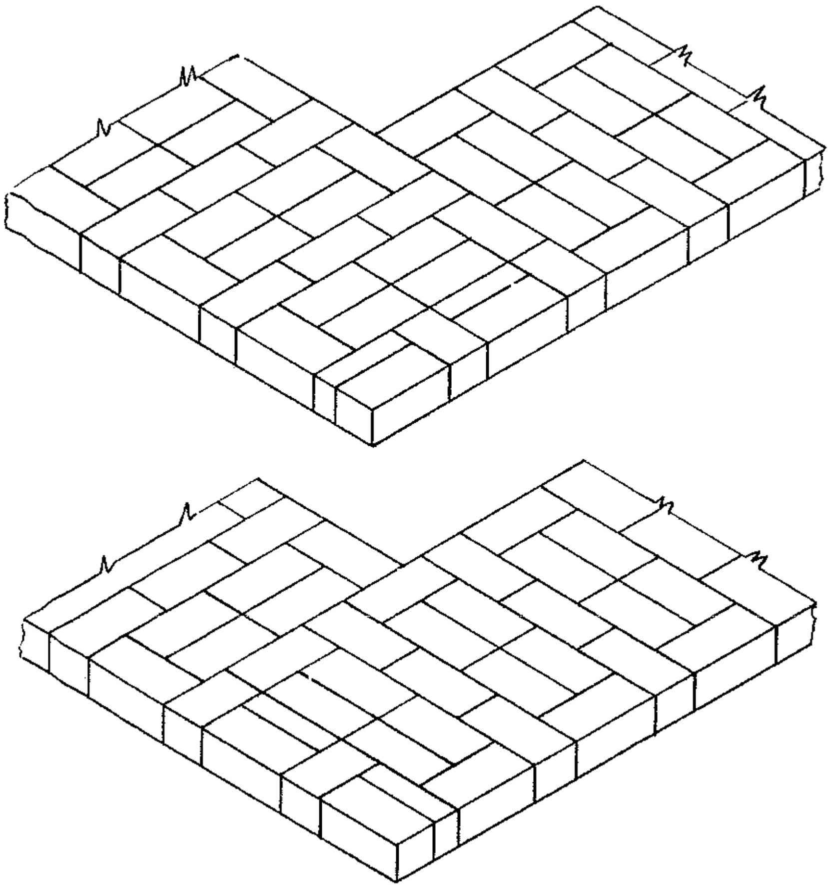


Figure 2.37 An isometric projection of a three-brick quoin built in double Flemish bond, between two three-brick walls.

- **Stopped intersection (T-junction)**

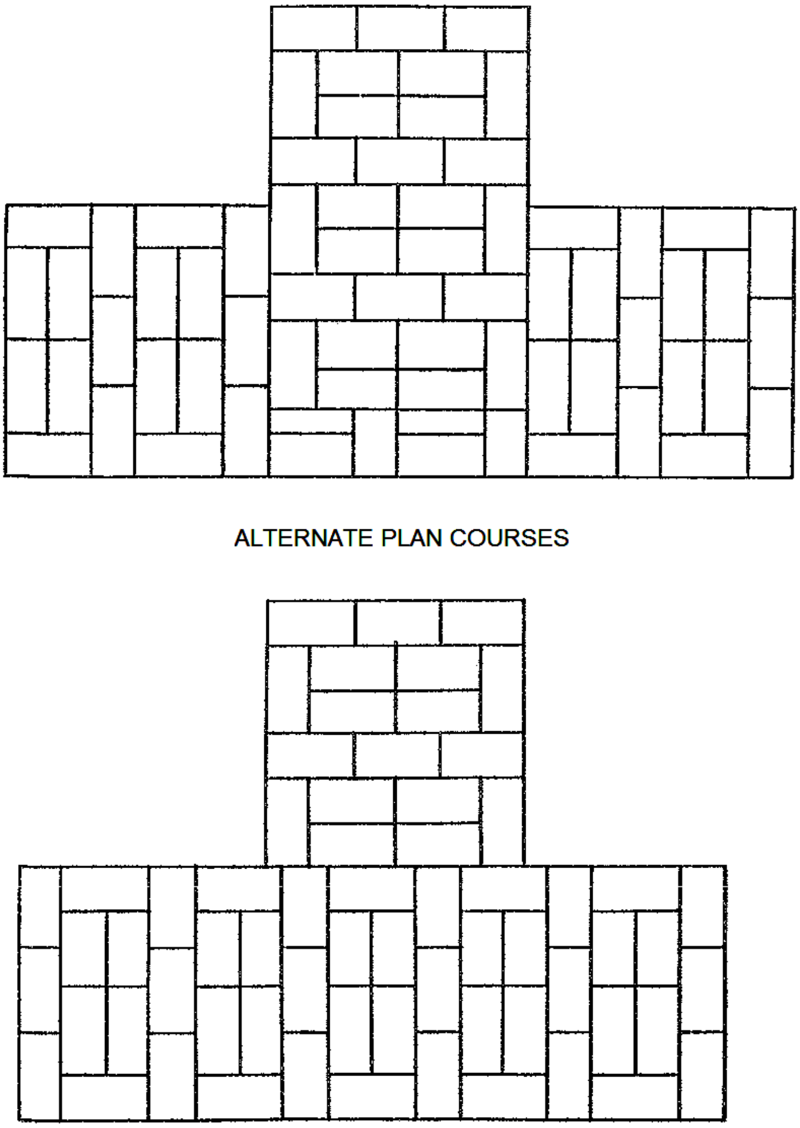


Figure 2.38 The stopped intersection between two three-brick walls built in double Flemish bond. The drawing is done in orthographic projection.

2.4.4 Three-brick thick wall in single Flemish bond
Figure 2.39 illustrates the above.

- **Quoin**

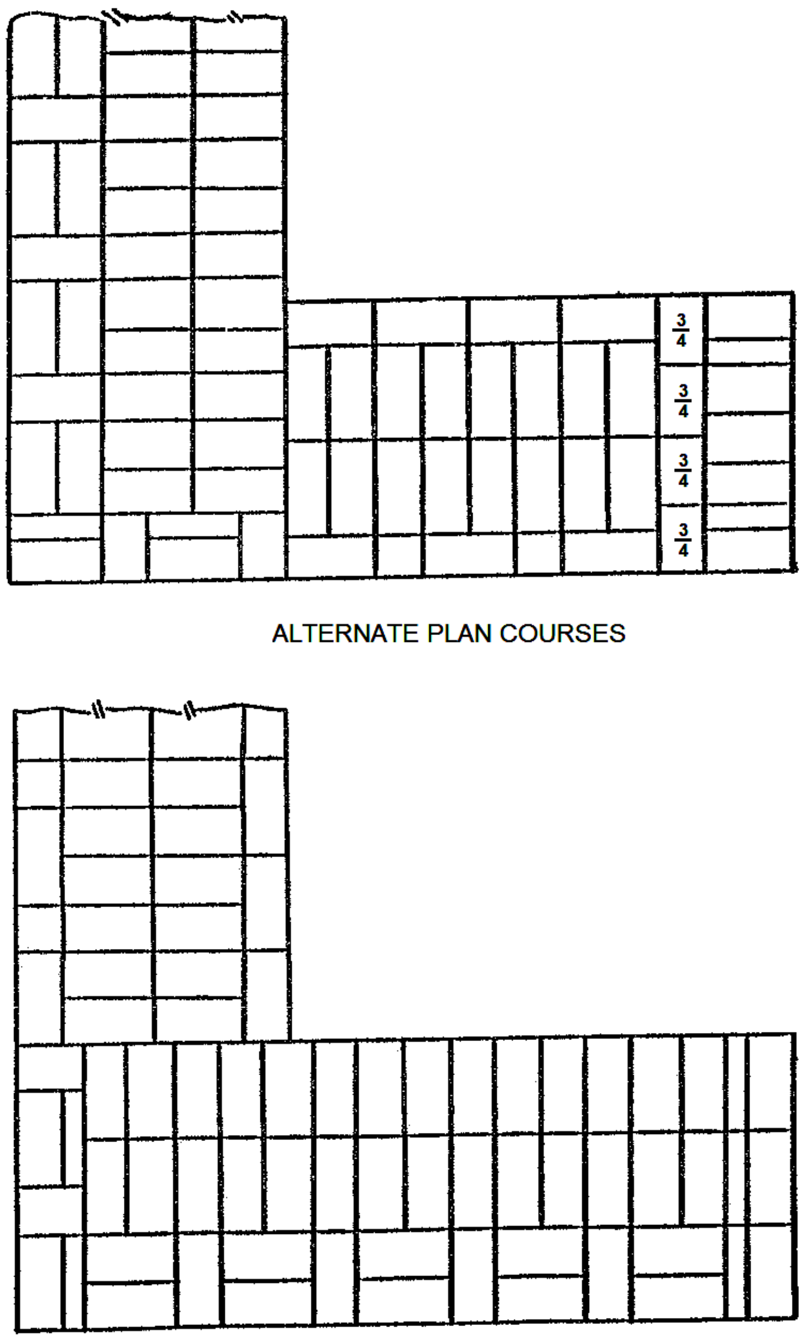


Figure 2.39 A quoin between two three-brick walls built in single Flemish bond with a stopped end on one side. The drawing is done in orthographic projection.

2.4.5 Isolated piers in Flemish bond

Figure 2.40 to **2.44** illustrates the bonding for three- brick walls, in Flemish bond.

- **Two-brick square**

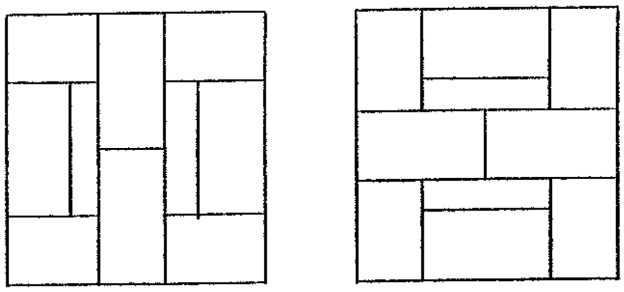


Figure 2.40 The orthographic drawing of two alternate plan courses of a two-brick isolated pier drawn in Flemish bond.

- **Two-and-a-half brick square**

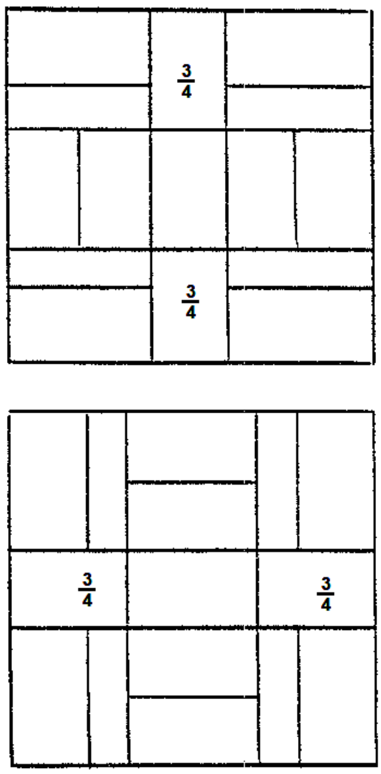


Figure 2.41 The orthographic drawing of two alternate plan courses of a two-and-a-half brick isolated pier drawn in Flemish bond.

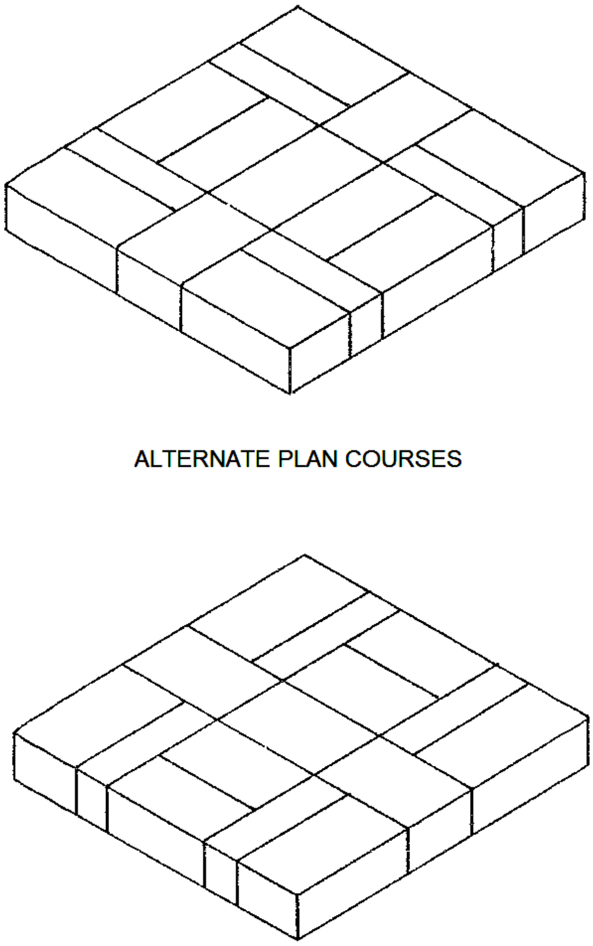


Figure 2.42 The alternate plan courses of a two-and-a-half isolated brick pier built in Flemish bond.

- **Three-brick square**

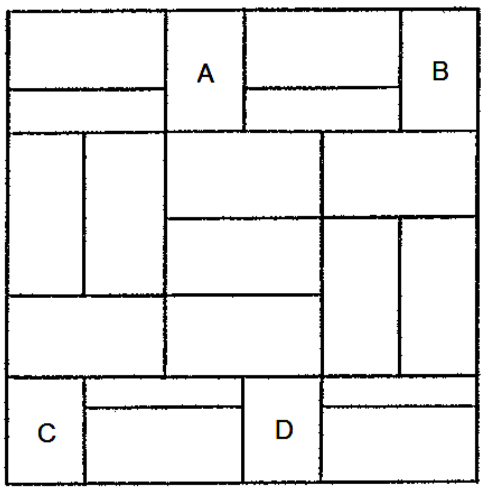


Figure 2.43 The orthographic drawing of two alternate plan courses of a three-brick isolated pier drawn in Flemish bond.

ALTERNATE PLAN COURSES

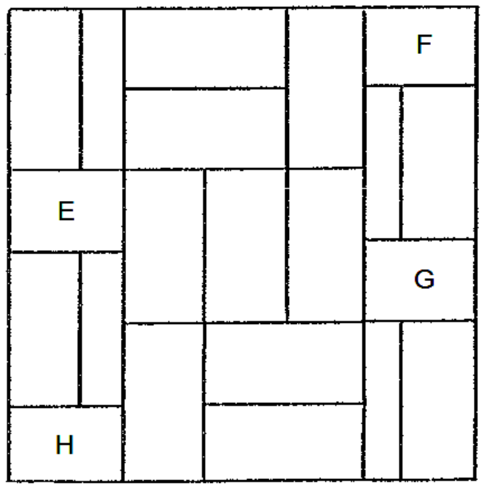
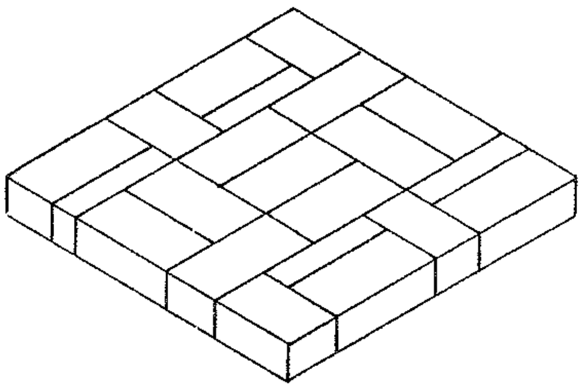


Figure 2.43 The orthographic drawing of two alternate plan courses of a three-brick isolated pier drawn in Flemish bond (continued)



ALTERNATE PLAN COURSES

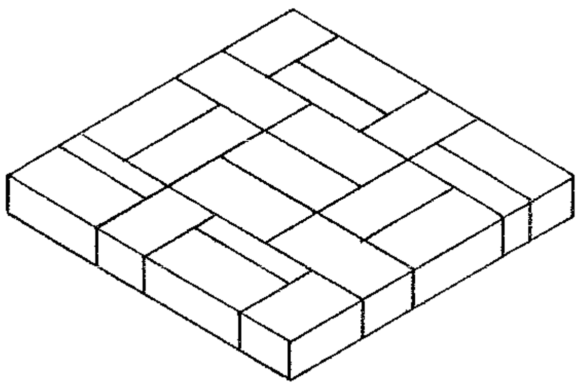


Figure 2.44 The isometric projection of the alternate plan courses of a isolated three-brick pier built in Flemish bond.

2.5 Bonding acute and obtuse angles

Squint quoins have been defined as those quoins made by walls joining each other at an angle other than a right angle, and are described as "acute" or "obtuse", depending upon the angle formed by the junction of the walls.

Acute squint quoins are not common in ordinary work, although sometimes required on non-rectangular sites, but obtuse squint quoins are frequently necessary, particularly in the construction of splay-sided or polygonal-shaped bay windows.

Such squint quoins are sometimes stated to be constructionally weak, owing to the necessary cutting of the bricks to form them, and recommendations are often made that stone should be used for such features.

The skillful craftsman, however, will not admit that such quoins are seriously weaker than the ordinary right-angled quoins and, with reasonable attention to the bonding, satisfactory quoins can be constructed in brick.

In building squint quoins, the bonding should be arranged with the largest possible pieces of brick. Sharply jointed pieces and awkward cutting should be avoided.

The practice of merely making the face appearance good and filling the interior with broken bits of brick and mortar, in a sort of brick concrete, should be avoided since the angles are vital parts of the structure and should be as strong as the main body of the will.

The arrangement of bonding to squint quoins can be made strong if the general principles of bonding and the above remarks are adhered to.

2.6 Bonding acute squint quoins in English bond

The angle of the squint is only important in that it affects the size and actual shape of the closer, which, as in right-angled quoins, is placed next to the quoin header.

This is because, the sharper the squint, the smaller and more awkward in shape the closer becomes.

The face of the quoin header and closer together must always be 172 mm, so that the correct amount of lap can be maintained.

In all cases, the face appearance must be maintained, and this invariably necessitates the splay cutting of the first stretcher in order to provide the quoin header, and the width of this brick is often reduced, so that the closer may be more reasonable in size.

When standard bricks with the ordinary frogs are used for these quoin bricks, the margin around such frogs is apt to be cut away and would thus result in wide and unsightly joints which can be ignored if the brickwork is to be plastered.

If a fair face is required, wire cut bricks which have no frogs, or specially made quoin bricks must be used, and these can often be obtained with a slightly rounded or bull-nosed angle.

If the bricks have to be cut, a wood mould or template is made of the proposed shape. This is placed upon the brick and marked. The brick is then cut with the hammer and bolster and the rough edges smoothed off with the brick hammer and or scutch.

Figure 2.45 illustrates the one-brick wall and **Figure 2.46** illustrates the two-brick wall which shows the normal arrangement: the heading course being carried through and finishing at the back of the face stretchers on the return face of the wall.

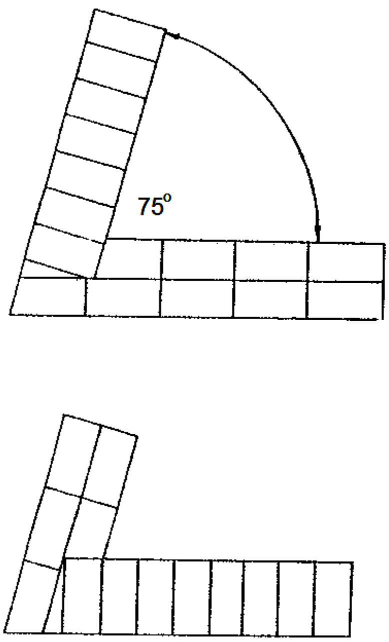


Figure 2.45 The one-brick wall

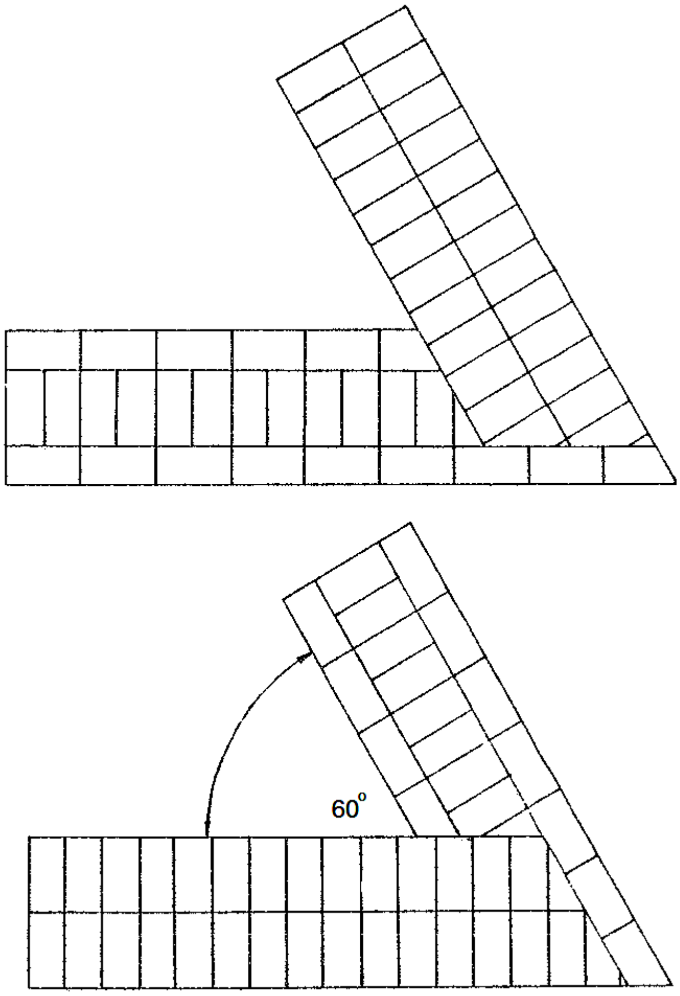


Figure 2.46 The two-brick wall

The one-brick walls shows a quoin at 75° and the two-brick walls make an angle of 60°.

The one-and-a-half-brick walls, seen in **Figure 2.47**, at an angle of 75° indicate a modification shown by the dotted lines in not carrying the whole of the heading course through to the-face.

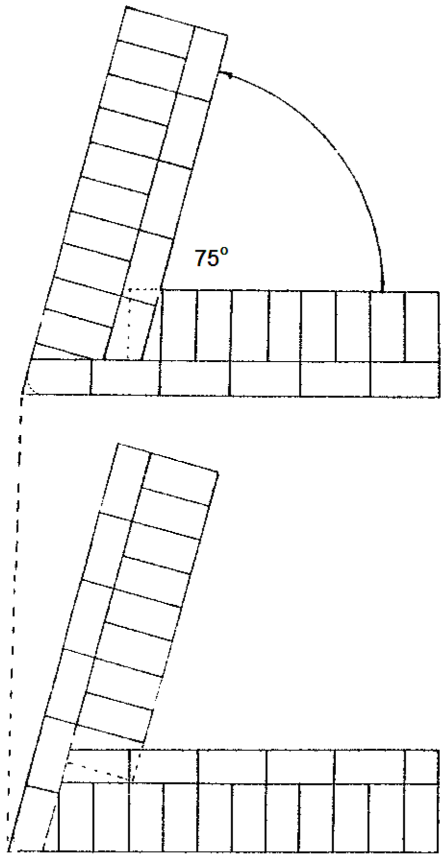


Figure 2.47 The one-and-a-half-brick walls, at an angle of 75°

Instead, by placing the additional header in each stretching course, the internal or re-entering angle is kept clear of the sharp pointed pieces of brick.

The one-and-a-half-brick walls, as seen in **Figure 2.47**, at an angle of 75° indicate a modification shown by the dotted lines in not carrying the whole of the heading course through to the-face.

Instead, by placing the additional header in each stretching course, the internal or re-entering angle is kept clear of the sharp pointed pieces of brick.

2.7 Bonding acute squint quoins in double Flemish bond

The one-brick walls at an angle of 75° are simple and require only that the bricks at the internal angle should be metered to each other. See **Figure 2.48** which illustrates this.

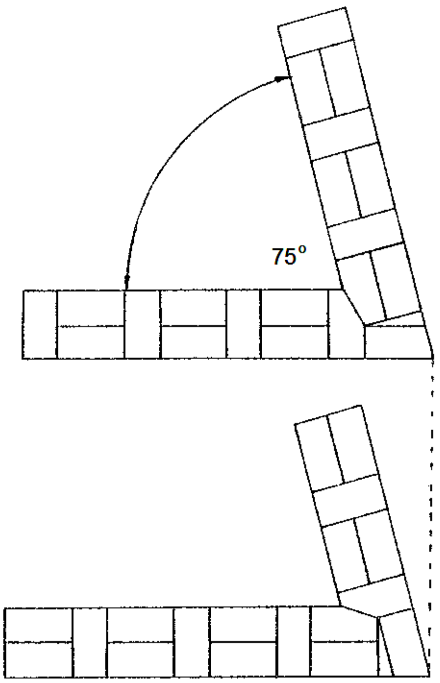


Figure 2.48 The one-brick walls at an angle of 75°

The one-and-a-half-brick walls, at the same angle, partly owing to its special unit of bond, necessitates rather more cutting and fitting of the bricks than the other cases.

The example shown in **Figure 2.49** is only one of a number that might be adopted for the purpose.

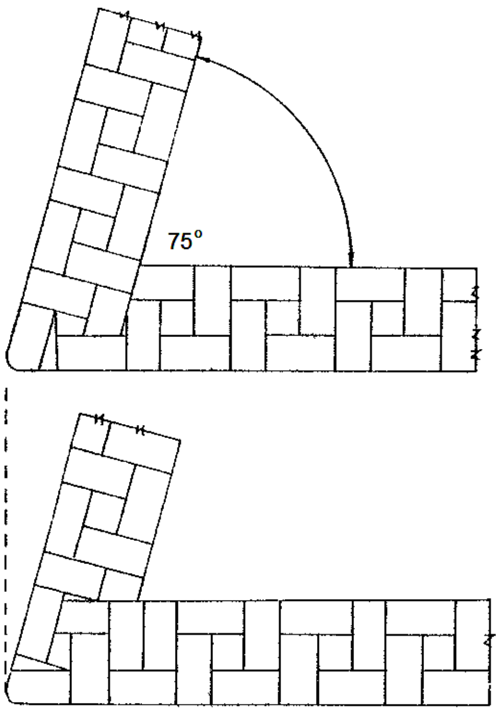


Figure 2.49 The one-and-a-half-brick walls, at the same angle

The two-brick walls, **Figure 2.50** shown at an angle of 60°, conform to the rules of bonding. and at the same time as large a part of each heading course "ties" into the other wall as far as possible, a few of the bricks having to be cut to a metre.

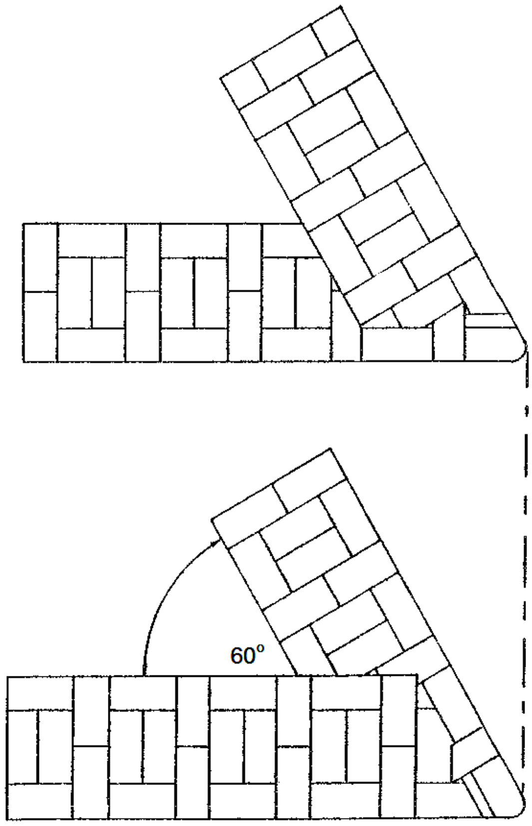


Figure 2.50 The two-brick walls, shown at an angle of 60°

It may sometimes be possible to dispense with the actual sharp quoin made by the acute angle.

The illustration in **Figure 2.51** shows a treatment of the quoin which cut from standard bricks entirely eliminates the awkward cutting of the bricks at the acute angle.

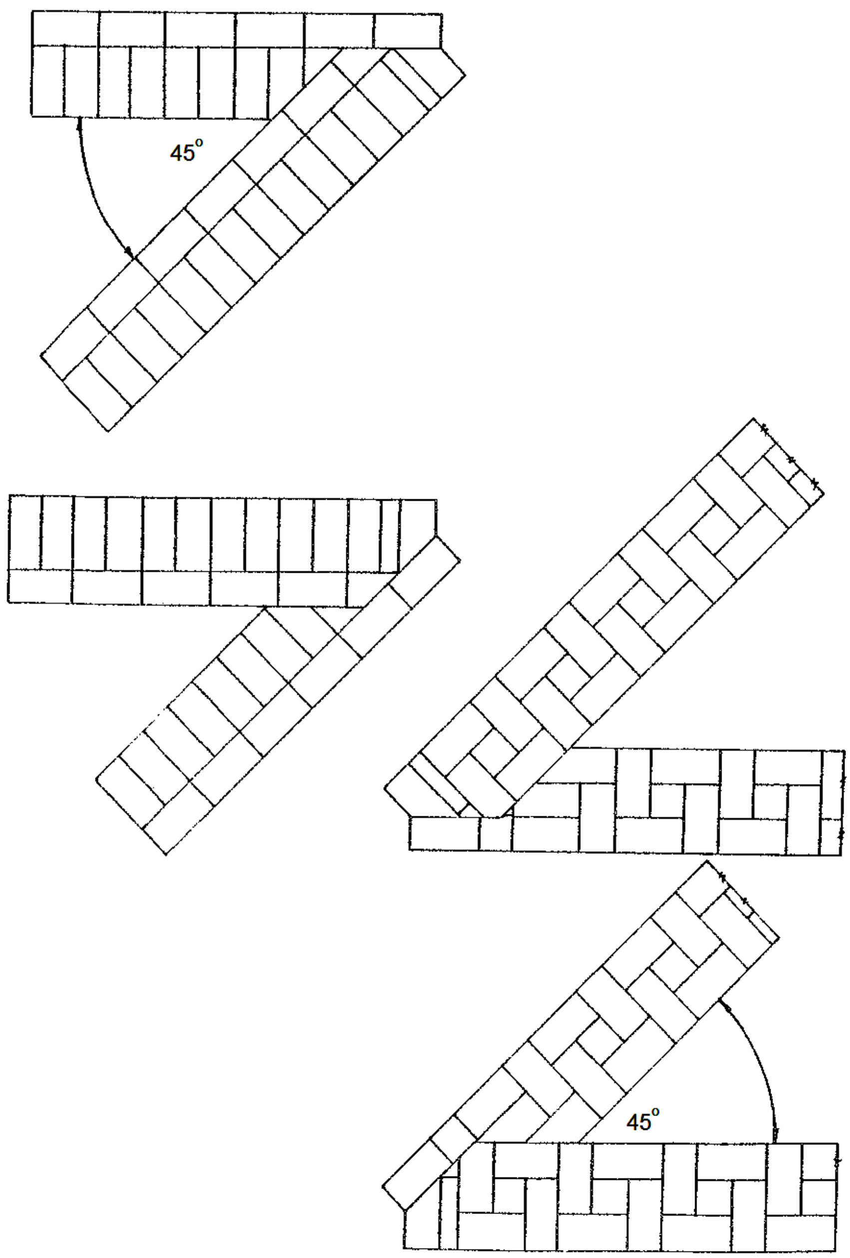


Figure 2.51 Treatment of the quoin

This method of construction is sometimes known as "bird's mouth". Applied either in English or Double Flemish Bond, the arrangement is simple and suitable for many positions.

2.8 Obtuse squint quoins

The rules of bonding are fully applicable to the construction of the obtuse squint quoins, but since the angle made by the two walls is greater than a right angle, the size of the quion bricks will always be less than the normal header and stretcher, This is because in no case should a brick joint be permitted on an external angle, nor can a brick longer than 230 mm be used at the quoin unless it be specially made for the purpose.

It has also been stated that these quoins are mostly required for the construction of splay-sided bay windows, and in this position it should be noted that, while the external face appearance is important, the internal faces are usually plastered or otherwise covered, the correct face appearance is not so essential.

Since the quoin bricks must be cut to the special shape required, it is evident that standard bricks, which are made with frogs, will frequently show unsightly joints.

Most brick manufacturers make special quoin bricks (squint bricks) suitable for all the common angles used in bay windows, but in some cases and especially where unusual angles are desired, the quoins are built in “wire cut” or “pressed” bricks.

At whatever angle the splay of the squint is made, the quoin brick must always be so cut or shaped that, with or without a closer, the heading face will show 37 mm less than the stretching face, so that the ordinary wall bonding may be correctly started.

For the obtuse angle, a brick is either cut or purposely made to the required angle, and has usually a 57 mm face on one side and 172 mm on the other.

When using this brick, it is usual to regard the 57 mm side as the header side of the brick, and a closer is placed against this side to obtain a 57 mm lap.

Sometimes, however, it is necessary to shorten the 172 mm face to 115 mm in order to prevent using broken bond in the wall or to obtain the strongest bond in a pier.

When this is done the closer falls away and the quoin brick is placed to suit the bond.

2.8.1 Bonding obtuse squint quoins in English bond

The 230 mm walls at an angle of 150° (30° splay) are simple and if the rules of bonding are adhered to no difficulty should be encountered in the bonding of all the obtuse squint quoins. **Figure 2.52** illustrates this.

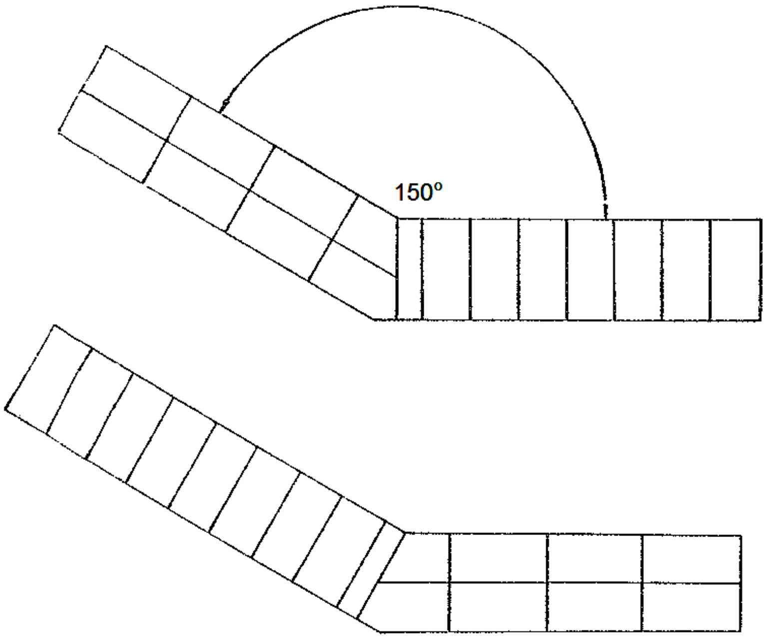


Figure 2.52 Bonding of obtuse squint quoins

When drawing an obtuse squint quoin, the procedure is as follows:

1. First draw your squint brick at the required angle, remembering that the 57 mm face is the header side while the 172 mm face is the stretcher side.
2. Place your closer (57 mm) next to the corner header and continue the course with headers.
3. Obtain your sectional bond as soon as possible.
4. Tie in with the headers as far as possible.
5. Check for internal straight joints.

The 345 mm one-and-a-half-brick walls at any angle of 135° (45° splay) are shown at **Figure 2.53**. **Figure 2.54** shows a two-brick wall at an angle of 135° (45° splay). Notice here how the headers tie into the wall.

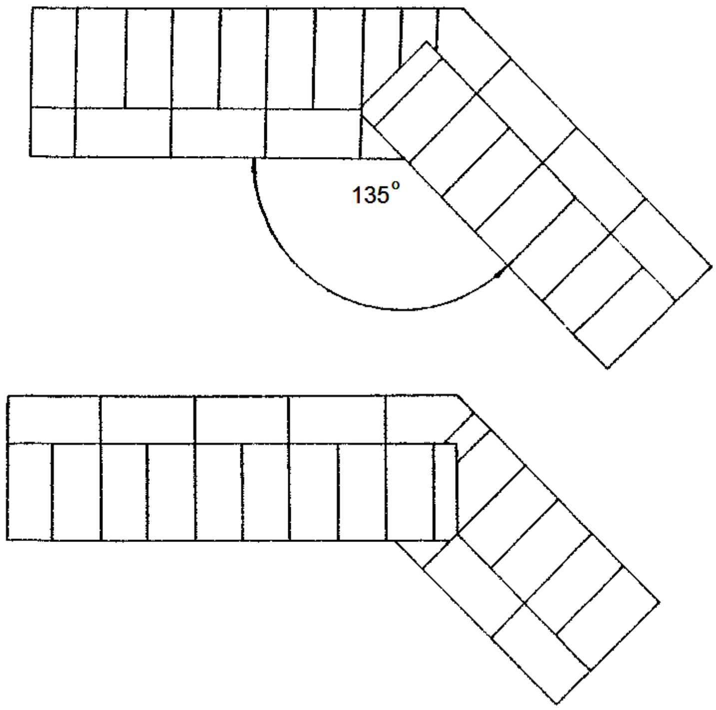


Figure 2.53 A 345 mm one-and-a-half-brick walls at any angle of 135° (45° splay)

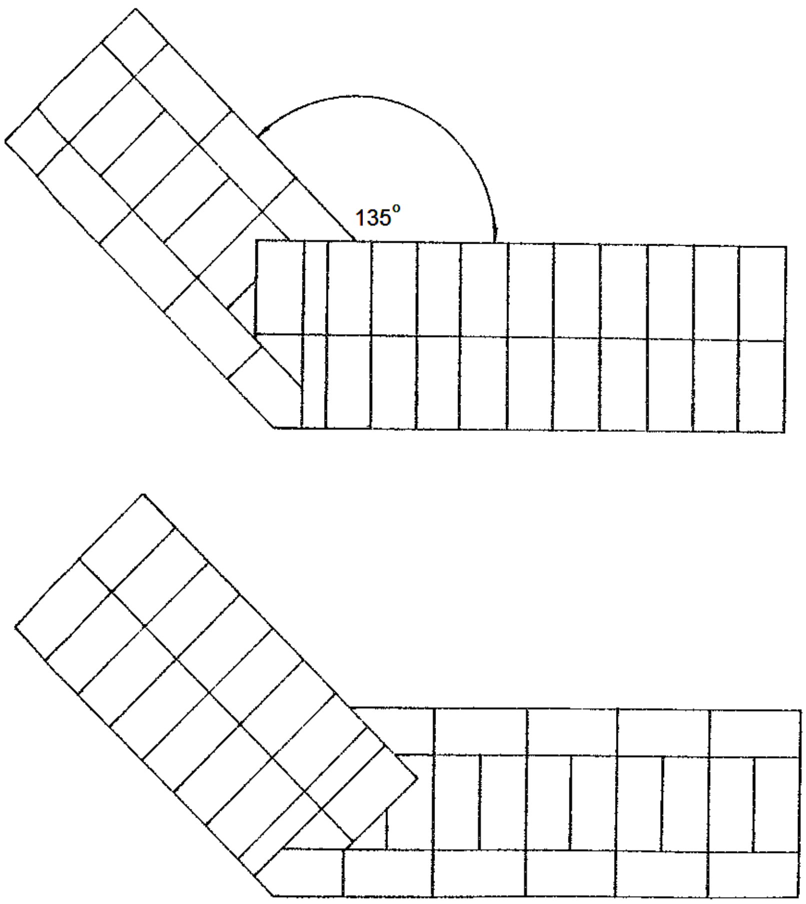


Figure 2.54 A two-brick wall at an angle of 135° (45° splay)

2.8.2 Bonding obtuse squint quoins in Double Flemish Bond

For purposes of comparison, the squint quoins illustrated in **Figures 2.55, 2.56** and **2.57** are shown for walls of the same thickness of those in English Bond in **Figures 2.52, 2.53** and **2.54**.

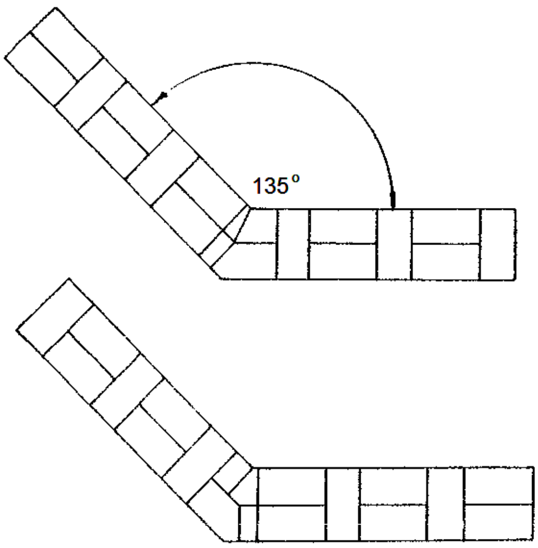


Figure 2.55 A one-brick wall forming a quoin at an angle of 135° (45° splay).

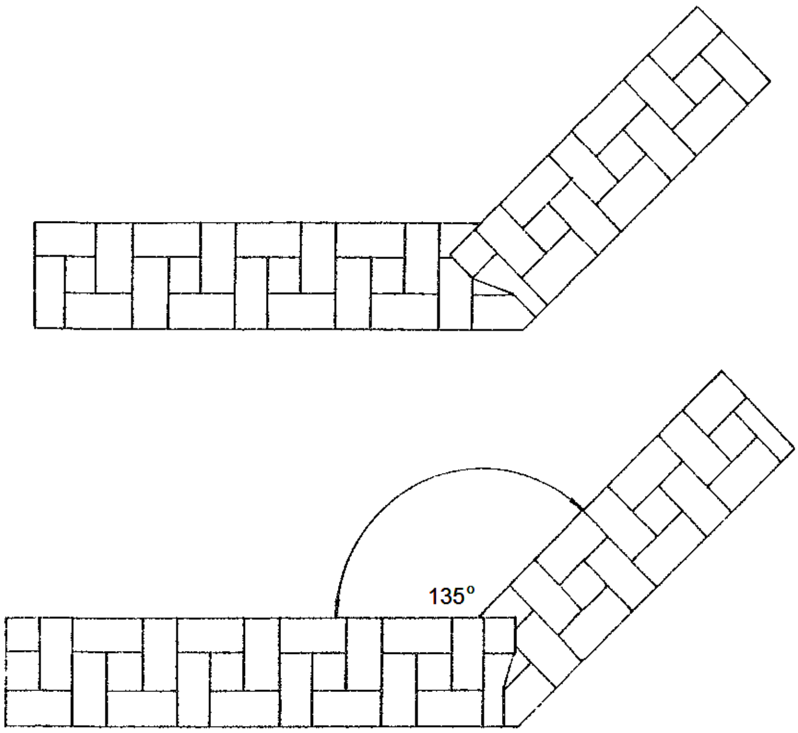


Figure 2.56 A one-and-a-half brick wall forming a quoin at an angle of 135° (45° splay)

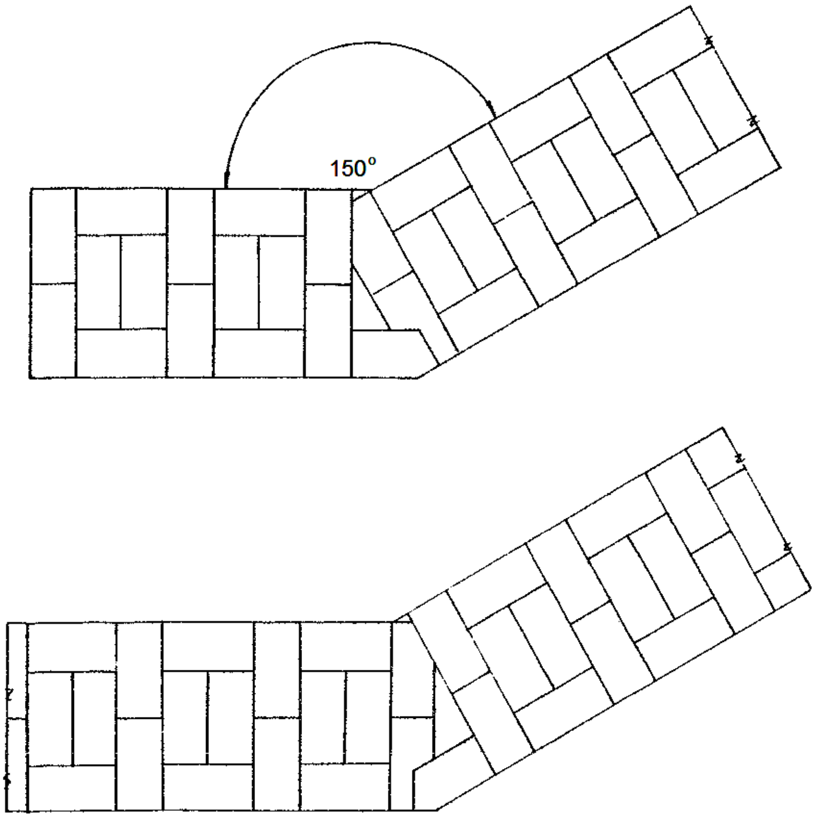


Figure 2.57 A two-brick wall forming a quoin at an angle of 150° (30° splay).

Figure 2.55 illustrates a one-brick wall forming a quoin at an angle of 135° (45° splay). **Figure 2.56** illustrates a one-and-a-half brick wall forming a quoin at an angle of 135° (45° splay).

Owing to the awkward unit of bond there is more cutting in the Flemish Bond than in English Bond.

Figure 2.57 illustrates a two-brick wall forming a quoin at an angle of 150° (30° splay). The procedure adopted when drawing these obtuse quoins is similar to that adopted for English Bond.

Activity 2.1

1. Explain and illustrate the difference between English, stretcher and garden wall bonds up to two bricks solid.
2. Describe the construction of cavity walls up to a double storey height.
3. Describe concrete buildings blocks.
4. Explain the correct method for using quoins and T-Junctions with stopped ends.
5. Explain wall binding for external facing.

Self-Check

I am able to:	**Yes**	**No**
• Describe the following wall bonds up to two bricks thick (solid)		
o English		
o Stretcher		
o Garden wall		
• Describe cavity walls up to double storey		
• Explain the use of concrete buildings blocks		
• Explain quoins and T-junctions with stopped ends		
• Explain wall binding for external facing		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 3

Damp Proofing

Learning Outcomes

On the completion of this module the student must be able to:

- Describe the materials and applications of damp proofing including basements

3.1 Introduction

Damp proofing in construction is a type of waterproofing applied to building walls and floors to prevent moisture from passing into the interior spaces. Damp problems are one of the most frequent problems encountered in homes. Damp proofing can be done in several ways.

A damp-proof course is a barrier in a wall designed to resist moisture rising through the structure by capillary action such as through a phenomenon known as rising damp using various materials.

The DPC (damp-proof course) may be horizontal or vertical. A damp-proof membrane (DPM) may be used for the DPC. Moisture resistance is not necessarily absolute: it is usually defined by a specific test method, limits, and engineering tolerances.

A DPC layer is usually laid below all the walls, regardless of the issue that the respective wall is a load bearing wall or a partition wall.

Integral damp proofing in concrete involves adding waterproofing materials to the concrete mix to make the concrete itself a water barrier.

Surface coating with thin water proof materials for resistance to non-pressurized moisture such as rain water or a coating of cement sprayed on such as shot crete which can resist water under pressure.

Cavity wall construction, such as rain screen construction, is where the interior walls are separated from the exterior walls by a cavity.

Pressure grouting cracks and joints in masonry materials.

Materials

- Flexible materials like butyl rubber, hot bitumen, plastic sheets, bituminous felts, sheets of lead, copper, etc.
- Semi-rigid materials like mastic asphalt
- Rigid materials like impervious bricks, stones, slates, cement mortar or cement concrete painted with bitumen, etc.
- Stones
- Mortar with waterproofing compounds
- Coarse sand layers under floors
- Continuous plastic sheets under floors

A DPC is usually a thick plastic strip bedded into the mortar between two courses of bricks or blocks. It can often be seen as a thin plastic line in the mortar near ground level.

A DPM is usually a thick polythene sheet laid under the floor slab, to allow the slab to dry out and keep out groundwater. It is often laid on a bed of sand, to prevent the sharp edges of the hardcore damaging it.

To create a continuous barrier, pieces of DPC or DPM are welded together. In addition, the DPC is welded to the DPM around the outside edges of the ground floor, completely sealing the inside of the building from the damp ground under it.

In a cavity wall, there is usually a DPC in both the outer and inner wall. In the outer wall it is normally 150 - 200mm above ground level (the height of 2-3 brick courses). This allows rain to form puddles and splash up off the ground, without saturating the wall above DPC level.

Note:
The wall below the DPC may become saturated in rainy weather.

The DPC in the inner wall is usually below floor level, (under a suspended timber floor structure), or, with a solid concrete floor, it is usually found immediately above the floor slab so that it can be linked to the DPM under the floor slab. This enables installation of skirting boards above floor level without fear of puncturing it.

Alternatively, instead of fitting separate inner and outer DPCs, it is common in commercial house building to use a one-piece length of rigid plastic, (albeit an angled section), which fits neatly across the cavity and slots into both walls (a cavity tray).

This method requires the need for weep vents to enable rainwater ingress to drain from the cavities otherwise rising dampness could occur from above the DPC.

3.2 Thermal insulation and ventilation

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.

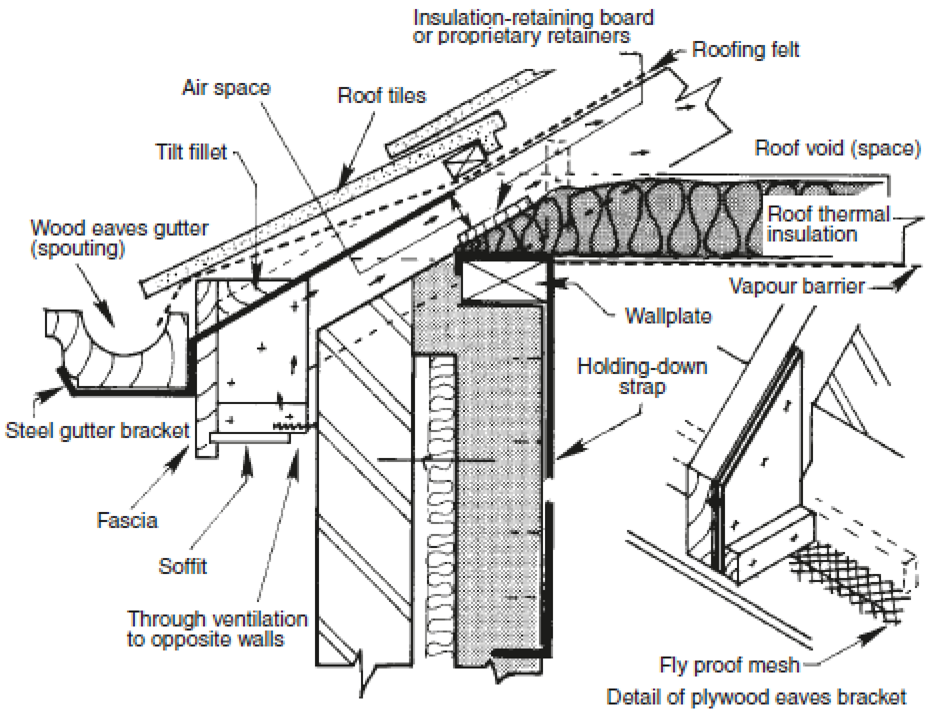


Figure 3.1 Insulation and eaves detail (traditional roof construction)

A vapour barrier can be positioned on the underside of 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 3.1 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.

Figure 3.2 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.

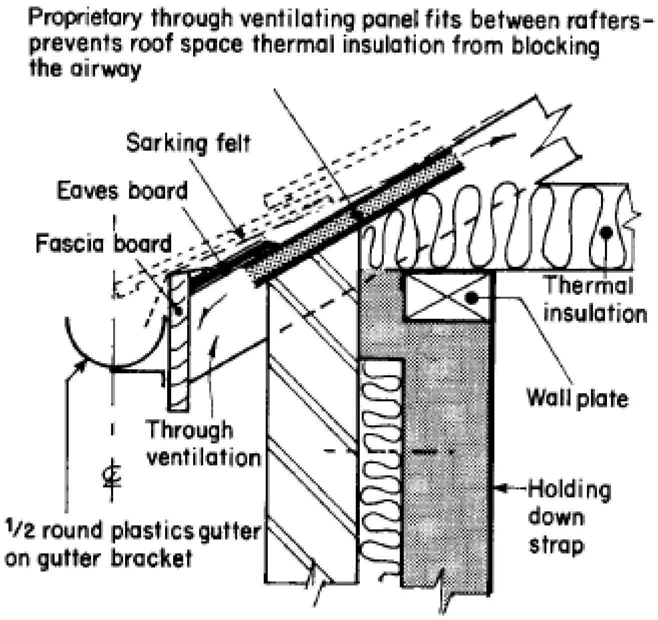


Figure 3.2 Proprietary roof ventilator used in conjunction with open eaves

For roofs of 15° 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° pitch the gap should be increased to 25 mm.

Examples of promoting cross-ventilation are shown in **Figure 3.3**.

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.

This could possibly be 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.

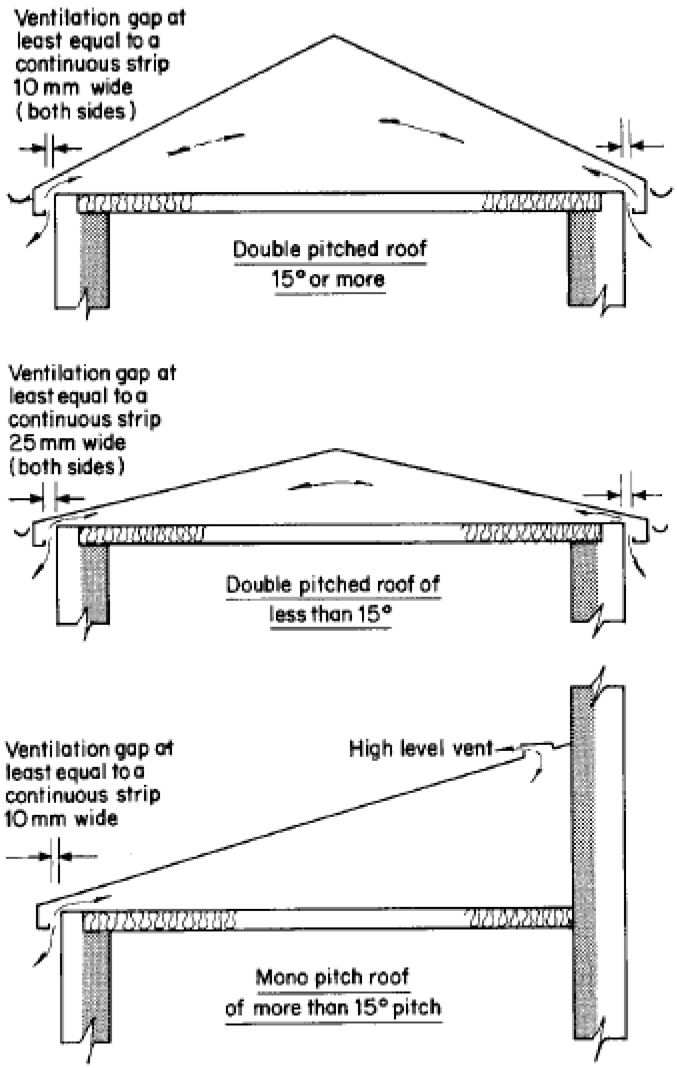


Figure 3.3 Method of promoting cross-ventilation to a roof space

3.3 Eaves details

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: 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: 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: 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: 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.

3.4 Fascias and soffits

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 is a common material.

Definition: Waterproof
It literally means that water cannot get in. This is often qualified by certain degrees of exposure, such as to a given depth of immersion, for a specified period of time.

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.

Definition: Weatherproof
This refers to qualities that add to an items "resistance" to water entry. There may be seals, flaps, etc. that contribute to better seals against water entry; but usually these products are not intended to be fully, or even partially immersed in water.

Activity 3.1

1. Explain the purpose of damp proofing in construction.
2. Describe the applications of damp proofing and the materials used.

Self-Check

I am able to:	Yes	No
• Describe the materials and applications of damp proofing including basements		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 4

Steel Doorframes and Windows

Learning Outcomes
On the completion of this module the student must be able to:

- Describe setting up and fixing of steel doorframes for openings of one and a half brick walls and cavity walls
- Explain the setting up of steel windows
  - Domestic
  - Industrial
- Describe the types of glass available and give short descriptions of each types characteristics

4.1 Introduction

Steel door and window frames are made from mild steel pressed into one of three standard profiles and are suitable for both internal and external positions. The hinges and striking plates on the doors are welded on during manufacture and the whole frame receives a rust-proof treatment before delivery.

The frames are fixed in a similar manner to timber frames using a tie or lug which fits into the back of the frame profile and is built into the bed joints of the wall. The advantage of this type of frame is that they will not shrink or warm but they are more expensive than their timber counterparts.

4.1 The steel door frame

These parts of the frame are the vertical ones on which the hinges and lock catch plates are mounted.

- The transom is the rail between the fanlight and the door.
- The small rubber cushions mounted in the jambs, so that the shock when closing or slamming the door is decreased.
- The bar at the bottom of the frame which keeps the jambs in position.
- Fixing lugs are the pieces which are used to hold the frame firmly. It can be welded or loose lugs.

- The plate is usually fitted to the lock jamb to receive the lock and is adjustable.

The following steps need to be followed when fitting the door:
- Check the clearance around the door
- Check the drawings and measure
- Mark the door

4.1.1 Check the clearance around the door
In ***Step 1***, you need to decide the size of the clearance you need around the door. You must be able to open and shut a door easily. This means that you need to fit the door perfectly into its door frame.

A door does not open straight out. It swings open or closed. For the door to do this, you need to make sure there is a slight gap or clearance all the way around the door. This clearance allows the door to swing open and shut without scraping against the door frame and to expand in wet weather.

If you fitted the door without this clearance then it would be so tight that each time you wanted to enter or leave a room, you would have to push the door down!

If you know that you will have to paint the doors, you need to leave a clearance of 2 mm around the door. The reason for this is that the paint sits on top of the wood and so adds to the thickness of the door.

For doors that will be varnished, you can leave a margin of less than 2 mm as the varnish soaks into the timber and so does not add to the thickness of the door.

4.1.2 Check the drawings and measure
In ***Step 2***, you need to check your drawing plans to make sure that your door is the right s1ze and type and that it will fit the door frame. Also check which way the door will swing.

In ***Step 3***, use a spirit level to check the doorway to make sure it is plumb on both the left and right sides. If the doorway is not plumb explain to the supervisor or client that the door will swing open or closed once it has been fitted.

Use a roofing square to check that the doorway is square. If it is not square, remember to cut top and bottom of the door out of square to match the doorway. Check too that jambs are in the same plane. If they are not, the door will not close properly against the jamb.

In ***Step 4***, you need to check the size of the door frame. The door schedule tells you what size the door frame should be. To check this, measure the door frame from top to bottom on both sides. Then measure the width of the inside of the door frame - at the top, centre and bottom - to see if it bulges or narrows anywhere.

Use a straight edge against the frame and check to see if it rocks or there is a gap in the middle, between the edge and the frame. If the door frame is not correct then you might need to scribe and plane the door to fit the door frame.

In ***Step 5***, measure the door in the same way as you measured the door frame. Make sure the door is not twisted or bent. Check the drawings to see to which side of the door the hinges will be attached. We call this edge of the door the hanging side or edge.

Note:
The other edge of the door is called the lock side. If your door is a hollow-core door, you need to locate the lock block in the door.

In ***Step 6***, you need to check how well the door fits into the door frame. To do this, use some packing or scrap timber set level with the threshold, and ask your assistant to hold the door on it and against the frame. (You should be on the opposite side of the door to your assistant.)

Position the door carefully and mark the outline of the frame against the door. You will then work towards these marks for a tight first fit.

Note:
The standard door is 813 mm wide and the standard door frame is 810 mm. This means it is always necessary to scribe and plane a door to fit.

Remember you need to allow for the 2 mm clearance or gap on each side. Ask the client or supervisor what the clearance should be at the bottom of the door. This will vary depending on the floor finish.

4.1.3 Mark the door

In ***Step 7***, you will mark the door where you need to trim it, if the door needs to be trimmed. If you need to shorten the door in height, then first measure 1t carefully.

Note:
Remember to include the 2 mm clearance you need, as well as the correct clearance at the bottom.

Mark the door carefully. You will use a hand- saw to cut the ends at your markings. You will need to smooth the surfaces where you cut, working from the edge to the centre.

Note:
If you need to plane down the width of the door, then measure carefully. Remember to include the 2 mm clearance when you measure.

Divide the amount that you need to plane away equally between the two sides of the door. Mark the door carefully. You will use a power plane to plane the length of the door following your markings.

A door is hung using hinges. Fit hinges very accurately to make sure that the door does not sag or hang at an angle.

4.1.4 Mark the hinges and fit them in the specified position
If you examine different doors and doorways, you will see that each door is fixed to the door frame with hinges.

Definition: Hinges
Pieces of metal used to hang a door and allow it to open and shut.

The hinge consists of two leaves - the one leaf is attached to the door and the other to the door frame. The two leaves are joined at the centre of the hinge by a pin, which passes through a thickened part of each leaf, called the knuckle. The pin allows the two leaves to open and close.

There are many different types of hinge, for different kinds of door. For example, there are projection hinges, rising butt hinges and butt hinges.

Mark the hinge before fitting it in the specified position
The top hinge must be positioned 150 mm from the top of the door and the bottom one 230 mm from the bottom of the door. Always check your work against these measurements.

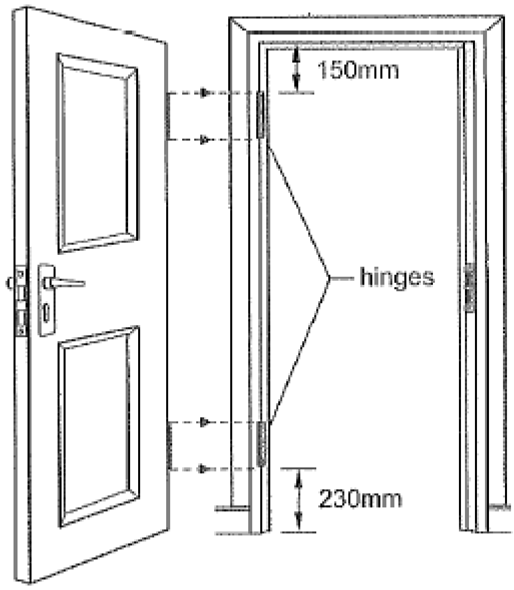


Figure 7.16 The specified position of butt hinges on a standard door

Steps to mark and fit hinges

- Mark the hinges
- Chisel the cutout
- Fit the hinge in the specified position

Mark the hinges

In ***Step 1***, examine the drawing to find out which the hanging edge of the door is, and where to position the butt hinges.

In ***Step 2***, you need to mark the position of the hinges on the door and door frame. To do this, place the door in the door frame in the exact position it will be hung. Use wooden wedges to hold it in the position it will be when the door is closed. Measure and mark the position of the top edge of the top hinge on the door and the door frame.

The marks on the door and the door frame must be exactly level, at 150 mm from the inside of the door frame. Then measure and mark the position of the bottom edge of the bottom hinge on the door and the door frame.

Note:
The mark on the door and the door frame must be exactly level, at 230 mm from the bottom of the door.

In ***Step 3***, you need to mark the outline of the top hinge on the door and the door frame.

- Start by taking the door down.
- Open the hinge so that the knuckle faces away from you.

- Place the leaf flat against the door frame, with the top edge in line with the mark and the knuckle a hair's thickness away from the edge of the door frame.

In ***Step 4***, you need to do the same for the bottom hinge on the door frame, as well as both positions on the door. Make sure that the hinge fits inside the lines you have marked. Also make sure that the pivot or knuckle is just clear of the door frame.

In ***Step 5***, you need to mark the depth of each hinge on the door and door frame. Later on, you will cut out this area out of the wood. This cutout is called the hinge's housing.

Start by using a marking gauge to mark the depth of the hinge cutout on the face. The depth is equal to the thickness of the hinge leaf.

Note:
Make sure you do not cut too deep. It is much better to cut out too little than too much. If you cut out too little you can always work down.

Chisel the cutout
In ***Step 6***, you need to chisel out the housing for the hinge. Use a broad chisel to chisel out the marked lines. Start in the centre and work towards the outline.

- Make some cuts across the edge of the door to the correct depth. You can tap the chisel with a mallet to do this.
- Now hold the chisel horizontally with the bevel edge facing downward.
- Start paring to clean out the bottom. Work very neatly.

Note:
Remember to cut too shallow rather than too deep.

In **Step 7** you need to check how well the hinge leaf fits into the housing for it. Start by placing a hinge leaf in each cutout to make sure the leaf fits and that It IS flush with the edge of the door.

If the cutout is too shallow, then remove more wood using the chisel. If the cutout is too deep you will need to pack it with sandpaper or cardboard.

In **Step 8**, you need to check how well the other hinge leaves fit into their housings. So follow the same process as before to check the other hinge leaves on the door and door frame.

Fit the hinge in the specified position

In **Step 9**, you need to drill pilot holes for the middle holes in each hinge leaf. Notice that the screw holes on the hinges are not set in a straight line. They are offset to keep the screws from splitting the wood of the door or the door frame.

Offset screws also keep the hinge flat and stable on the base of the recess. Drill a pilot hole through each of the middle two screw holes of each hinge leaf on the door and door frame. Do not drill the other two holes in each leaf yet.

In **Step 10**, screw the hinges onto the door using the middle screw holes. Now hold the door in the open position, close enough to the door frame to allow you to fit the top hinge's leaf to the cutout in the door frame. Now fit the bottom hinge into the bottom cutout and screw it.

In **Step 11**, you need to check the door does not catch. So open the door gently to make sure that it is not catching on anything as it moves. If it catches on the floor, plane a little wood off the bottom edge of the door.

Note:
Remember to check what clearance is required for the floor finish.

Keep opening the door to check that it is not catching or binding (sticking) on anything. Each time the door catches on something, take the door down, plane it and fit it again. Keep doing this until the door fits perfectly.

In **Step 12**, you need to drill the remaining holes in the hinge leaves. You do this when you reach the stage that the door sits flat in its door frame and stays there without being held. At this point, you can take the door down and drill the remaining holes.

In **Step 13**, you refit the door with all its screws. Make sure that the heads of the screws are flush with the hinge. This will allow the hinge to fold flat. Countersink the screws to do this. You do this by cutting a shallow conical depression into the wood, which allows a screw with a countersink head to finish flush with the surface.

4.2 Setting up the window

- The frame must be placed in line with the brickwork, with the bottom propped to allow for DPC and window sill, and checked for plumbed level, by means of a spirit level at the top and at both sides for any possible twist in the frame.

Definition: DPC
Damp proof course

- The frame must be checked for squareness and symmetry by means of a square and steel tape.
- It must be propped to eliminate any possible defection and must be secured in position by means of carefully placed scaffolding support with braces on both sides which could not form an obstruction during normal building activities.

4.2.1 The purpose of wall plate

The purpose of wall plate is to ensure an even distribution of the force acting down on the wall, due to roof construction. It is both light and easy to work with as well as cheap and durable.

4.2.2 Building in window frames

- Ensure that the opening parts open outwards.
- Build wall to sill height.
- Place two or more bricks flat across the wall and place the frame on top of these bricks in the centre of the wall.
- Secure frame in position by means of supports.
- Set the frame level and plumb as well as to the correct height using wedges.
- Build in the lugs.

4.3 Glass

4.3.1 Drawn (clear) glass

This is made from silica sand, soda ash, limestone and dolomite.

Raw materials are melted together at a temperature of 1 500°C. The working temperature is 900°C and the refined molten glass is ready for forming. The Pittsburgh process is used to manufacture sheet glass. The glass is drawn vertically from the free surface of the molten glass flowing from the furnace and a high standard of surface quality is achieved.

The glass is drawn upwards by asbestos rollers. The upward moving ribbon cools in a controlled manner to achieve good annealing as it is drawn up. When the glass is cool enough it is cut into sheets. Clear sheet glass is economical and easily available but breaks easily and the view is distorted.

4.3.2 Rolled glass

The rolling method is used in the production of figured glass - that is where one or both surfaces are textured or impressed with a pattern, which prevents clear vision. The molten glass is drawn horizontally between double rollers. The pattern on the roller is impressed in the surface of the glass.

4.3.3 Polished plate glass

The demand for a glass with perfectly flat, parallel surfaces, allowing undistorted vision, led to the process of grinding and polishing rolled sheet glass. Both surfaces are ground simultaneously as glass emerges from the rollers. This glass is expensive due to the long process and not freely available.

4.3.4 Float glass

In this method, molten glass is floated on a surface of molten tin and allowed to cool. This produces glass having flat, parallel surfaces and the fire-finish associated with drawn sheet glass. This type is also expensive and not freely available.

Both surfaces of float glass are flat and parallel like plate glass, to give clear, true vision and reflection, free from distortion. Float glass has the strength of sheet glass without the distortions inevitable in sheet.

4.3.5 Laminated glass

This consist of two panes of glass, bonded together with a plastic interlayer. The two pieces of glass with the plastic interlayer are first put-through heated rollers where they are semi-bonded. The glass is then placed in an autoclave where the glass is subjected to heat and pressure. This causes the remaining air to be driven out between the glass and plastic.

The glass and plastic tend to suck together as a result of the vacuum between the layers. Laminated glass is strong and safe, because when it breaks it adheres to the plastic. It is also difficult to penetrate, control heat of the sun and sound. Disadvantages are that it is very expensive and heavy thus difficult to handle.

Glass	Advantages	Disadvantages
Clear sheet glass	Cheap Easy to cut	Breaks easily Distorted view
Laminated glass	Strong and durable Undistorted view	Expensive Difficult to cut
Float glass	Undistorted view Easy to cut	Expensive Breaks easily

Table 4.1

Activity 4.1

1. Explain how to set up and fix steel doorframes for openings of one and half brick walls and cavity walls.
2. Describe how to set up steel windows for domestic and industrial buildings.
3. Describe the types of glass available and give a short description of the characteristics of each one.

Self-Check

I am able to:	Yes	No
• Describe setting up and fixing of steel doorframes for openings of one and a half brick walls and cavity walls		
• Explain the setting up of steel windows		
o Domestic		
o Industrial		
• Describe the types of glass available and give short descriptions of each types characteristics		
If you have answered ‘no’ to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 5

Arches: Brickwork

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the following types of arches
  - Semi-circular
  - Segmental
  - Rough
  - Axed
- Explain steel and timber centering for arches

5.1 Introduction

In this module you will learn about the construction of arches in detail. We will examine semi-elliptical and camber arches, as well as cavity walls to specification. Proper ventilation and precautions against termite infestation will also be discussed.

5.2 Semi-elliptical or three-centered arch

A semi-elliptical or three-centered arch is shown in **Figure 5.2.** As in the case of the Tudor arch, several methods are possible in the geometrical setting out, but the method shown is general.

Assume the rise to be 305 mm and the span to be 900 mm.

1. Set out the springing line and the rise.

2. Join AB. With the point of the compasses at C and with a radius equal to half the span, describe a quadrant to intersect the centre line at D. With the point of the compasses at B and with a radius equal to BD, describe an arc to cut AB at E.

3. Bisect the line AE, and where this bisector intersects springing line and centre line, the first and second striking points occur respectively. The third striking point G is on the springing line equidistant from the centre line, as F.

Figures 5.1 and **5.2** show semi-elliptical or three-centered arches.

As previously explained, the three-centered and five-centered arches are approximate ellipses. The more centres used in the geometrical construction, the truer the ellipses become.

> **Note:**
> For an arch span of up to and including 1 500 mm, three centres give a pleasing curve.

Beyond this size and up to, say 2 700 mm the span limit which a bricklayer meets in general practice, five centres should be used.

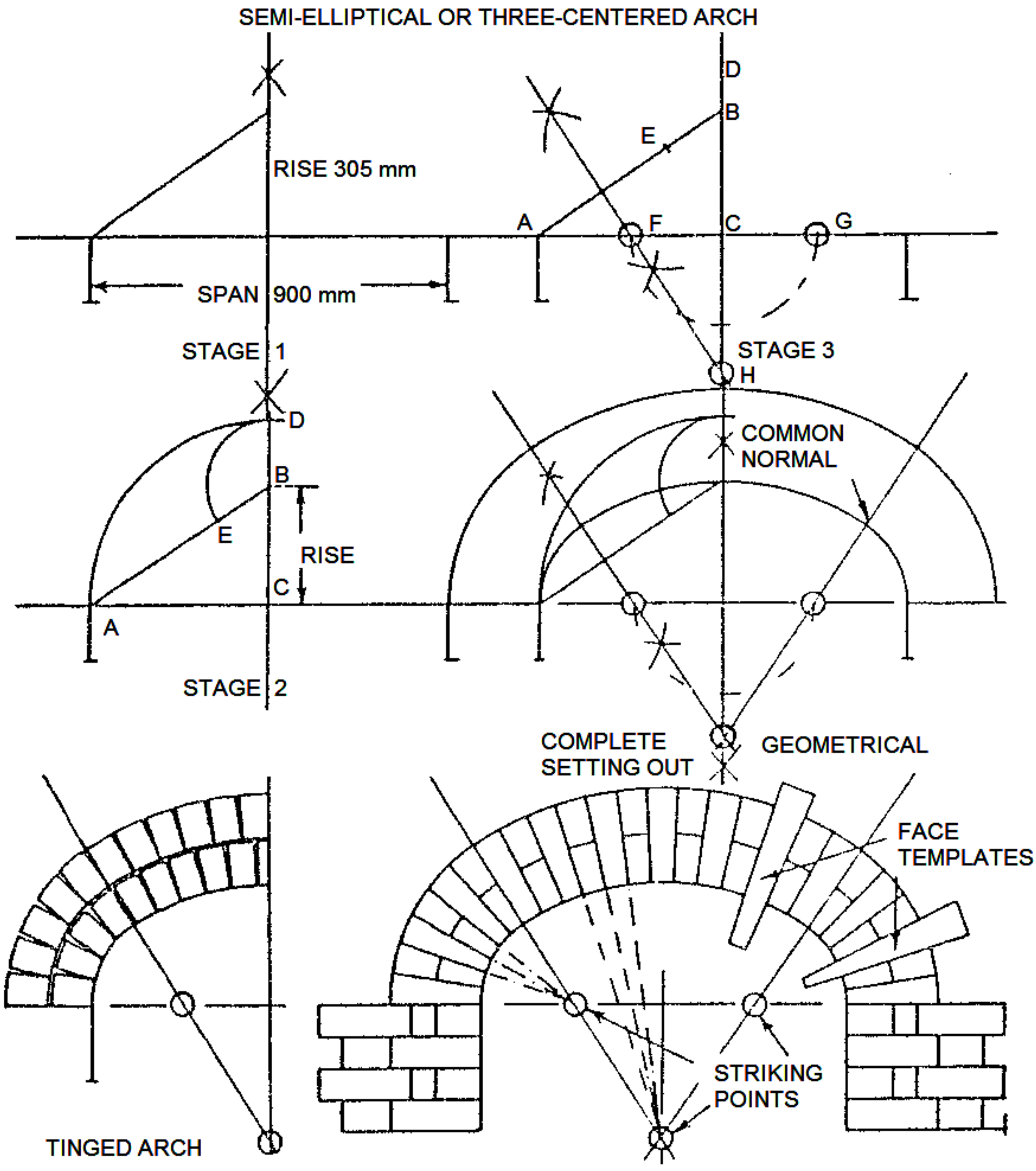


Figure 5.2 Ringed arch

Figure 5.1 Three-centered arch

5.3 Camber or flat arch

The name of this arch is explained by the fact that the arch is intended to be perfectly horizontal, but in order to prevent the optical illusion of sagging, it is given a slight camber or rise.

At one time, the arch was given a very acute skewback, but it has found to fracture across the top points of the skewback.

When given this acute skewback, the flat arch can be likened to a wide flat cork in an ordinary pickle jar - when pushed on one side the cork will come up on the opposite side because it has never made a true wedge.

For a considerable time, opinions differed as to what should be the correct skewback for a flat arch in order to obtain this true wedge.

Eventually, the setting out illustrated became general and is adopted by most bricklayers and persons responsible for the design and construction of a building.

To set out:

1. Draw the springing line, and parallel to this and 300 mm above it, draw the setting out line.

2. Erect a perpendicular at the springing point to intersect the setting out line. From this intersection, mark off the skewback, allowing 25 mm of skewback to every 300 mm of span.

Thus, for a 900 mm span, a 75 mm allowance is given, for a 1 371 mm span, 112 mm, and so on. This inclination is constant for any depth of arch face, as seen in **Figure 5.3**.

Note:
The amount of camber given to the soffit is 3 mm to every 300 mm of span, thus for a 900 mm span, the rise is 9 mm and for a 1 350 mm span, 14 mm.

In setting out of the voussoirs in a camber arch, some architects require stretcher to occur on the soffit at both the key and skewback, as seen in **Figure 5.3**. To effect this, the number of voussoirs must be a multiple of four, plus one.

This procedure is not always adopted, however, as it is sometimes not considered to be economical or practical.

It is held that the introduction of extra bricks needs additional labour and materials and tends to make the appearance that of a tile arch rather than an axed camber.

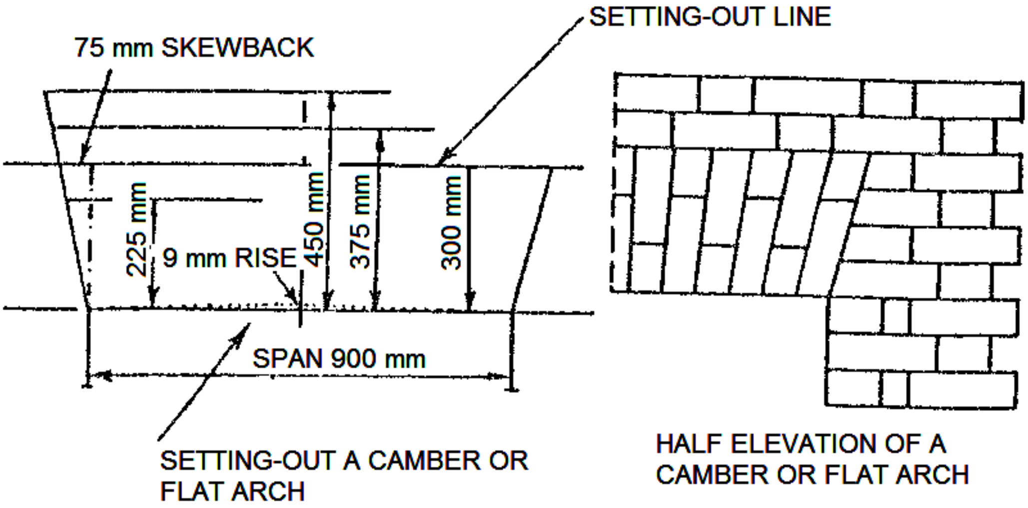


Figure 5.3 Arch construction

Note:
Wherever possible, place a stretcher at the key with either a stretcher or header at the skewback, as the case may be.

5.4 Cutting an axed arch

To set out:

The acquisition on the job of a flat table or bench for setting out is probably the chief difficulty encountered by the bricklayer in the preparation for arch cutting.

The carpenter will, however, usually supply two stools and a supply of floor-boards for this purpose.

The tools required are:

- Trammel heads
- Measuring rule
- Dividers
- Bevel
- Traversing rules
- Straight edge
- Carpenter's tools for cutting wood templet.

It is necessary to set out only half the arch, to include the key brick. For the purposes of this description, a segmental arch has been chosen.

Draw the centre line and set off the springing line at right angles to this. Ascertain the springing point and draw intrados, extrados, and skewback, as illustrated in **Figure 5.4**.

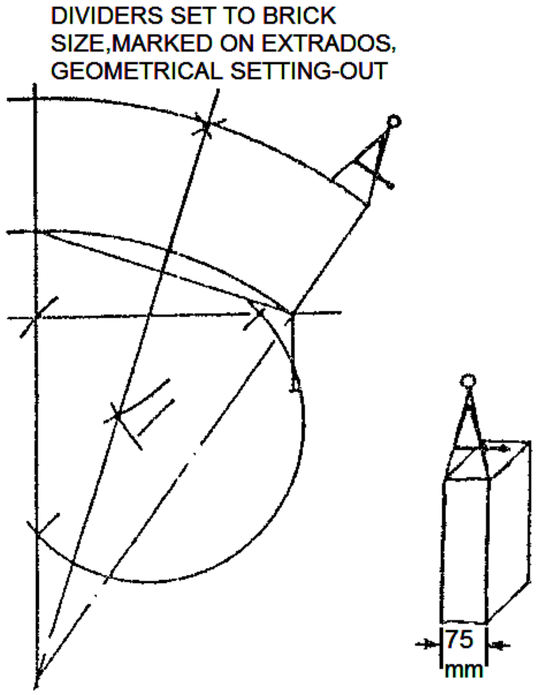


Figure 5.4 Axed arch

Set the dividers to the type of brick being used, as seen in **Figure 5.4**, and mark out voussoirs on the extrados. Having once set the dividers, do not open them any further, but, if necessary, close them a little.

If opened, and a templet is made to the resulting voussoir shape, the bricks will not "hold out" or will be too narrow to use. Mark out the templet to project approximately 50 mm above extrados and 150 mm below intrados.

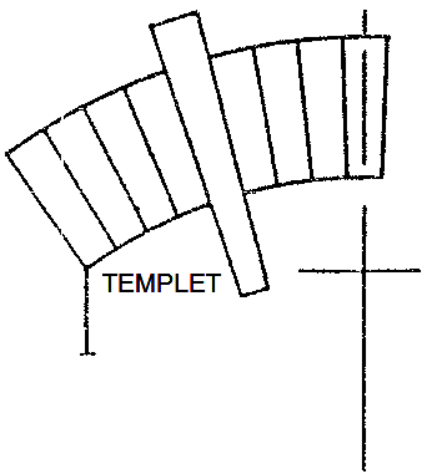


Figure 5.5 Templet

The templet can be made from a piece of wood 6 mm to 12 mm in thickness, as seen in **Figure 5.5** above.

5.4.1 Traversing the arch

The finding of the templet shape, as described above, gives only the approximate size. To obtain the true shape, it must be traversed or traced over the face of the arch.

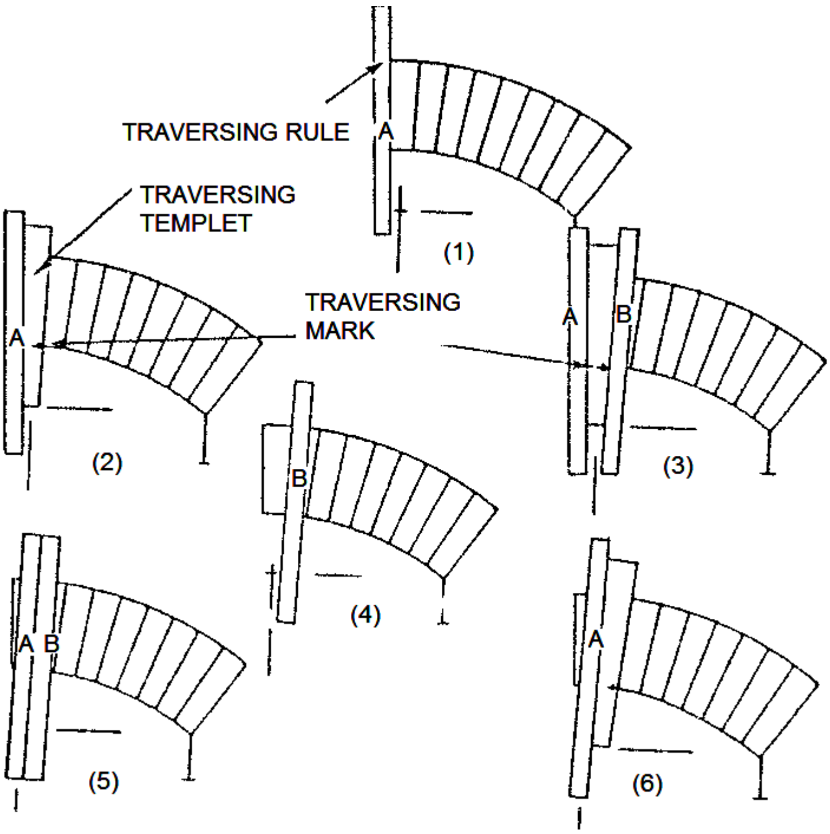


Figure 5.6 Traversing the arch

Follow **Figure 5.6** and do the following:

1. Place the traversing rule A to the key brick.
2. Arrange the templet to fit voussoir and mark a line on the side of the templet to coincide with intrados. This is called the "traversing" or "filling-in" mark.
3. Place the traversing rule B.
4. Remove A and the templet.
5. Place A to B.
6. Remove B and again fit templet, allowing traversing mark to coincide with intrados.

Repeat these operations until the skewback is reached.

If the templet "fills in" faster at the extrados than at the intrados, i.e. if it touches the top of the skewback but does not reach the bottom, it must be made smaller at the top by being planed down. The reverse applies if the templet fills in faster at the intrados.

If, having being traversed, the templet is parallel to the skewback but fails to reach it, or "under-fills" the area between the key and the skewback; the templet must be brought down by placing the traversing mark higher up the templet.

If the templet "over-fills" the traversing mark must be lowered.

The operation of traversing is repeated until the templet fits exactly between the key and the skewback, having in mind the number of voussoirs first ascertained in the setting out.

Traversing is an important operation in the construction of arches. Having obtained the correct shape of the templet, the voussoirs cut to this templet will find their true place in the arch.

"Trial and error" methods involve waste of labour and materials, and an unsightly job.

Allowance must be made for the mortar joint, and the cutting mark is obtained as follows:

1. Place the templet between two traversing rules.
2. Mark a line on one traversing rule to coincide with the traversing mark on the templet.
3. Holding the traversing rules firmly, tap the templet up until the edge of an ordinary 1 000 mm four-fold rule can be inserted between the traversing rule and the templet.

This gives approximately a 5 mm joint. This size is not invariable, although it is usual. It can be made greater according to the type of job and the wishes of the architect.

4. Transfer the mark on the traversing rule (which was the traversing mark on the templet) to the templet; this is the cutting mark.

Ascertain the bevel, as seen in **Figure 5.7**, remembering that the bevel is tangential to the curve of the arch and is found by taking the mean of the squares drawn from both sides of the templet.

Fix a short length of lathe to the templet at this bevel, and the templet is ready for use.

Figure 5.7 illustrates the above steps described to obtain the cutting mark. Refer to **Figure 5.7(a)** to **(f)** to see the process of cutting an axed arch.

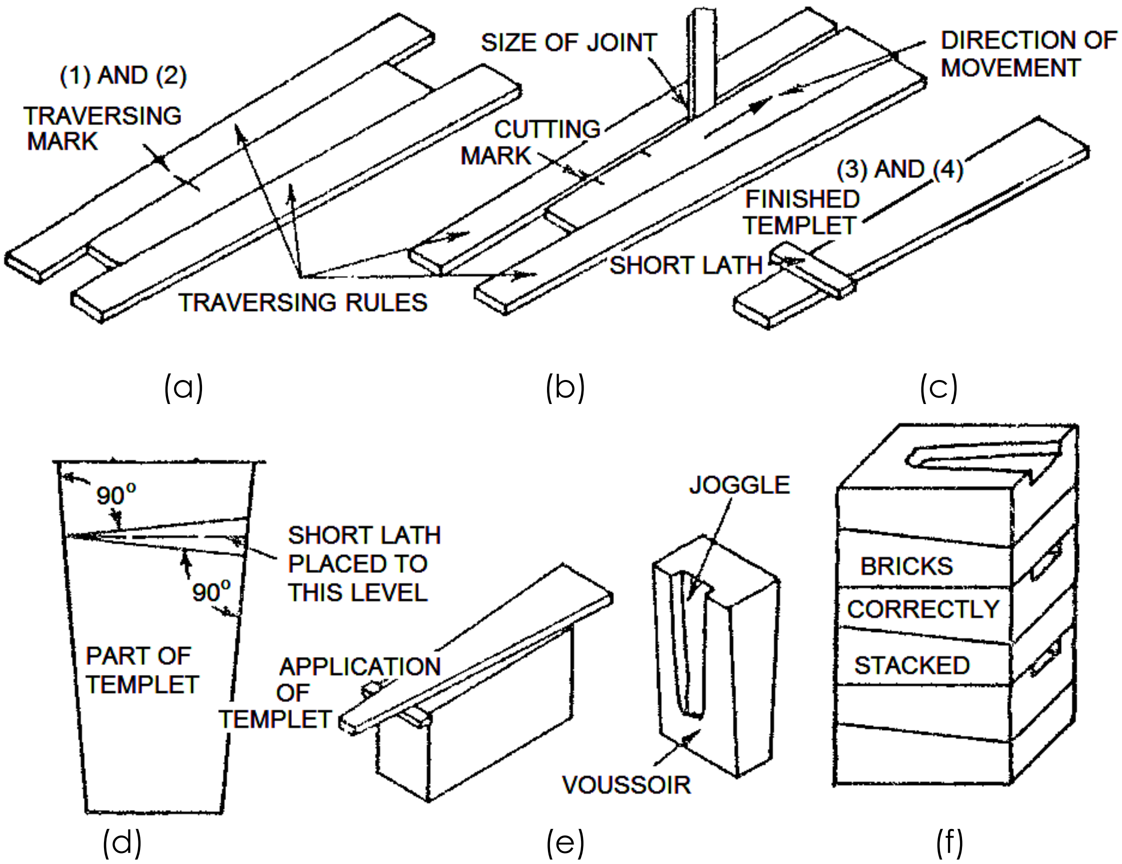


Figure 5.7(a) to (f) Cutting an axed arch

5.4.2 Cutting

The tools required are:

- Hammer
- Bolster
- Grub saw
- Scutch
- Comb hammer
- Templet
- A piece of carborundum, to be used to give a clean, sharp arris to the voussoirs

Apply the templet, as seen in **Figure 5.7(e)**, scribe with a grub saw and proceed with the cutting.

When finished to the required shape, cut a joggle, as seen in **Figure 5.7(e),** which allows the arch to be grouted when set in its position, giving added security.

Definition: Grout
A mixture of neat cement and water made into a thin slurry.

Stack the bricks carefully when cut, as seen in **Figure 5.7(f)**. A well-cut arch should stack evenly, each brick fitting snugly to the one above and below it.

5.5 Cutting an axed camber arch

The cutting of the camber arch is different from any other arch in that the bevels are not tangential to the same curve and are therefore all different.

Some bricklayers consider this arch to be the most difficult to prepare and cut, but if the operations are carried out systematically, no difficulty should arise.

5.5.1 Preparing the Templet

Set out the arch as previously described; only half the arch is necessary for practical purposes. There are two methods of drawing the camber:

1. Insert a small tack or panel pin at the springing points and the top of rise respectively. Spring a lath between these points and draw a pencil line round it.

   This method gives a suitable curve, and although it cannot be used on an arch with a deep rise, it is quite adequate for a camber, and is in general use.

2. The camber slip method gives a true curve and is suitable for an arch with any rise. Construct a triangular framing of laths, insert a tack at each of the springing points, and place the framing to these tacks.

   The apex of the triangle must be at a distance equal to the rise, above the springing line.

   Place a pencil at the apex of the framing and trace it round, always keeping the arms of the triangle in contact with the tacks at the springing points.

Other methods are possible in the striking of the camber, but either of the two methods described above is sufficient to undertake this work.

As suggested, the first method is simple, needs little preparation, and is suitable for such a small rise as that on the camber.

Prick the voussoirs on the extrados, marking the key brick only, for the time being.

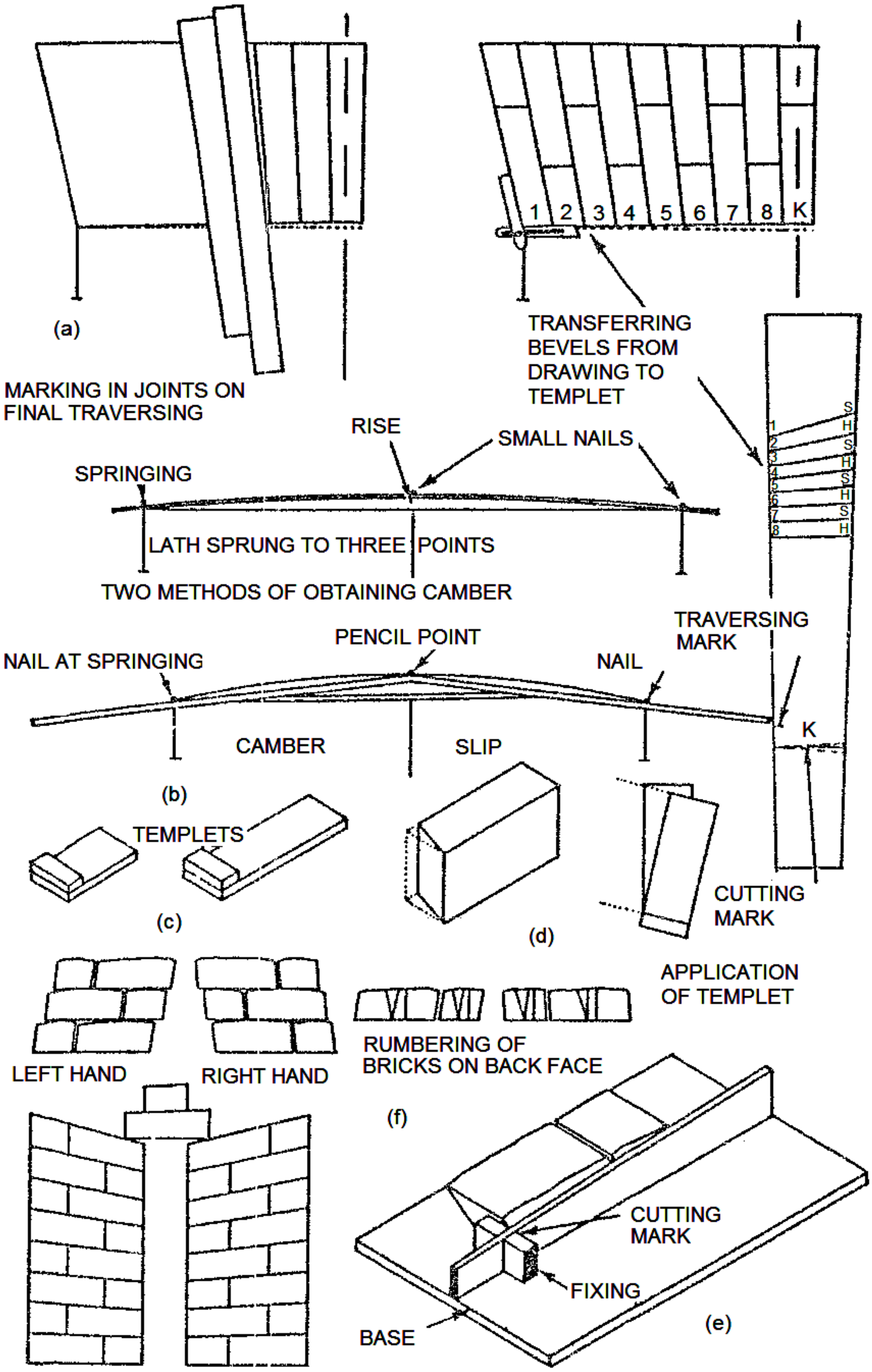


Figure 5.8 Cutting an axed camber arch

To obtain the approximate size at the intrados, divide the distance between the key and the skewback into the same number of parts as there are voussoirs in the extrados.

Make the approximate sized templet and traverse as previously described. When the correct size of the templet has been finally reached, traverse again, marking in the joint lines whilst doing so, as seen in **Figure 5.8.**

This will give the precise size of the voussoirs at the intrados, having in mind that each is slightly different.

Note:
The obtaining of the correct size is important for purposes of setting or fixing the arch.

An alternative method of obtaining the joint lines is to produce the skewback lines downwards towards the centre line of the arch, thus obtaining a striking point from which to mark the joint lines.

This would, however, be at a considerable distance from the springing line and the method shown above is much more convenient. The final preparation of the templet differs from that required for the ordinary arch.

As already stated, each brick has a different bevel, which must be cut on the brick before it is reduced to its voussoir size.

Important note:
Take note that the natural face of the brick can be maintained on the soffit of a normal arch, but with the camber arch this is impossible.

To complete the preparation of the templet, therefore, transfer all the bevels from the drawing to the templet, numbering from the skewback to the key.

If the arch is bonded, as in a 300 mm face, letter “H” or “S”, i.e. header or stretcher, according to the brick's position on the soffit.

All the information needed will then appear on the templet and this is a wise precaution, as a drawing may be lost or obliterated.

Important note:
Note that the practice of marking the bevels on the templet is for convenience only. Remember that the templet is wedge-shaped, so that if the bevels are placed on the templet from the right-hand side, they must be taken off in a similar manner.

5.5.2 Cutting

The camber arch has, right- and left-hand sides, again differing from the ordinary arch, where a voussoir will take any position on its own curvature.

Consider the cutting of an arch with a 300 mm face. In addition to the voussoir templet, two others are required, as seen in **Figure 5.8(b)**. These are called the 200 mm and 100 mm templets. The arch must be cut to a definite system.

For instance:

1. Cut the bevels on all bricks, stacking as shown in **Figure 5.8(c).**
2. On the back face of each brick, scribe its particular number in Roman numerals, so that it will be placed in its correct position.
3. Reduce the bricks to their voussoir size.

In operation 1 above, apply the bevel which has previously been set to its number, scribe with a grub saw to give a clear cutting line, and cut.

To obtain the header face, apply the 100 mm templet, and for the stretcher face apply the 200 mm templet, as seen in **Figure 5.8(d)**.

In operation 3, when ready to reduce the bricks to voussoir size, fix the templet to a rigid flat base. It will be found convenient to make the fixings coincide with the cutting marks, as shown in **Figure 5.8(e).**

Place the bricks to the templet, scribe, and cut. Stack neatly in the manner illustrated in **Figure 5.8(f)**.

5.6 Cavity walls

We shall now consider the cavity or hollow type wall which has found much favour in recent years. The walling materials in ordinary use are porous, and bricks and stones of all types absorb water.

It will, therefore be seen that an unprotected wall will absorb the greater part of the water which hits against it during a rainstorm.

5.6.1 Purpose of cavity walls

Cavity walls may serve any or all of the following purposes:

- To ensure dryness of the interior surfaces of external walls.
- To obtain a more constant temperature in the interior of a building without increasing the quantity of material in the wall.
- To increase the stability of comparatively thin walls by broadening their section while using the same quantity of material.
- To utilise economically two kinds of brick which may vary considerably in thickness.

We shall briefly discuss each of these purposes.

5.6.2 Resistance to damp

Damp may be conveyed to the interior surfaces of an exposed wall in two obvious ways, namely;

- by absorption of rain water streaming down the face, and
- by reception of moisture from a humid atmosphere.

The former is the cause of most damp walls which are open to the air because the bricks may become saturated by direct contact with the water.

Cavity walls cut off the contact and stop transmission while they provide for the possible leakage through faulty joints by draining off through the cavity any water which may penetrate.

The reception of moisture from a damp atmosphere is unavoidable, whatever kind of wall be employed, so long as the bricks and mortar are porous, but the effect is usually noticed only by a reduction of temperature.

When cavities are well ventilated and damp atmosphere allowed to circulate freely through them, then this effect is not noticeable.

5.6.3 Equability of temperature

Apart from the effect of damp air on the temperature of the inner portion of the wall above referred to, cavity walls do assist in preventing rapid changes of temperature if the cavity is not over-ventilated.

This greater constancy of internal temperature is due to the air sheath enclosed by the cavity being a slower conductor of heat than the brickwork

The result is that with the same total thickness of brickwork the outward flow of heat from the interior is retarded in the winter and in the inward flow the sun-heated atmosphere is retarded in the summer.

We must keep in mind, however, that if too free ventilation is provided through the cavity, this condition may be quite destroyed, especially in the winter time.

5.6.4 Hollow or cavity wall plans

In positions exposed to inclement weather, and particularly to driving rain, it is often found that moisture will penetrate the comparatively thin walls (230 mm and 345 mm) which are generally sufficiently strong for the external walls of the smaller domestic types of buildings.

Hollow, or cavity, walls are frequently used for such positions.

These consist of two separate walls, divided from each other by a space usually 50 mm wide and which, to comply with the model by-laws, must not exceed 76 mm, commonly referred to as an 280 mm cavity wall.
For brick walls, the outer thickness is usually 115 mm while the inner thickness must be sufficient to support any floors or roofs, but the total thickness of the walls, excluding the width of the cavity, must also comply with the thickness prescribed by the model by-laws.

In the case of stone-fronted buildings, which are difficult to construct with thin outer walls, the separate half-brick wall is built on the inside, and any girders or beams must be carried through this wall to bed upon the outer and thicker wall.

5.6.5 Bonding
Stretching bond is generally used for the half-brick walls, but a more pleasing appearance can be obtained in the outer walls by adopting Flemish bond, or a modification of Flemish garden wall bond.

All the headers used would be half bats or, as they are sometimes called, "snap-headers". The inner walls, when thicker than 115 mm are built in English bond.

It is essential that the two walls not touch each other, but they must be tied together with special bonding bricks, or metal ties.

The former are made in stoneware to various patterns splayed and curved and perforated, and roughly glazed to ensure well-baked material and impervious surfaces (the ends have serrated surfaces) which are built at least 58 mm into the walls.

Metal ties may be of cast iron, wrought iron, zinc or steel wire, twisted or depressed for passing across the cavity, so that any water collecting or falling upon them will drop clear of the inner wall.

Metal ties should be protected from rust by painting, galvanising or dipping in a hot bituminous compound. They are illustrated in **Figures 5.10 (a)** and **(b)**.

The latter is the more protective covering, but galvanising gives better adhesion of the mortar, and they should be built at least 76 mm into the face of each wall.

Brick or metal ties are placed in the horizontal mortar joints at a distance of about 900 mm apart, and at heights of four to six courses, arranged alternatively over one another in a diagonal pattern.

It is claimed that hollow walls not only prevent the damp from reaching the interior of the building, but that the layer of air within the cavity, being a non-conductor of heat, tends to keep the building warm.

Further advantages are: they render possible the use of two different kinds of bricks, and they tend to increase the stability of comparatively thin walls.

All bricks are more or less porous, and will absorb moisture from the air and from rain water streaming down the face, often causing the walls to become damp, and the building unhealthy.

The cavity in hollow walls prevents the moisture from penetrating to the inner wall, intercepting any leakage through faulty joints and providing a means of draining off any water that may gain access to the cavities.

The absorption of moisture from a damp atmosphere is unavoidable, but provided the cavities are sufficiently ventilated, this condition is largely destroyed, particularly during the winter time.

With the objective of gaining architectural effect or "texture" or to provide an impervious and durable external surface to walls; specially selected facing bricks are sometimes used, with cheaper and possibly less pleasing bricks as a backing.

It frequently happens that these special facing bricks do not completely conform to the "standard" sizes or, in the case of glazed brickwork, thinner joints are demanded.

The result is that the inner and outer brickwork do not rise at the same rate and the horizontal joints only coincide at infrequent intervals.

With hollow walls, such variations in the type of bricks are comparatively easy to build, care being taken to tie the two thickness walls together with a suitable tie whenever such horizontal courses do coincide.

Two storey buildings can be built with 230 mm thick external walls, and in many districts such walls can be carried to a height of 7 600 mm above the footings without violating the local by-laws.

However, their stability is not very great because they are too high in relation to their thickness and this defect is accentuated if bricks and mortar of poor quality are used.

When the two half-brick thicknesses of a hollow wall are firmly held together with suitable metal or brick ties, the enlarged area of the wall tends to increase and improve its stability.

5.7 Absorption by bricks and stones

The power of absorption possessed by materials depends upon texture and density. Consequently porosity is related conversely to hardness and ability to sustain weight.
A good, hard, useful "stock" brick, weighing about 3,2 kg, will absorb about 0,5 kg of water. A "face" brick of a soft kind will absorb much more; and a very hard vitrified or glazed brick very much less.

Among limestones, any stone which is hard enough to be suitable for nearly all kinds of surface masonry will absorb 17% of its bulk of water.

Granite only absorbs about 1% of its bulk, while marble is practically non-absorbent and was used in ancient Rome for baths because it holds water.

It will, therefore, be realised that in these parts of the country, which experience long, heavy rainstorms, water absorbed by the walls will pass through them and eventually reach the interior plasterwork.

Dampness in any form is not only unpleasant in a building, but injurious to health.

You will recollect that, in order to prevent dampness from rising from the subsoil, we insert damp-proof courses in the wall 152 mm above ground level.

Solid brick or stone walls can be rendered watertight by plastering the outer surface with an impervious coat of cement, to which has been added a water-proofer, or by simply painting with an oil base paint which seals the pores of the wall material.

The modern method of damp prevention is, however, to build two 115 mm walls with a space or cavity between them; the cavity varies from 38 mm to 89 mm. The two walls are connected with wall ties of various types.

5.7.1 Types of wall ties

Figure 5.9 illustrates how the Hollow vitrified clay tie is used in a cavity wall.

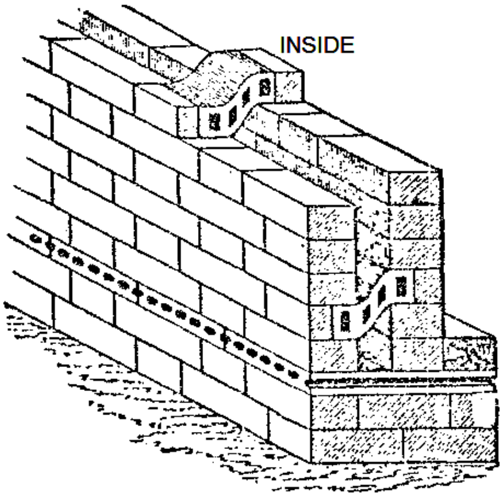


Figure 5.9 Hollow vitrified clay in cavity wall

Figures 5.10 (a) and **(b)** shows two types of wall ties. The wrought iron twisted type is the better of the two but more expensive. Spacing of the ties is important.

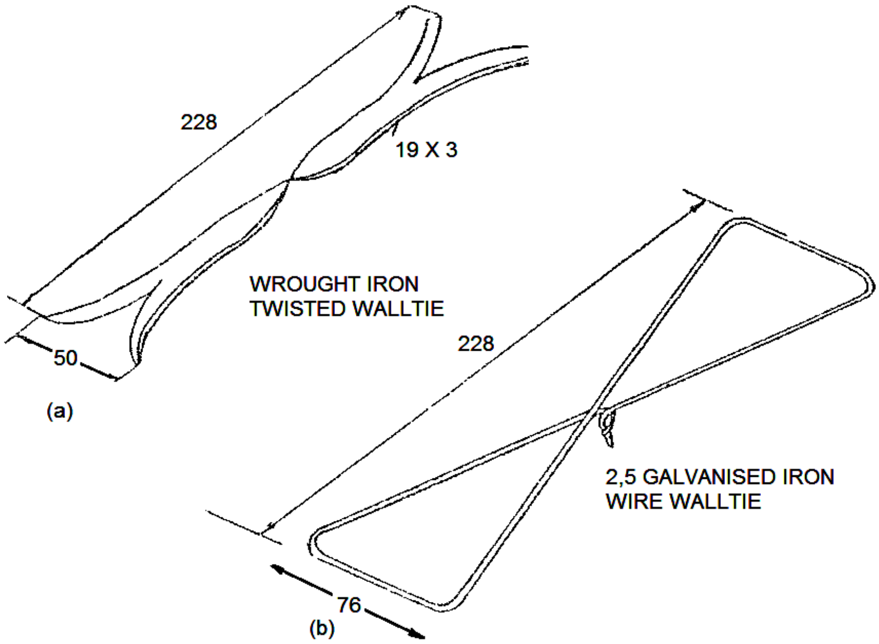


Figure 5.10((a) and (b) Types of wall ties

Figure 5.11 illustrates the method of spacing the ties. The corners are well secured with wall ties.

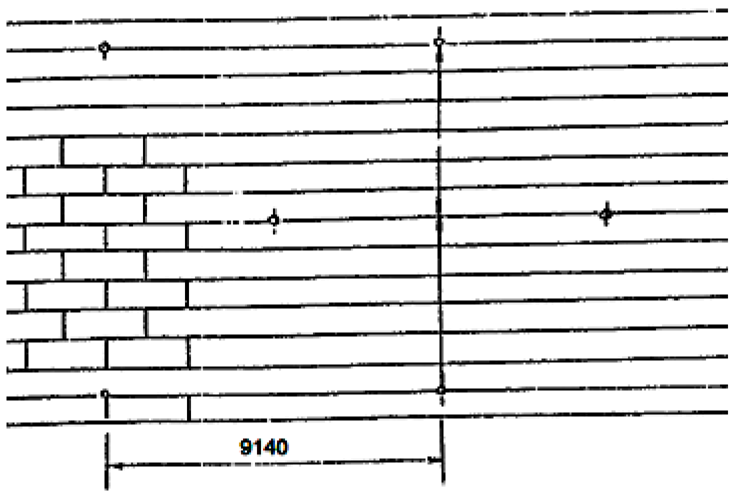


Figure 5.11 Spacing wall ties

Glazed stoneware and hollow vitrified clay ties Types of wall ties not commonly used today are.

5.8 Sections through cavity walls

Earlier we discussed cavity construction and the advantages of this type of construction over the solid type of wall construction.

The chief advantage we discovered was the prevention of water passing through the cavity to the interior of the building.

This is due to the fact that the inner skin is completely isolated from the outer except for wall-ties, and even these are provided with a twist in the centre which prevents water bridging the cap by simply dropping off in the cavity.

What would happen, however, if, during building operations mortar droppings were allowed to fall into the cavity and on to the wall ties?

Immediately a perfect bridge would be formed for water to cross into the inner-skin and thus nullify the very purpose for which the cavity was designed.

Great care must be exercised during building operations to keep the cavity clean.

This is accomplished by suspending a batten wrapped with old sacking in the cavity, and drawing it up as the work proceeds.

Inspection openings must also be left at the bottom of the cavity for cleaning out any droppings during building operations. These are finally sealed off.

Another question is; what happens where door-frames and windows bridge the cavity? **Figure 5.12** shows the vertical section through a wooden-framed window.

Water will not pass through the wood, as this has previously been painted, and is not porous to the same extent as brick or stonework.

The brick sill, which is composed of bricks on edge, does not touch the inner-skin. Therefore no water will pass across here.

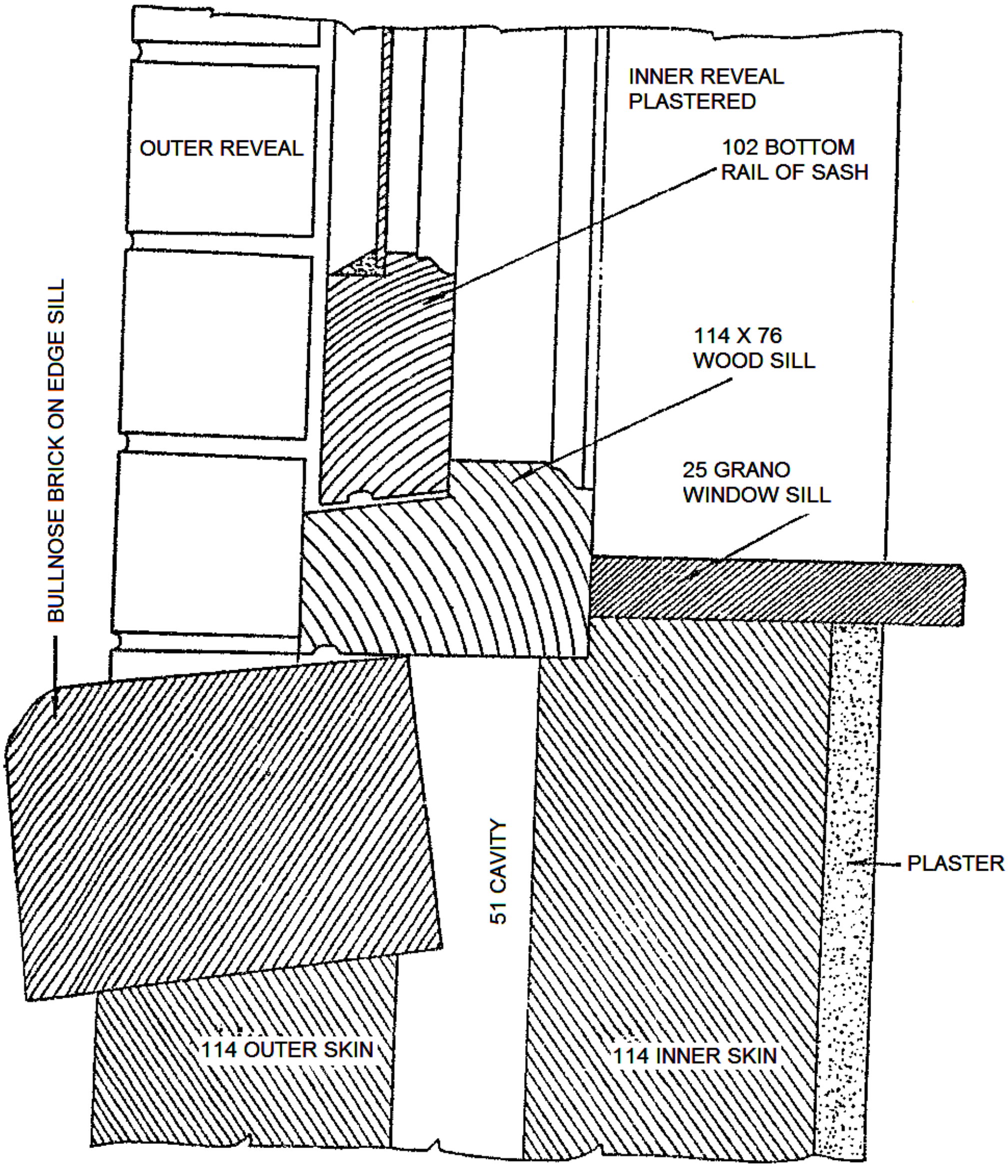


Figure 5.12 Section through 280 mm cavity wall showing treatment of wood window sill

On the following page, **Figure 5.13** shows a section through the head of the same window as shown in **Figure 5.12**. However, more elaborate precautions are required here.

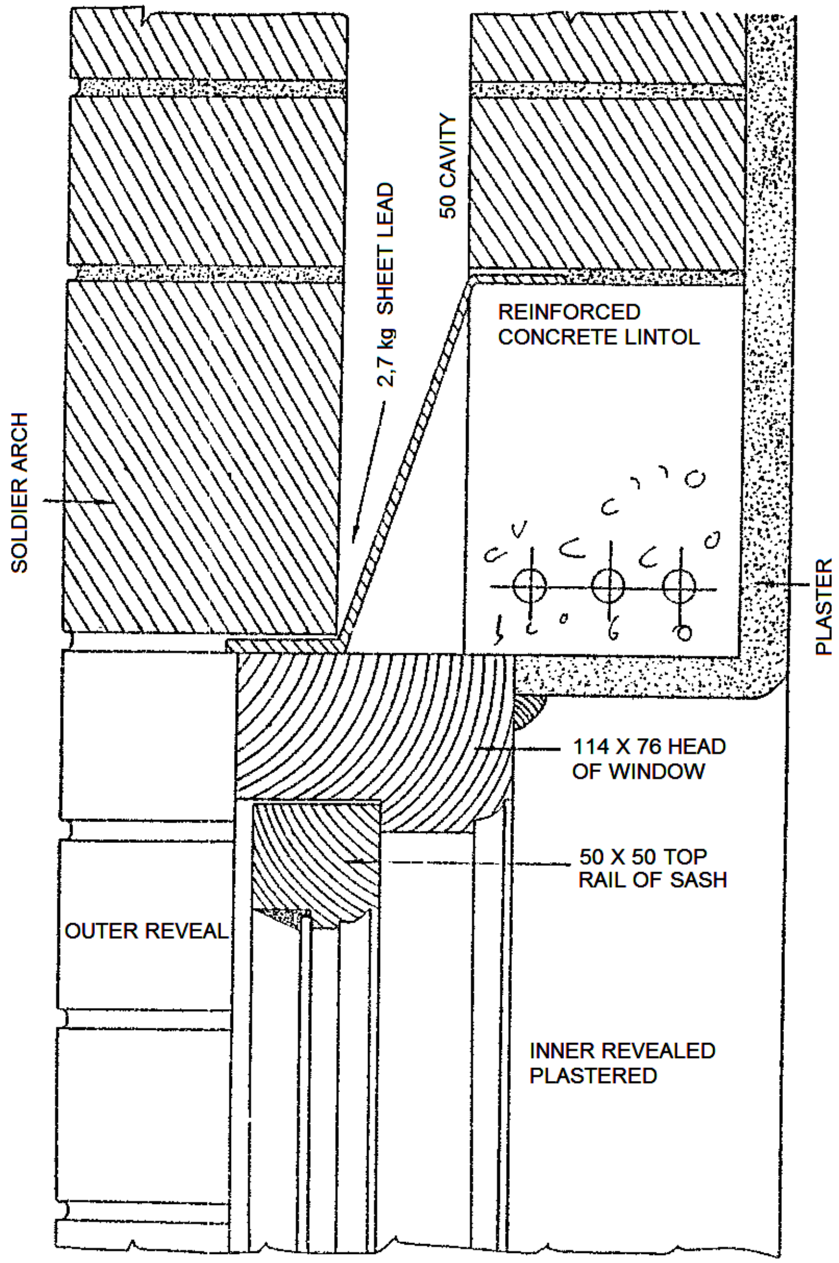


Figure 5.13 Section through 280 mm cavity wall showing treatment at head window

Water, which may penetrate the outer skin, can run down in the cavity and accumulate on the head of the frame and penetrate to the interior.

To prevent this, we place a sheet lead apron in the cavity terminating on the outer edge of the frame, thus any water which might accumulate is allowed to percolate to the outside.

The sealing of the cavity at the window jambs is efficiently accomplished by bedding slates in cement mortar between the bricks sealing the cavity as slates are impervious to moisture, as seen in **Figure 5.14**.
Below, **Figure 5.14** shows the section through a 280 mm cavity wall showing the treatment at the jamb of the window.

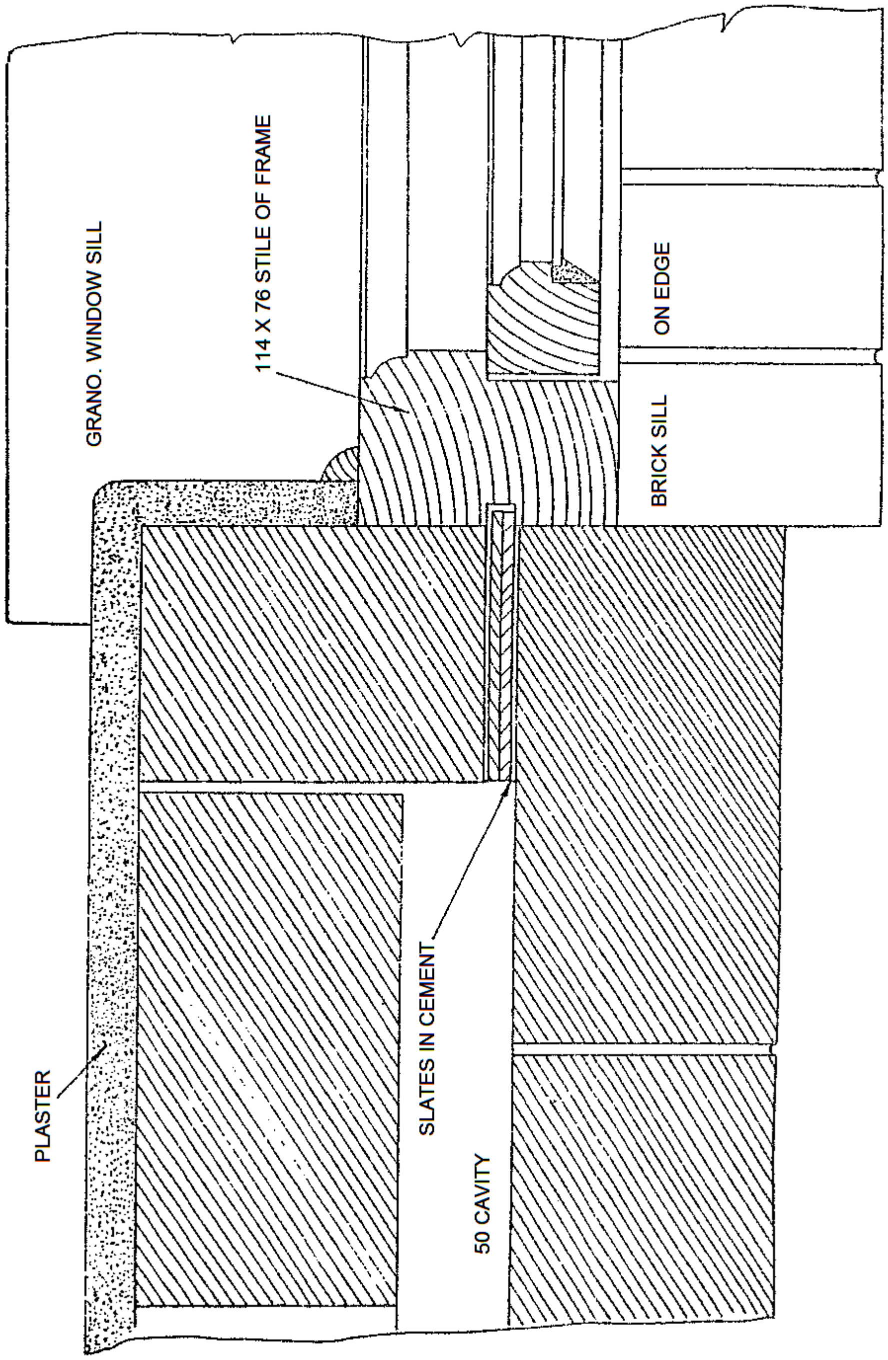


Figure 5.14 Section through 280 mm cavity wall showing the treatment at the jamb of the window

It is usual to seal off the cavity at the top to prevent the cavity forming a nesting place for vermin.
This is done where the wall will be protected by the overhang of the eaves from driving rain, as illustrated in **Figure 5.15** below.

This figure shows the section through a 280 mm cavity wall at the eaves, showing the "sealing off" of the cavity.

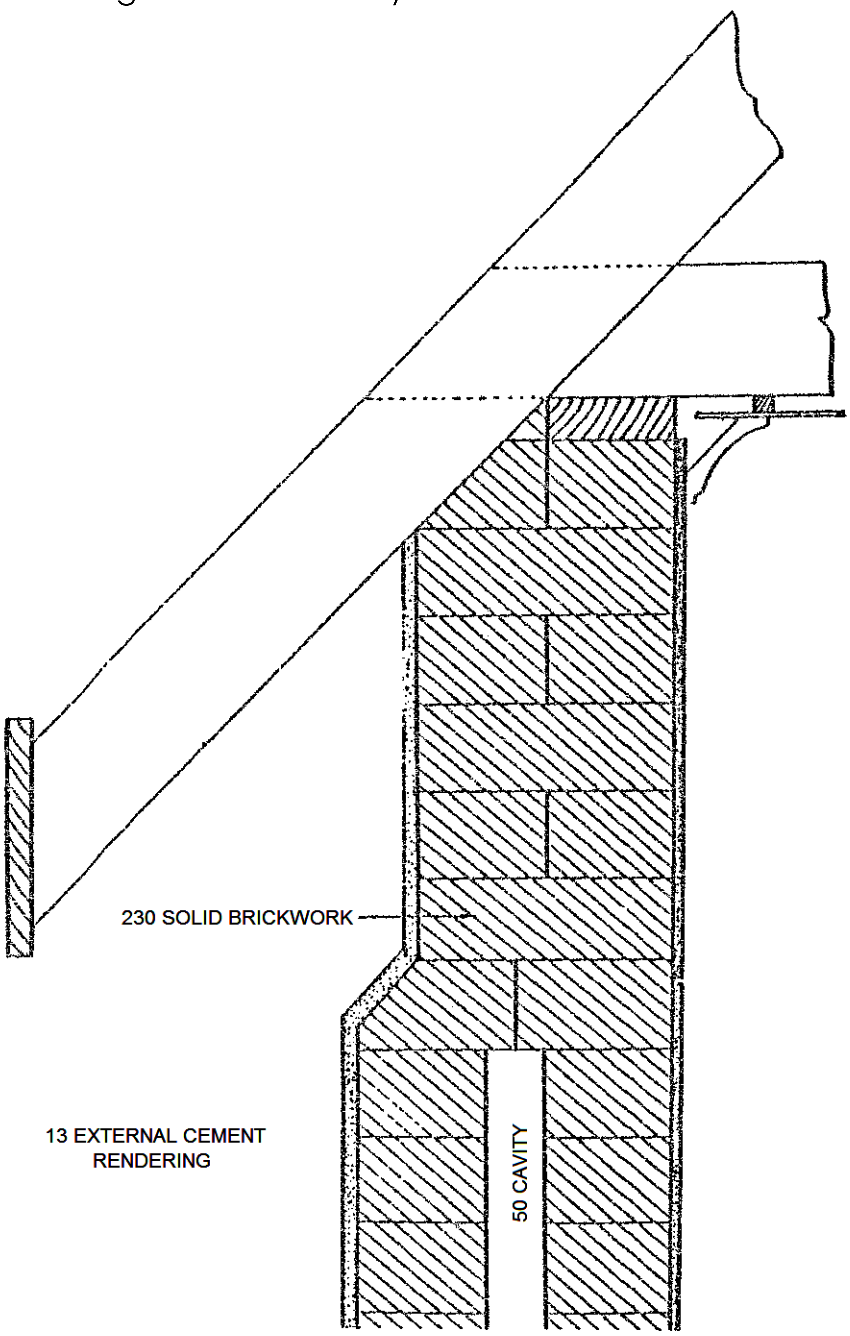


Figure 5.15 Section through 280 mm cavity wall at the eaves showing "sealing off" of cavity

On the following page, **Figure 5.16** shows the method of preventing dampness entering a building where the roof is composed of a flat concrete slab and a parapet wall.

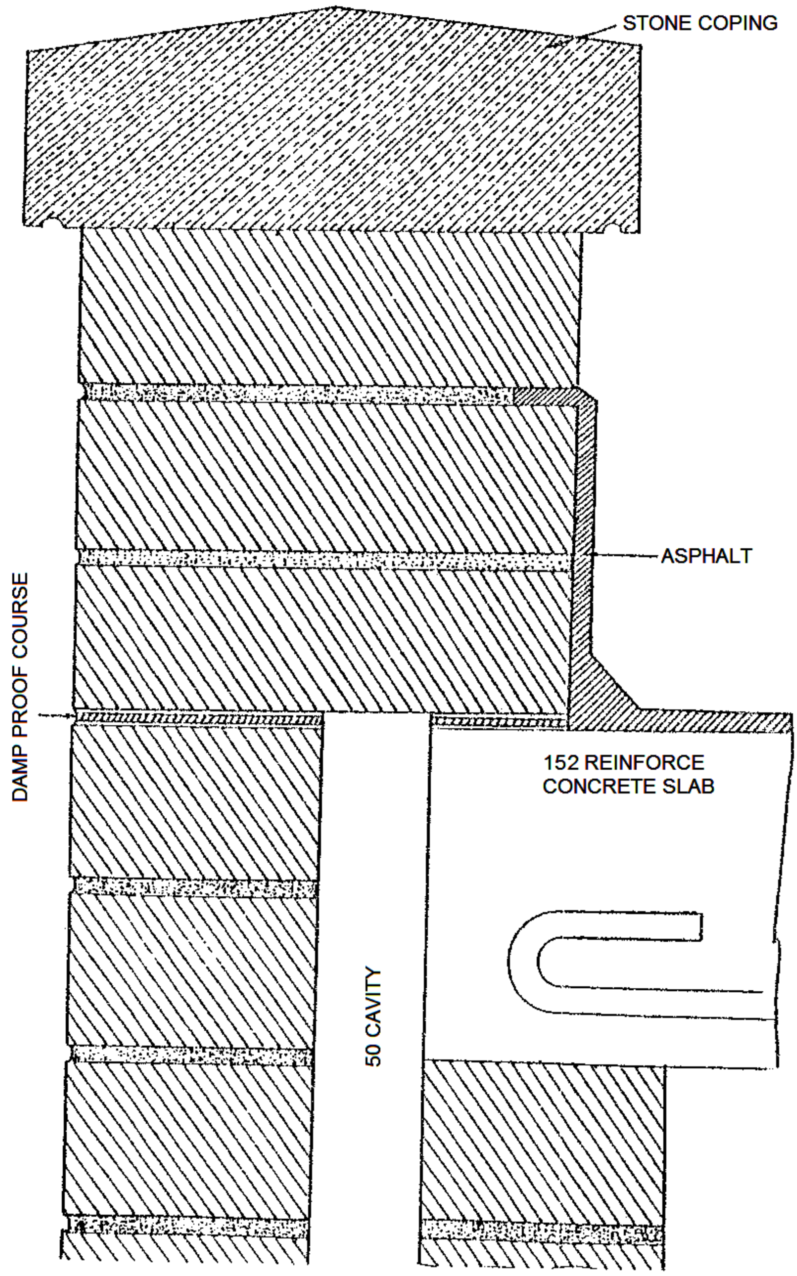


Figure 5.16 Section through 280 mm cavity wall showing treatment through flat roof

Any water which may be absorbed by the brickwork in the parapet wall will be unable to pass the horizontal damp proof course, or through the asphalt covered concrete.

Figure 5.17 shows the vertical section through a 280 mm cavity, complete with footings and foundation.

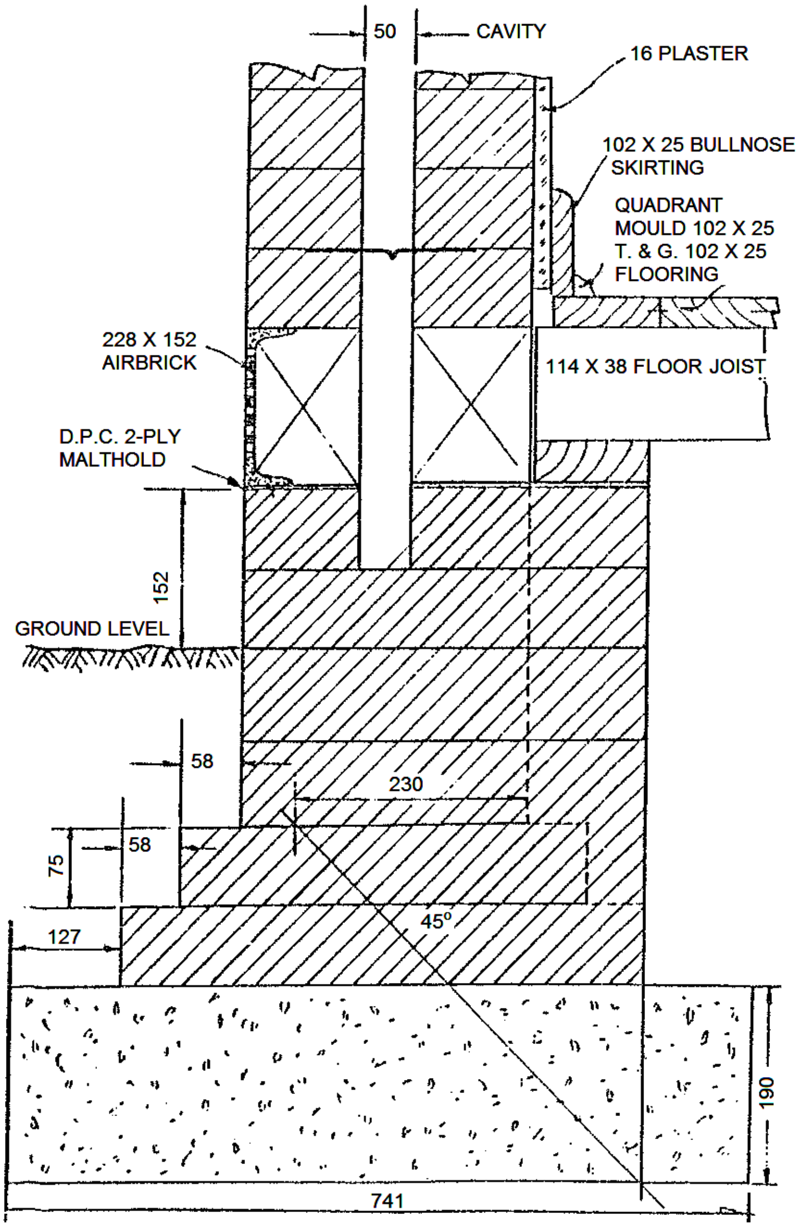


Figure 5.17 Section through 280 mm cavity wall showing method of obtaining foundation and footing courses

As this type of wall replaces the 230 mm solid wall, the foundation for the 230 mm solid wall is quite adequate.

Important note:
Note carefully that the cavity does not exist below ground level but terminates above it. This is to allow any water which may have entered it, to drain away through vertical weep holes.

A section through the foundation of a cavity wall, which is generally used throughout South Africa, is shown in **Figure 5.18.**

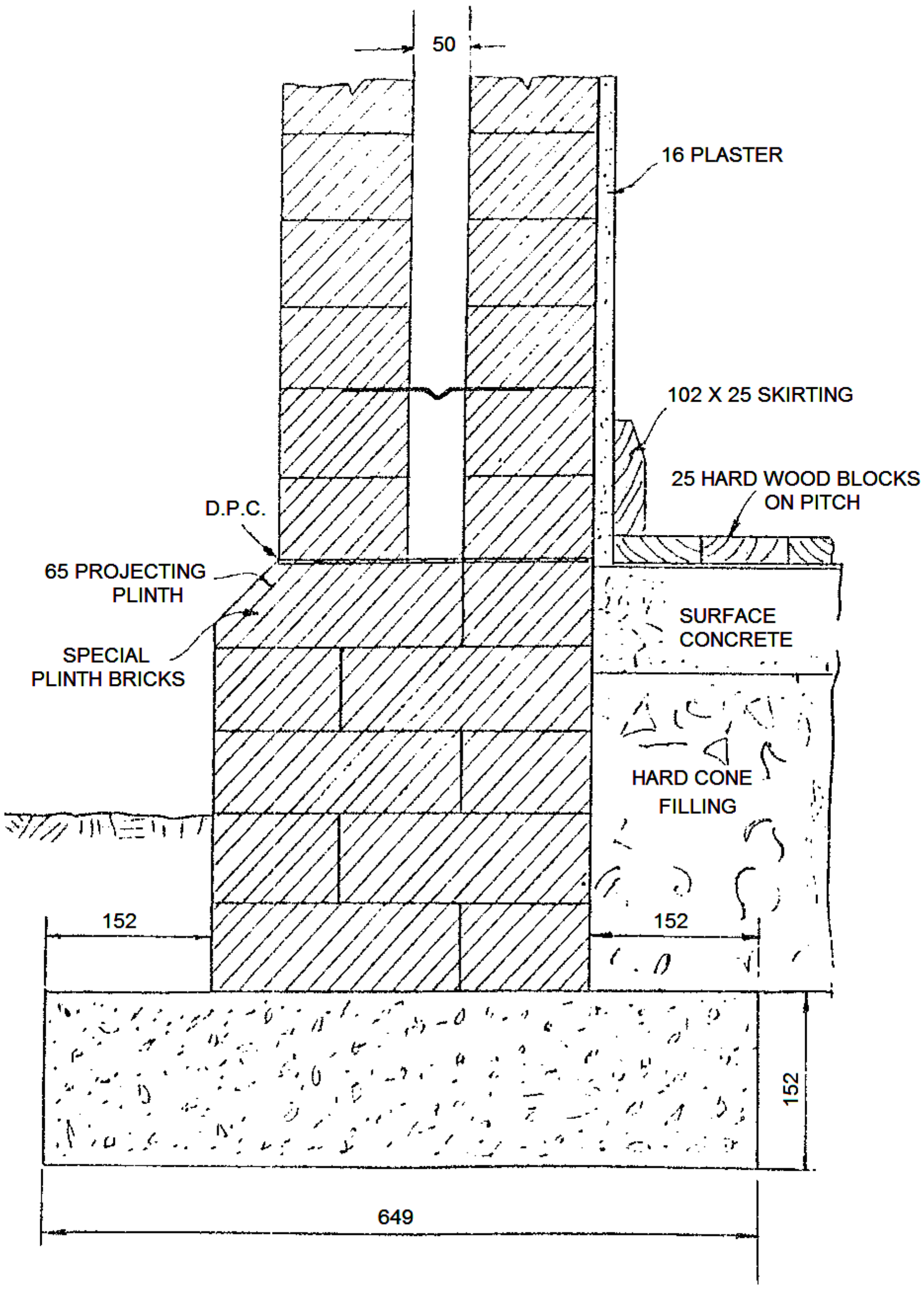


Figure 5.18 Section through 280 mm cavity wall showing typical South African foundation procedure

No footing courses are used, but a 345 mm solid wall is built up to D.P.C. height, terminating in a plinth course.

The surface concrete is usually placed when the bricklayers have arrived at the plinth course.

Where extra strength is required, the inner skin of brickwork may be built solid to any desired thickness, with the outer skin remaining 115 mm thick.

Figure 5.19 shows the vertical section through a 395 mm cavity wall, with a 230 mm inner skin.

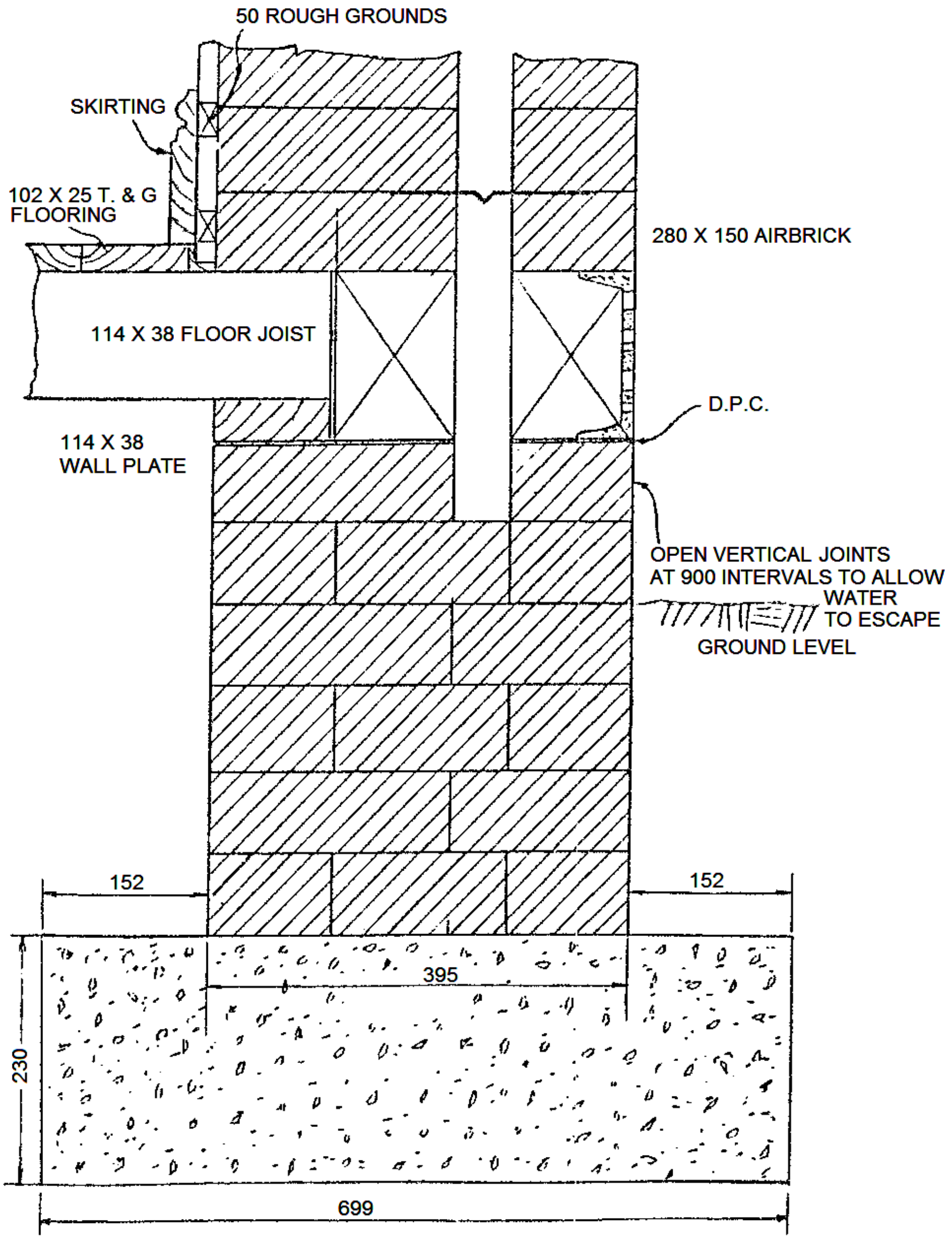


Figure 5.19 Section through a 395 mm cavity wall

Cavity walls not only serve the important function of preventing water passing through the walls, but owing to the air in tile cavity acting as a non-conductor, houses remain comparatively cool in summer and warm in winter.

5.9 Various arrangements in cavity walls

5.9.1 Alternate plan courses

Below, **Figure 5.20** shows the alternate plan courses of a 395 mm cavity wall.

The inner skin, shown in **Figure 5.20 (b),** is 228 mm of English bond and the outer skin, as shown in **Figure 5.20 (a)**, is 115 mm of Stretcher bond.

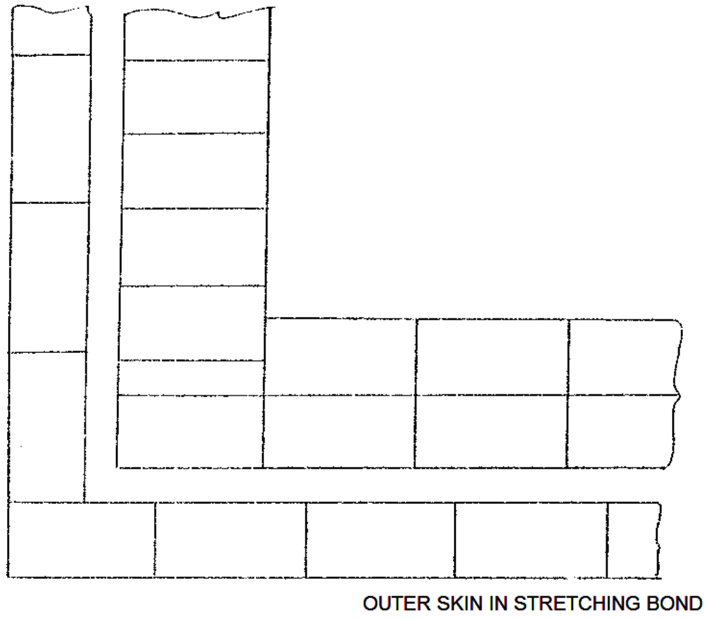


Figure 5.20 (a) Alternate plan courses for 395 mm cavity wall – outer skin

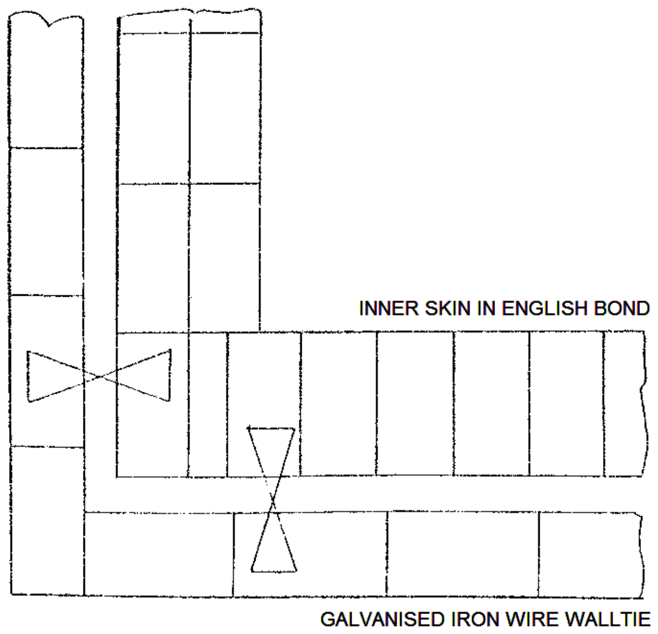


Figure 5.20 (b) Alternate plan courses for 395 mm cavity wall – inner skin

5.9.2 Arrangement at stopped end
Figure 5.21 illustrates an arrangement at a stopped end.

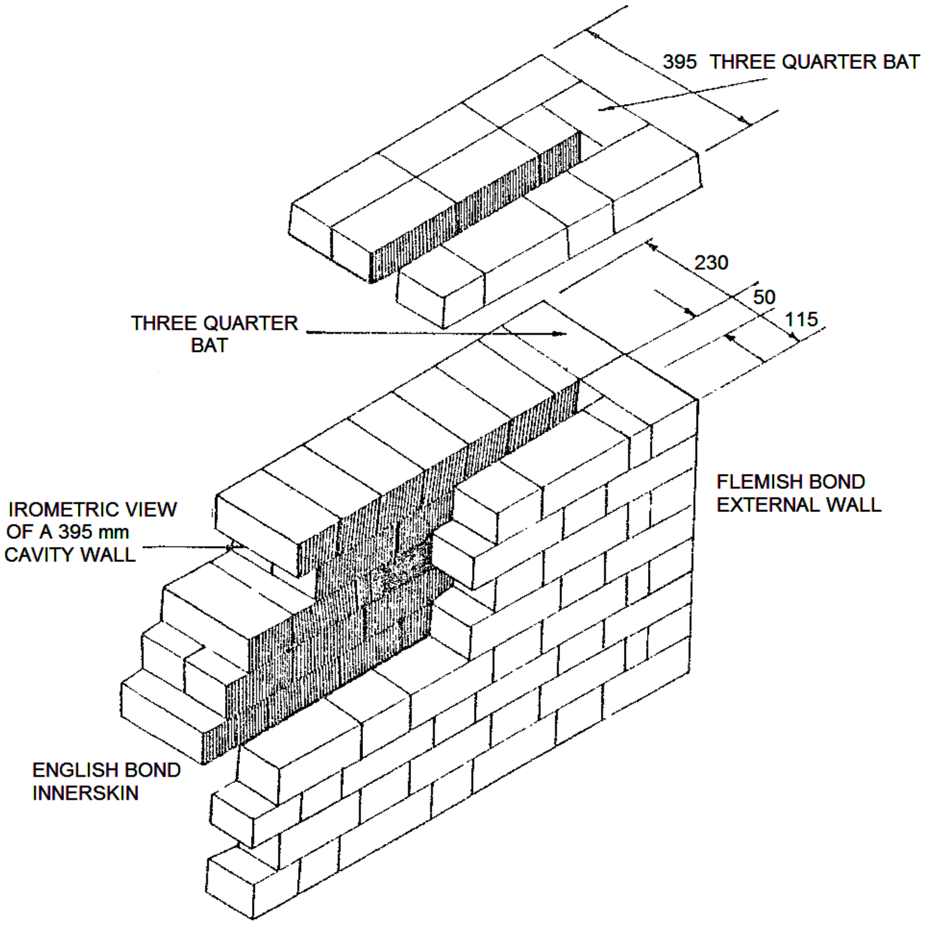


Figure 5.21 Arrangement at stopped end

5.9.3 Arrangement at reveals employing King and Queen closers

Below, **Figure 5.22** illustrates an arrangement at reveals, employing King and Queen closers.

> **Important note:**
> A layer of mastic must be inserted where inner and outer skin comes into contact.

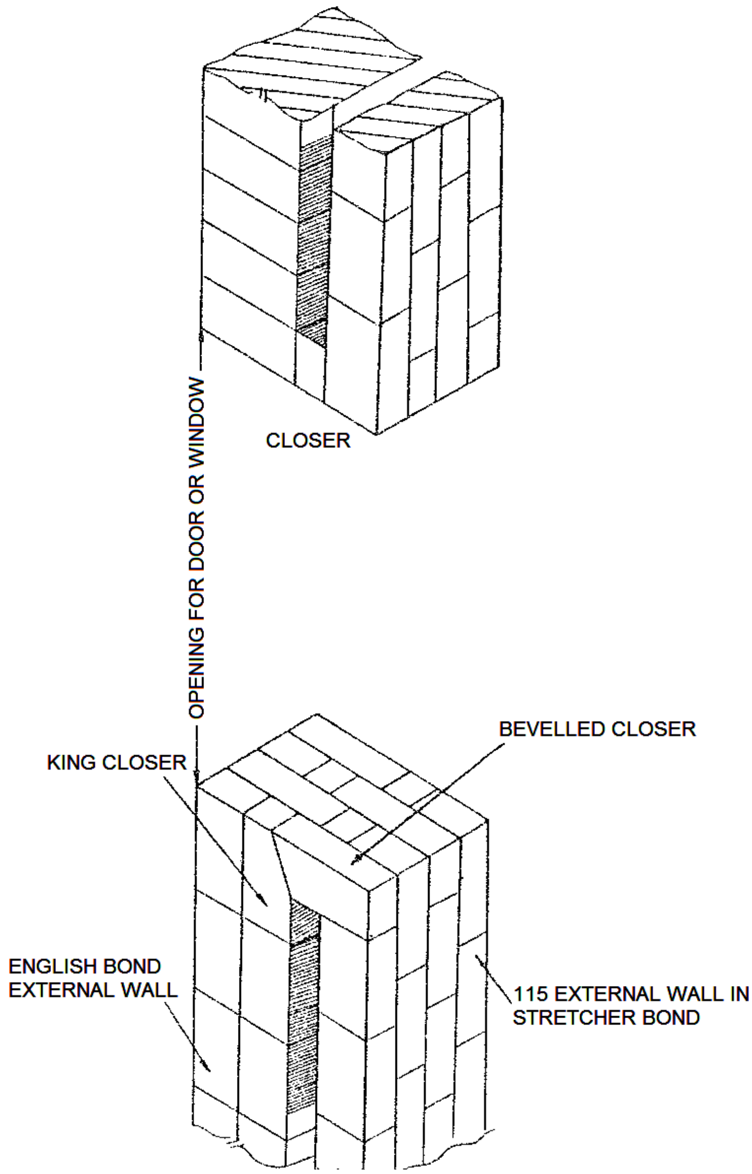


Figure 5.22 Arrangement at reveals employing King and Queen closers

5.9.4 Arrangement at reveal employing slates to close cavity
On the following page, **Figure 5.23** shows an arrangement at reveal employing slates to close cavity. The slates are vertical courses laid in cement mortar.

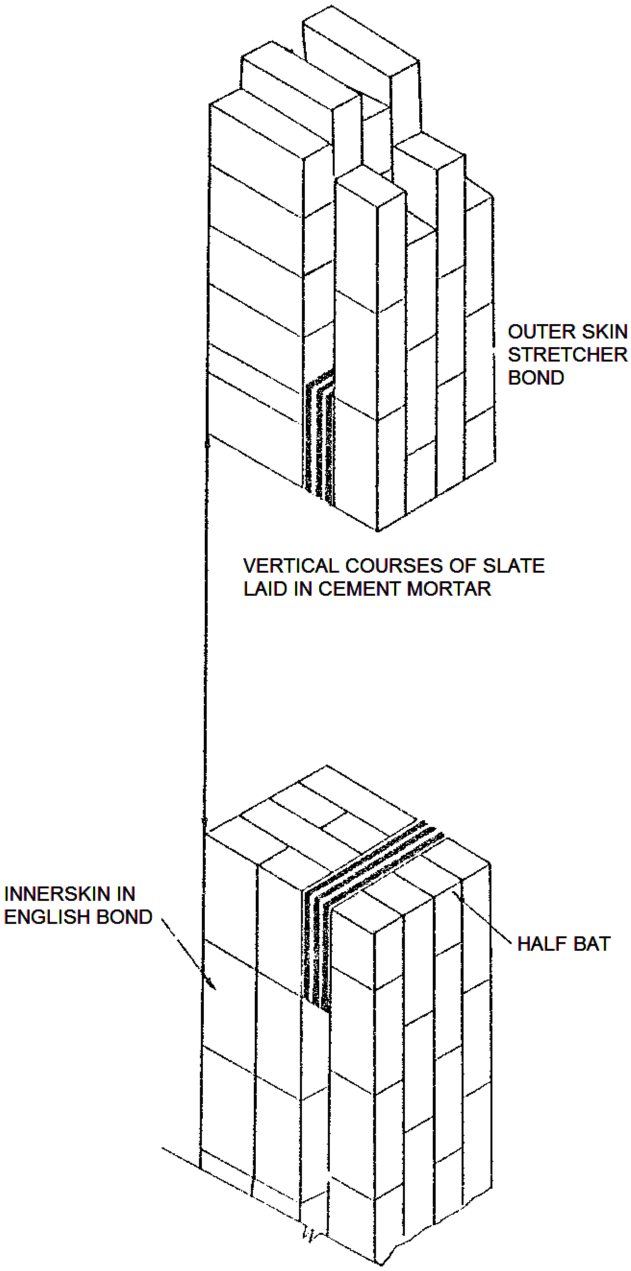


Figure 5.23 Arrangement at reveal employing slates to close cavity

5.10 Disadvantages of cavity walls

With work on cavity walls, we shall note that, although they have many advantages, the following points must also be considered:

- They waste a little interior space.
- They require special treatment at door and window openings.
- In thin walls, the whole of the weight from floor timbers may have to be borne by the 114 mm inner portion.
- The cavity may harbour vermin if these can gain access, and thus produce an insanitary condition which is difficult to remedy since the cavity cannot be inspected.

Activity 5.1

1. To a scale of 1:10, draw the front elevation of a semi-elliptical arch using the three point method. The span is 900 mm, rise 300 mm, and the depth of the arch 230 mm. Your drawing must also show four courses of brickwork executed in English Bond.
2. To a scale of 1:10, show the construction lines of setting out a flat arch as shown in **Figure 5.3**.

Activity 5.2

1. Make neat freehand sketches to illustrate the following:

   a) Spacing of wall ties;
   b) Two types of wall ties.
2. What are the types of wall ties not commonly used today?

Activity 5.3

1. To a scale of 1:10 and full size, draw a vertical section through the head of a wooden-framed window in a 280 mm cavity wall showing the method you would employ to prevent dampness entering the building.
2. To the same sca1e as in Question 1, draw a horizontal section of the same window through one of the jambs, showing treatment of the cavity as this particular point.
3. A recently erected building with cavity walls shows, during continued heavy rains, damp patches in one room. State reasons for this, and describe how you would set about to remedy this.
4. To a suitable scale, show the method you would adopt to prevent dampness entering a building which has a flat concrete roof, a cavity wall, and a parapet wall.

Activity 5.4

3. Draw a vertical section through a 395 mm cavity wall showing foundations and footings. Provision must be made for a wooden floor 152 mm above ground level. Use a scale of 1:10.
4. State the advantages of brick cavity wall construction over solid brick walls.
5. Draw, to a scale of 1:10, a vertical section through a 280 mm cavity wall showing plinth course. D.P.C., hardwood block floor and a concrete foundation.

Activity 5.5

1. To a scale of 1:10, draw the two alternate plan courses of a 395 mm cavity wall. Your drawing must show an inner skin built in 230 mm English Bond and the outer skin built in 115 mm Stretcher Bond.
2. To a scale of 1:10, make an isometric drawing showing a portion of a 395 mm cavity wall, with the inner skin 230 mm in English Bond and the outer skin 115 mm in Stretcher Bond. Your drawing must also show the method of sealing the cavity at a door or window opening.
3. State four disadvantages of a cavity wall construction.

Self-Check

I am able to:	Yes	No
• Describe the following types of arches		
o Semi-circular		
o Segmental		
o Rough		
o Axed		
• Explain steel and timber centering for arches		

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Module 6

Roofs up to 9 m span

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the following roof trusses of riveted and bolted construction
  - Fink
  - Monitor
  - Saw tooth
- Describe the following timber trusses
  - Bolted construction
  - Nailed construction
  - Gang nail construction
- Describe lean-to roofs
  - Steel
  - Timber

6.1 Introduction

The purpose of this module is to discuss and explain how to identify and detail bolted and welded roof trusses. Trusses are used in the roof construction of buildings of medium to large spans.

They are able to support heavy loads on greater spans than beams or rafters made from universal sections. They are also used in footbridges, conveyor gantries, walkways, and so on. Trusses may be of welded or bolted construction, depending on the fabricator's preferred production method.

The decision to bolt or weld will also depend on whether the component can be transported to site in one or two sections or must be dispatched piece-meal for on-site assembly. The decision to weld or bolt trusses is usually made by the designers; however, it is not unusual for the fabricator to propose alternate options.

6.1.1 Important terms

Apex	The top of the truss where the two rafters meet
Batten	Small timber sections nailed across the top chords at small spacing's to carry concrete tiles, slates, metal tiles etc.

Base-plate:	This is a plate attached to the bottom end of a column, drilled for holding-down bolts.
Backmark:	This is a set distance from the heel of the steel sections in I and H sections, channels and angles.
Beam:	A beam is a horizontal structural member supporting vertical loads.
Bracing:	These are lighter diagonal members connected to a system of tension/compression members connected to the main members to stabilize it.
Bottom Chord (Tie)	Also tie-beam. That part of the truss that forms the bottom edge, and connects the two heel joints, usually flat, and supports the ceiling. Sloped in scissor trusses. Abbreviated B.C.
Cantilever	When the truss support on the bottom chord is some distance inside the heel joint.
Cleat:	Usually a short length of angle or channel section welded or bolted to a steel member enabling it to be fastened to another member.
Column:	A vertical steel member that generally transfers loads to a support foundation.
Crane girder or Crane-beam:	A girder that supports the loading from an electric overhead travelling crane.
Crane rail:	A track or rail that supports and guides the wheels of a gantry crane.
Cross-section:	A view of the interior of an object as if it had been sliced across with an infinitely sharp and straight knife. Also see ‘profile’ or ‘section’.
Edge distance:	distance from the centre of a bolt hole to the nearest edge of an element, measured perpendicular to the direction in which the bolt bears
End distance:	distance from the centre of a bolt hole to the edge of an element, measured parallel to the direction in which the bolt bears
End-plates:	A plate welded to the end of a steel beam to facilitate a connection.
Fabrication:	The process of manufacturing steel section and plate into structural steel components.
False rafter:	A small section running parallel to the rafter usually bolted to the underside of the purlin, providing a means of fastening the top end of the cladding at the gable.
Flashing:	The metal used to "trim" or cover connections between sheets of cladding to make it waterproof and of neat appearance.
Floor beams:	Horizontal steel members supporting the floor decking, this is commonly of concrete.
Friction grip	a bolted connection that relies on friction to transmit shear

connection:	between components
Gantry crane,	Also known as an "EOTC" (Electric Overhead Travelling Crane) - An overhead crane, usually in a workshop, that travels along rails supported on crane-beams. Usually the crane is able to lift and lower items at any point in the workshop.
Girder:	Generally a beam manufactured from plate material, used for large spans.
Girt:	A light structural member attached horizontally to columns for the purpose of supporting the side sheeting. Girts serve the same purpose as purlins, except that girts support the side-sheeting, but purlins support the roof sheeting.
Grout:	A high-strength concrete that is inserted under the base-plates of columns, in other words between the base-plate and the foundation.
Grid flooring:	A type of grid-flooring made of metal bars, at right-angles to each other forming a pattern of squares. Grid flooring is commonly used in industrial buildings. Industrial stair treads are often manufactured in the form of the same grid material.
Gussets:	Piece of plate welded at the intersection of two steel members to facilitate a connection between the two.
Haunch:	The deepened portion of a rafter designed to strengthen the rafter at the intersection of column and rafter.
Holding-down bolt:	A steel bolt cast into the concrete foundation. The holding-down bolt ("HD bolt") secures the column to the foundation through the column base-plate.
H-section:	Steel section with a central web and two flanges, that has an overall depth not greater than 1.2 times its overall width
I-section:	Steel section or profile with a central web and two flanges, that has an overall depth greater than 1,2 times its overall width.
Joint:	element of a structure that connects members together and enables forces and moments to be transmitted between them
Minimum pitch:	This is the minimum distance between centres of bolts or holes.
Notched end:	connected end of a member with one or both flanges cut away locally
Overhang	That part of the truss top chord that extends past the truss heel. Measured horizontally from the truss heel on the truss, but from the outside wall face on the building.
Plate girder:	A heavy and strong type of beam welded together from 3 plates, to form an 'I' - section. The 3 plates are called the 'top flange', 'bottom flange' and the web.
Pitch:	The spacing between the centre lines of bolts in the

	longitudinal direction of a member (beam, girder, column and so on).
Preloaded bolt:	bolt tightened to a specified initial tension, sometimes called High Strength Friction Grip or HSFG bolt
Purlin:	Section used to support the roof sheeting.
Rafter (Top Chord):	In a steel building, rafters are the main beams supporting the roof. That part of the truss, which forms the top edge, usually at a slope and has battens/purlins fixed to it to carry the roof covering.
Runner	Bracing members that connect the same point of each truss, continually through the entire roof, or set of the same trusses.
Sag rods:	Sag rods, or sag angles, are attached to purlins to strengthen them against the tendency to sag or twist.
Span	A Truss span is the distance along the bottom chord between the truss ends (heels).
Structural steel:	Refers to the various steel sections produced in a steel mill.
Truss:	A triangulated structural member, made up of several individual parts welded or bolted together, designed to carry tension or compression forces with the complete structure acting as a beam.
Webs	The truss members that connect the top and bottom chords, usually in a triangular pattern
Welding:	Welding is the fusion of two pieces of steel by heat.
Welded section:	cross-section fabricated from plates by welding

6.2 Roof structures and components

We can describe a roof truss as a plane frame consisting of:

- Sloping rafters, which meet at the ridge (apex)
- A main tie beam connecting the feet of the rafters
- Internal bracing members (struts and ties) called web members
- Gussets, which hold the web members in position and are fixed to the rafter and tie beam (joined by welded or bolted connections)
- Purlins, which are fixed to the rafters to support the roof covering.

Figure 6.1 shows the various components of a steel roof truss.

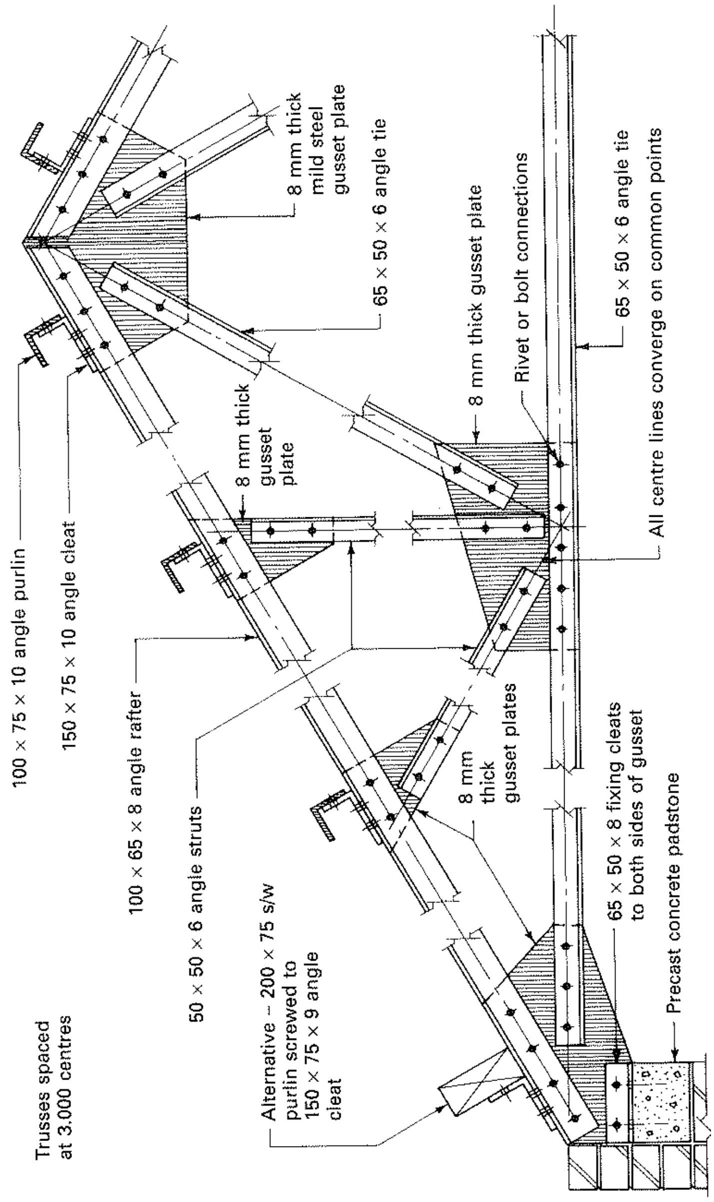


Figure 6.1 Steel roof truss components

6.2.1 Roof truss fabrication

The fabrication of steel roof trusses differs from that employed in timber, although the principles of truss and purlin centres are the same. All components are set out on the shop floor and accurately cut to lengths, then drilled, welded or riveted before assembly on site.

The working stress on steel is approximately 15 times greater than that of timber in direct tension. Sizes of truss members and centres depend on the clear span, roof covering and shape, style and walls or stanchion (column) supports, and climatic conditions. The design and manufacture is strictly controlled by a consulting engineer working from the architect or designer's drawings.

Plates and angles are sheared to size and length. Holes are punched into plates of 12 mm and less. Thicker plates require drilling. Other large sections are cold sawn to length. Standard angle, channel or lipped channels are used as purlins.

The connections between sections are known as nodes and are made by means of flat plate gussets to which members are bolted.

The aim is to put as many members into tension as possible and to make compression members such as struts as short as possible. For large spans it is best to put a camber in the bottom chord. Steel structures are designed to carry their own weight including purlins, coverings and other loadings and stresses like wind and rain.

6.3 Types of trusses

There is a great variety of layouts or configurations for trusses and girders. In the case of roof trusses the panel length is usually dictated by the purlin positions - and would thus range between 1800 mm and 2300 mm.

In other applications the engineer will have chosen the panel lengths and overall depth to yield the greatest economy of steel usage.

In all cases the principle of triangulation is used, in other words the shape of the girder is made up of a series of adjoining triangles. The members are all subject to axial forces, either compression or tension.

The most commonly used shapes are shown in **Figure 6.2.** The triangular trusses shown in details **(a)** and **(b)** have been used for many years and because of their steep pitch, were especially suited to roof sheeting having end laps within the slope length.

With the advent of deeper profile sheeting, supplied in single lengths from eaves to ridge, much flatter slopes are possible and the low-pitch trusses shown in details **(c)** and **(d)** have become popular as a result.

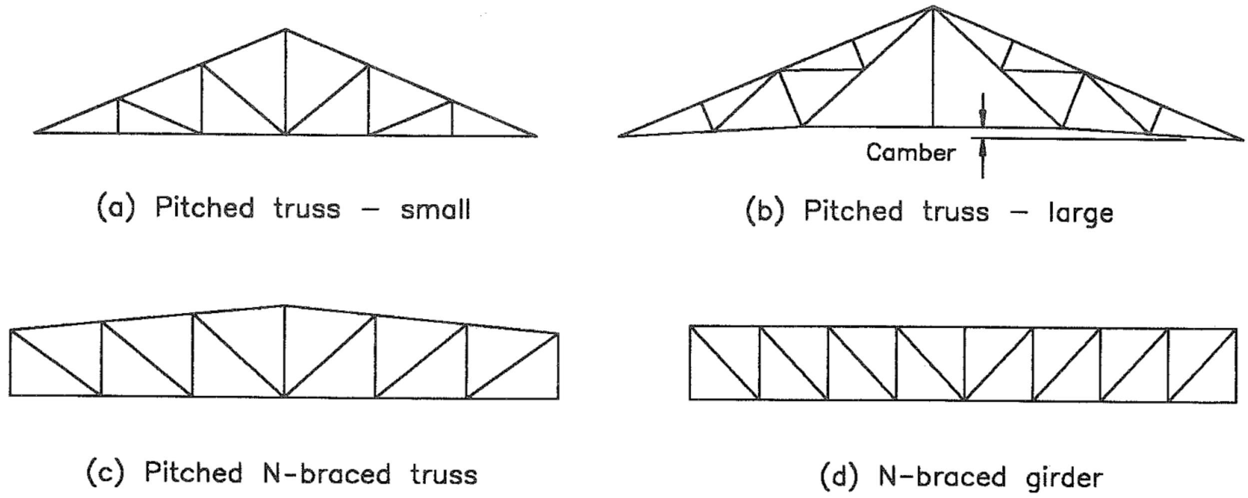


Figure 6.2 Truss and girder configurations

6.4 Describe different roof trusses

There are a great variety of layouts or configurations for trusses and girders. In the case of roof trusses the panel length is usually dictated by the purlin positions - and would thus range between 1800 mm and 2300 mm. In other applications the engineer will have chosen the panel lengths and overall depth to yield the greatest economy of steel usage.

In all cases the principle of triangulation is used, in other words the shape of the girder is made up of a series of adjoining triangles. The members are all subject to axial forces, either compression or tension.

The most common use of trusses in buildings is to provide support to roofs, floors and such internal loading as services and suspended ceilings. There are many types and forms of trusses; some of the most widely used are shown in **Figure 6.3.**

The type of truss adopted in design is governed by architectural and client requirements, varied in detail by dimensional and economic factors.

We will discuss a few of these briefly.

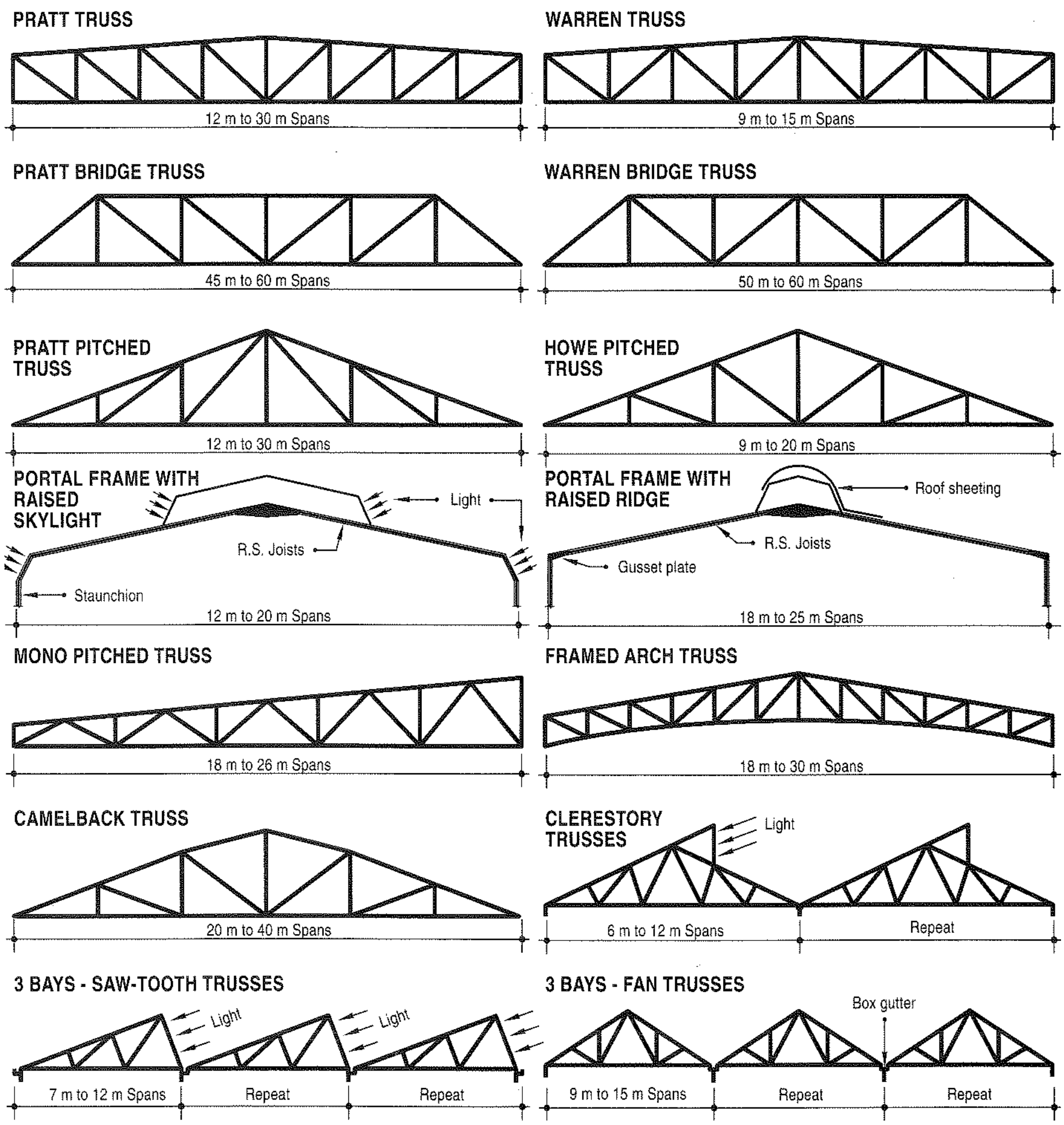


Figure 6.3 Types of roof trusses

6.4.1 Pratt roof truss,

This truss has diagonals in tension under normal vertical loading so that the shorter vertical web members are in compression and the longer diagonal web members are in tension.

This advantage is partially offset by the fact that the compression chord is more heavily loaded than the tension chord at mid-span under normal vertical loading.

It should be noted, however, that for a light-pitched Pratt roof truss wind loads may cause a reversal of load thus putting the longer web members into compression.

6.4.2 Fink roof truss,

The Fink roof truss offers greater economy in terms of steel weight for long-span high-pitched roofs as the members are subdivided into shorter elements. There are many ways of arranging and subdividing the chords and web members under the control of the designer.

6.4.3 Warren roof truss

The Warren truss, which has equal length compression and tension web members, results in a net saving in steel weight for smaller spans. The added advantage of the Warren truss is that it avoids the use of web members of differing length and thus reduces fabrication costs.

For larger spans the modified Warren truss may be adopted where additional restraint to the chords is required (this also reduces secondary stresses).

The modified Warren truss requires more material than the parallel-chord Pratt truss, but this is offset by its symmetry and pleasing appearance.

6.4.4 Howe roof truss

The converse of the Pratt truss is the Howe truss (or English truss), The Howe truss can be advantageous for very lightly loaded roofs in which reversal of load due to wind will occur. In addition the tension chord is more heavily loaded than the compression chord at mid-span under normal vertical loading.

6.4.5 Saw-tooth roof truss

The saw-tooth or butterfly truss is just one of many examples of trusses used in multi-bay buildings, although the other types described above are equally suitable.

6.5 Explain different types of roof sheeting

The basic requirements for covering materials to steel roof trusses are:

- Sufficient strength to support imposed wind and snow loadings
- Resistance to the penetration of rain, wind and snow
- Low self-weight, so that supporting members of an economic size can be used
- Acceptable standard of thermal insulation if habitable or occupational
- Accommodation requires space heating
- Acceptable fire resistance and resistance to spread of flame
- Durable to reduce the maintenance required during the anticipated life of the roof.

6.5.1 Types of roof sheeting

Most of the materials used for covering a steel roof structure have poor thermal insulation properties so a combination of materials is required if heat loss or gain is to be controlled.

There are several common types of covering:

- **Corrugated galvanised steel:** This is the original product that was wrought iron/steel sheet coated with zinc and then formed into corrugated sheets. This product is still used today. The newer push of modern architecture and 'green' products has brought this type of covering back to the foreground.
- **A blend of zinc, aluminium and silicon-coated steel**: This type is sometimes left in the raw zinc finish, but is more widely used as a base metal under factory coated colours.
- **Metal tile sheets:** These are usually painted or stone-coated steel.
- **Stainless steel:** Available for harsh conditions or as a distinctive design element. It is usually roll-formed into standing seam profiles, but shingles are available.
- **Aluminium:** One of the longest-lasting metals, but somewhat expensive compared to steel products. Aluminium roofs are very lightweight, corrosion-resistant, have high natural reflectivity and even higher natural emissivity, increasing a building's energy efficiency.
- **Copper:** Copper is expensive for a roofing material and is usually used for flashing or smaller, highly detailed areas such as entryways and bays. At the Lyle Center for Regenerative Studies, copper is used for regenerative principles of sustainable design. If the building were ever to be dismantled the copper could be reused because of its high value in recycling and its variety of potential uses.
- **Stone-coated steel:** This covering consists of panels made from zinc/ aluminium-coated steel with an acrylic gel coating. The stones are usually a natural product with a coloured ceramic coating.
- **Inverted box rib (IBR):** A low-cost corrugated square-fluted iron roofing material used mainly in the South African market. It can be commonly found on anything from industrial sites to low-income shacks.

6.5.2 Examples of roofing sheets
There are various types of roofing sheets on the market. We will mention some of the most popular names.

6.5.3 Klip-Lok
'Klip-Lok' is a sheet with an interlocking profile and clip-fixing system that eliminates the need for holes in the sheets. The clips allow expansion and contraction of the sheets without straining the securing points.

The design provides the sheets with an excellent water-carrying capacity as well as structural strength, ease of erection, dust and water tightness, and the versatility to be cranked. A typical profile is shown in **Figure 6.4.**

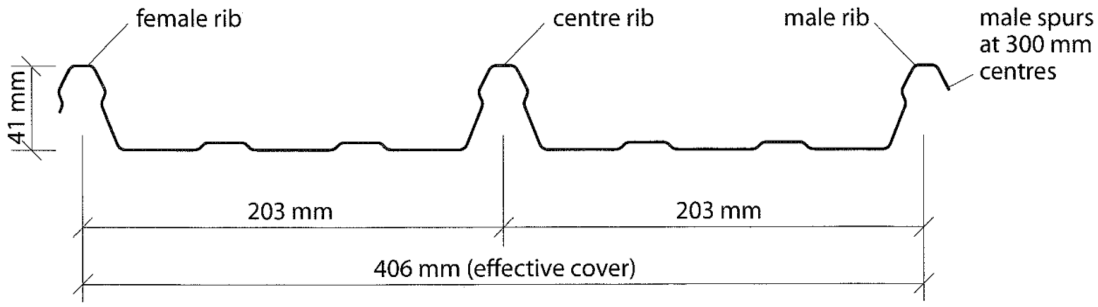


Figure 6.4 Klip-Lok roof sheet profile

5.5.4 Design requirements (SANS 10400)
The recommended centres for roof purlins supporting Klip-Lok roofing sheets set out in **Table 6.2** are based on test loads equivalent to an ultimate uplift wind-pressure of 1,6 kPa.

The minimum allowable roof slope and its relationship to the recurrence intervals of rainfall in South Africa determines the maximum allowable continuous run between the high point and low point of a Klip-Lok roof.

Type of roof span	**Sheet thickness**	
	0,5mm	0,6mm
	Purlin spacing (m centre to centre max)	
Single span	1,40	1,80
End span	1,60	2,10
Internal span	1,90	2,40
cantilever	0,18	0,26

Table 6.2 Recommended centres for roof purlins

6.5.5 Inverted box rib steel sheeting (Galvanised or chromadek)

Inverted box rib (IBR) is also an interlocking sheet system and is available in stainless steel, copper or aluminium. The clip-on system is labour saving, leak proof (no holes), aesthetically acceptable and above all cost effective.

Milling, cutting and cranking is executed on site anywhere in South Africa. Roof pitches as low as 1° are permitted, depending on wind and rain conditions in the area.

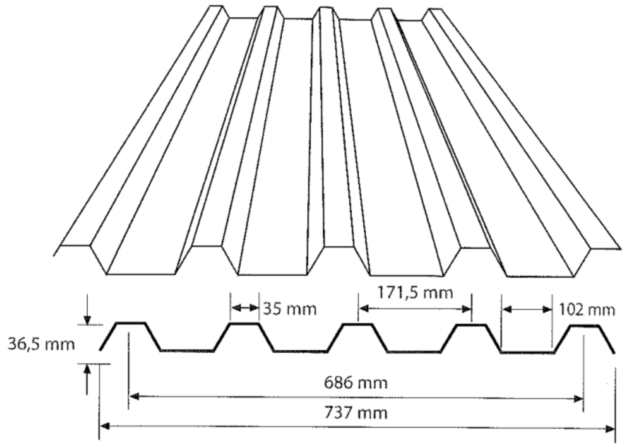


Figure 6.5 Standard IBR steel roof sheeting

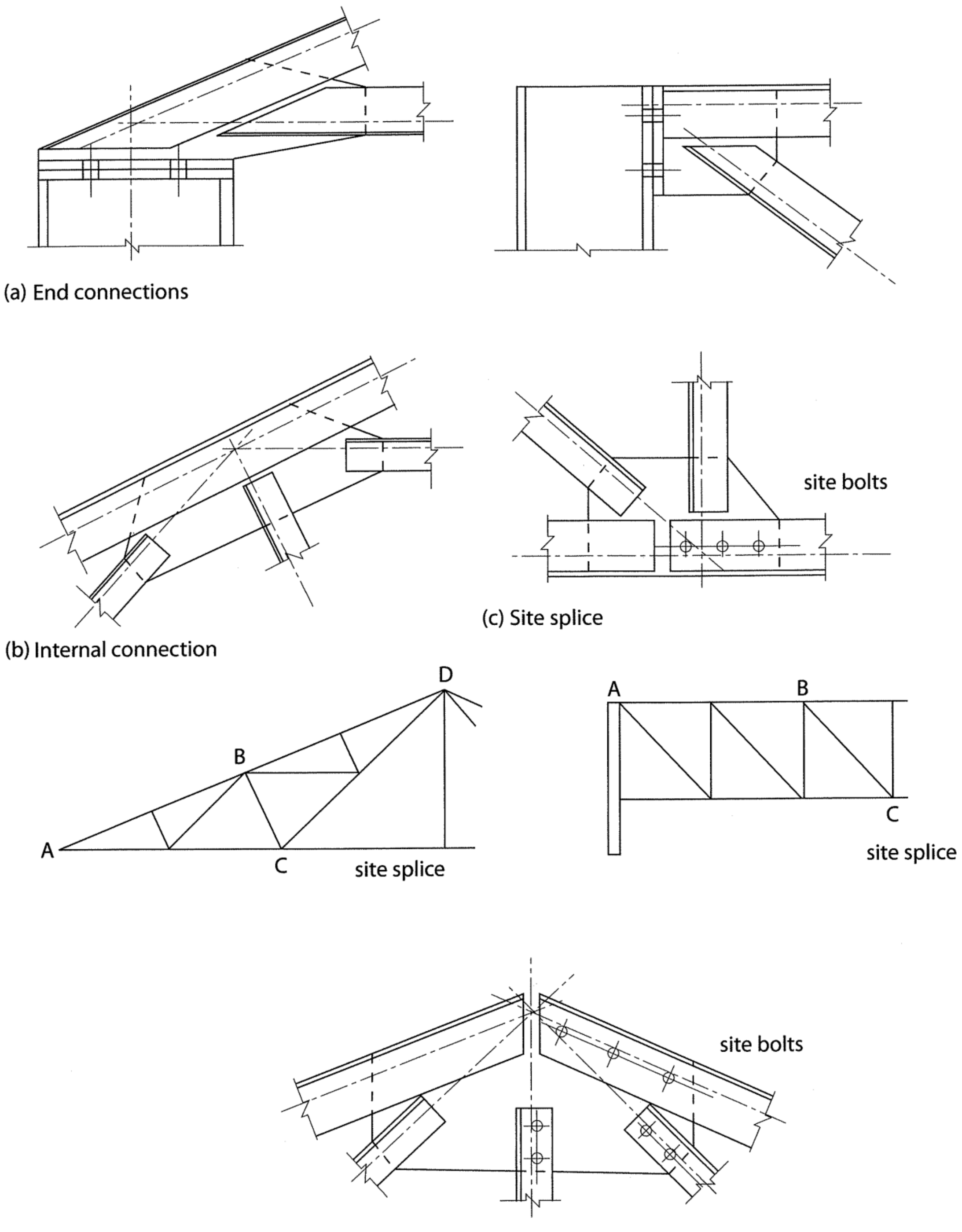
Sheets are cut to any required length and are available in 0,5, 0,6 or 0,8 mm thicknesses and in twelve chromadek colours. Galvanised steel manufactured from 2275 zinc-coated strips having a yield strength of 300 MPa minimum, and a total coating mass of 275 g per square metre.

6.6 Typical connections in truss and lattice girders

The following types of connections are used in steelwork trusses and lattice girders:

- Column cap and end connections
- Internal joints in welded construction
- Bolted site joints – internal and external.

The internal joints may be made using a gusset plate or the members may be welded directly together. Some typical connections using gussets are shown in **Figure 6.6.** In these joints, all welding is carried out in the fabrication shop. The site joints are bolted.



(d) Ridge joint

Figure 6.6 Typical connections in truss and lattices girders

6.6.1 Truss joint design

Joint design consists of designing the bolts, welds and gusset plate.

6.6.1.1 Bolted joints

The load in the member is assumed to be divided equally between the bolts. The bolts are designed for direct shear and the eccentricity between the bolt gauge line and the centroidal axis is neglected (see **Figure 6.7(a)**). The bolts and gusset plate are checked for bearing.

6.6.1.2 Welded joints

In **Figure 6.7(a)**, the weld groups can be balanced as shown. That is, the centroid of the weld group is arranged to coincide with the centroidal axis of the angle in the plane of the gusset.

The weld is designed for direct shear. If the angle is welded all round, the weld is loaded eccentrically, as shown in **Figure 6.7(b).**

However, the eccentricity is generally not considered in practical design because much more weld is provided than is needed to carry the load.

6.6.1.3 Gusset plate

The gusset plate transfers loads between members. The thickness is usually selected from experience but it should be at least equal to that of the members to be connected.

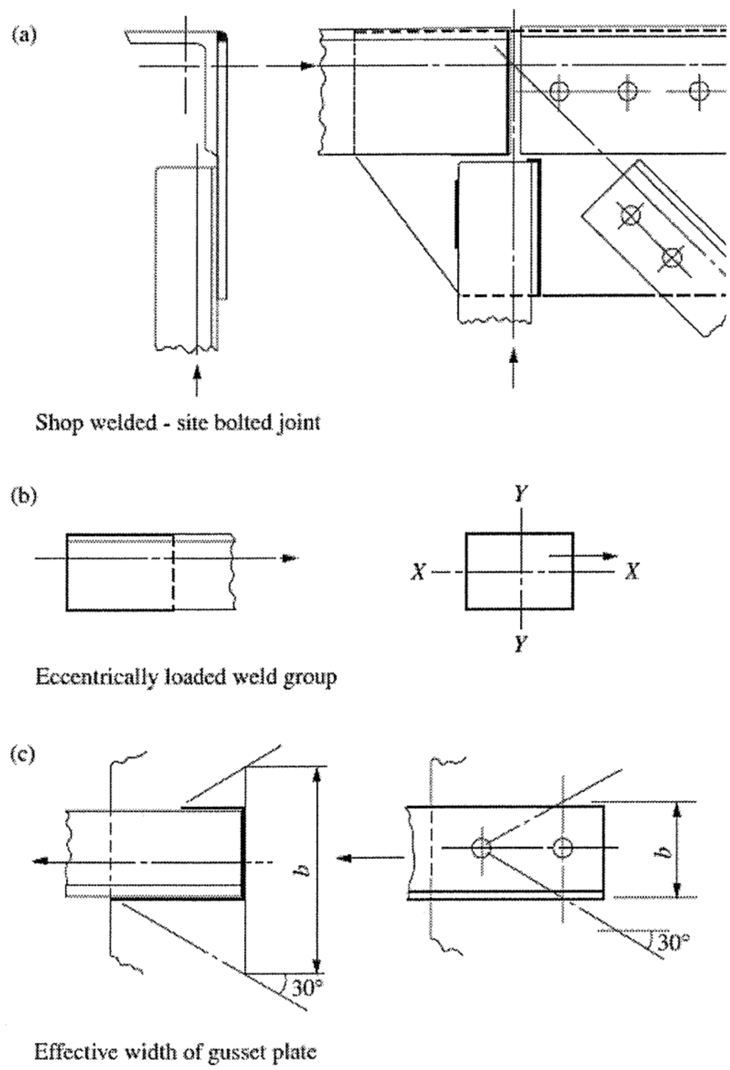


Figure 6.7 Truss joint design

6.6.2 Gusset connections on roof trusses

The gusset plate transfers loads between members. The thickness is usually selected from experience but it should be at least equal to that of the members to be connected. When gussets are used for connecting the web members to the chords at the node points, the groups of holes for the bolts must be set out by the detailer.

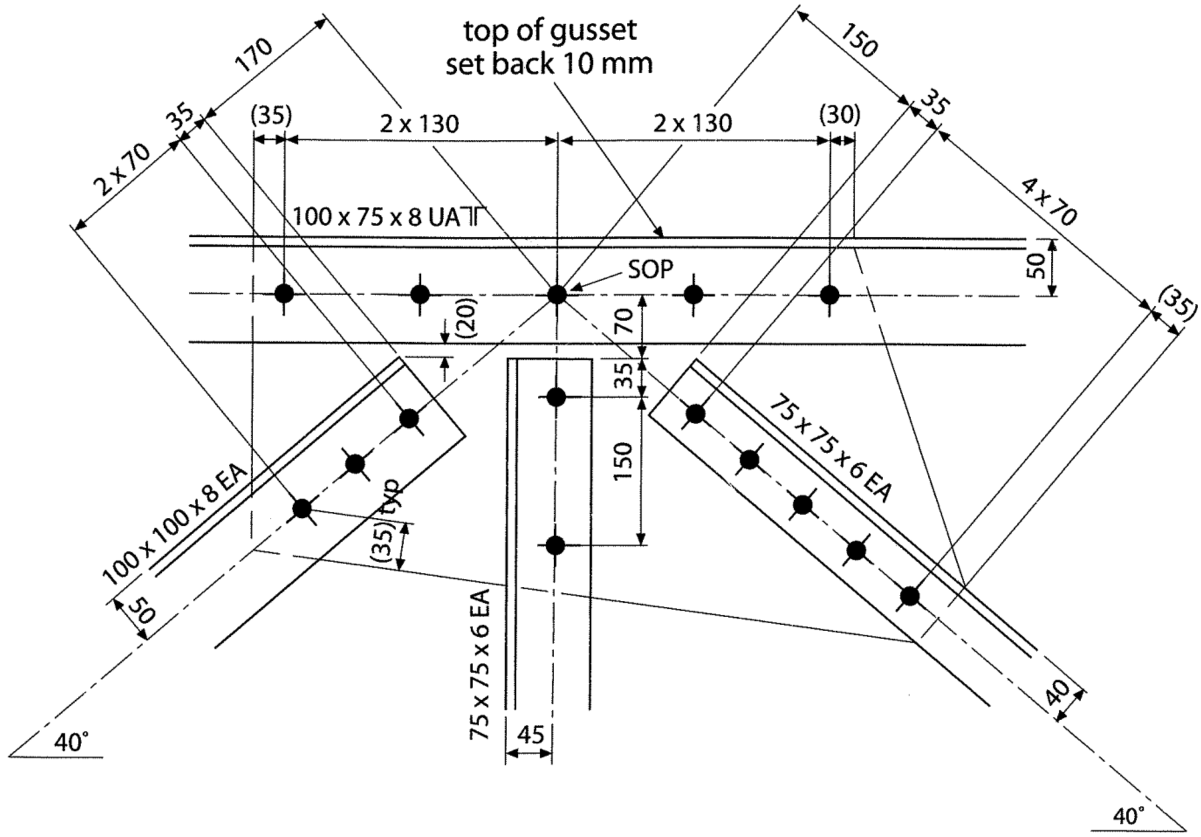


Figure 6.8 Gusset connections example

This is drawn roughly for each joint before the detail drawing is started. An example is given in **Figure 6.8**, which shows that standard bolt pitches and end distances are used where possible and at least a 10 mm clearance is provided at member ends.

In some cases, clearances of up to 20 mm may be requested by the fabricator. An example of a typical bolted truss and gusset plate connection is shown in **Figure 6.9.**

Figure 6.9 Typical bolted truss and gusset plate connection

Economy in gusset fabrication can be obtained by following a few simple rules as shown in **Figure 6.10** and set out below:

- Opposite edges should be parallel where possible.
- Adjacent edges should be at right angles where possible.
- Corners should not be sniped unless the included angle is less than 90°.
- The number of edges should be kept to a minimum.

In **Figure 6.10** gussets **(a)** to **(d)** are arranged in descending order of simplicity. They can all be cut economically, either by shearing or by machine-gas cutting, from a large plate because the shapes can be 'nested' when being marked off.

In following the above rules it is sometimes necessary to depart from the standard bolt pitch, as for example in gusset **(c)** where the bolt pitch in the vertical line has been increased for the sake of having parallel edges to the plate. Using a uniform pitch would result in a shape as in gusset **(e).**

In gusset shape **(f)** standard bolt pitches are employed for all members, but this is an expensive gusset to make. In detail **(g)** the large number of bolts along the left edge implies a heavy load in the vertical member, and consequently the gusset should be widened as shown in the dotted line to spread the load over a greater width of plate.

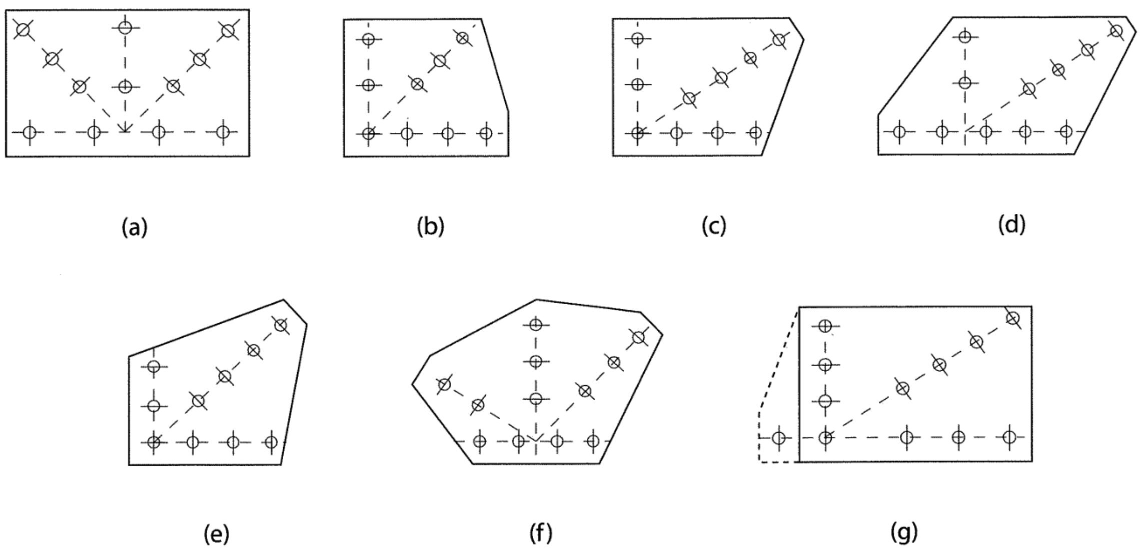


Figure 6.10 Gusset shapes for roof trusses

6.7 Explain and detail the typical connection at shoe/eaves

The rafter and tie beam are connected to a gusset at the base of the truss. This is the called the shoe or eaves detail of a roof truss. The shoe cleat, as shown in **Figure 6.11 (a)** is fixed to the cap plate of the top of the column. In certain cases, the shoe gusset cleat is connected to the inner flange of the column as shown in **Figure 6.11 (b).**

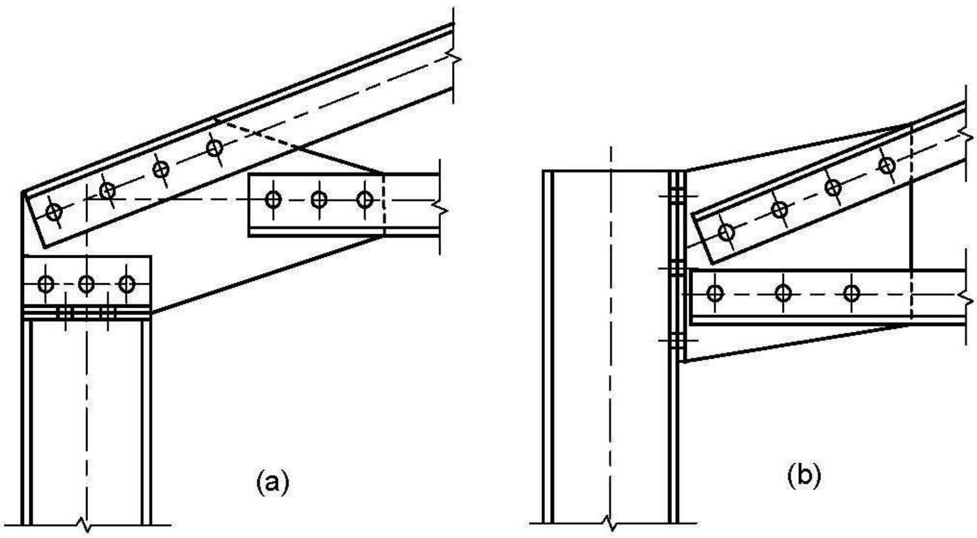


Figure 6.11 Shoe (eaves) details of a roof truss

6.7.1 Detailing the eaves of a roof truss

The following points must be considered:

- Scale 1:5 or 1:10 may be used for the details.
- The SOPs are drawn with a centre line.
- Standard bolt pitches and end distances should be used where possible and a 10 mm clearance should be provided between members.
- Use 1,5 × bolt diameter for edge distances and 3 × bolt diameter for the pitches between hole centres. (These are the minimum distances.)
- Gusset plates should be bolted in position between the members.

Ends and edges of gusset plates are defined by the minimum edge distances.

6.8 Explain and detail the typical ridge connection

The sloping rafters are connected to a gusset and internal support members (web members) at the ridge (apex) of the truss. This is the called the ridge or apex detail of a roof truss. **Figure 6.21** (Detail B) shows the ridge detail of the truss. The ridge of the roof truss is either welded or bolted together with gusset plates in-between.

6.8.1 Detailing the ridge of a roof truss

The following points must be considered:

- Scale 1:5 or 1:10 may be used for the details.
- The SOPs are drawn with a centre line.
- Use standard bolt pitches. End distances should be used where possible and a 10 mm clearance should be provided between members.
- Use 1,5 × bolt diameter for edge distances and 3 × bolt diameter for the pitches between hole centres. (These are the minimum distances.)
- Gusset plates should be bolted in position between the members.
- End and edges of gusset plates are defined by the minimum edge distances.

6.9 Explain and detail the typical connection used in internal joints

6.9.1 Bolted roof truss internal member connections

Figure 6.12 shows the key diagram of the roof truss. Within the frame of the roof truss there are internal web meembers, which are detailed to specifications.

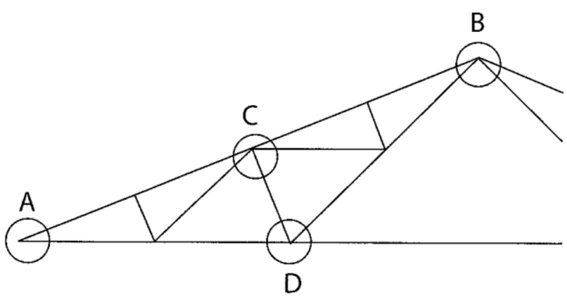


Figure 6.12 Key diagram for a bolted roof truss

From the key diagram, as shown in **Figure 6.12,** we now show in **Figure 6.13** the details of the internal web member connections. This will serve as guidelines to the detailing of the bolted internal web member connections.

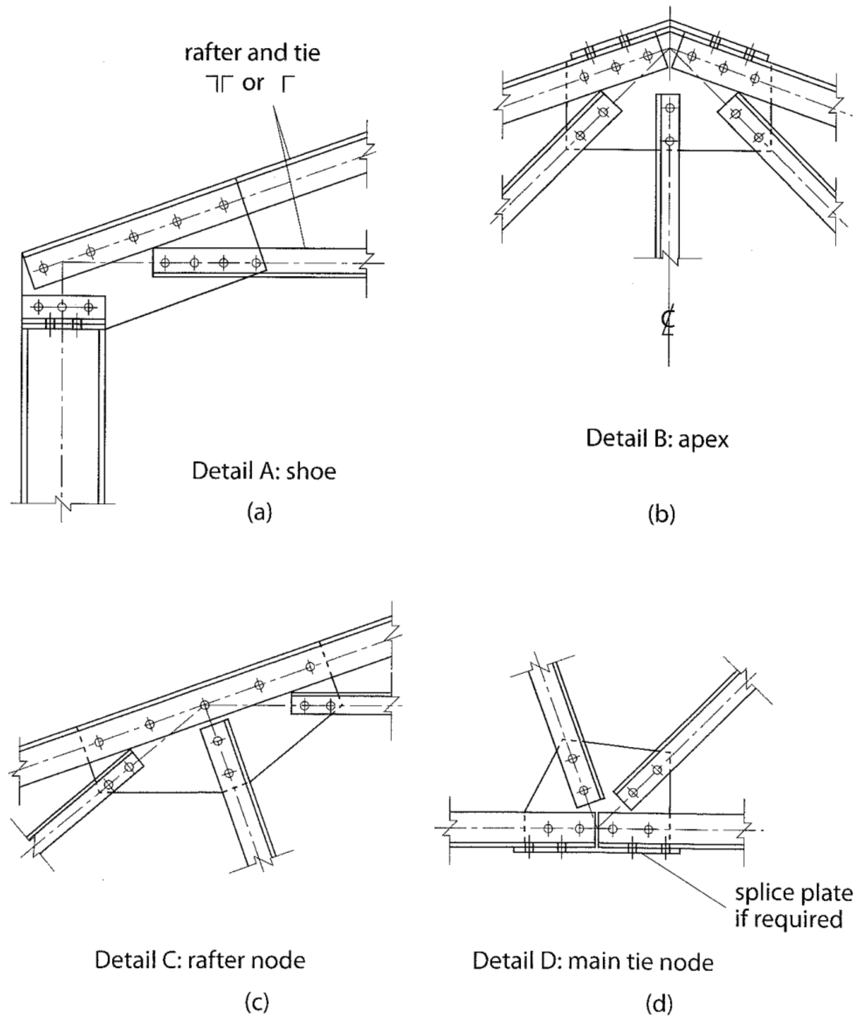


Figure 6.13 Roof truss details for bolted internal web member connections

6.9.2 Welded roof truss internal member connections
Figure 6.14 shows the key diagram for a welded roof truss.

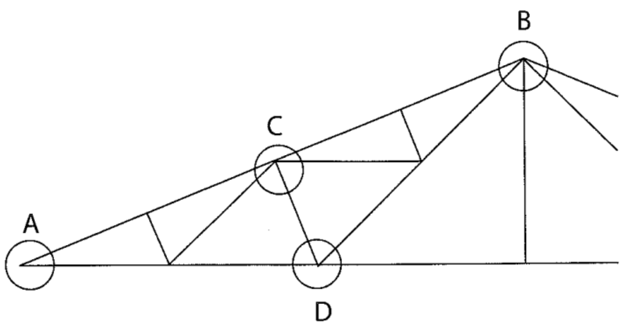


Figure 6.14 Key diagram for a welded roof truss

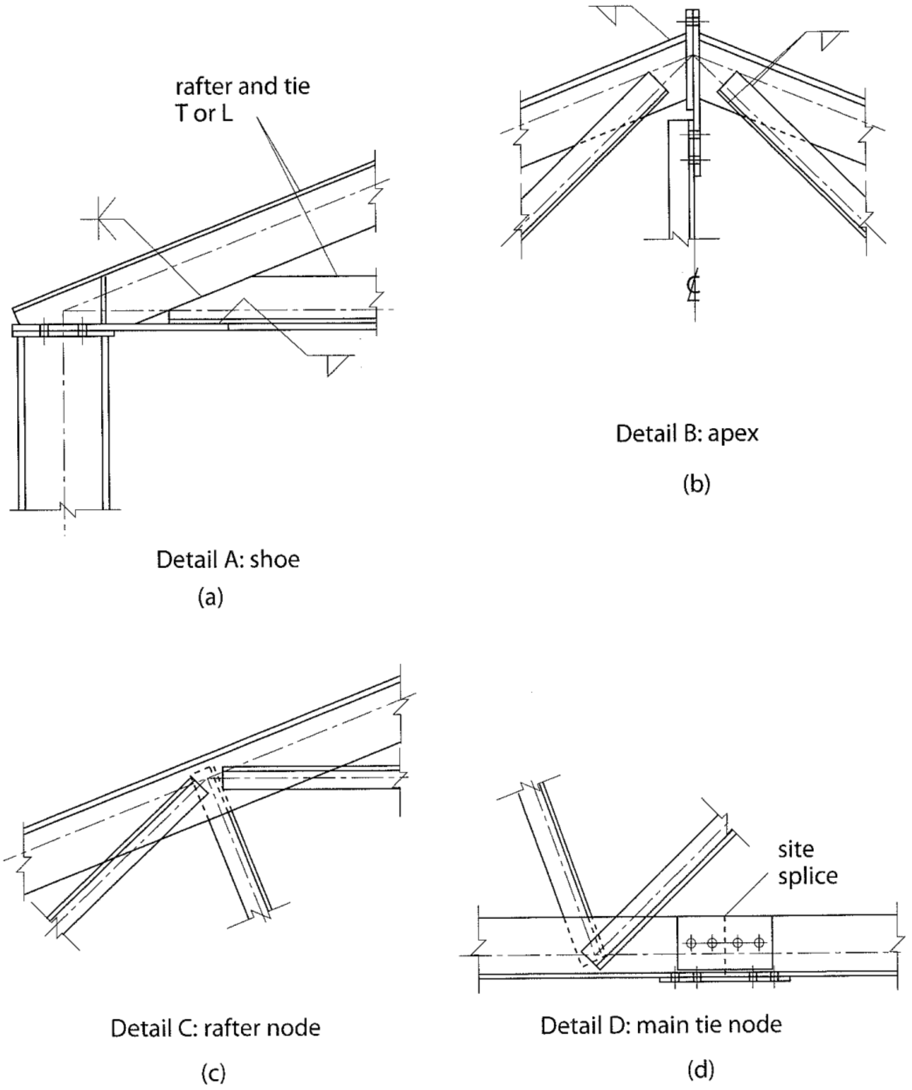


Figure 6.15 Roof truss details for bolted internal web member connections

6.10 Distances between setting-out points on roof trusses are calculated according to specifications.

The upper and lower longitudinal members of a truss or girder are called the top and bottom chords. The vertical and diagonal members, filling the space between the chords, are called the web members or verticals and diagonals.

The points at which the member ends intersect are called nodes or panel points. The common point at which the member axes meet at a node or panel point is called a setting-out point (SOP).

In theory the centroidal axes of members meeting at a node should all meet at a common point. However, in bolted angle construction the bolt lines are used instead of the centroidal lines, as shown in **Figure 6.16**

This makes for easier setting-out of the truss, both in the drawing office and in the shop. With welded angle trusses, gussets are often omitted and the web members welded directly to the chords, as shown in detail **(f)** of **Figure 6.16.**

Here, the web members are *'nested',* in other words their ends are placed as close to each other as possible, but their axes do not meet at a common point.

This practice is generally acceptable for smaller trusses, but should only be used with the consent of the designer. For larger trusses, where eccentricity of axes is unacceptable, gussets or plate extensions to the chord can be used, as shown in details **(c)** and **(d)** of **Figure 6.16.**

The common point at which the member axes meet at a node or panel point is called a setting-out-point (SOP).

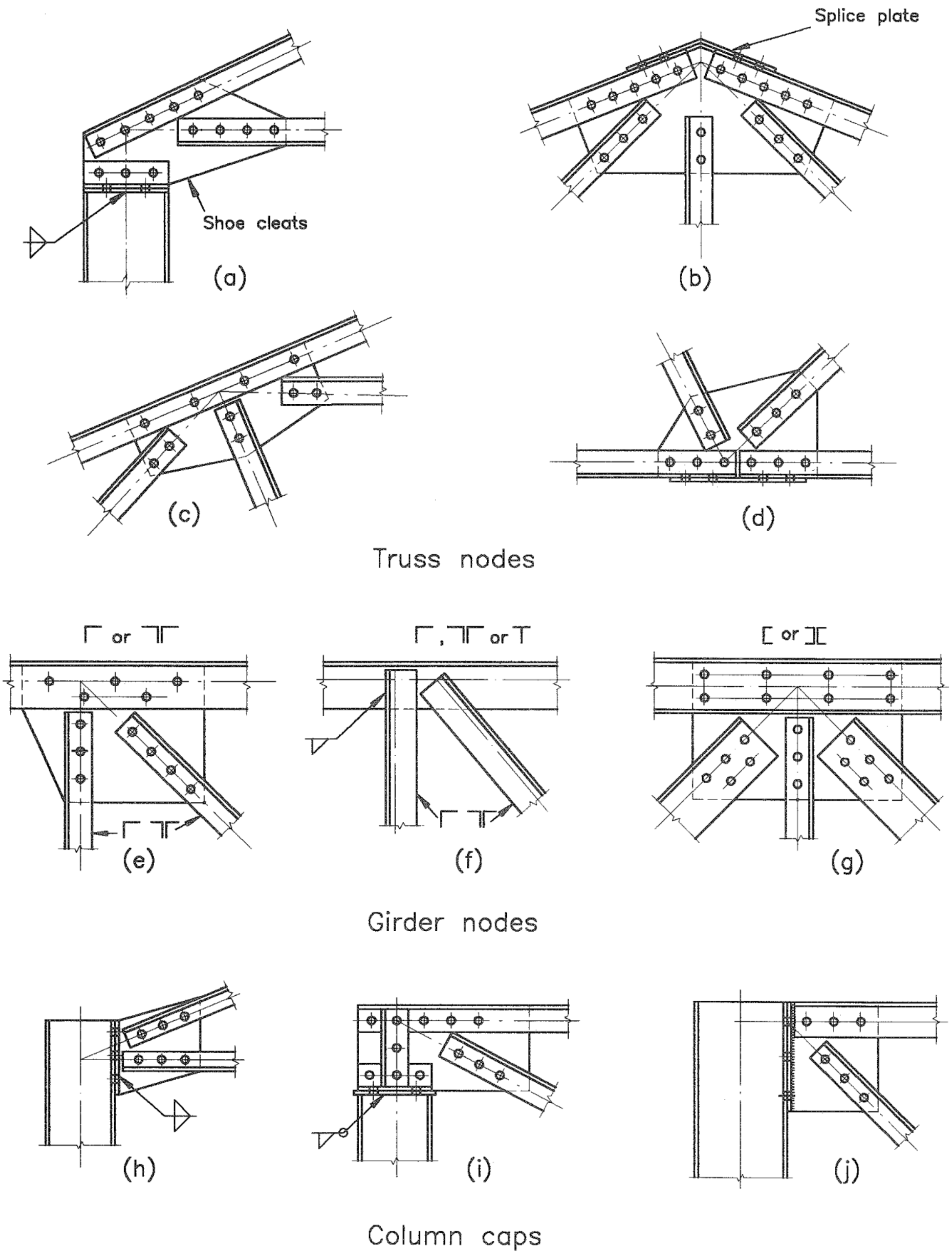


Figure 6.16 Truss setting-out points (node points) details

6.10.1 Bolted or welded construction

The decision on whether to use bolted or welded construction for a truss or girder will be governed mainly by the preference of the client or the fabricator.

Welding produces a simpler truss of attractive appearance, slightly lower in mass than a bolted truss and easier to paint.

A fabricator may, however, prefer to use bolting if his workshop is suitably equipped with automatic punching or drilling equipment. Bolted trusses are much easier and quicker to assemble because they are self-jigging and do not require the assembly beds that are needed for welded trusses. They also do not have to be turned over for access to far side welds.

A disadvantage of a tensile member with bolted end connections is that the effective sectional area is reduced by the extent of the bolt holes

Before you as a detailer can detail the roof truss, you would need to calculate the distances between the setting-out points (SOPs).

You will need to understand how to determine the setting-out-points. The roof truss is basically divided up into right-angle triangles. So we will now demonstrate and discuss how to go about this by using basic calculations using right- angle triangles.

Let us now look at a worked example for calculating the SOPs (setting out points) of a truss.

Worked example 6.1

Take a roof truss, as shown in **Figure 6.17** below and calculate the SOPs.
Follow the steps carefully.

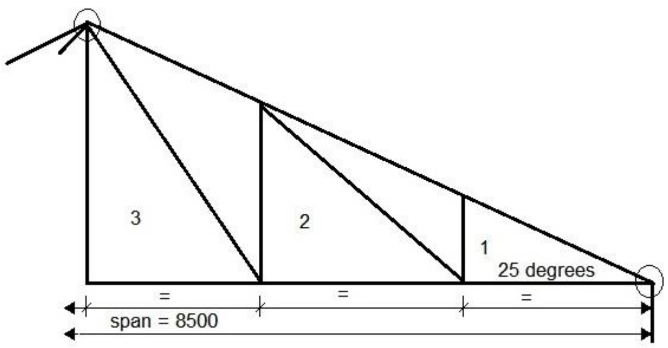


Figure 6.11 Roof Truss SOPs

Now determine the SOPs in the above frame diagram as shown **Figure 6.17**.

<u>Step 1:</u> Determine right-angle triangle in **Figure 6.18.**

Draw out the diagram as shown below in **Figure 6.18.**

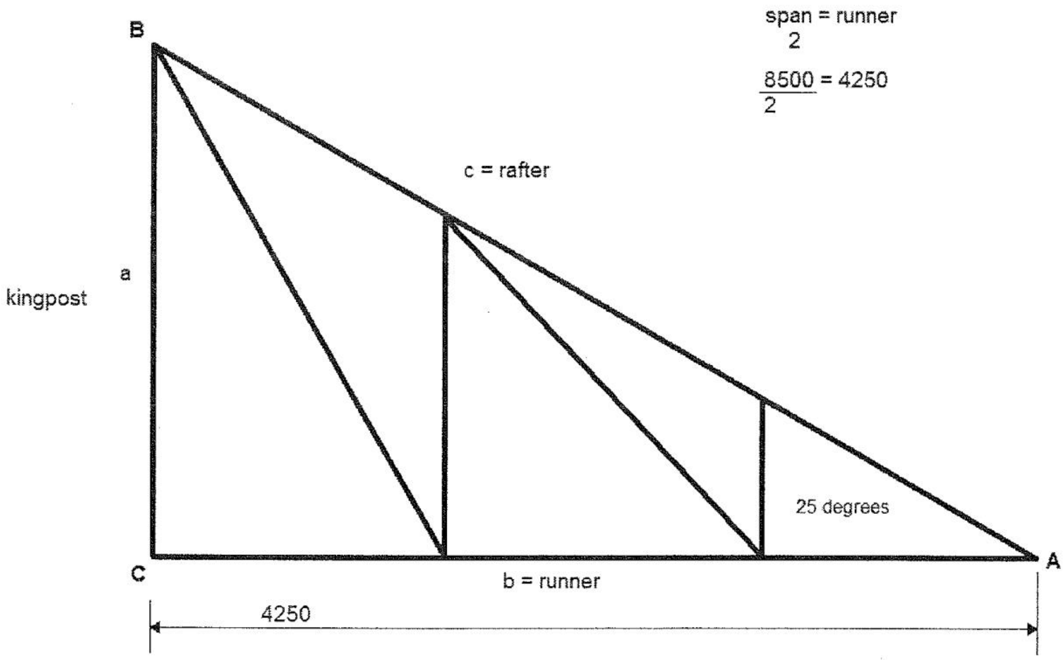


Figure 6.18

Use the trigonometric ratios:

It can be helpful to remember these relationships as:

- SOH = Sine is the Opposite side divided by the Hypotenuse
- CAH =Cosine is the Adjacent side divided by the Hypotenuse
- TOA = Tangent is the Opposite side divided by the Adjacent side

These ratios are commonly abbreviated to SIN, COS and TAN.

What are we given and what do we know?

Given:

Span = 8500 mm
Pitch = 25°

Now let us use the following to determine the slanted length of the truss (rafter 'c'):

$$\text{Cos } \theta = \frac{\text{Adjacent side}}{\text{Hypotenuse side}}$$

Cos θ = A

H

Cos 25° = $\frac{4250mm}{\text{Hypotenuse side}}$

Hypotenuse side = $\frac{4250mm}{\text{Cos } 25°}$

Hypotenuse side = $\frac{4250mm}{0{,}9063}$

Therefore:

Hypotenuse side
(Rafter c) = 4689mm

Now let us Pythagoras' theorem to determine the height of the truss (Kingpost 'a')

Pythagoras' theorem applies to any right-angled triangle.

The theorem states: the sum of the squares of two sides of a right-angled triangle is equal to the square of the hypotenuse.

This is also known as the 3, 4, 5 method.

What are we given and what do we know?

Given:

Span	**=**	**4689mm**
Pitch	**=**	**25°**
Hypotenuse	**=**	**8500 mm**

Now let us use the following to determine the height of the truss (kingpost 'a'):

$a_2 + b_2$	= =	c_2
a_2	= =	$c_2 - b_2$
a_2	= =	$4689^2 - 4250^2$
a_2	= =	**3924221**

a	**=**	**1980,96**
	=	
say	**=**	**1981mm**

Therefore:

Height of the truss (kingpost) = 1981mm

Step 2: Determine right-angle triangle marked '1'

Now we must determine all the sides in the right angle triangle marked '1' shown in ***Figure 6.19*** *of the given truss.*

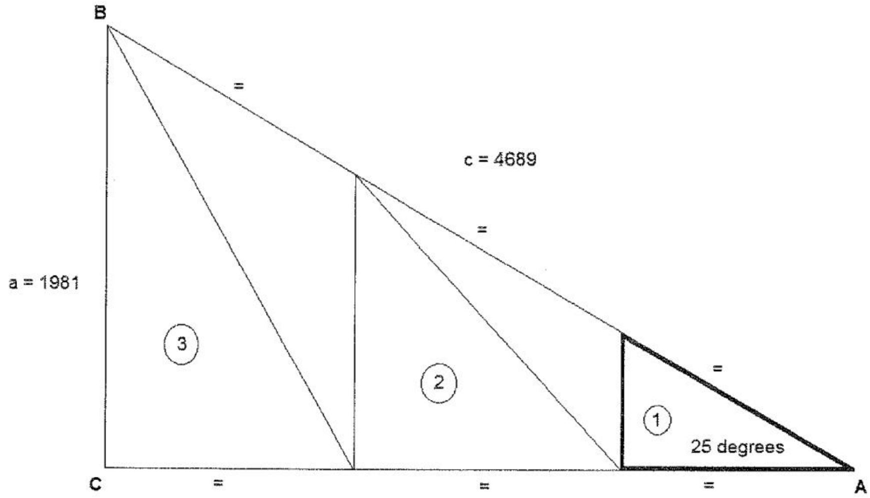


Figure 6.19

Find all the sides in right-triangle '1'

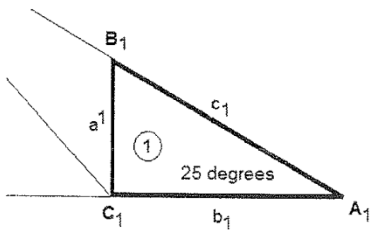


Figure 6.20

To find 'b1':

$$b1 = \frac{4240}{3}$$

b1 = 1417mm

To find 'c1':

$$c1 = \frac{4689}{3}$$

c1 = 1563mm

To find 'a1':

$$\text{Tan } A = \frac{a1(\text{opposite})}{b1(\text{adjacent})}$$

Tan A x b1 = a1

Tan 25° x 1417 = a1

0.4663 x 1417 = a1

660,75 = a1

a1 = 661mm

Step 3: Determine right-angle triangle (vertical web member) marked '2'

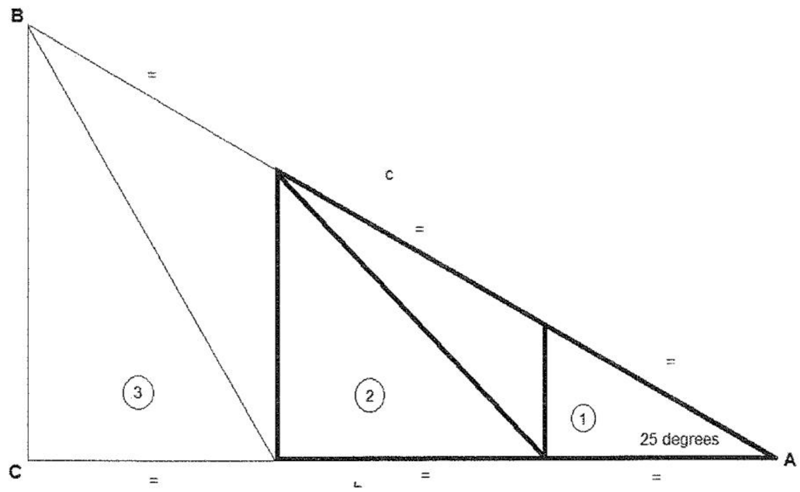


Figure 6.21

Let us use Pythagoras' theorem

$$\mathbf{a^2 + b^2 = c^2}$$

$$a^2 = c^2 - b^2$$

$a^2 = 3126^2 - 2834^2$

$a^2 = 17400320$

$a^2 = 1319mm$

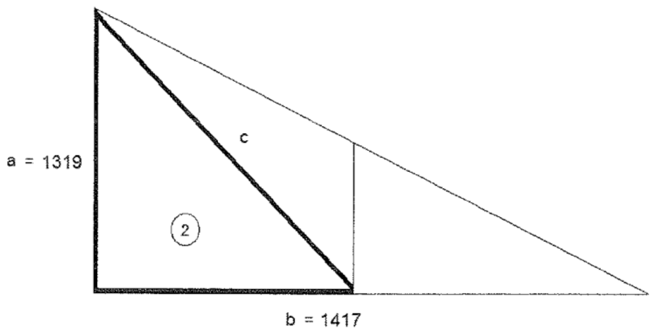


Figure 6.22

Let us use Pythagoras' theorem

$\mathbf{a^2 + b^2 = c^2}$

$c^2 = a^2 + b^2$

$c^2 = 1319^2 - 1417^2$

$c^2 = 3747650$

$a = 1936mm$

<u>Step4:</u> Determine right-angle triangle (diagonal web member 'c') marked '3'

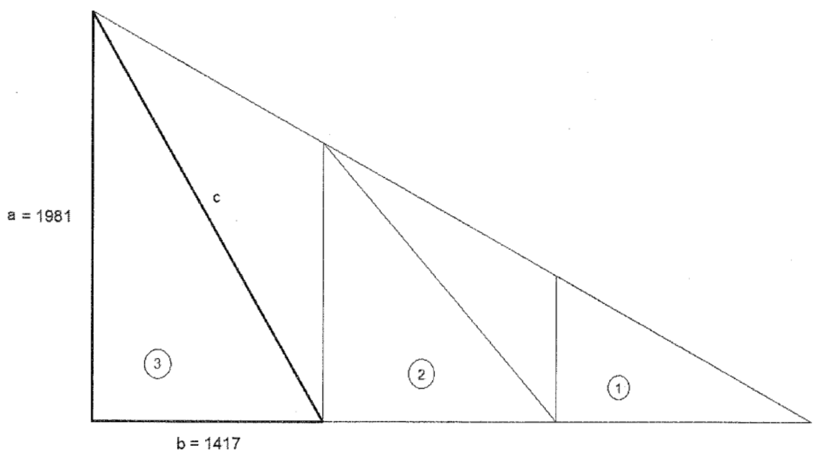


Figure 6.23

Let us use Pythagoras' theorem

a^2	+	b^2	=	c^2
1981^2	+	1417^2	=	c^2
c^2	=	5932250		
c	=	2435,6		
c	=	2436mm		

Solution:

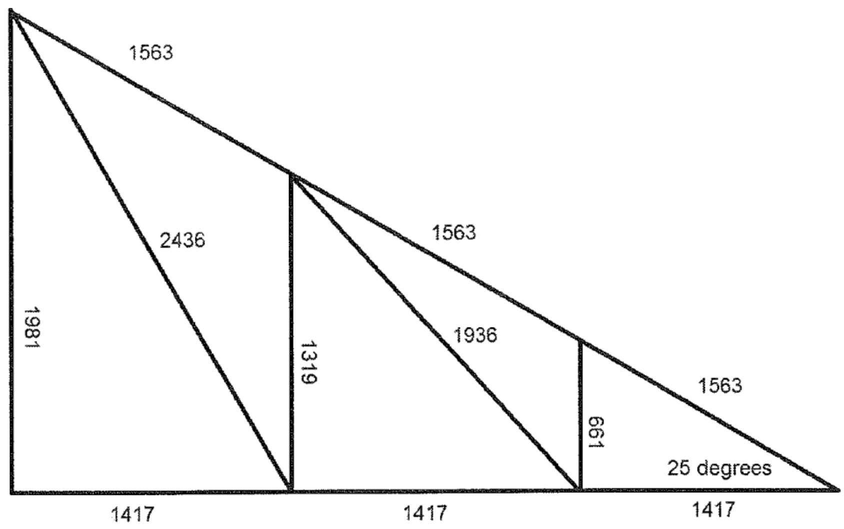


Figure 6.24

6.11 Rafter and tie beam angles on a roof truss are detailed according to specifications

You now need to understand how to detail rafter and tie beam angles on a roof truss.

Figure 6.26 represents a shop detail of a small-span bolted roof truss.
The following points should be noted:

1. Because of symmetry, only one-half of the truss need be drawn
2. A composite scale may be used. In this case the scales on the drawing would be 1:20 for the general layout (in other words, distances between SOP's) and 1:10 or 1:15 for the details, including member widths.
3. The distances between SOP's are worked out on a calculator from first principles by solving right-angled triangles and are recorded on the drawing. The procedure is illustrated in **Figure 6.25**. Note that dimensional lines b and f are introduced to assist in the sequence of calculations.

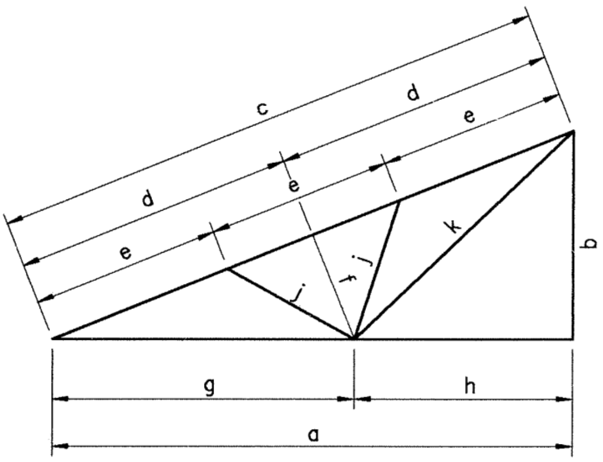
4. The SOP's are emphasised by a dot on the intersection of the member axes

5. The backmarks of the angles are given

6. The dimensions between bolt holes at each are obtained from large-scale set-outs (not Shown), as was done in **Figure 6.8**

7. The net or cut lengths of all the members are given. They are derived from the SOP distances minus the distance back to the first hole at each end plus two end distances of 30mm

8. For the gussets, only the hole positions are given. In the shop the marker-off will be guided by the general geometry of each gusset as drawn and by the 'edge distance' and 'gusset edge' requirements in the General Notes.



TRUSS LAYOUT

$a = 5600 \quad b = 2240 \quad b/a = 0{,}40$

$c = \sqrt{a^2 + b^2} = \sqrt{5600^2 + 2240^2} = 6030$

$d = c/2 = 6031/2 = 3015$

$e = c/3 = 6031/3 = 2010$

$f = 0{,}4d = 0{,}4 \times 3015 = 1206$

$g = \sqrt{d^2 + f^2} = \sqrt{3015^2 + 1206^2} = 3248$

$h = a - g = 5600 - 3248 = 2352$

$j = \sqrt{(e/2)^2 + f^2} = \sqrt{1005^2 + 1206^2} = 1570$

$k = \sqrt{b^2 + h^2} = \sqrt{2240^2 + 2352^2} = 3248$

Figure 6.25 Truss layout

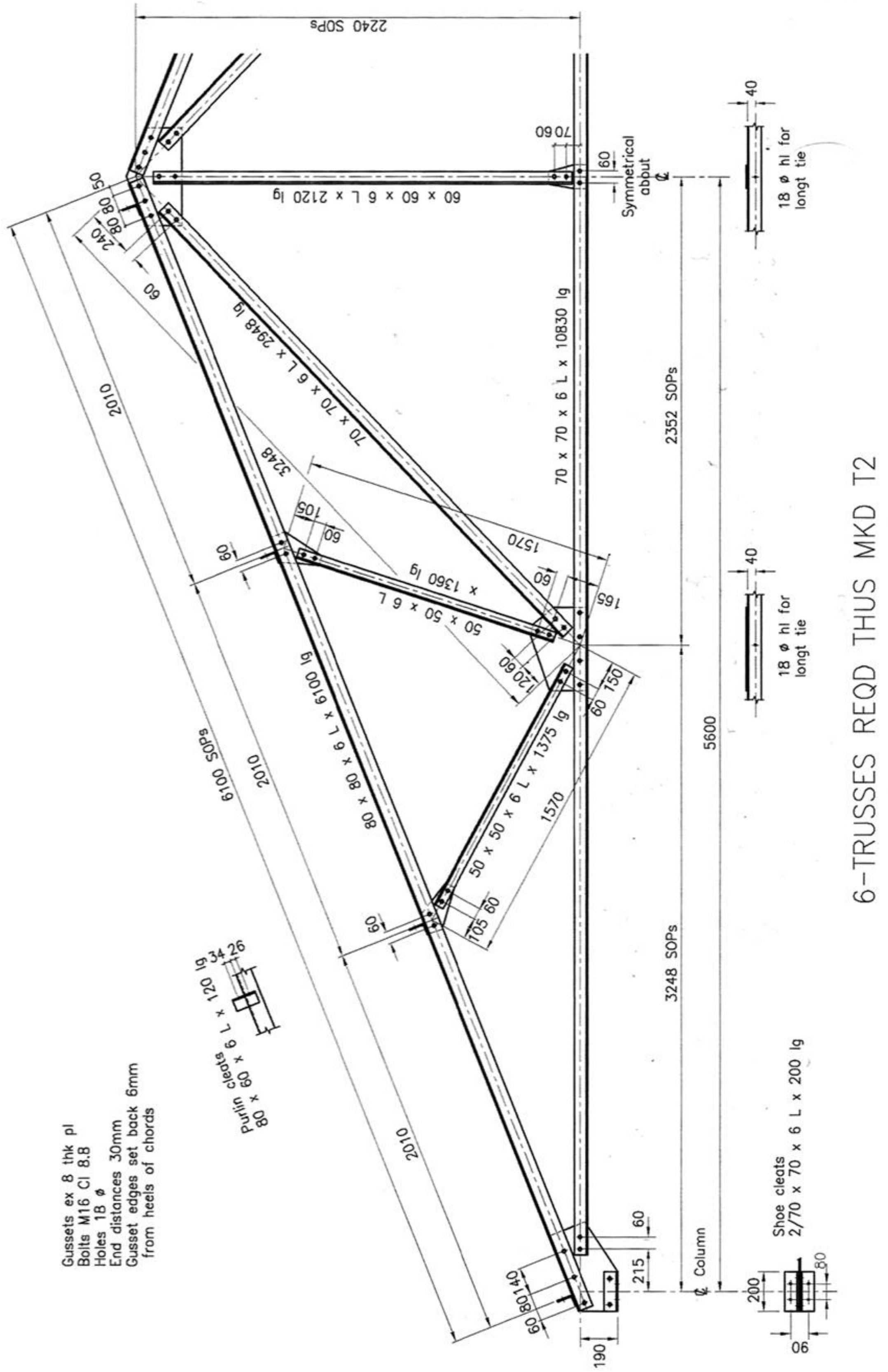


Figure 6.26 Typical detailed roof truss

Activity 6.1

Decide whether the following statements are true or false. Write only 'true' or 'false' next to each statement.

Statements	TRUE	FALSE
1. Trusses are used in the roof construction of buildings of medium to large spans.		
2. Trusses are not able to support heavy loads on greater spans than beams or rafters made from universal sections.		
3. Roof trusses are also used in footbridges, conveyor gantries, walkways, and so on.		
4. The most common use of trusses in buildings is to provide support for roofs, floors and such internal loading as services and suspended ceilings.		
5. The type of truss adopted in design is not governed by architectural and client requirements, and varies in detail by dimensional and economic factors.		

Activity 6.2

1. List the different types of roof trusses.
2. Make a freehand of any three types of roof trusses.
3. Make a freehand drawing of a roof truss and name the components.
4. Explain and describe the five types of coverings.
5. Make a freehand drawing of a Warren type lattice girder.

Activity 6.3

1. Make a freehand drawing of a typical ridge connection for a truss.
2. Draw freehand a typical eaves detail for a steel roof truss.
3. Draw a single line diagram of a lattice girder and name the various components.
4. Explain how the length of each member on a roof truss or lattice girder is obtained

Activity 6.4

Figure 6.27 shows a key diagram for a bolted roof truss. Make a freehand drawing of all the internal web member connections.

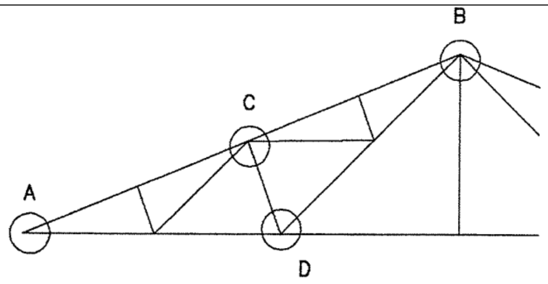


Figure 5.27

Activity 6.5

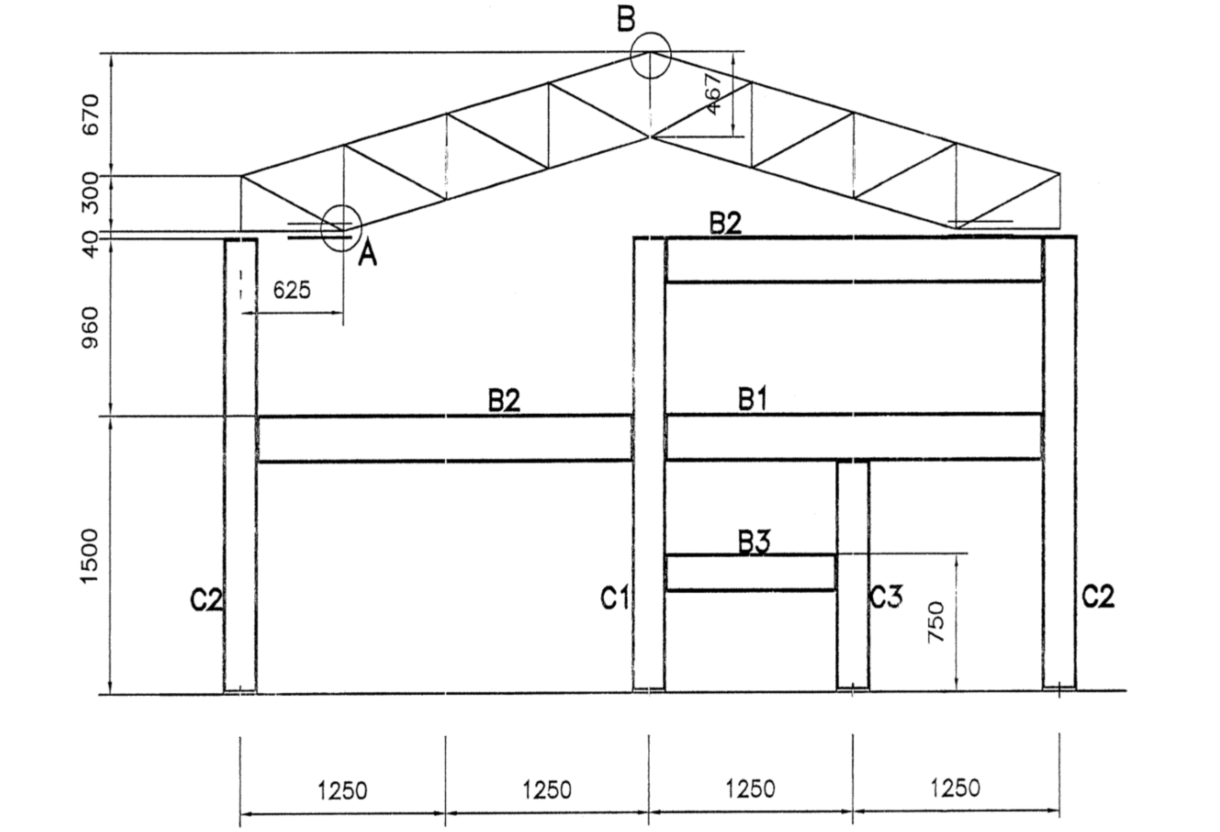
1. Make freehand line diagrams of the different truss and girder configurations.
2. Show by means of a freehand drawing the various types of truss nodes (setting out points).
3. Draw a freehand drawing of a roof truss to indicate the various components
4. List the three areas where you need to apply joint design on a roof truss.
5. Name three types of truss connections.

Activity 6.6

1. Refer to **Figure 6.28** and draw to scale 1:20 a line diagram of the bolted steel roof truss.
2. Draw to scale 1:5 typical bolted details at A and B.
   Use the following specifications:

- Top and bottom boom: 80 x 80 x 8 rolled steel angle profiles
- All internal members: 70 x 70 x 8 rolled steel angle profiles
- Gusset plates: 10 mm thick

Use your discretion for bolt hole centres and edge distances. All bolt holes are drilled on the centre lines of the angles and all bolts are M16. Insert suitable dimensions.



B1 – UB 254 x 146 x 31 kg/m
B2 – UB 254 x 146 x 31 kg/m
B3 – UB 203 x 133 x 25 kg/m
C1 – UC 203 x 203 x 46 kg/m
C2 – UC 203 x 203 x 46 kg/m
C3 – UC 203 x 203 x 46 kg/m

END PLATES – 10 mm WITH 4 x M20 BOLTS
BASE PLATES – 20 mm WITH 2 x M20 BOLTS

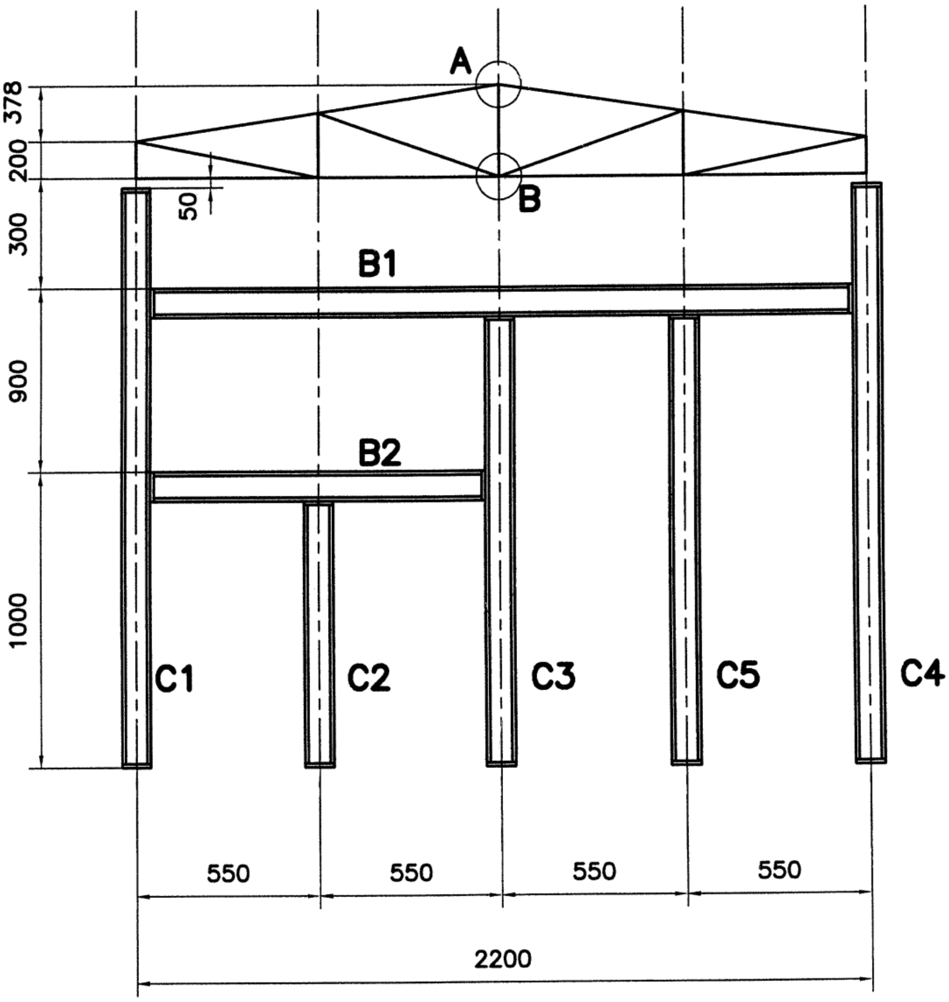
Figure 6.28 View on a steel structure

Activity 5.7

1. Refer to **Figure 6.29** and draw to scale 1:20 a line diagram of the welded steel roof truss.
2. Draw to scale 1 :5 typical bolted details at A and B.
   Use the following specifications:

   - Top and bottom boom: 100 x 100 x 10 rolled steel angle profiles
   - All internal members: 70 x 70 x 8 rolled steel angle profiles
   - Gusset plates: 10 mm thick

Do not insert any dimensions. Gusset plate sizes, as well as information not given, are left to your own discretion. Print a suitable title and scale centrally below the details.



B1 - UB 254 x 146 x 31 kg/m
B2- UB 203 x 133 x 25 kg/m
C1, C2, C3, C4,C5
End plates - 10 mm with 4 x M20 bolts
Base plates - 20 mm with 2 x M20 bolts

Figure 6.29 View on a steel structure

Activity 5.8

1. Refer to **Figure 6.30** and draw to scale 1:20 a line diagram of the bolted steel roof truss.
2. Draw to scale 1:5 typical bolted details at A and B.
   Use the following specifications:

   - Top and bottom boom: 100 x 100 x 8 rolled steel angle profiles
   - All internal members: 70 x 70 x 6 rolled steel angle profiles

- Gusset plates: 10 mm thick

Use bolt hole centres of 100 mm and edge distances of 35 mm. All bolt holes are drilled on the centre lines of the angles and all bolts are M20. Insert suitable dimensions.

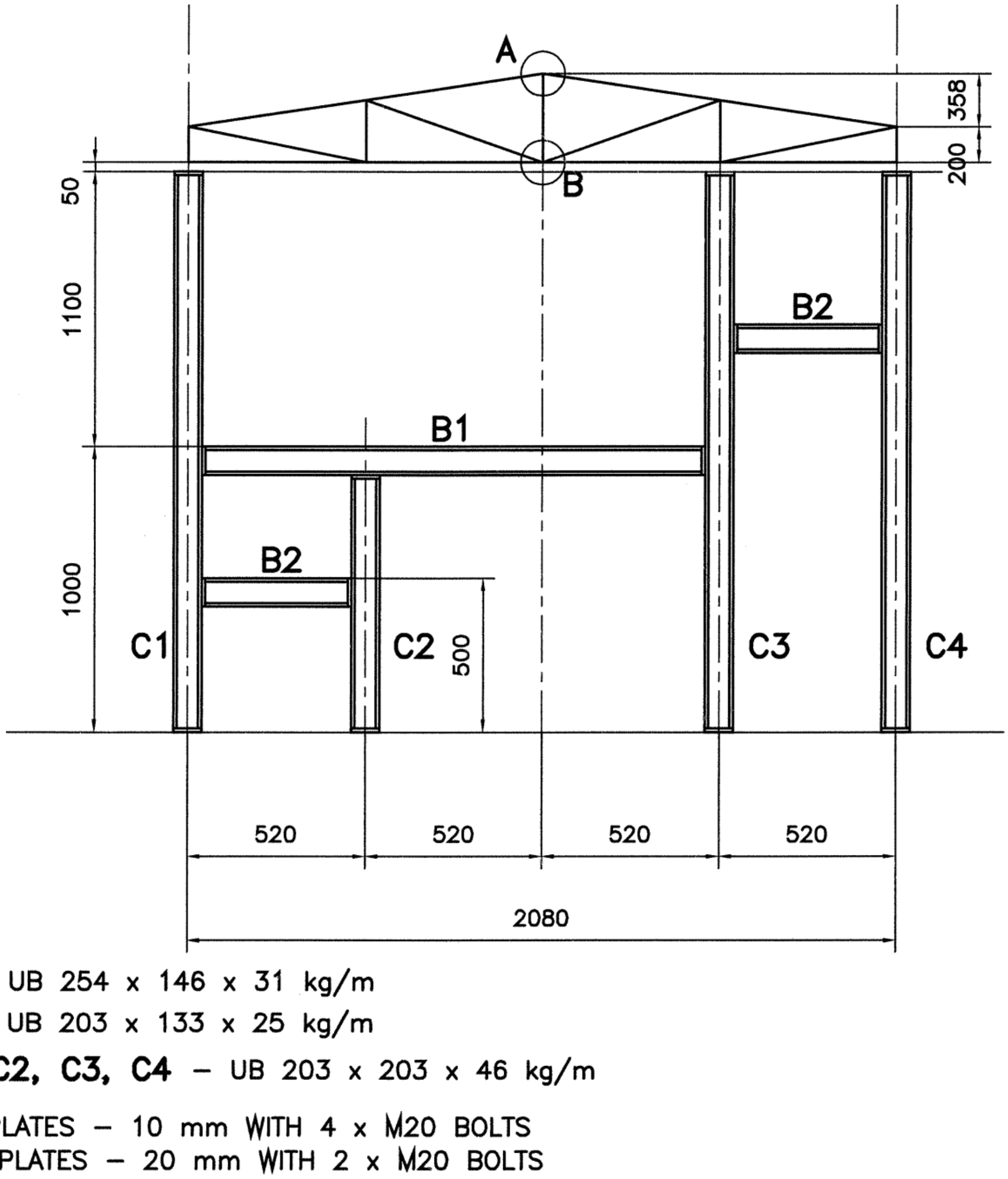


Figure 6.30 View on a steel structure

	Self-Check	
I am able to:	**Yes**	**No**
• Describe the following roof trusses of riveted and bolted construction		
o Fink		
o Monitor		

o Saw tooth		
• Describe the following timber trusses		
o Bolted construction		
o Nailed construction		
o Gang nail construction		
• Describe lean-to roofs		
o Steel		
o Timber		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 7

Roof Covering

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the following roof coverings
  - Galvanized corrugated iron
  - Galvanized long span ribbed sheets
  - Corrugated fibre-cement sheets
- Describe fixing on the following trusses
  - Timber
  - Steel

7.1 Introduction

There are many different roof covering materials that can be installed in a building over the roof deck. The type of covering used depends on the roofing system specified to weatherproof the structure properly.

7.2 Sheeting

Metal roof sheeting is a common roof covering and comes in various different profiles, e.g. corrugated and IBR. These profiles give strength to the sheeting and also satisfy specific aesthetic requirements.

Profiles in the sheeting can also be rolled on site to a specific profile. Sheeting is manufactured using various metals, alloys and coatings, e.g. aluminium, copper, stainless steel, galvanised steel, paint coating applied during manufacture. Cromadek is a popular choice for coloured sheeting manufactured in various colours.

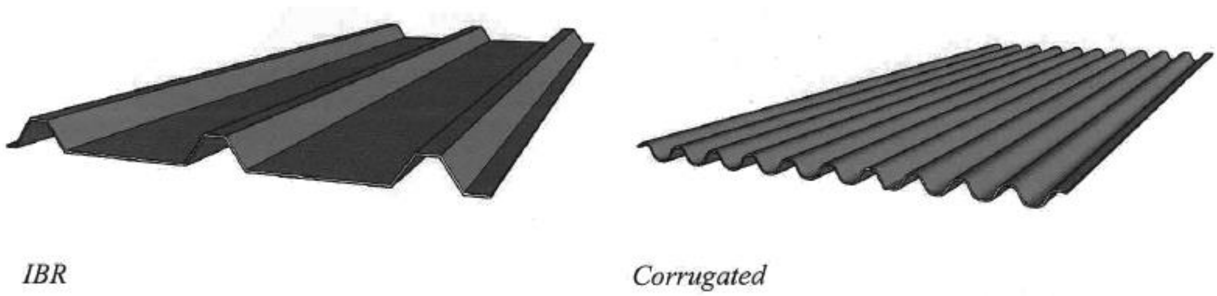


Figure 7.1 Two typical types of sheeting used in building

Fibre cement sheeting is manufactured in various different profiles in a cement colour finish. Using the correct primers and paint, fibre cement sheeting can be painted.

7.3 Roof tiles

Concrete roof tiles are a common and cost efficient roof covering. Aggregate, cement and water are mixed and placed in a mould to form the shape of a tile. Each tile is consistently the same shape and size. Colours are added to the mix to form a 'through colour'. Some colours I coatings are sprayed on after moulding. There are various roof tile profiles to satisfy aesthetic requirements.

Clay tiles are aesthetically similar to concrete tiles except clay tiles are less uniform than concrete tiles. Clay tiles are extruded (like a sausage machine), cut to size and then fired in a kiln. This is why no two clay tiles are exactly the same shape and size.

Note:
Roof tile manufacturers have different names for the various roof tile profiles. The ones listed in **Figure 7.2** are Marley Roofing profile names.

Metal roof tiles, as the name suggests, are made from metal. Various surface finishes and colours are available to suit aesthetic needs. Metal tiles are more durable and robust. These tiles don't break like concrete or clay tiles. One could argue however that they are not as aesthetically pleasing as concrete or clay tiles.

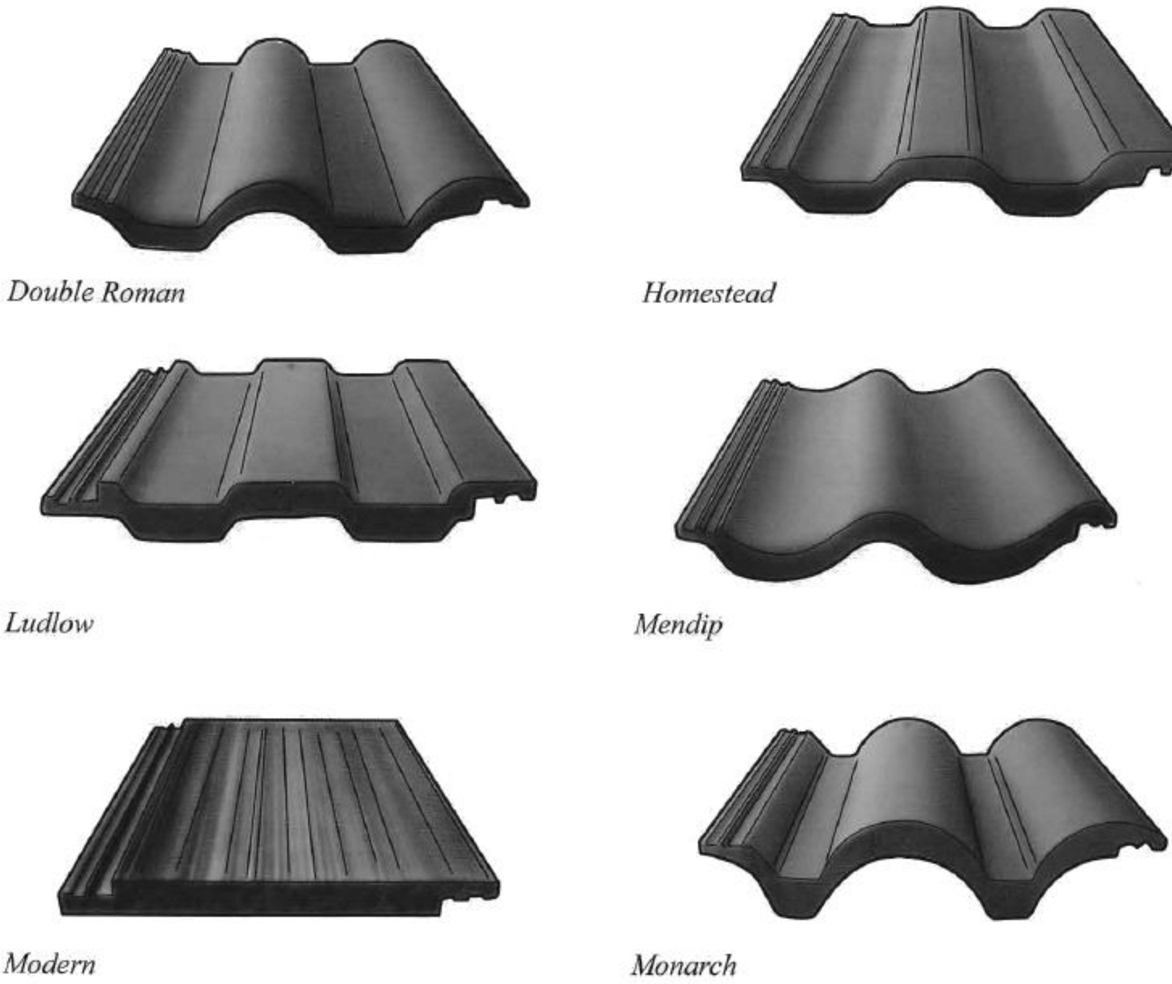


Figure 7.2 Roof tile profiles

7.4 Thatch

Thatch roofing is one of the oldest types of roofing and is still viable today. Thatch roofs should be constructed at a minimum angle of 45°. If good quality, clean, dry grass is used, the lifespan of the thatch will be increased (in general the top layer of thatch will need to be replaced and dressed every 12 - 15 years).

With a well planned and designed thatch roof home, the inside roof area created by the 45° pitch can be utilized for additional living space at a minimal cost (simply by building a floor slab or deck). If a thatch roof catches fire, it will obviously burn better than a concrete tile roof. This deters a lot of people from using thatch.

There are two applications that will prevent thatch from burning. The preferred method is dipping the thatch into a fire-proof solution before the thatch is laid. The second, which is more a retardant than a fire-proofing, is sprayed on after the roof is complete. This method can however prevent the roof from breathing - thatch grass is a natural building element.

A lightning conductor is a steel pole bolted to a base, set into a 1 cubic metre concrete base and placed at least 1 m away from the roof overhang. Copper wire straps are used to earth the pole, giving it a resistance of less than 50 Ohms. The length of the pole should not be less than 15 m and not more than 24 m. Poles longer than 24 m would be susceptible to wind resistance.

If necessary, two or more poles can be used. Drawing an imaginary line from the top of the pole to the ground at a 45° angle will show the line that lightning will travel to earth. This imaginary line must not pass closer than 1 m from the roof.

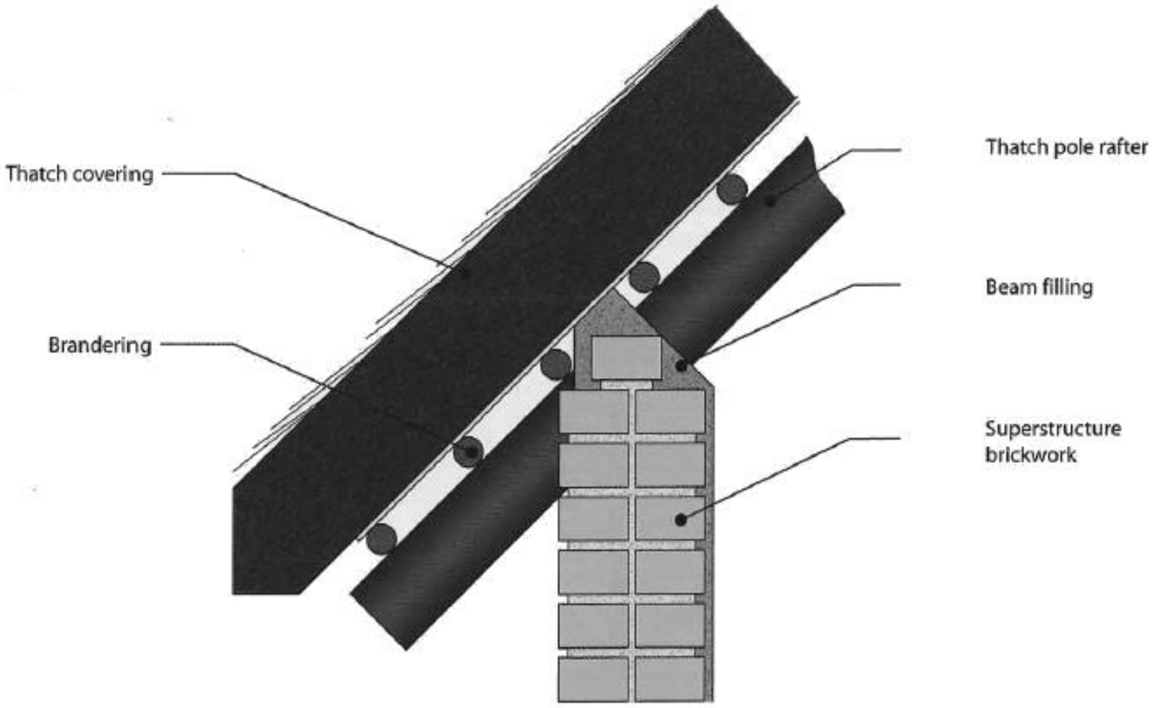


Figure 7.3 Section detail through the eave of a thatch roof

7.5 Roofing slates

Natural slates are cut from natural slate and come in various different natural slate colours.

Fibre cement slates are smoother and more modem than natural slate. The slates come in various colours.

7.6 Transparent roofs and skylights

Polycarbonate and fibre glass roof sheeting are generally used where light is required from/through the roof in a specific area. It is very unusual to see a whole roof constructed using these materials except in agriculture where maximum light is required. Skylights are generally constructed of specially manufactured glass offering durability while allowing light into the inside of a building. The glass can be manufactured to reflect light thereby only allowing the desired amount into the building. The glass can also be toughened to circumvent breakage.

7.7 Types of Roof Trusses

The type of truss used in a building project relates to the type of covering used, roof span and aesthetics. There are many types of truss configuration. Trusses, can be made on site or prefabricated and then brought to site.

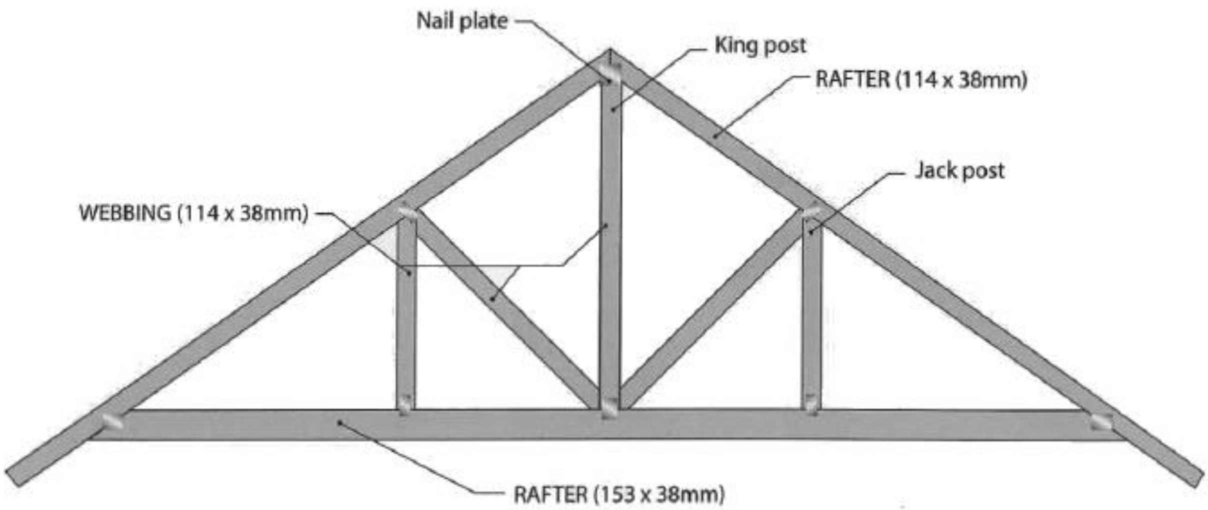


Figure 7.4 A typical roof truss and its members

Prefabricated trusses are made in a factory to strict engineering principles and according to the architect's design The timber components of the truss are butt-joined and connected with a connector/nail plate.

Site made trusses as the term implies, are made on site. It is vital to first establish the type of truss required and then to create a template of the truss, showing the required pitch to ensure that all the elements are taken into account and to assist in quantifying the materials required.

Site made trusses must comply with SABS 0400. Truss spacing depend on the weight of the roof covering but are typically about 700mm apart. Cross bracing placed diagonally between and tying the trusses together are provided to strengthen the roof against wind forces acting in the direction that would topple the trusses sideways.

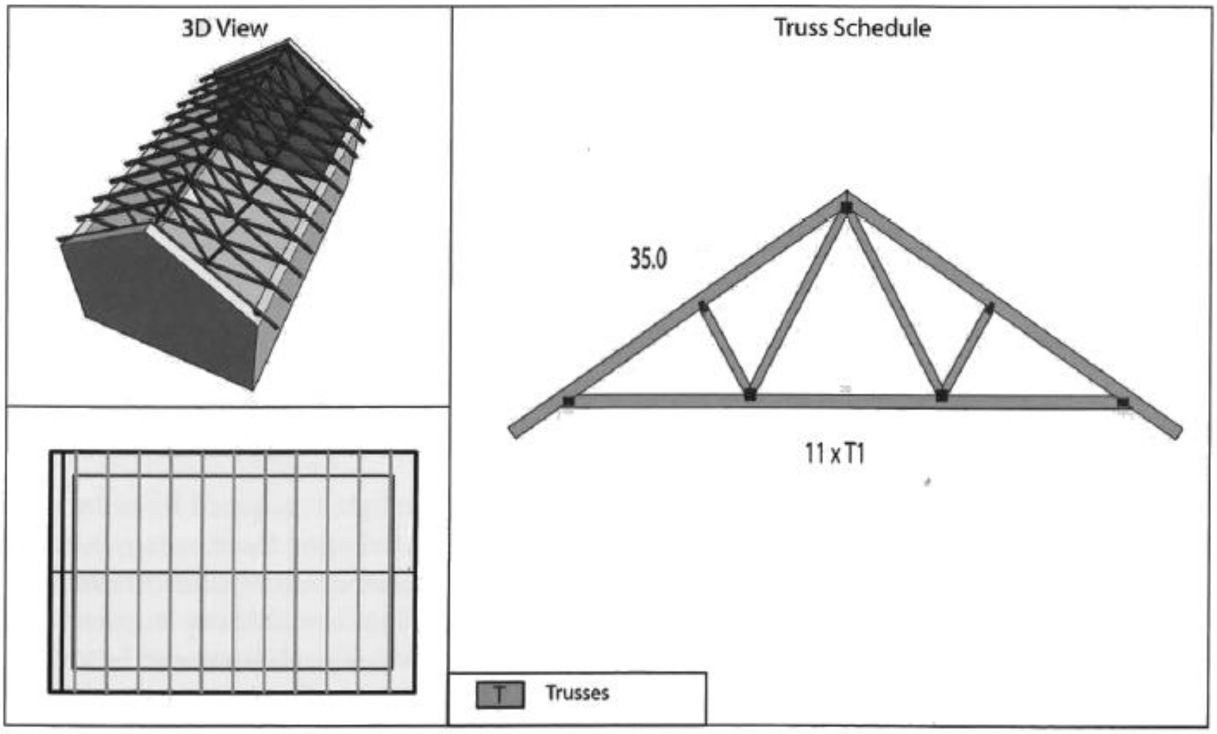


Figure 7.5 Gable roof layout and truss schedule

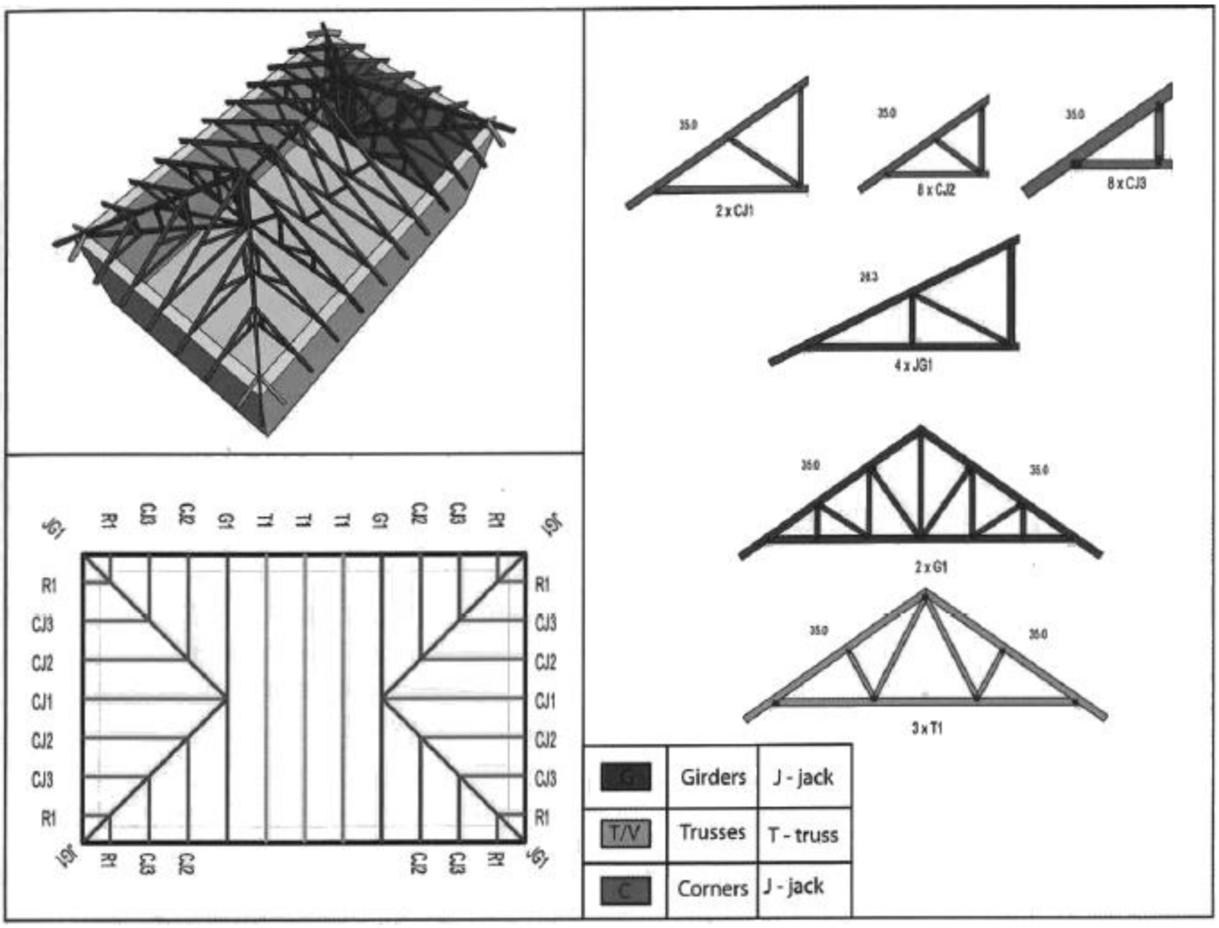


Figure 7.6 Hip roof and truss schedule

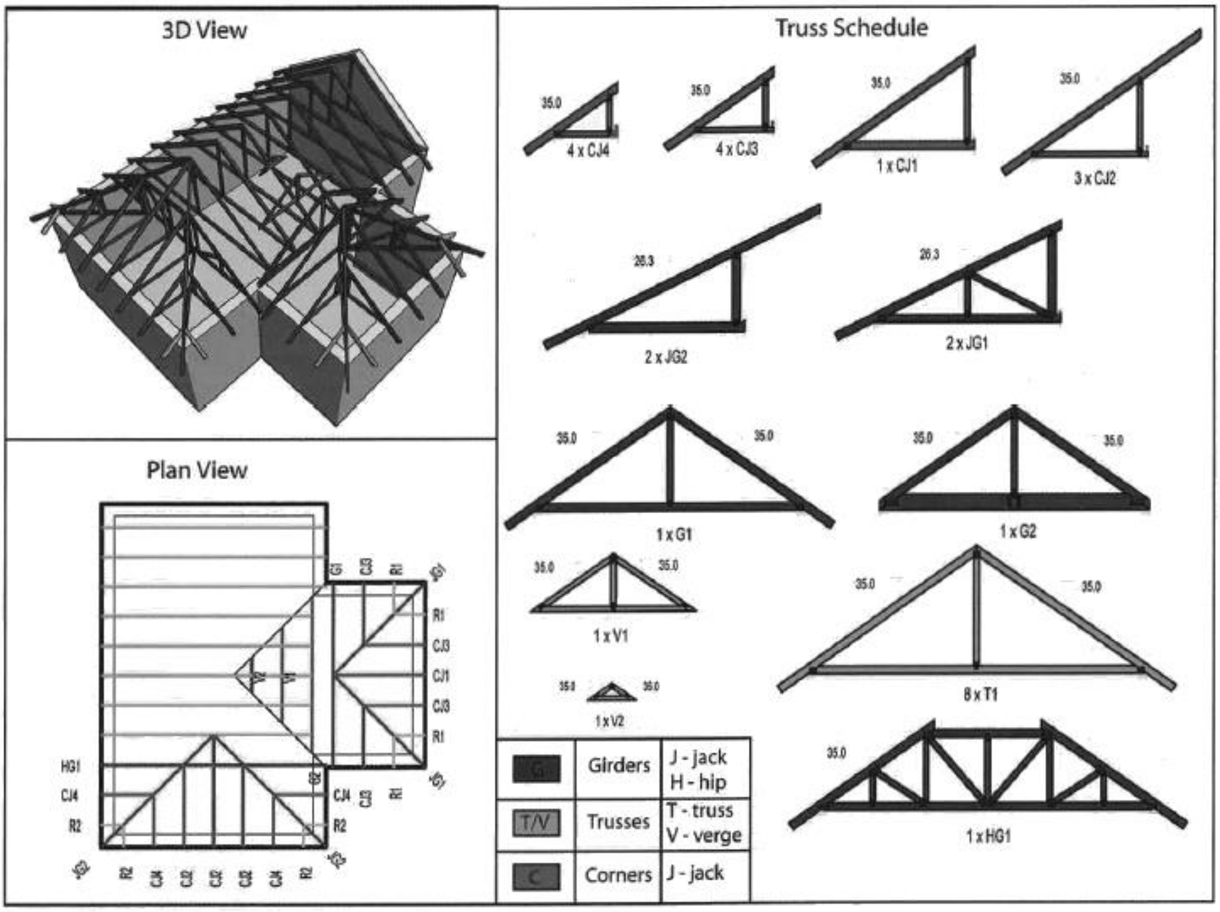


Figure 7.7 Hip valley gable roof and truss schedule

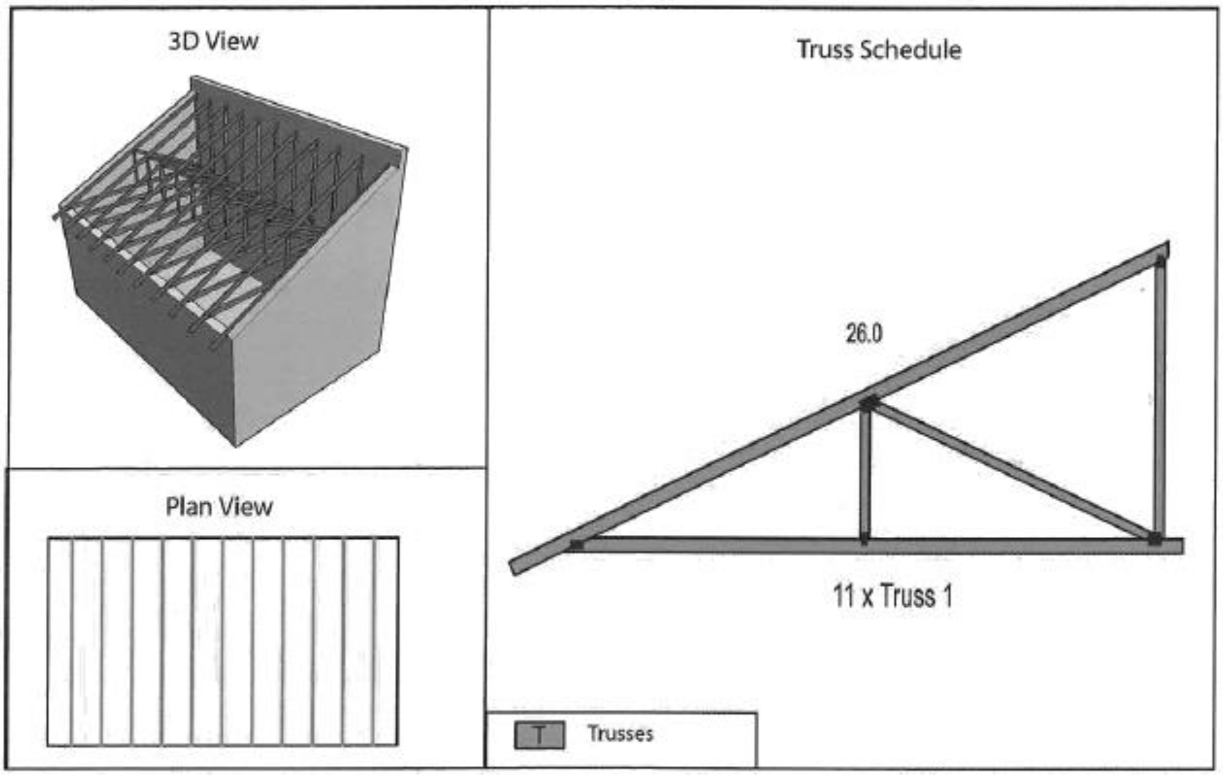


Figure 7.8 Mono-pitch roof and truss schedule

7.8 Steps to erecting a roof

1. Align the wall plate to the inside wall. The wall plate should be at least 76 mm x 50 mm in size. Nail into position using 75 mm steel nails every 400 mm along the wall plate.
2. Mark the position of all trusses at a maximum centre of 900mm on the timber wall plate. Adjust the position of the first and last truss at the gable ends to ensure equal spacing at gable ends
3. Position the first and last truss using a temporary support bracing. Make sure that trusses are plumb and protrude equally on both sides over the wall plate. Nail the trusses to the wall plate
4. . The next two trusses can be positioned and fixed temporarily to the first truss. To keep the trusses in a vertical position, fix 38 x 38 mm battens to either side of the ridge.
5. Fix diagonal cross bracing to the long web of the first three trusses to create a rigid unit so the other trusses can be attached temporarily. The temporary battens and bracing must be removed once the permanent battens are fixed.
6. To check alignment, span a fish line above the wall plate from the first to the last truss. If alignment is not correct, insert a wooden wedge under the tie beam of the truss.
7. Nail all trusses with 100 mm nails to the wall plate. Permanent diagonal bracing must now be installed at one gable end. Bracing members must be a minimum of 38 x 76 mm. Bracing members must be nailed to the underside of the trusses, with two nails, at about 45° angle from the top to the bottom of the truss. Bracing members should be nailed to the wall plate with three nails.
8. Trusses must be permanently anchored to the wall and wall plate with roof wire.
9. The roof underlay must be fixed horizontally over the rafter. Underlay should be secured using clout nails, nailed to the centre of the rafters. The horizontal overlap should be a minimum of 150 mm. Vertical laps should be secured over the rafter, allowing for a side overlap of 150 mm.
10. When there is a one-tile overhang at the eaves, place a tiling batten in line with the outside wall, this will be a finishing batten for plastering the outside wall. Measure 335 mm from the top of the first tiling batten, down the slope of the rafter and make a mark on the first and last rafter. Then use a chalk line to mark all rafters and cut off the rafter ends at right angles if you are not going to use gutters or fascia boards.
11. Place the top tiling batten a maximum of 25 mm away from the top of the trusses and nail it into position. Measure the distance from the top tiling batten to the top of the bottom tiling batten. Work out the number of courses required for batten centres (this should be between 320 mm and 345 mm). Mark the batten centres at each end of the first and last truss. Use a chalk line to mark the batten centres.
12. Fix battens with 75 mm wire nails on the chalk lines. Battens must span over at least three trusses and the joints must be staggered.

13. Allow enough overhang at gable ends for trimming. Work out the verge overhang at gables by setting out a full course of tiles at the eaves and at the ridge. Adjust the tiles to make sure that the overhang is equal on both gable ends.
14. Mark the correct overhang with a chalk line from the top batten to the bottom batten. Cut off the end of all the tiling battens, except the bottom one. Nail the verge counter batten to the ends of the tiling battens at both gable ends. Nail the bottom end to the tiling batten. The tiling batten must extend 20 mm past the verge counter batten. Now cut the tiling batten.
15. Mark every third course of tiling with a chalk line to make the vertical alignment perfect. Tiling should always be done from right to left working from bottom to top, three tiles wide at a time. This will keep lines straight at the gable ends.
16. Every tile at the roof overhang and under the ridge must be nailed. Clout nails must go into the batten by a minimum of 25 mm.
17. Rake tiles must be marked from the first rake tile and cut to line up with the eaves course. The first rake tile must butt up against the second course of tiles. Rake tiles must be fixed with serrated nails. The top rake tiles should be mitred on site - this will then form a neat junction on the roof.

7.9 Waterproofing

Bituminous membranes are made up of more than one product:

- Bitumen - Mixed with a filler component such as limestone or sand. Polymers are added to the bitumen such as APP (atactic polypropylene) a plastic additive that gives rigidity and tear resistance, or SBS (styrene butadiene styrene) a rubber additive that gives more elastic benefits.
- Base Products - Polyester, fibre glass, rag fibre (hessian), and paper. These products are bought in roll format and are pulled through the bitumen mixes on huge rollers. The base product becomes saturated in huge tanks by the tar like bitumen substance, creating rolls of waterproof material.
- Mineral - (Optional) Small granules are added to the top of the felt, decreasing the products fire vulnerability.
- Thin, transparent film - This product is added to the base of the felt during manufacturing on all torch-on products. This stops the felt from sticking to itself when rolled up during the packaging process.

7.9.1 Acrylic systems

Acrylic systems are generally no longer used to waterproof flat concrete roofs. However, they are ideally suited to waterproof the inside and top faces of parapet walls, as well as roofs that have good water run-offs.

Acrylics are not ideally suited for waterproofing areas where standing water will accumulate or damp areas, such as below tiles or box gutters. Due to their variable quality during manufacture and the practice of replacing good quality polymers and pigments with cheap fillers, it is necessary to ensure a reliable and reputable supply source.

Many excellent acrylics are available, with well-known brand names as a reassurance of good quality. On the other hand, acrylics can be, and are being manufactured with small high speed mixers with no quality control.

7.9.2 Torch-on Systems

Torch-on systems using four millimetre membranes are generally the most suitable and the most commonly specified waterproofing specification for concrete roofs.

These contain polymers, pigments, modified bitumen's, and a host of other components such as rot-proof polyester reinforcements. These ensure a system that can withstand structural movement caused by ambient temperature fluctuations.

These systems provide stability, with a high puncture resistance and a high tensile strength. Four millimetre thick membranes are the most commonly used. The ideal system that can be specified, however, is the 'double layer' system.

This incorporates the application of two torch-on membranes; one being a 3 mm and one a 4 mm; this is commonly practised in all European countries.

At present, there is a proliferation of torch-on membrane being imported into South Africa. Some are not suitable for our climate and some are only suitable and designed for the purpose of "cap sheet", as used in the double layer system.

Asphalt: A bituminous waterproofing agent applied to roofing materials during manufacturing.
Asphalt plastic roofing cement: An asphalt-based cement used to bond roofing materials. Also known as flashing cement or mastic.

Torch-on membranes in the 4 mm category are guaranteed for a period of ten years, subject to maintenance during this period.

Membranes of 3 mm are not suitable as a single layer waterproofing system and are often guaranteed for a period of up to six years only. A 3 mm torch on membrane, however, can be used as a cap sheet when installing a double layer system.

The torch-on systems are obviously black in colour as they are bituminous-based. The roof must be coated or painted with a compatible top coat as this is a critical part of the long-term performance of any system.

An ultra-violet reflective top coat is most commonly used, in the form of a bituminous coating. This provides excellent thermal insulating properties and raises heat off the roof. The most damaging element of roofs in South Africa is ultraviolet degradation.

If a roof is left in its laid-up form without top coating, it will probably just outlast its ten years guarantee period. Ideally, one should look beyond this period. By applying a suitable ultra-violet protective coating at regular intervals over the entire torch-on system, the life expectancy of the system can be extended by many years beyond the ten year period.

7.9.3 Boarded Roof Systems

Boarded roof systems are increasing in popularity and have numerous advantages. The insulated boarded roof system effectively insulates and waterproofs troublesome, leaking metal roofs. The insulation boards are installed over the existing metal roof.

A dual reinforced 4 mm membrane (or similar) is then placed over the insulation board using the torch-on fusion application method which is then guaranteed for ten years.

This provides a flat surface like a concrete roof, which is not completely waterproof, but keeps occupants warm in winter and cool in summer. It also provides an excellent soundproof system.

7.9.4 Parking Decks

Parking decks involve all existing materials, preparing the area and then applying the reinforced membrane, which is rot-proof, extremely durable and has a high puncture-resistance. The double layer system (3 mm and 4 mm) is used. Finally, two complete compacted layers of specially designed premix/asphalt are applied over the entire area.

These decks, once waterproofed with the correct system, can also be covered with interlocking pavers which offer the advantage of easy inspection and removal.

7.10 Storage of materials

If you've ever driven by a building site and paid any attention to the materials stored on site, you have probably seen a lot of things that aren't right, but didn't know it.

To build a superior roof, you need superior materials, and these materials need to be handled in a specific way if they are to give you the best roof possible. If you drive by one of these sites and everything seems to be in a haphazard condition, chances are the contractor is not a high quality one, and is probably inexperienced.

Once materials are installed, storage problems cease to be a problem. If, however, they are left stored improperly for any length of time, a lot of damage can occur that will mean a roof is built that has three strikes against it before it is a year old. Knowledgeable contractors know this, and use caution in storage.

Bitumen roofing materials become very stiff and easily cracked if you attempt to install them when outside temperatures are below 5 °C. For this reason, crews should never be allowed to install these materials below this temperature. The materials, being stiff, will not lay flat on the roof. Damage is easily done to the materials because of their stiffness and cracks and tears can appear.

Be very wary of anyone who tells you it doesn't matter how cold it is when installing a roof. Here's why. Asphalt shingles have a sticky tar strip on them that adheres to the shingle above it. When weather is cold, the adhesion does not work well, leaving a shingle loose and subject to being torn off in any higher than normal wind.

Generally, a good contractor will apply a few dabs of roofing cement to the shingles when the weather is cooler to help the adhesion process. This roofing cement has to be kept warm to ensure it sticks properly.

Every shingle comes with a set of installation instructions, giving temperature range, nail location, number of nails per shingle and how deep the nails are to be driven. Shingle companies have engineers that determine these guidelines, so it is wise to follow them. If you install shingles outside of these guidelines, the warranty on the shingles will not be valid. Never proceed if there is any question about weather conditions.

You might reach a point when you have no alternative, such as when high winds take shingles off your roof. If this is the case, ensure that you follow the installation procedures correctly and use roofing cement during installation. Ensure that the shingles are actually sticking, or have some black gooey tar underneath. Check at least six places on the roof.

7.10.1 Storage Requirements

Bundles of shingles should be stored in a covered, ventilated space where temperatures won't exceed 43 degrees C. Rolled roofing should be stored on end, off the ground.

Materials such as flashing and insulation should be kept dry, and not covered with plastic or shrink wrap. This ensures condensation doesn't form and wet the product, which can damage it. Manufacturers recommend these be covered with canvas tarp.

Unload materials carefully to ensure they are handled correctly. If the weather is unpredictable, ensure that there are at least two days of warm temperatures before you proceed.

Note:
Try to get a roof installed in good weather. If you have high winds that damage your roof in colder weather, it is generally best to repair the roof, and wait until the weather is warm before proceeding with a full installation.

Activity 7.1

1. Describe and explain galvanized corrugated iron and galvanized long span ribbed sheets.
2. Describe corrugated fibre-cement roofing sheets.
3. Explain correct fixing on timber and steel trusses.

Self-Check

I am able to:	**Yes**	**No**
• Describe the following roof coverings		
o Galvanized corrugated iron		
o Galvanized long span ribbed sheets		
o Corrugated fibre-cement sheets		
• Describe fixing on the following trusses		
o Timber		
o Steel		

If you have answered ‘no’ to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Module 8

Guttering

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the following types of guttering
  - Half-round
  - Square
  - Box gutter
- Explain the use of the guttering above with downpipes of the following material
  - Asbestors
  - Cement
  - Plastic

8.1 Introduction

Though most gutters are installed on existing roofs, adding them during reroofing simplifies installation and allows them to be fully integrated into the roof system.

Gutters are formed in several profiles and sizes. The standard profiles are a simple "U" shape and a "K" style, which has an ogee- shaped front vaguely resembling the letter "K."

Channels are 10, 12, 5, or 15 cm in diameter; 15 cm K-style gutters are a popular type. Matching downspouts are 5 by 7, 5 cm or 7, 5 by 10 cm rectangular profiles or 7,5 or 10 cm round (often corrugated) pipes.

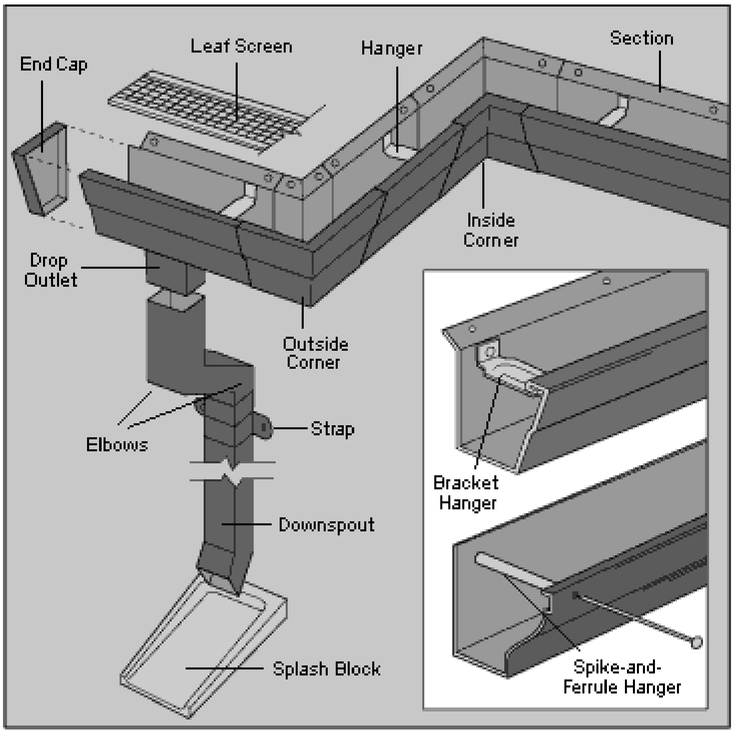


Figure 8.1 Rain gutters and downspouts parts diagram

The larger systems are generally worth the difference in price because they're less likely to clog. Especially if trees overhang the building, 7, 5 by 10 cm downspouts are the wisest choice.

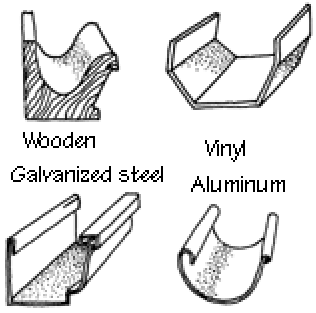


Figure 8.2 Rain gutter types

Gutters are attached along a house's eaves by any of several means, including straps, brackets, and hangers.

A crossbar hanger is particularly sturdy. It clips onto the front, goes over the top of the gutter, and clips on the bracket at the back.

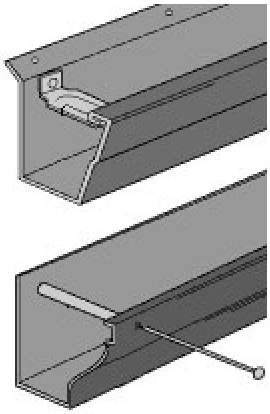


Figure 8.3 Rain gutter mounting systems include hidden hanger (top) and spike (bottom)

8.2 Eaves gutters

Wood eaves gutters are still quite popular in some areas. Butt and mitre joints 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 which act as water outlets are pushed through holes cut through the channel of the gutter – an expansive bit is used to bore the hole through the gutter.

Note:
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 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 10mm 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.

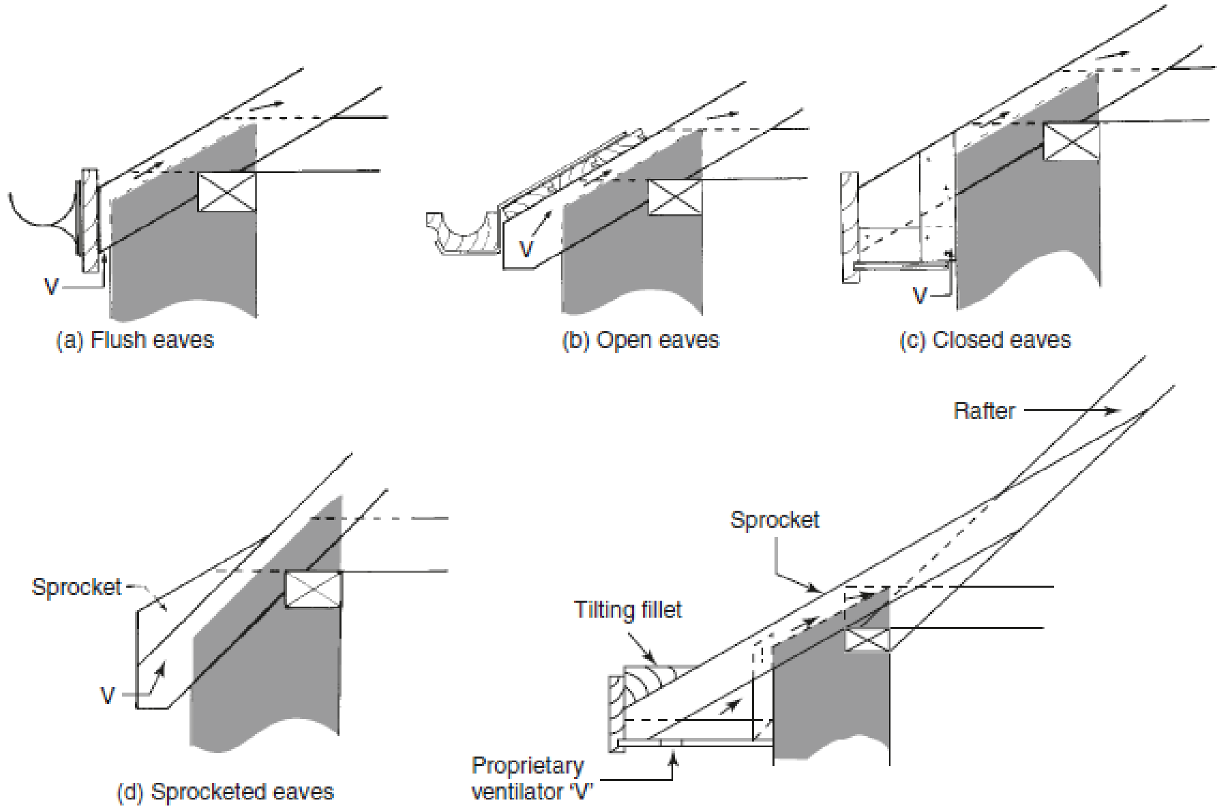


Figure 8.4 Eaves details, *V = ventilation to roof space, mesh covered to deter insects and birds, etc.*

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 is important as this not only ensures that roof water enters the gutter correctly, it makes adequate provision for the eaves sarkin felt to enter the gutter back, and provides for reasonable access to gutter channels for cleaning and maintenance purposes.

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

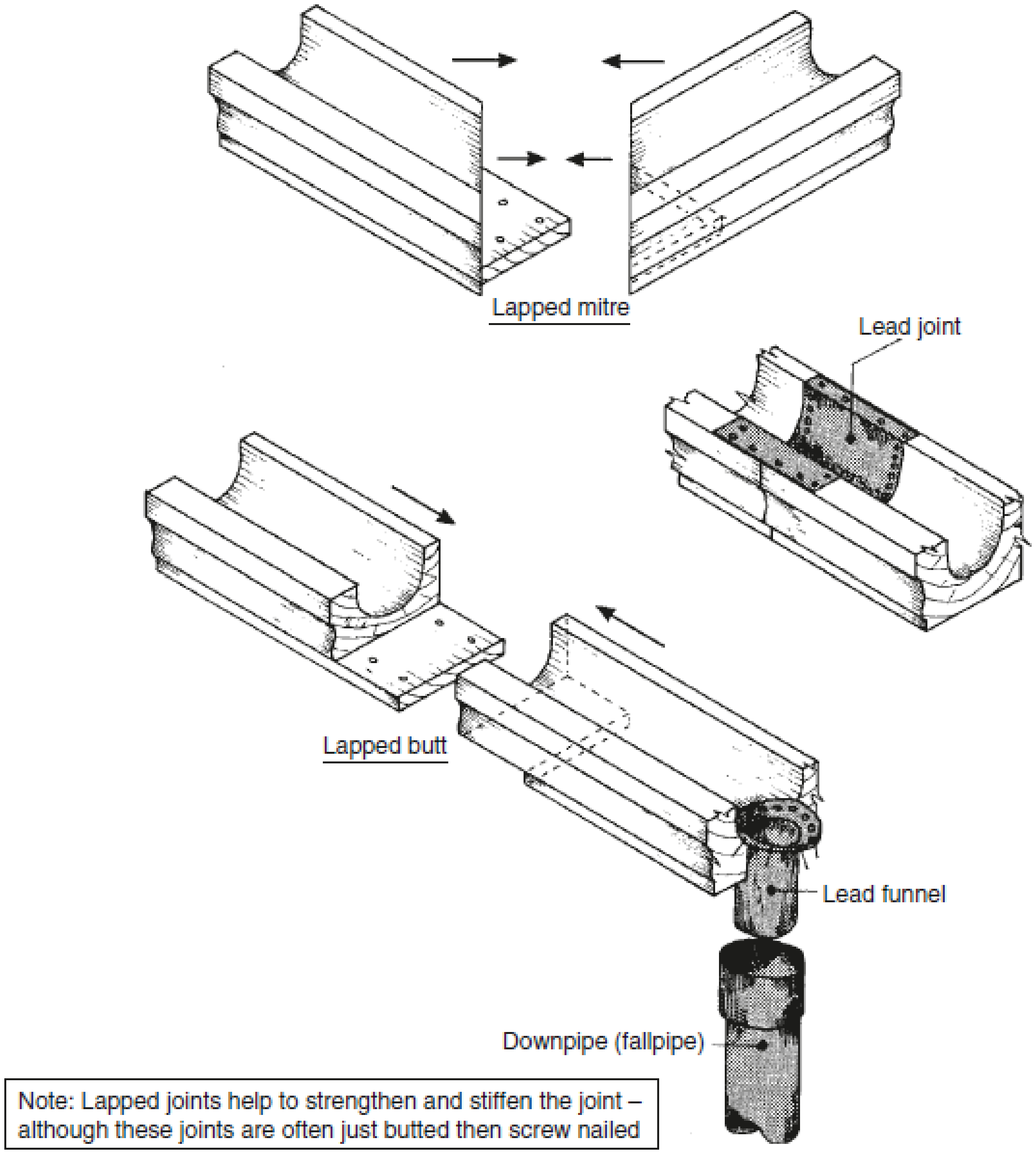


Figure 8.5 Traditional wooden gutter joints and connections

Activity 8.1

1. Describe half-round, square and box guttering.
2. Explain the use of the above guttering with downpipes of asbestos, cement and plastic.

Self-Check

I am able to:	**Yes**	**No**
• Describe the following types of guttering		
o Half-round		
o Square		
o Box gutter		
• Explain the use of the guttering above with downpipes of the following material		
o Asbestos		
o Cement		
o Plastic		
If you have answered ‘no’ to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 9

Ceilings

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the following types of board
  - Gypsum plaster board
  - Fibre board
- Describe the use of asbestos cement
- Describe acoustic ceiling materials
- Describe pressed steel suspended ceilings
- Explain suspended ceiling systems
- Describe tongue and groove timber ceilings

9.1 Introduction

Planning and preparation is important in the case of ceilings. Support for a ceiling is less complicated. Most ceilings are simply attached directly to the joists that support the floor of the room above, or to battens nailed at intervals across a concrete ceiling. Hanging a suspended ceiling requires little more technical skill than hanging a picture; prefabricated snap-together metal strips strung from the ceiling provide a framework for drop-in panels.

9.1.1 Planning a plasterboard ceiling
To install a ceiling you need to firstly, make a plan of the ceiling before you start, and decide on the position of the sheets. First, get the exact measurements of the room where the ceiling will be installed.

- Sketch the room dimensions to scale
  Draw the exact dimensions to scale on graph paper.
- Sketch the layout for the planned ceiling on graph paper. Try sketching several layouts before beginning the actual installation to determine which one looks best.
- The drawing will help you pretty accurately estimate the total cost of the materials you'll need. Add or delete materials for the job you're planning.

- Use **Table 1.1** as a guide in estimating the costs for your ceiling installation.

Item	Number of	Cost per piece	Total cost
Joists		@	R
Brandering		@	R
Plasterboard sheets		@	R
Join strip tape		@	R
Jointing compound		@	R
Cornices		@	R
Nail and/or screws		@	R
Total cost of ceiling			**R**

Table 9.1

- Use a level to apply the wall angle at a proper height around the room.

9.1.2 Planning a suspended ceiling

First, get the exact measurements of the room where the suspended ceiling will be installed. Use special care in measuring any odd-shaped alcoves, bays, etc.

- Sketch the room dimensions to scale.
  Draw the exact dimensions to scale on graph paper.
- Select the grid pattern you want to use.
- Sketch the layout for the planned ceiling on graph paper.
  Regardless of which pattern you select, draw the main tees 10,2 cm apart. Position the tees so that the border patterns at the room edges are equal on both sides and as large as possible.
  Try sketching several layouts before beginning the actual installation to determine which one looks best.
- It is important to space the cross tees so the border panels at the ends of the room are equal and as large as possible.
- If the ceiling will be recessed and built-in lighting will be installed, decide where to locate the panels of light and clearly identify them on the drawing.
- The drawing will help you pretty accurately estimate the total cost of the materials you'll need. . Add or delete materials for the job you're planning.
- Use this as a guide in estimating the costs for your ceiling installation.

Item	Number of	Cost per piece	Total cost
Main beam pieces		@	R
Main beam splicers		@	R
10,2 cm cross tees		@	R
5,1 cm cross tees		@	R
30,5 cm wall mould		@	R
Ceiling tiles		@	R
Total cost of ceiling			**R**

Table 9.2

- Use a level to apply the wall angle at a proper height around the room.
- Fasten the wall angles securely to the wall at all points.

9.1.3 Drawing up cutting lists

To estimate the number of sheets of plasterboard you'll need:

- First measure the total area of wall or ceiling to be covered.
- Don't subtract at all for doors and windows.
- Then add 10% for a waste allowance.
- It is usually more efficient to discard off-cut pieces than to make a number of joints between small sections, each of which must be taped and filled.

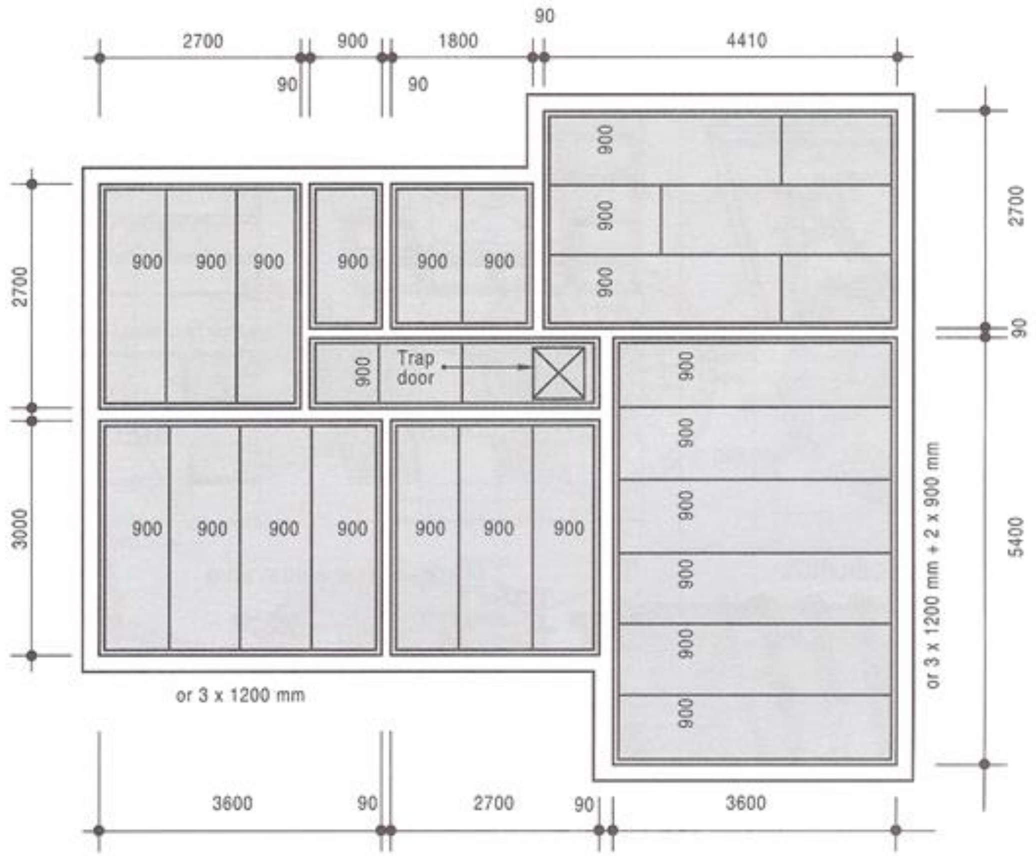


Figure 9.1 Typical ceiling plan for a house

9.2 Materials used to erect ceilings

9.2.1 Nails and screws

Different nails and screws are used for different tasks, always make sure that you use the correct nails and screws for a specific job. (**Table 1.3**).

Concrete anchor screw can be used in masonry without the need for a wall plug.	

Standard screw can be used in combination with wood or masonry.	
Coach bolt and washer ,heavy-duty screw fixing.	
Drywall screw can be driven without drilling a pilot hole first, used for fixing plasterboard to joists and studwork.	
Traditional wood screw, for general carpentry, available in a huge range of sizes and finishes.	
Oval nail , the head punches easily below the surface and the shape is less likely to split the timber, used for fixing architrave and skirting boards in position.	
Masonry nail is used for fixing into masonry	
Round head nail, for general carpentry work, ideal for fixing noggings to joists.	
Plasterboard nail is used for fixing plasterboard to stud work, sometimes has a rough shank to improve grip when in position.	
Clout nail, for general purpose use.	
Lost head nail can be punched below the surface and gives a neat finish, used in all manner of carpentry work.	

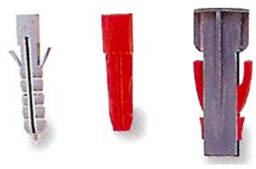
Panel pin is used for fine fixing purposes like window frames.	
Wall plugs are positioned inside pre-drilled holes before the screws are inserted, used for fixing joist hangers and timber to masonry and brickwork.	
Shield anchor bolt, for attaching hardware such as heavy-duty joist hangers to masonry.	

Table 9.3

How and where to use different fixings

- Use galvanized plasterboard nails if the underpinnings are timber studs or joists.
- Special plasterboard nails (**Figure 9.2a**), should be used to fasten the plasterboard to wooden framing members or to battens.
- The nails are driven in until their heads are slightly below the surrounding paper surface, leaving a hammer-made dimple that is later filled with joint filler. Neither the nail head nor the dimple should break the paper surface.
- Use special screws made for walls framed with metal studs. Screws (**Figure 9.2b**) can be used with either metal or wooden framing structures. The screws must be sunk to just below the plasterboard surface, leaving the paper intact.

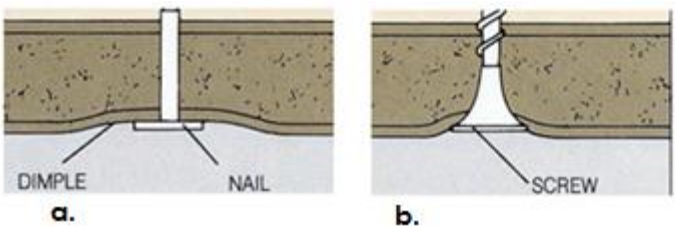


Figure 9.2

Whether to use nails or screws:

- The Building Regulations are very strict about how many fasteners need to be used to attach plasterboard.
- Nails are the easiest to use if you are not comfortable with a screw gun.

- For 13 mm drywall, use 31mm ring shank nails. This type of nail holds better into wood framing and prevents "popping" later on.
- With nails you usually need one every 180 mm on ceilings and every 200 mm along walls. This may not be enough, depending on the thickness of the drywall and the spacing of the joists or studs.
- Using drywall screws can go a lot faster, if you have the right tool. You want to use a special electric drywall screw gun that lets you adjust it to sink the screws a little below the surface.
- Screws are stronger than nails. You usually only need to use one screw every 300 mm along the ceilings and every 400 mm on walls.

Note:
Trying to pry out a bent nail may tear up more drywall than it's worth. Just nail it in so it's not sticking out from the surface and then mud over it later.

9.2.2 Wall plugs

Wall plugs are sheaths that expand when matching screws are driven into them. Plastic or nylon plugs are split, to allow expansion, and ribbed, to prevent the plug pulling out of the hole.

Fibre plugs allow the screw to form its own thread and expand the plug without damaging its structure.

They can be used in masonry, brickwork and concrete, but some materials, such as lightweight blocks, require special plugs with projections along the sides.

To install a wall plug, drill a tight-fitting hole and drive in the plug, then tap a screw through the fixture and use a screwdriver to tighten it into the plug.

9.2.3 Selecting the correct fixing

To choose the correct fixing for the wall or ceiling you have drilled, estimate the load to be supported and then consult **Table 9.4**.

If the load is to be relatively light, or if the wall is framed with timber studs, the fixings may be as simple as masonry nails or wood screws. For some situations, however, specialized fixings, such as those shown below and on the right, will be needed.

Matching the load to the ceiling. The chart below shows the fixings that can be used for ceilings of different materials. There are many types of nails, screws, plugs and bolts designed to fix objects and attach objects.

To choose the right fixing for the job, you must first find out what the wall or ceiling is made of, and then considers the weight of the object that is to be attached to it.

Construction Material	Light Loads	Light-to-Medium Loads	Heavy Loads
Solid concrete ceilings	Masonry nails to penetrate up to 12 mm into wall or ceiling. Plastic plugs with appropriately sized screws.	Plastic or fibre wall plugs with No.8 to 10 screws.	Plastic or fibre wall plugs with No. 12 screws. Expansion shields 6 mm diameter or larger. Self-drive screws and bolts.
Plasterboard over wood or metal studs/joists	Hollow-wall plugs. Oval or lost-head nails, into timber studs or joists. Self-tapping screws into metal studs.	Hollow-wall plugs or toggle bolts. Screws twice thickness of object, into timber studs or joists. Self-tapping screws into metal studs.	Not recommended for ceilings. No. 10 screws at least twice thickness of object, into timber studs or joists. Sheet metal screws into metal studs.
Plaster over lath	Toggle bolts. Oval nails into studs or joists.	Toggle bolts. Oval nails into studs or joists.	No. 10 to 12 screws into studs or joists.

Table 9.4

If you are unsure of the construction materials of the wall or ceiling, drill a test hole in a place that is out of sight.

- Plaster or plasterboard will produce white dust and offer little resistance to the bit.
- Brick will produce red dust, with moderate resistance.
- Concrete and concrete block will produce grey or brownish-grey dust with heavy resistance.
- If the bit breaks through to a timber or metal stud, wood or metal chippings will also appear.

9.2.4 Wood and mouldings used when erecting ceilings

- Prepared softwood 50 x 25mm - used for frameworks for cladding or plasterboard.
- Prepared softwood 125 x 25mm - common floorboard size and used for other multi-purpose building uses.
- Tongue and groove boarding - thicker heavy-duty varieties are sometimes used for timber ceilings or floor boarding.

- Panel moulding - decorative feature added to flush doors or to create a panelled wall effect.
- Architrave - decorative trim fitted around doorways, available in all sizes and many designs.
- Skirting board - decorative and protective trim fitted at floor/wall junction, available in all sizes and many designs.
- Mitres and joints are used around doorframes and ceilings.

9.2.5 Joint compounds

Whatever the material used, it must be fixed in strict accordance with the manufacturer's instructions.

Joint compounds are available powdered or pre-mixed. Powdered joint compounds come in different textures.

- Taping compound is used for the tape coat. It is stronger and courser than the compounds used for the finishing process.
- Topping compound is thinner and finer. It's used for the fill and finish coats, and for texturing.
- All purpose joint compound is halfway between a taping and a topping compound. It comes pre-mixed and is a good choice if you are going to do the installation yourself.
- Chemically setting compounds come in powdered form only. They are generally very strong and therefore difficult to sand. You might use this to patch and fill gaps created when re-modelling plaster for walls.

9.4 Ceiling boards and sheets

9.4.1 Plasterboard

Plasterboard is the material most often used today for constructing ceilings (also called gypsum wallboard or rhino board). It is reasonably priced, neat and quite simple to install.

It is made of gypsum plaster pressed into a sandwich, with a layer of ivory-coloured paper on the front, and heavy grey paper on the back.

The gypsum core is softened with additives that make the board easy to cut, and slightly flexible.

Figure 9.3 A plasterboard cross-section

It is fairly fire-resistant and it provides good sound and thermal insulation.

The sheets are not very strong, it breaks if you bend it enough, and its corners crumble if the sheet is dropped. A heavy hammer blow will punch right through it. But you can nail through it cleanly, break it neatly and quickly along a scored line, and saw it quickly with a wood saw.

It will hold a hook strongly enough to hang light pictures, and it readily takes anchors of various types.

If you have to cut into plasterboard, you can patch it to its original smoothness, and it makes a good match for existing smooth plaster.
It may be easily trimmed to size with a cutting blade.

Figure 9.4 Sheets of 6,4 mm thick plasterboard

Plasterboards usually come in a thickness of 6,4mm although 9,5mm board is also available. It consists of a core of plaster sandwiched between layers of strong paper.

Description and use	Thick	Width	Length	Mass	Support centre
Ceilings and general	6,4 mm	900, 1 200 mm	2 700 to 4 800 mm in 300 mm increments	6 kg/m²	400 mm MAX
Drywall and ceilings	9,55 mm	1 200 mm	2 700 to 3 600 mm in 300 mm increments	9 kg/m²	500 mm MAX
Drywalls	12,5 mm	1 200 mm	2 700 to 3 600 mm in 300 mm increments	12 kg/m²	600 mm MAX

Table 9.5 Gypsum core with paper liner

Boards are available in standards sizes – in widths of 900 mm and 1 200 mm and in lengths ranging from 2 700 mm to 4 800 mm in increments of 300 mm.

Plasterboard can be fastened by a variety of means - nails, screws, adhesives to a variety of supporting structures: joists, battens, timber or metal studs. Some types of plasterboard can also be fastened directly to a cement wall. But usually, a panel is fastened to the ceiling with special ridged nails.

The joints between the panels are hidden by a paper tape overlaid with a patching and filling compound called joint filler.

Advantages of plasterboard:
- It is cheaper than plaster
- It can be put up faster
- It is less likely to develop any cracks or holes.

Disadvantages of plasterboard:
- It is easily punctured
- Because of expansion and contraction as weather conditions change or a house settles, the taped joints between the panels may open up and the nails holding the board in place may pull, or pop, away from the surface.

Figure 9.5 Newly erected plasterboard ceiling with access into the roof

9.4.2 Fibre cement flat sheets

These ceiling boards ("Nutec boards"®) are manufactured from a combination of Portland cement, silica and organic fibers, and do not contain any asbestos fibres. These materials are very strong and will not deteriorate with age. It forms a strong and durable ceiling board.

Flat sheets can be used in a wide range of external and internal projects.

A good quality range of flat sheets are made without asbestos as a raw material. These products are similar to fibre-cement flat sheets, but are better in many ways.

Qualities
- Certain makes of ceiling boards are non-combustible (do not catch fire easily) and slows down the spread of fire.
- They provide perfect protection against flying sparks.
- They are light in weight and easy to install.
- The ceiling boards are not affected by moisture, will not rot and cannot be damaged by termites or rodents (mice and rats).
- As a partition board, it is better because it is stronger and can resist rodent infestation.

Density

Flat sheets are available in medium and high density material and in plain and medium density textured finishes. The sheets are usually 4 mm thick and available in widths of 900 mm and 1 200 mm. Standard lengths vary from 1 800 mm to 3 600 mm in 300 mm increments.

Use the 4 mm thickness for ceilings and the 6 mm thickness for drywall and ceilings.

Flat sheets
Medium Density – Plain

4,0 mm	@	5.54 kg/m^2
6,0 mm	@	8.32 kg/m^2
9,0 mm	@	12.47 kg/m^2
12,0 mm	@	16.63 kg/m^2

Colours

- Fibre-cement flat sheets are supplied in natural grey colour, but can be painted with a large variety of colour coatings and paints.
- The sheets are best painted with pure acrylic paint. When using oil or alkyd paints it is essential to prime both faces of the sheet with an alkali-resistant sealer.
- Use only high density sheets for external flat sheet facades where the surface is to be painted.

Advantages of Fibre-cement flat sheets are:

- A cheap all-purpose building board which does not get wet easily and is therefore ideal for internal and external use.
- Light in weight.
- Easy to handle and erect.
- Does not catch fire easily and perfect protection against fire.
- Resistant to corrosion.
- Good thermal properties.
- Manufactured to the highest internal quality standards.
- Some Flat sheets carry a SABS mark for compliance to the specification SABS 803.

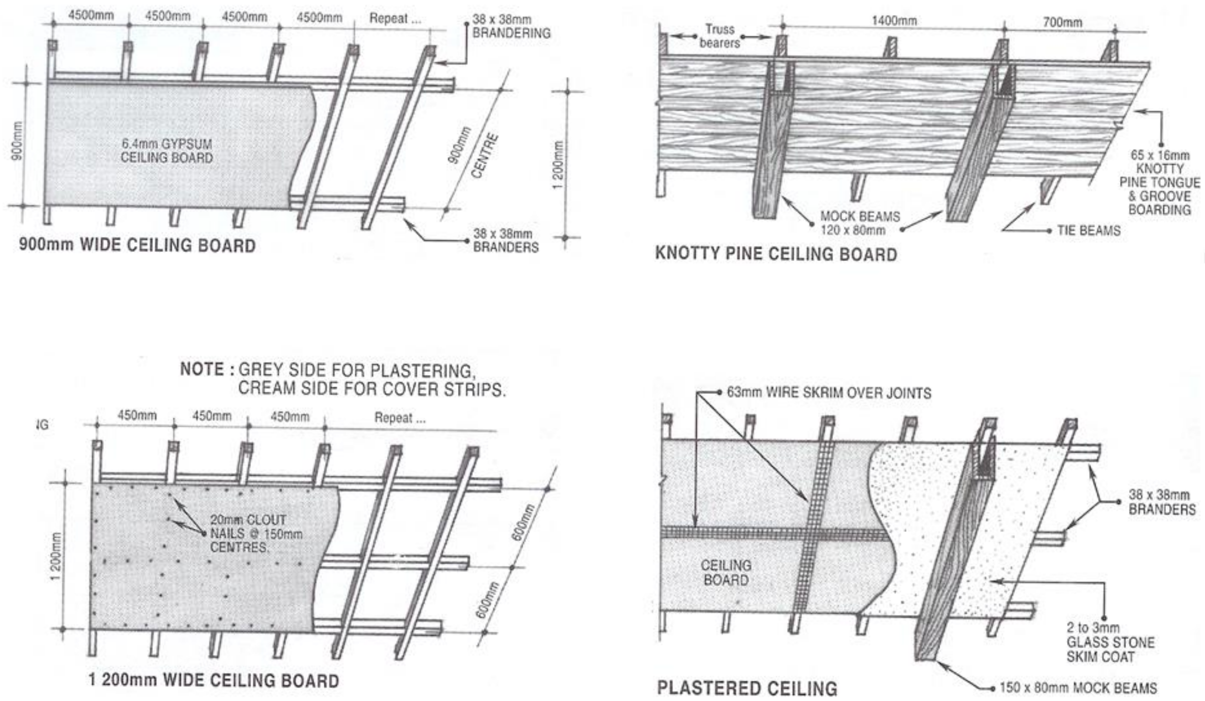


Figure 9.7 Examples of conventional ceilings

9.5 Suspended ceilings

Both tiles and panels are easily damaged or marked and painting them is more difficult than refinishing plasterboard. Tiles can be installed on an unfinished ceiling by suspending a grid of metal strips and place acoustic or plasterboard panels in them.

A suspended ceiling may be best if you wish to lower the ceiling, or if you need to cover pipes and ducts extending below the joists.

A suspended ceiling with removable panels also allows great flexibility in installing overhead lights and permits access to hidden fixtures such as shut-off valves in water supply pipes.

You can buy complete suspended ceiling packages that include both panels and metal supports, designed to suit your own particular needs.

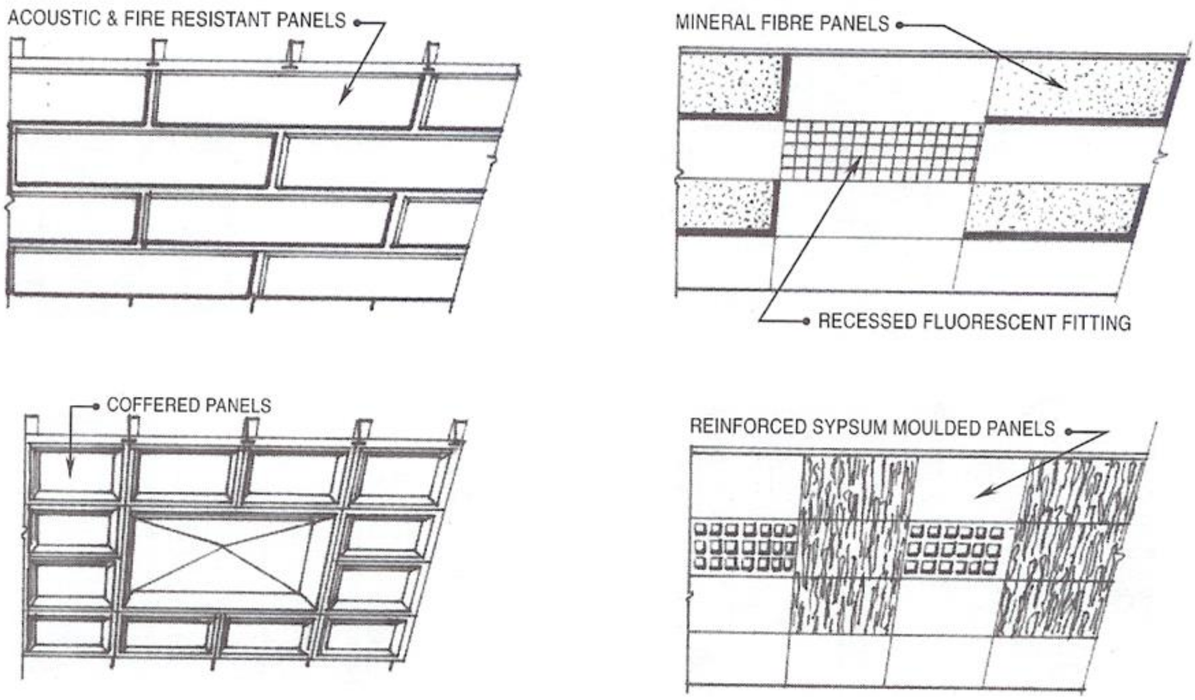


Figure 9.8 Suspended ceilings

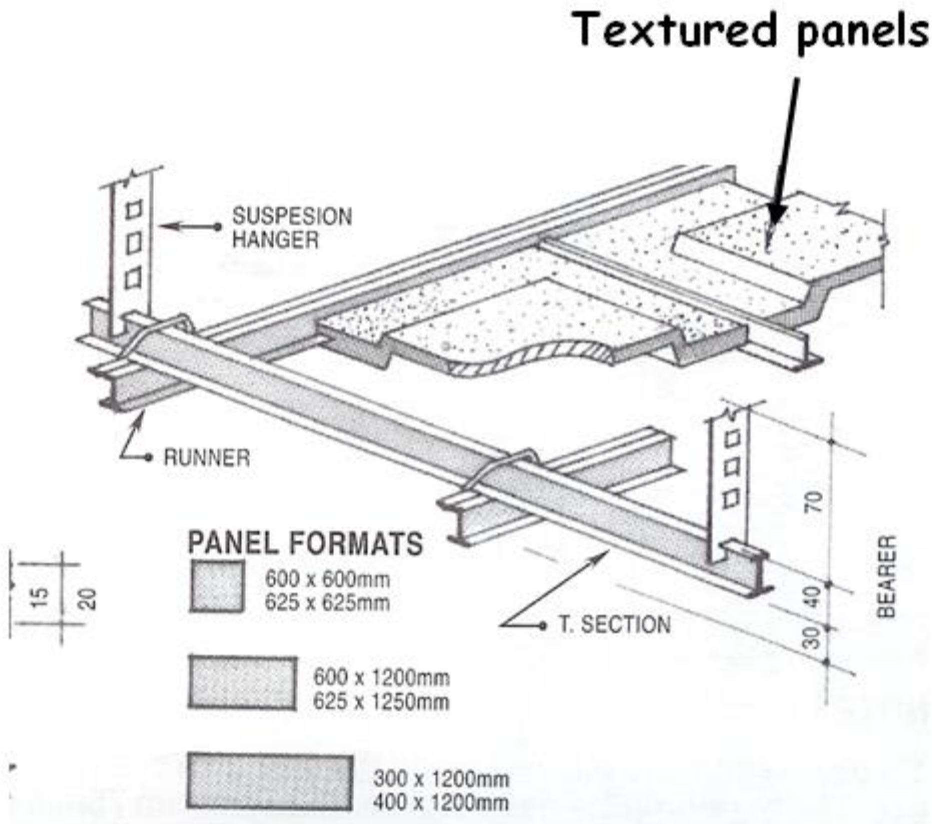


Figure 9.9 Example of a mild steel grid system for a suspended ceiling

Note:
In **Figure 9.9** the panel selection is unlimited.

9.5.1 Tile finishes for a suspended ceiling

The sizes indicated are available with a white background and the pattern printed in blue, pink, grey or dark grey.

Although flexibility is obtained in the coating process, special colours can be supplied providing 5000 mm^2 or more are ordered and the colours are tried, tested and approved.

Colours – White, Grey, Dark Grey, Blue

9.6 Installing a plasterboard ceiling

A plasterboard ceiling is a great way to cover the studs, electrical, and piping that hide inside your ceiling. You can even use plasterboard to replace cracked plastered ceilings without the technical expertise needed to smoothly cover a ceiling with plaster.

Did you know?
Hanging plasterboard does not require a lot of technical skill. After hanging a couple of boards, you'll be able to quicken the pace.

- Don't force plasterboard into a tight area. Doing so will crush the plasterboard and create taping problems.
- Lay panels flat on the floor until you're ready to use them to avoid bending and breaking.
- Make sure the blade on your knife is sharp to avoid tearing.
- Hang plasterboard with the goal of minimising the number of seams. The taping will go faster and the end result will be better.
- Getting sheets of drywall up to the ceiling can be tricky. And once you get them up, holding them in place while you screw or nail them is another challenge. You'll need the help of a drywall lift or drywalls jacks for this or get another person to help you.
- Once you get a sheet in place, just nail or screw around the edges of the sheet. Then you can take the lift or jacks away.
- You can wait until all the sheets are up to put the fasteners in the middle. Although, sometimes it's easier to do this right away because you can see better where the joists are.
- When fastening around the edges keep the screw or nail at least 10mm back from the edge so you don't fracture the drywall.
- Start the ceiling using full sheets, and cut them so the edge is centered on a joist.
- Stagger the joints between sheets from row to row, this will make your walls stronger.

Think about it!
When hanging plasterboard on the ceiling, a second person will not only speed up the job, but will also make it much easier.

9.6.1 Preparation

- Check the area for obstruction like protruding pipe and ductwork.
- Install furring strips to the framing to extend the wall so the plasterboard will hang flat.

9.6.2 Marking guidelines for nails

- Make a vertical mark at the joist locations on top plates below the centre of each joist or batten end.
- This will help you to find the joists easier when you are fastening ceiling sheets.
- The marks will establish the sight lines your plasterboard nails must follow after the plasterboard sheets hide the joist or batten itself.
- Referring to your ceiling plan, cut 50 by 25 mm wooden battens to go round the edges of the ceiling, and secure them with 63 mm No 8 screws and plugs.
- Also, whenever possible place boards so that joints fall along the frames of doors and windows; this results in fewer joints to fill.
- Fit battens across the shortest dimension of the ceiling at 1200 mm intervals.
- Check that the wooden battens lie flat, shimming them from behind if necessary.
- Get someone to help you lift the plasterboard, which is too heavy for one person to handle.
- Always start in a corner area where you can use full sheets and hang the drywall across the ceiling joists.
- Putting up plasterboard.
- Make a T-brace the height of your ceiling for your assistant to use in holding up the sheet while you nail.
- When you have the end of a sheet centred on the joist or batten where it will join the next sheet, push the first nails into the board 12 mm from the edge at 400 mm intervals.
- The tapered edges of each plasterboard sheet should always butt together and face the floor.
- The purpose of the tapered edges is to accommodate your joint tape and joint compound.
- Then nail additional battens between them at 400 mm intervals, checking each one against the others with a straightedge and spirit level to make sure that the undersides are level and flat.
- Standard 30 mm plasterboard nails are made sharp enough to penetrate the board.
- To drive them home, try the position professional plasterboard hangers use. Hold the hammer in front of your face, with your thumb against the handle, and hit the nails by rotating your wrist and forearm.

- With either screws or nails, drive the fastener so that their heads just dimple the surface but do not break through the paper facing.
- Later you will fill the dimples with joint compound.
- Continue like this, until the entire ceiling is covered. Stagger the joints so that the seams of adjacent boards are not aligned along the same joist. This will give the plasterboard stability.

Definition: Adjacent
Next to or adjoining something else.

- Therefore, start the second row with a half sheet of plasterboard.
- To cut short or narrow pieces, score and break it.
- Measure holes for lighting or ventilation, and cut holes for fittings before installing the board.

9.6.3 Adding a filler strip

- Fill any gaps in the ceiling with strips of plasterboard cut to fit and secured with one or two fasteners driven into each joist.
- If the gap is adjacent to a wall, cut the filler strip from the side of a board so that it will include a bound edge, and place the strip so that the bound edge butts against the bound edge of the adjoining board, assuring a smooth joint.
- If the gap runs parallel to the joists, cut earlier boards shorter so the filler strip will span at least two joists.
- Use a trimming knife to trim away small amounts of excess gypsum.
- Finish the joints between panels with jointing compound and tape.
- Fill the dimples with jointing compound.

Figure 9.10 Adding a filler strip

9.6.4 Finishing the joints

Seams between sheets of plasterboard are concealed with a special paper tape embedded in two layers of joint filler, which is feathered smooth at the edges. The tape reinforces the joint while the filler levels the depression along the seam line.

9.7 Tape Coat

- Before starting the taping process, make sure corner bead is installed on all outside corners.
- Also make sure that all the fastener heads are sunk below the surface of the drywall. You can check them by running a taping knife over the drywall. If you hear a "click" you've got a nail or screw that needs to be sunk deeper. Just give the nails an extra tap, or give the screws a twist with a screwdriver.
- Professional tapers sometimes notch out the butt joints so they have more space for the first pass of joint compound. This helps eliminate the "hump" that you might get when taping these joints.
- The entire finishing process is about a 4-step, 4-day process. The first step is called the "tape coat." This is when you apply joint compound to the seams and embed paper joint tape in it.

9.7.1 Equipment needed to finish the joints with joint filler

For a professional-looking job, you will need:

- A container to hold the joint filler.
- A taping knife for laying on the first coat of filler
- The tape
- A 200 mm jointing applicator for smoothing the second coat.
- Joint filler can be bought either pre-mixed, as a thick slurry, or in powder form, to be mixed as required. The correct consistency for the joint filler is a stiff cream that will not fall off the taping knife.

Did you know? Handy hints to finish the joints

- To apply filler neatly, always dip the taping knife sideways into the pan, so that you cover only half the width of the blade.
- Keep the blade clean, especially of dried bits of filler, to avoid leaving scratches in the wet filler as you draw the knife over it.
- Clean the blade by drawing it over a scrap of wood, not over the edge of the pan, or debris will be continuously troublesome.
- The tape is bedded into the first layer of filler while the filler is still wet.
- It will be easier to work if you dip the cut lengths of tape briefly into a bucket of water, to make them more pliable and to help remove any air bubbles that might form beneath the tape when it is pressed firmly over the joint.
- Sanding of joints is not normally necessary, but if you have grit and lumps

of dry filler showing through, wait until the top coat of filler is thoroughly dry, then sand down lightly with very fine paper.
- Take care not to damage the surface of the plasterboard beneath.

9.7.2 First pass: tape coat

Before starting the taping process, make sure corner bead is installed on all outside corners.

Mix up your joint compound. If you're working with pre-mixed compound, don't mix it too much, this can work air into the mixture and then you can get little bubbles and craters on the surface of the wall.

Starting on the ceiling, first spread out a layer of "mud", as the professionals call it, over the joints. For this first coat use a ± 12,5 cm taping knife.

Be generous with the mud at this point. Spread out more than you need to fill the seam.

Applying joint filler

- Scoop a taping knife sideways into the filler so as to load only half the width of the blade.
- Centre the blade over the joint, cocking the blade at a slight angle so the loaded side of the blade is the leading edge.
- Hold the knife almost perpendicular to the plasterboard at the start of the stroke, but gradually angle it closer to the board as you draw it along the seam, forcing the filler into the depression created by the tapered edges of the board.
- Leave a smooth surface that more than fills the depression.
- Reload the knife as necessary to fill the longest seam length you can conveniently tape at one time.

Did you know?
The trick to spreading out mud is to hold the knife almost vertical to the drywall when it's full of mud, and press it flatter as you move along the joint. This spreads the mud evenly over the whole stroke of the knife.

For an end-to-end joint, where the boards do not have tapered edges, apply filler over the joint in a layer about 4 mm thick.

For ease in handling tape, bend a wire coat hanger into a V-shape that will hold the roll of tape, and hook the coat hanger on your belt.

9.7.3 Second pass: embedding the joint tape

For the second pass, lay a piece of joint tape over the center of the joint. Press it lightly with your hand-just to make it stick for now.

Then go back and flatten the tape into the mud, working from the center of the joint out to the sides. This will remove any air bubbles, and scrape off most of the excess.

You can use pretty firm pressure with this stroke. You'll end up scraping off some of the excess mud, just leave some mud under the tape.

At an end-to-end joint, where the tape rides on the surface, do not scrape off the excess filler completely. Leave a combined tape and filler thickness of about 3 mm.

Did you know?
As you tape, keep your knife clean. Constantly scrape it off the side of the pan. Mud that stays on your knife will dry out faster.

The last step for the tape coat is to spread a very thin layer of mud out on top of the tape. This requires a gentle touch. The layer should be thin enough that the tape is still visible through the mud.

Don't worry too much about a few grooves and streaks on the surface for now. There'll be more coats to smooth it out later.

Inside Corners
Inside corners also get treated with joint tape. There may or may not be tapered edges here, but it doesn't really matter too much. Slightly uneven walls won't be as visible in the corners as on a flat wall.

First apply a thin layer of joint compound inside the seam and on both sides of the corner.

Measure and cut off the length of joint tape you need. Then fold the tape in half and press it into the corner. Most brands of tape come with a crease in the middle to make this easier. Press the tape into corner, then run a knife down each side to set it into the mud and to work out any excess mud.

Lightly coat both sides with joint compound again.

Outside Corners
The outside corner bead will have a little valley between the metal ridge on the corner and the surface of the drywall. Now you want to fill this with mud.

With mud on your knife, run it down each side of the corner bead. Hold the knife at about a 45 degree angle; it should be touching the wall and the ridge at the corner. Scrape off anything that rises above that level. Clean off any bits of mud left on the ridge.

Note:
You should end up with about a 10,5cm wide band of mud on either side of the corner.

Mudding Fastener Heads

The last thing you have to do for the tape coat is to cover all of the screw and nail heads.

It just takes a small amount of mud to cover these, but start by troweling on more than you need. And cover an entire row of screws with one stroke.

Gently scrape off the excess mud with the taping knife almost perpendicular to the surface. This will leave a very thin layer of mud all the way up and down the wall.

The mud over the screw and nail heads will shrink a little, so you'll have to repeat this step with each of the next two coats.

Wrapping up for the day

When you finish the tape coat, you need to let it all dry at least overnight.

Note:
Clean all your tools real thoroughly. If you have any dried mud left on your knives it'll cause little gouges when you do your next coat.

Throw out any mud left in your pans. Scrape down the sides of the mud bucket, and pour a little water on top of it to keep it from drying out. Pour this water off before using the mud the next time.

9.7.4 Finishing the joints with fill coat

The tape coat levelled off everything, and the next two coats will make the surfaces smooth.

You need to use wider taping knives for these coats. You want to build the joints up a little in the middle and then feather them out smoothly. And you want to apply the mud a little differently, too, with a little less pressure and a little more patience.

Mudding Joints on Flat Walls and Ceilings

Use your taping knife to put more mud on the joint. Then smooth it out with a stroke down each side, then one down the middle.

For the side strokes, put more pressure on the outside of the knife and let it ride a little high in the center. For the center stroke keep even pressure on the knife.

With factory joints, this coat should extend about two inches wider on each side than the tape coat. Butt-joints, if you recall, don't have the bevelled edges that the factory joints do so they'll tend to build up higher with each coat of mud. Because of this you'll have to feather them even farther than with the factory joints.

After this coat is done you should not be able to see the joint tape.

Screw and nail heads get covered with another layer of mud at this stage too. The mud from the first coat has probably shrunk a little so you just want to fill them in flush with the surface.

Inside Corners
Inside corners are a little trickier than flat joints. Once you've feathered one side it's tough to work on the second side without disturbing the first.

One way to solve this is to use a corner knife.

Did you know?
Professionals do a coat on one side of the corner, and then wait for that to dry before doing the second side.

Finish Coat and Texture
The finish coat is where you have to be a real artist. You don't want to leave any grooves or streaks after you're done.

Before starting, scrape a wide knife over all the joints to smooth them out a little. This removes the ridges and tool marks. You want the base to be as smooth as possible for this final coat.

When the joints are still dry, check to see if you have any large humps. Do this by holding the edge of a knife against them and rocking it back and forth. If you've got a large hump, you'll have to feather the joint more.

If you do thin your mud, do it with only a cup of water at a time. And don't get it so runny that it falls off the knife. And keep in mind that thinning the mud too much will weaken it.

For this coat you should be using wide knives, for the screw and nail heads, and for the joints. Use the same techniques as the last coat, only here you want to feather the joints as smoothly as possible. You are now ready to sand and prime the ceiling.

9.7.5 Different techniques used for a plasterboard ceiling
Before painting a plasterboard ceiling:
Cover all the nail heads with a flat primer, to stop rust stains from coming through, and then fill and sand to a smooth finish.

⚠	**Note:** Popped nails may occur at any point where a panel is attached to a ceiling joist, and the nail head may be covered or partly covered by tape and joint filler.

- Hold the hammer squarely over the nail and strike the head firmly to drive it flush with the surface.
- Then tap the nail gently to embed it a millimeter or so below the surface, so that the rounded face of the hammer creates a small depression, or dimple, in the surrounding plasterboard without breaking the surface.
- If the nail still pops slightly, countersink it with a nail set and insert a new nail 50mm directly above or below.
- Dimple the new nail as you did the old one.

Patching the dimples
- Apply a thin, smooth layer of joint filler over the dimpled nail with a filling knife.
- Let the filler dry (its colour will change from dark to light beige).
- Add a second layer of filler slightly larger than the first.
- Be sure there are no rough spots, especially at the edges.

Concealing the joints by applying jointing compound to seams
The jointing compound is spread and feathered out with tools made especially for the task.

Making smooth joints to hide the seams between sheets takes practice, so Use plasterboard that has a slight bevel along the long edges because it makes the job easier.

Tools and equipment needed:
- 200 mm jointing applicator (applying and feathering the compound).
- a taping knife for embedding the tape.
- A sponge for smoothing each application.

Spread jointing compound like butter to fill the trough formed by the bevelled edges of the plasterboard, with a layer covering the adjacent surface approximately 1 mm deep .

Then run the applicator down the joint in one motion, to smooth out the compound.

⚠	**Note:** Wipe the applicator frequently, otherwise the compound will harden on it and score grooves in the wet compound.

Taping the joint
- Cut the length of tape needed to fill the joint.

- With your finger, press one end of the jointing tape into the wet compound at the top of the joint.
- Keep the tape straight with one hand and use the other hand to embed the tape in the jointing compound with a 100 mm taping knife. Watch for air pockets and wrinkles in the tape; if they appear, lift the tape, pull it tight, and embed it again.
- If the tape is badly wrinkled, peel it up and tear it off the damaged section.
- Start again with fresh tape, positioning the ends of the sections as close together as possible.

Feathering the joint

- As the tape is embedded, compound will squeeze out along the sides of the joint.
- Run the taping knife down each side, spreading the compound outwards.
- Press hardest on the outside edge of the knife so the compound gradually spreads to a feathered edge.
- Apply jointing compound to the nail dimples on the in¬termediate studs, feathering the edges.
- A day later, apply a second coat to the joints with a 200mm jointing applicator.
- Use a sponge to feather the compound about 250 mm on either side of the joint.
- After another day, apply a third layer of jointing compound, thinned with water if necessary to make it spread evenly, and feathered just beyond the 250mm line.

Smoothing the surface

When the last coat of compound is completely dry, smooth the surface with fine grade sandpaper on a sanding block This will smooth down any last little ridges you may have.

- Sand gently, working in a circular motion from top to bottom.
- Take care not to sand the paper tape.
- Feather the edges of the patches and complete the job by dusting the patched areas.
- Similarly, sand over the filled-in nail dimples.

Safety warning!
Much dust is generated during this process. Wear protective goggles, mask and hat, and keep the working area well ventilated.

Wet sanding

- If your mud is pretty smooth already, you might want to try wet-sanding with a sponge. You need a dense sponge that's been wrung out pretty well. Rub it over the joints, smoothing them out. This method eliminates the huge mess you get with dry sanding.
- Clean the sponge out frequently. This method doesn't scrape up the bare paper, and doesn't raise a lot of dust.

- Cleaning up is a significant part of drywall work. You'll need to vacuum up the dust several times as it gets in the smallest cracks.

Priming

- You may notice that once you sand the joints smooth, they have a harder and glossier texture than the drywall, which is softer and more papery to the touch.
- A good primer/sealer will help hide these differences and any imperfections on your walls. It'll also serve as a good under-coating for your finish paint so it won't absorb into some areas more than others
- If you're just going to be painting over the primer, you can use a primer specifically for finish paints.

Erecting a ceiling on timber

- Install the sheets at right angles to the joists.
- Remember that the ends of the sheets must land on the centre lines of joists, and that joints must be staggered to prevent a continuous seam on a single joist.
- For a concrete ceiling, fit wooden battens first to provide nailing surfaces.
- Try to arrange the panels so that cut edges lie next to the wall, and that joints consist of two bevelled edges together wherever possible to enable you to make a smooth finish with jointing compound and tape.

9.8 Installing fibre-cement ceiling sheets

Are erected in a similar way to plasterboard, and the requirements for storage and handling is the same. It is often used as an alternative to plasterboard in damp conditions – in bathrooms and for outside eaves enclosures.

Fixing the sheets

For fixing Fiber cement sheets, it is advisable to use 32mm galvanised wire nails at 150mm to 200mm intervals.

Fiber cement sheets are not skimmed like plasterboard, so cover strips that are made of wood, aluminium or PVC is used at the joints. You can use PVA or any acrylic-based paint to paint the ceiling with.

9.9 Installing suspended ceilings

Guidelines for easy installation:

- Do not apply loose fill or batt insulation so that it rests directly on the panels.
- Keep your hands clean to avoid smudges on the finished ceiling.
- Always cut the ceiling panels face up with a sharp utility knife.
- Main beams run the opposite direction of the joists.
- Main beams are on 1.2m centers.
- The minimum drop is 8cm.
- Locate Hidden joists by tapping on the ceiling until you hear a solid thud.

- Drive a nail in here. Repeat this to locate other joists and determine their direction.
- Mark the joist locations with chalk lines.

Layout

- For best appearance, border panels should be the same size on the opposite sides of the room.
- Determine which way the panels will run. On timber joisted ceilings the rails must run at right angles to the joists, so the long edges of the panels will run parallel to the joists.
- Plan the panel layout to stagger cross joints.

9.9.1 Install wall moulding

- Mark the height desired for the ceiling. Add the height of wall moulding and mark a level line around 3 walls.
- Snap a connecting chalk line on the 4th wall.
- Nail wall moulding to the wall studs.
- If the nailing moulding directly to the wall is not possible (for example, a solid concrete or stone wall), hang a section of main runner next to the wall as a substitute for regular wall moulding.

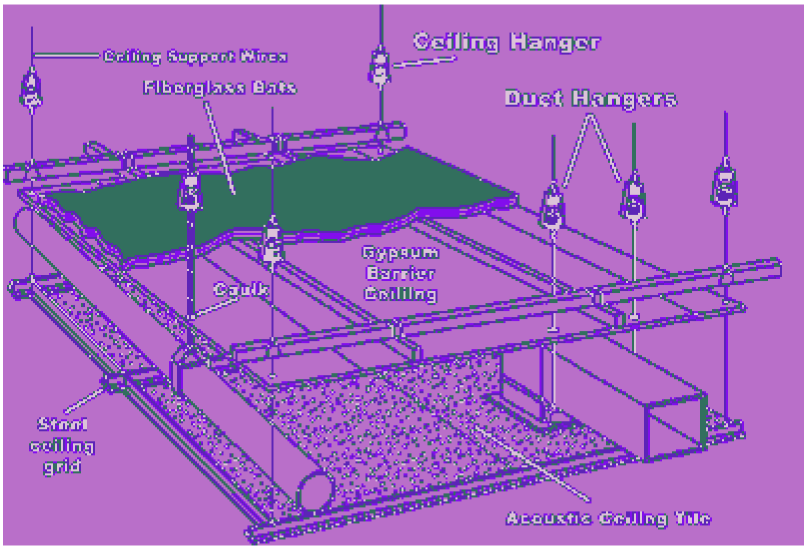


Figure 9.11 Suspended ceiling

9.9.2 Install suspension system

- Install Fasteners and Hanger Wires.
- Snap Chalk Line for Main Beams 10cm Apart.
- Screw in Wire Fasteners 10cm Apart.
- Wrap hanger wire securely around itself 3 times.

Note:
Add extra wires for light fixtures, one at each corner of the light and pre-bend hanger wires.

- Measure up from the bottom of the moulding.
- Drive a nail into the wall just above the moulding.
- Do the same on other side of room.
- Stretch a string from nail to nail along a row of wires.
- Swing hanger wires over to string and bend each one at 90° where they touch the string. Stretch additional strings to pre-bend other hanger wires, to help level the entire ceiling.
- Remove the levelling string(s) after pre-bending the wires.

9.9.3 Trim the Main Beam

Trim the end of the first main beam so that a Cross Tee slot on the Main Beam is the border panel distance from the wall.

9.9.4 Hang First Main Beam

- Stretch a guide string from one end of the room to the other below the moulding where the first main beam will hang.
- Place the cut end of the main beam on the wall moulding and insert a hanger wire in a hole near the other end of the main and wrap the wire around itself three times.
- Insert the other wires into the main beam and wrap the wires around themselves three times.
- Cut Border Cross Tees.
- Find the location of the first border cross tee. (Border panel distance from end of main).
- Place the end of the white face of the cross tee against the edge of the wall moulding at the side and cut the cross tee where it crosses the guide string.
- Insert the uncut end of the cross tee into the main and rest the cut end of the tee on the moulding.
- The far edge of the main should be directly above the string.
- If you are using hook end cross tees, measure from the wall to the string and cut the cross tee to that length.
- The string will then line up with the near edge of the main.
- Cut the second cross tee to length and insert it.
- Temporarily fasten the tees to the wall moulding so they do not move.

9.9.5 Squaring the Grid

- Now install the first section of the second row of mains after cutting off one end so a cross tee slot is the border panel distance from the end.
- Install two four foot cross tees between the two mains in line with the first two border tees.
- Measure across the diagonals of the 5cm x 10cm opening.
- The measurements will be the same if the grid is square.
- If the measurements are not the same, shorten one of the mains until the diagonals are equal.
- Complete the rows of mains joining the ends with the built-in splices.

- Finish cutting border cross tees between the wall the first row of mains.
- Use the leftover ends of the mains to start other rows of mains if your room requires them.
- If you have additional rows of mains to install, stretch a second string from one side of the room to the other aligning it with the first cross tee.
- This second string will be your guide for cutting the remaining rows of mains.
- Just measure from the end wall to the string to determine the distance for the first cross tee slot you will use.
- You must line up cross tee slots for the grid to be square!

9.9.6 Installing the Grid

- After the first section of main is installed in each row, and the grid is square, install the rest of the mains and cross tees.
- Use left over pieces of main to start succeeding rows of mains after cutting to align cross tee slots.
- Measure and cut border cross at the other side of the room.

9.9.7 Install Panels

- Lift panel at angle through grid; drop into place.
- Trim border panels, cutting panel face side up.

9.10 Ceiling heights

9.10.1 Suspended ceilings

- Mark lines on the ceiling at 600 mm max centres.
- Fix the rails to ceiling at 600 mm centres.
- Set the rails on the lines and fix using the specified fixings.
- Stop the rails approximately 20 0mm short of the walls.
- Fix the rails in a continuous run around the perimeter of the ceiling.
- Where panel ends abut, fix two strips of rail, approximately 100 mm apart to support the panel ends. See Horizontal Joints for Walls below.
- Fix panels to the rail at 300 mm centres using 42 mm plasterboard screws.
- Locate the fixings below the dotted lines marked on the rails.
- At this stage do not install the fixings for the panel edges.
- Do not install any fixing within 80 mm of the panel edge.
- When all panels are in place, insert the fixings to all panel edges.
- Tape and seal joints and screw heads.
- Seal all perimeter joints and penetrations with acoustic sealant.

9.11 Installing a V-jointed tongue and groove timber ceiling

Installing planks to wood furring strips is easy, provided you use quality pine furring strips that are dry at the time of installation.

Note:
Ceiling planks cannot be installed directly to exposed wood joists.

Installation tips:

- Ceiling planks are installed upright to the furring strips.
- Begin the installation in the right-hand corner of the room.
- Work from right to left, completing one row at a time.
- Remember that ceiling planks will be only as level as the furring strips to which they are attached.
- Follow directions carefully when levelling your ceiling.

Figure 9.12 tongue-and-groove ceiling

9.11.1 Install Furring Strips

- Place the first strip flush against a wall upright to the ceiling joists.
- Nail the furring strip with two nails at each joist. (Locate and mark concealed joists.)
- Continue to nail the furring strips across the ceiling parallel to the first strip.
- Nail the last furring strip flush against the end wall.
- Check each furring strip with a carpenter's level.
- Correct all high spots by slightly pulling out the appropriate nails and inserting wood shims between the strips on the joists.

9.11.2 Install Planks

- Determine First Row of Plank: Install the first plank in the right-hand corner of the room.
- Work from right to left, completing one row at a time.
- Measure the length of the room.
- Divide this measurement by 15cm. Add 15cm to the remainder (if any); divide the sum by two. This is the first plank width.
- Measure out first plank width from both side walls and snap a chalk line between these points.

- This line will serve as a guide for installing the first row of planks.

Cut the first row of plank:
- Measure the distance from the end wall to the guide string.
- Transfer these measurements to the face of the plank and cut it to the measured width.

Staple up the planks:
- Place the first plank flange along the chalk line.
- Staple through the flange where it crosses each furring strip and at the end of the plank.

Important note:
Each plank must begin and end on a furring strip. This is important to keep in mind when cutting the planks to stagger the seams.

- Secure the first and last rows of planks through the plank face along the wall with nails (as close to the walls as possible to be covered by wall moulding).

Activity 9.1

1. Study the sections in **Figure 9.13** and draw up a cutting list for a room of 2,7m x 3 meters.

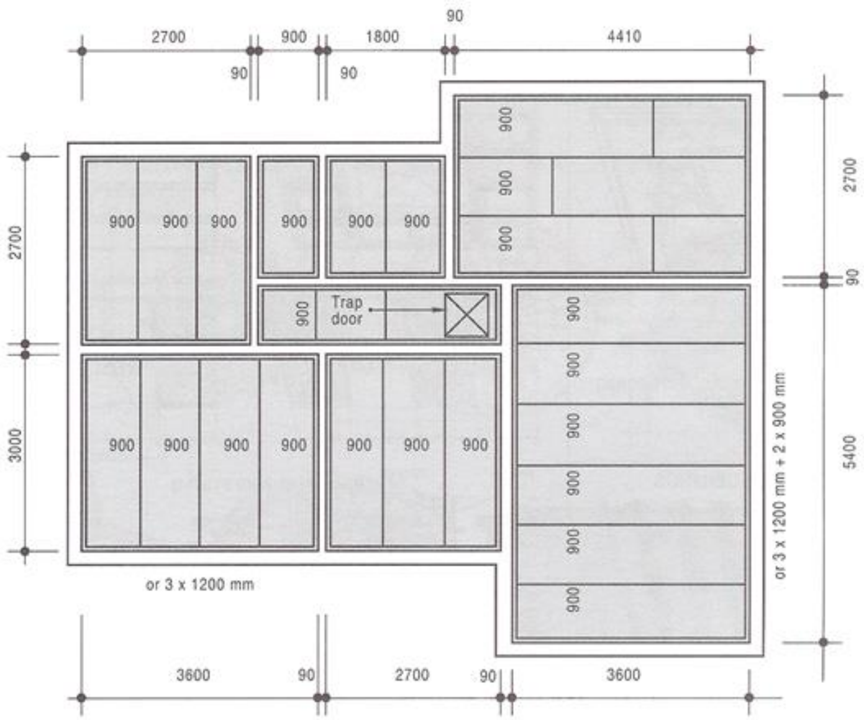


Figure 9.13

2. What is plasterboard made of?
3. List the advantages of plasterboard.
4. List the disadvantages of plasterboard.
5. What are acoustic ceilings materials?
6. Describe how the joints between two plasterboards are hidden.
7. List two qualities of fiber-cement flat sheets.
8. Describe how to install suspended ceilings.
9. Explain how to install a tongue and groove timber ceiling.

Self-Check

I am able to:	**Yes**	**No**
• Describe the following types of board		
o Gypsum plaster board		
o Fibre board		
• Describe the use of asbestos cement		
• Describe acoustic ceiling materials		
• Describe pressed steel suspended ceilings		
• Explain suspended ceiling systems		
• Describe tongue and groove timber ceilings		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 10

Structural Steelwork: Bolted, Riveted and Welded

Learning Outcomes
On the completion of this module the student must be able to:

- Identify welding symbols
- Identify types of bolts and rivets
- Describe column bases and column caps for
  - universal columns
  - columns with lattice beams
- Explain intersections at
  - Beams and columns
  - Beams and beams

10.1 Introduction

A detailer must be familiar with welding symbols and be able to insert them onto detailed drawings. The standard symbols used on production drawings to specify the type, size, length and other particulars of welds are reproduced in the *Steel Construction Handbook*.

10.2 Welding symbols

These symbols should be used consistently and accurately on all workshop drawings so as to maintain an acceptable level of information transmission.

10.2.1 Basic welding symbols

A welding symbol is a graphic symbol that shows complete information about a welded or brazed joint, including weld locations and specifications, in a standardised and abbreviated format on prints. The symbol shows where the welded joint goes, and how it must be made and tested. Many welding symbols contain a lot of complicated information.

As a result, most weld designers use only a few of the many symbols available. Weld designers and welders must use the same welding symbols so that they do not confuse each other.

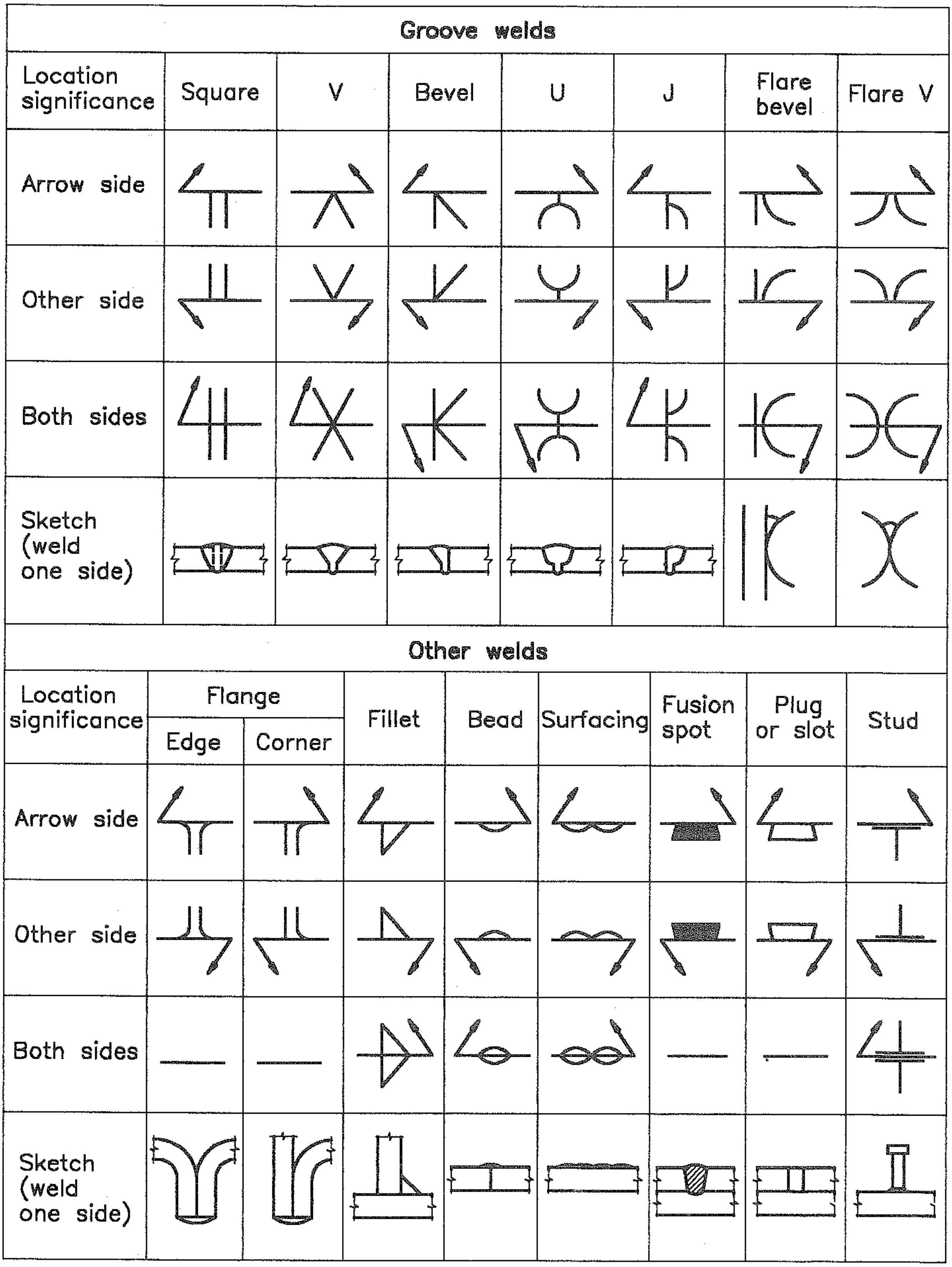
The standardised welding symbols that are recommended by the South African National Standards (SANS 1044) and the South African Institute of Welding (SAIW) are used to denote the type and size of welds on structural detail drawings. These standardised symbols are shown in **Table 10.1** on the following page.

Object lines on the prints show the joint members before welding. The actual weld, however, is not commonly shown on conventional detail drawings.

With CAD drawings, more and more welds are being shown on the prints. The weld location and specifications, including type, size, process and examination procedures, can be specified on the welding symbol.

1.11.2 Summary of the basic welding symbols

Table 10.1, on the next page, summarises the basic welding symbols used on shop detail drawings. It is important that you are able to recognise them.



Note: Arrow side means side of joint to which arrow points.

Table 10.1 Basic welding symbols

The following points should be noted in connection with the construction and use of welding symbols:

- The reference line is drawn in either the horizontal or the vertical direction (in other words, parallel to the horizontal or the vertical axis of the drawing).

> **Important Note:**
> If the reference line is placed vertically, the information on it should be legible when the drawing is viewed from the right.

- The arrow points to the weld(s) or welded joint being described.
- The fillet-weld symbol is a small isosceles triangle based on the reference line and having its vertical side to the left.
- The single-bevel weld symbol is a 45° V with its apex to the reference line and its vertical leg to the left.
- The double-bevel and double-V weld symbols have their legs at an angle of 60° to each other.
- Symbols and notations referring to the arrow side of the joint are placed below the reference line. Symbols and notations referring to the other side of the joint are placed above the reference line. By 'arrow side', we mean the side of the joint to which the arrow points. Examples of this principle, as applied to the most commonly used weld types, are given in **Table 10.2** on the following page**.** In the elevations on the joints, 'arrow side' and 'other side' have the same meanings as 'near side' and 'far side' respectively.
- In the case of groove welds where only one plate edge is prepared and the other plate edge is left square, the symbol arrow is cranked and is made to point towards the plate that has the bevel or groove. This is shown in **Table 10.2** on the following page**.**

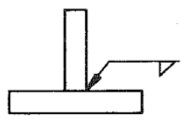
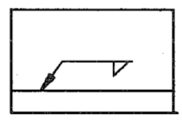
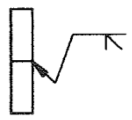
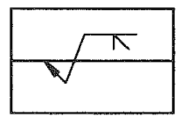
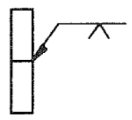
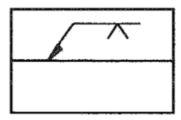
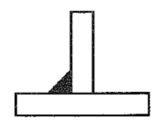
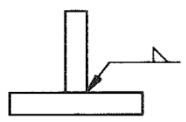
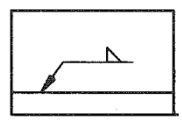
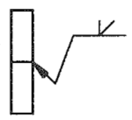
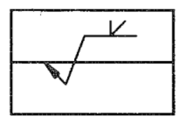
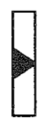
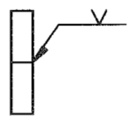
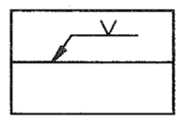
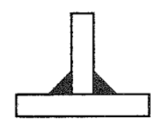
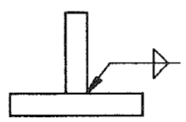
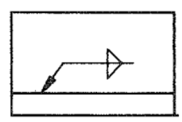
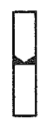
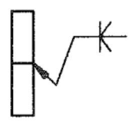
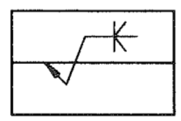
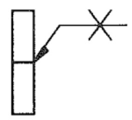
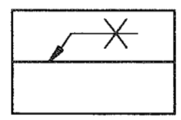
WELD			JOINT	
Location	Type	Detail	Section	Elevation
ARROW SIDE	Fillet			
	Bevel			
	Vee			
OTHER SIDE	Fillet			
	Bevel			
	Vee			
BOTH SIDES	Fillets			
	Double bevel			
	Double Vee			

Table 10.2 Location of weld symbols

Figure 10.1 shows the complete basic welding symbol for a joint that can be constructed, with each piece of information in the correct position.

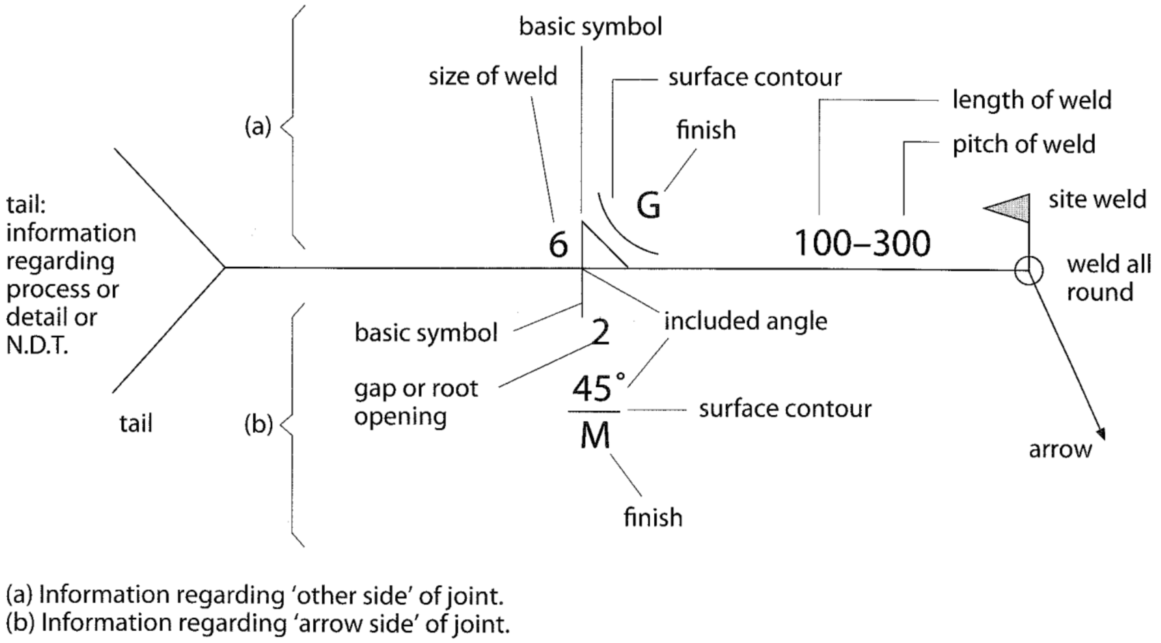


Figure 10.1 Construction of a welding symbol

Look at the example of a welding symbol in **Figure 1.38**.

Try to identify the basic elements you have just learnt about in this welding symbol, as most welding symbols are not this complex and usually use only a few elements. These elements are discussed in more detailed below.

10.1.3 Information contained in basic welding symbols

Only information pertaining to the particular weld is included on the welding symbol. If welding requirements are the same on all welds on the print, a general note is included on the print.

The parts of a welding symbol include:

- the arrow,
- the reference line,
- the weld symbol,
- the dimensions, and
- the tail.

Symbols and notations that refer to the arrow side of the joint are placed below the reference line. Symbols and notations that refer to the other side of the joint are placed above the reference line.

- **Arrow**

The arrow of the welding symbol identifies the location where the welding operation is to be performed. The arrow points to the joint and the tip of the arrowhead touches the object lines on the drawing.

The arrow includes an arrowhead and a leader line that connects to the reference line of the welding symbol. More than one arrow can be used to specify the same weld required at different locations.

Look at **Figure 10.2** below for the applications of the arrow of the welding symbol. The arrow of the welding symbol points to the location of the weld specified.

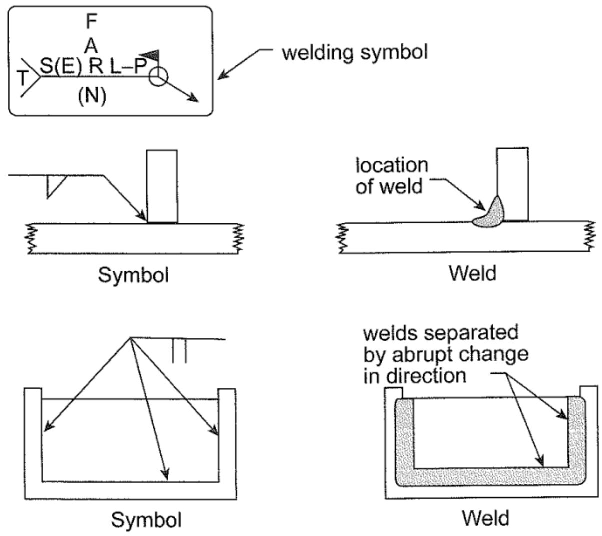


Figure 10.2 Applications of the arrow of the welding symbol

- **Reference line**

The reference line of the welding symbol identifies the side of the joint to be welded. It is a horizontal line attached to the arrow. Information about the weld type and specifications is divided by the reference line into two parts: the arrow side and the other side. The side nearest the observer is the arrow side.

Weld information located on the arrow side indicates the weld information pertaining to the view side of the weld joint nearest the welding symbol. Weld information located on the other side of the arrow indicates the welding operation to be completed on the side of the weld joint furthest from the welding symbol.

Look at **Figure 10.3** on the following page for the applications of the reference line of the welding symbol.

The reference line divides the welding symbol into the arrow and the other side.

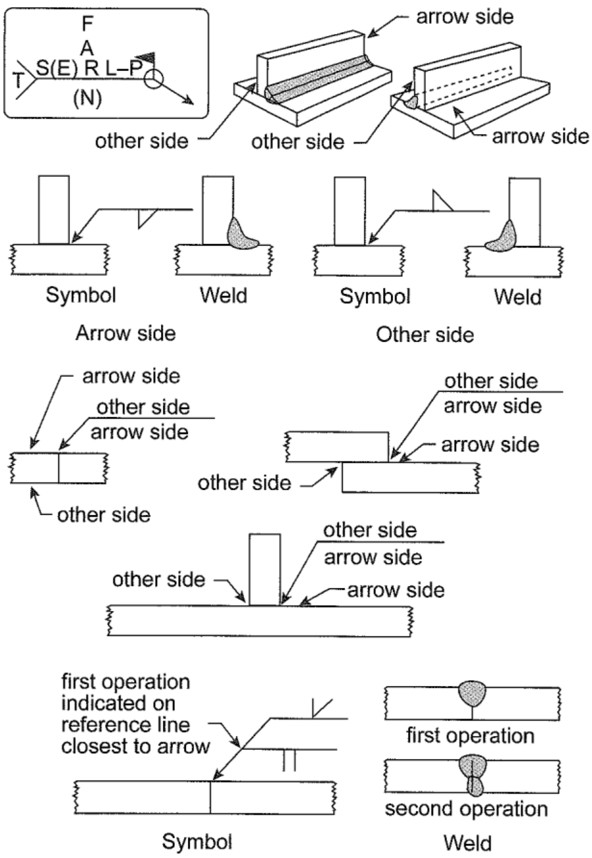


Figure 10.3 Applications of the reference line of the welding symbol

Multiple reference lines are used to indicate separate welding operations. The sequence of welding operations is determined by the proximity of the reference lines to the arrowhead.

The operation indicated on the reference line closest to the arrowhead is completed first. Operations on other reference lines further from the arrowhead are then completed.

- **Weld symbol**

A weld symbol defines the cross-sectional shape of the weld. This is different from a welding symbol, which contains all required information to complete the weld specified. Each weld type has a distinct weld symbol. Weld symbols are located on the reference line of the welding symbol.

If there is no significance on which side the weld is made, the weld symbol is centered in the reference line. Weld symbols with a vertical line always show the vertical line on the left side. More than one weld symbol may be required to specify a welding operation.

Look at **Figure 10.4** for the applications of the weld symbol. Weld symbols on the welding indicate the type of weld required.

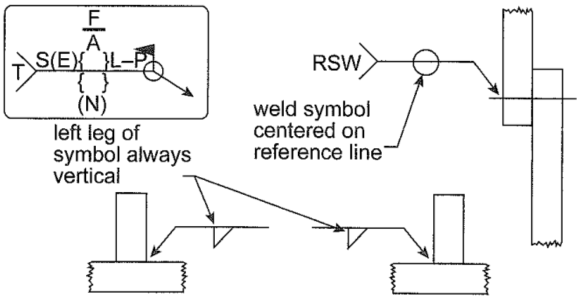


Figure 10.4 Applications of the weld symbol

- **Dimensions**

The dimensions of a welding symbol specify the weld size, number and location. The location of dimensions for welds varies depending on the weld type, joint and application, as seen in **Figure 10.4** and **Figure 10.5**.

Dimensions included in the welding symbol specify weld size and location requirements. When no length dimension is specified on the welding symbol, the weld is continuous and extends the maximum length of the joint member.

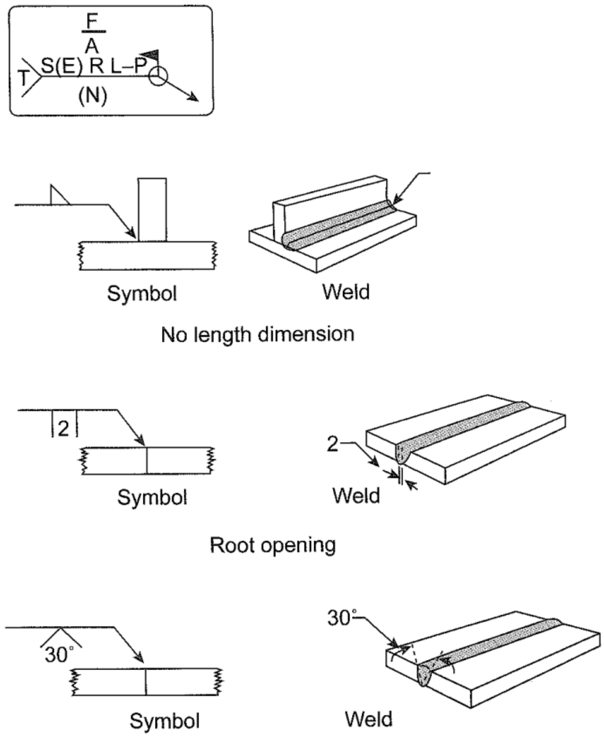


Figure 10.5 Applications of dimensions in the welding symbol

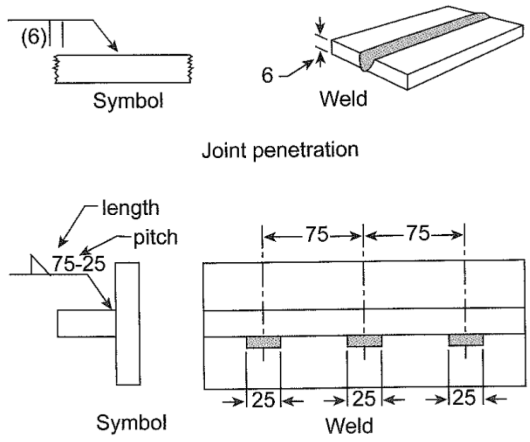


Figure 10.6 Applications of dimensions in the welding symbol

Generally, millimeter designation (mm) is omitted on the welding symbol. A general note on the print indicates the unit of measurement. Degree symbols are included with angular dimensions. Centre-to-centre dimensions are given for spacing of intermittent welds. The length of the weld increment should be increased to terminate a weld at the end of the joint.

- **Tail**

The tail is the part of a welding symbol included when a specific welding process, specification or procedure must be indicated.

Special notations about detail and cross-sectional drawings are also included in the tail. For example, the letters 'GTAW' in the tail specify that the weld must be completed using the gas tungsten arc welding process.

Welding and allied processes are abbreviated with letter designations. The tail is omitted when no information is required in the tail of the welding symbol. See **Figure 10.7** for the applications.

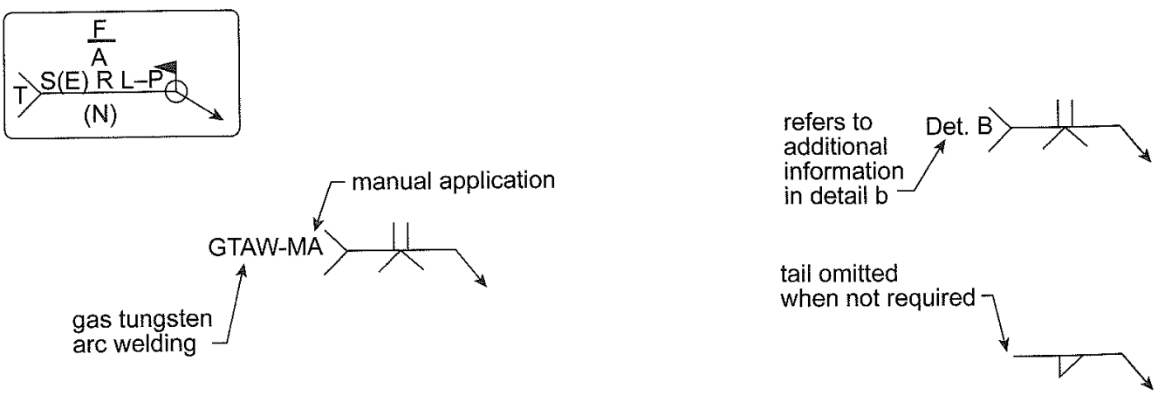


Figure 10.7 Applications of information in the tail of the welding symbol

10.1.4 Supplementary welding symbols

A supplementary symbol is a symbol that further defines the welding operation to be completed.

Supplementary symbols used on welding symbols include:

- the weld-all-round symbol,
- the site- or field-weld symbol,
- the melt-through symbol,
- the consumable-insert symbol,
- the backing symbol,
- the spacer symbol, and
- the contour symbol.

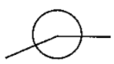
Supplementary welding symbols								
Weld-all-round	Site weld	Surface contour			Finish			
		Flush	Convex	Concave	Machine	Grind	Chisel	Flame
					**M**	**G**	**C**	**F**

Table 10.8 Supplementary welding symbols

10.1.5 Information contained in supplementary welding symbols

The supplementary welding symbols in **Table 10.8** are explained in more detail below.

- **Weld-all-round symbol**

The weld-all-round symbol is a supplementary symbol indicated by a circle at the intersection of the arrow and the reference line. The weld-all-round symbol specifies that the weld extends completely around the joint. The weld is continuous and does not have a break in joint penetration.

- **Site-weld symbol**

The site-weld symbol is a supplementary symbol indicated by a black dot at the intersection of the arrow and the reference line. The site-weld symbol specifies that the welding operation is to be completed on-site or in the field where the final installation takes place.

- **Surface-contour and finishing symbol**

The contour symbol is a supplementary symbol indicated by a horizontal line or arc parallel to the weld symbol. The contour symbol specifies the shape of the weld after the weld is completed.

A straight horizontal line specifies that the filler metal is to be flush with the joint member. A radius with the open side down specifies that the weld is to have a convex contour.

A radius with the open side up specifies that the weld is to have a concave contour. A letter above or below the contour symbol indicates the finishing operation for the weld. Letters used are C (chipping), H (hammering), G (grinding), M (machining), R (rolling) and U (unspecified).

10.1.6 Summary of the information shown in a welding symbol

Welding symbols show a range of information, depending on what the weld designer needs to communicate to the welder. Welding symbols show the following information:

- joint type,
- weld preparation shape,
- weld type,
- welding process,
- specifications or procedures,
- weld location,
- extent of welding,
- quality requirements,
- weld sequencing,
- weld size,
- final weld configuration, and
- production methods.

All this information is presented in the different elements or parts of a welding symbol. The following points should be noted in connection with the construction and use of welding symbols:

- The reference line is drawn in either the horizontal or the vertical direction (in other words, parallel to the horizontal or the vertical axis of the drawing). If the reference line is placed vertically, the information on it should be legible when the drawing is viewed from the right.
- The arrow points to the weld(s) or welded joint being described.
- The fillet-weld symbol is a small isosceles triangle based on the reference line and having its vertical side to the left.
- The single-bevel weld symbol is a 45° V with its apex to the reference line and its vertical leg to the left.
- The double-bevel and double-V weld symbols have their legs at an angle of 60° to each other.

10.1.7 Types of welding symbols

Different types of welding symbols are used in structural steel work detailing.
The most common welding symbols are:

- fillet,
- square butt,
- single V-butt, and
- double V-butt.

Table 10.9 shows the typical welding symbols used on structural steelwork detail fabrication drawings.

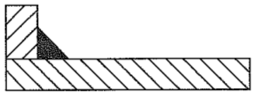
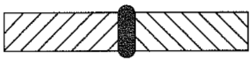
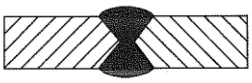
Typical welding symbols		
Type of weld	Sectional view	Symbol
Fillet		
Square butt		
Single V-butt		
Double V-butt		

Table 10.9 Common welding symbols used on drawings

10.2 Welding joints

Now we will identify and describe the different types of welds and welding joints used in the fabrication of steelwork structures.

10.2.1 Different types of welding joints

It is necessary to understand the difference between the terms 'joint types' and 'weld types'. 'Joint types' describes the configuration of the steel parts relative to each other, whilst 'weld types' refers to the type of weld used to hold the parts together.

- **Weld joint**

A weld joint is the physical configuration of the joint members to be joined.
The weld joint is the recipient of the filler metal that is deposited. Different weld joints are used on a fabrication to meet design requirements. The weld joint is selected according to location, preparation required, welding equipment used and the application of the weld joint. Joint penetration and the strength of the filler metal determine the strength of the weld joint.

- **Filler metal**

Filler metal is the metal deposited during the welding process. Filler metal in the weld joint is usually matched to the strength of the base metal. Weld joints are commonly specified by the engineer and are indicated on prints.

Table 10.10 shows the five basic types of weld joint used in structural engineering: butt joints, T-joints, corner joints, lap joints and edge joints. More detail on each of these joints is given below the table.

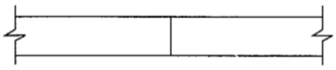
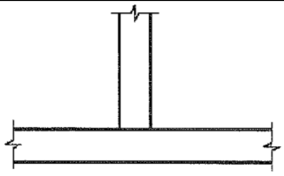
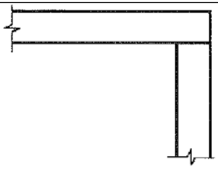
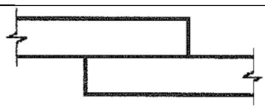
Types of welding joints	
Type of joint	Drawing
Butt joint	
T-joint	
Corner joint	
Lap joint	
Edge joint	

Table 10.10 Types of joints

Important

Note that the welds are not shown. In all cases except the first, either groove or fillet welds, as described below, could be used.

- **Butt joint**

A butt joint is a weld joint formed when two joint members that are located in approximately the same plane are positioned edge to edge. Butt joints can be used with or without preparation on joint members having the same or different thicknesses.

Butt joints are commonly used in sub-assemblies, and during fabrication and repair operations.

- **T-joint**

A T-joint is a weld joint formed when two joint members are positioned at approximately 90° to each other in the form of a T. If possible, the T-joint is welded on both sides for maximum strength. T-joints are commonly used in fabricating support structures where the load is transferred to different planes at approximately 90°.

- **Corner joint**

A corner joint is a weld joint formed when two joint members are positioned at an approximate angle of 90° with the weld joint at the outside of the joint members.

Corner joints are commonly used in tank and pressure-vessel construction. Filler metal may or may not be required depending on the design and function of the joint.

- **Lap joint**

A lap joint is a weld joint formed when two joint members are lapped over each other. A lap joint is stronger than a butt joint, but results in the thickness of one of the joint members being added to the overall thickness.

Lap joints are usually welded on both sides. They are commonly used during repair operations and to extend standard material lengths to required specifications.

- **Edge joint**

An edge joint is a weld joint formed when the edges of two joint members are joined. The edges are parallel to each other. Edge joints are commonly used to join support structures and short lengths of structural steel. They are also used to combine the strength of two joint members with exposed edges.

10.2.2 Welding processes used for welded-joint fastening on steelwork

Electric arc welding as applied to the fabrication of structural steelwork is almost invariably carried out by one of the processes described below.

- **Manual metal arc**

The electrode is handheld and is fed by hand into the weld pool. No shielding gas is used, but a flux is incorporated as a coating to the electrode. This is one of the most commonly used processes. An advantage is its flexibility, as it can be used in all welding positions.

- **Automatic, with continuous coated electrode**

This is an automatic equivalent of the manual metal-arc process. Instead of the electrode being handheld, it is stored on a drum and incorporated into a continuous automatic feed system.

To prevent the flux from breaking away from the coiled electrode, spin wires are helically wound around the outside of the flux. These wires act as the electrode and the central wire is not energised.

- **Gas shielded arc**

The base electrode, welding arc and weld pool are protected only by a gas shield, and there is generally no flux. A flexible hose supplies the welding gun with electrode wire from a drum, shielding gas and electric current.

All the consumables are controlled automatically. The shielding gas is usually a mixture of argon and carbon dioxide. The mixture varies from one manufacturer to another and also according to the base metal used. This gas emerges from an annular opening in the nozzle directly around the electrode.

The process is sometimes called metal active gas (MAG), CO2 or metal inert gas (MIG) welding. The last term should only be applied when argon or helium is used. A common variation is the use of flux-cored wire where the electrode wire has a tubular cross section and contains a central core of flux.

- **Submerged arc**

In this process, the arc is entirely submerged in a granular flux, which is fed into the weld pool by a separate feed pipe from a hopper. The bare-wire electrode is automatically fed through a contact or guide tube.

The unfused surplus flux is removed after completion of the weld. The process can only be used in flat, horizontal or vertical positions. The welding plant is mounted on a tractor unit, or the workpiece is rotated under the fixed welding head.

- **Electroslag**

This method is used only for the butt-welding of thick plates that are in the vertical or nearly vertical position. A large gap (about 30 mm) is left between the plate edges, and two water-cooled copper shoes, one on each side of the plates, travel up the joint as welding proceeds.

The weld pool, which is contained on two sides by the plate edges and on the remaining two sides by the shoes, is formed by one or more electrodes automatically fed from the top into the pool. The flux is conductive in its molten state.
Once it has melted, the process ceases to be an arc-welding process. The arc is extinguished and the heat input arises from electrical resistance through the electrode and the conductive slag.

10.2.3 Different types of welds

A weld type is the cross-sectional shape of the filler metal after welding. Weld types are different from weld joints as weld joints are the configuration of the joint members. The configuration of joint members and the edge preparation have an effect on the weld type.

The weld joint is shown on drawings by the description of the object. The shape of the joint member after welding is not shown on the drawings. The weld type specified for the weld joint is indicated by welding symbols on the drawings.

Weld types include:

- groove welds,
- fillet welds,
- plug welds
- slot welds,
- stud welds,
- spot welds,
- projection welds,
- seam welds,
- back and backing welds,
- surfacing welds, and
- flange welds.

Figure 10.8 shows the weld types. Different weld types can be used with different weld joints as necessary in the fabrication process.

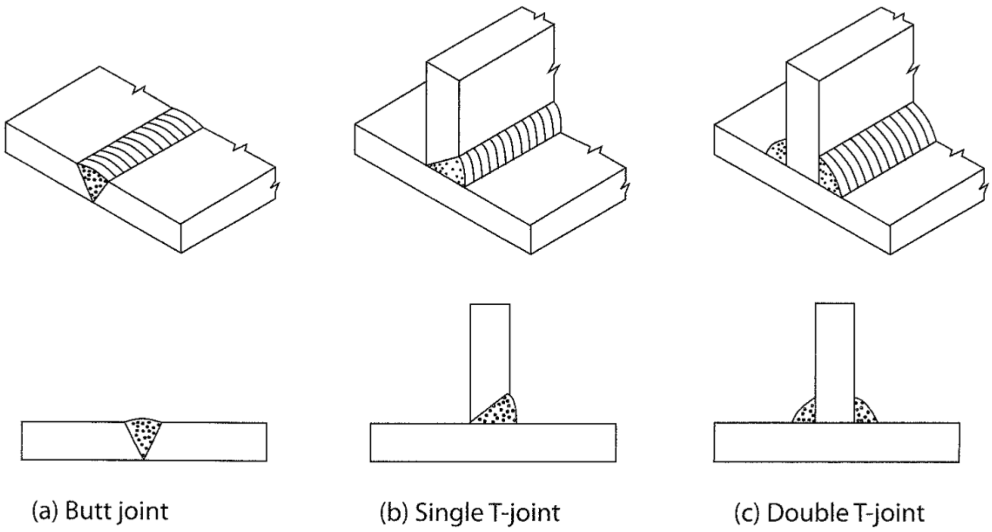


Figure 10.8 Basic weld types – groove and fillet

Weld types are classified by the cross-sectional shape of the weld, as seen in **Figure 10.9**. The two main types of weld used in structural steelwork connections are the groove weld and the fillet weld.

The groove weld is sometimes referred to as a flush weld because it is contained within the profile. The fillet weld is sometimes referred to as a projection weld because it is located outside the profile, as seen in the cross section in **Figure 10.9**, of the parts connected.

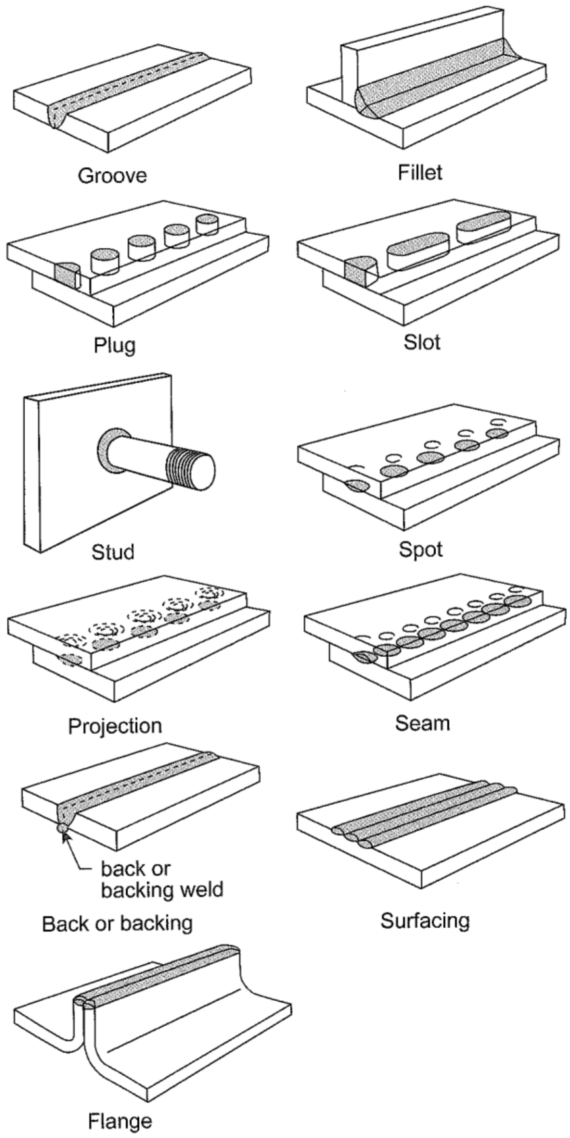


Figure 10.9 Classification of weld types

- **Groove welds**

A groove weld is a weld type made in the groove of the welded pieces. Groove welds can be modified for specific weld joints. The parts of the groove weld include the base metal, filler metal, weld face, weld toes, weld root, face reinforcement, root reinforcement, weld interface and root surface.

These parts are illustrated in **Figure 10.10** and are discussed in more detail below.

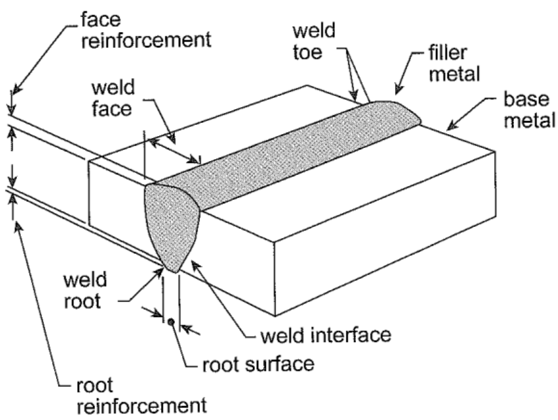


Figure 10.10 Elements of a groove weld

Base metal
Base metal is the material to be welded. Filler metal is added to the weld joint during the welding process.

Weld face
The weld face is the exposed surface of the weld, bounded by the weld toes of the side on which the welding was done.

Weld toe
The weld toe is the intersection of the base metal and the weld face.

Weld root
The weld root is the area where the filler metal intersects the base metal opposite the weld face.

Face reinforcement
Face reinforcement is filler metal that extends above the surface of the joint member on the side of the joint on which welding was done.

Root reinforcement
Root reinforcement is filler metal that extends above the surface of the joint on the opposite side of the joint on which welding was done.

Weld interface
Weld interface is the area where the filler metal and the base metal mix together (interface).

Root surface
The root surface is the surface of the weld on the opposite side of the joint on which welding was done. The shape of a groove weld is determined by the preparation of the edge or edges and the orientation of the joint members.

Groove welds are classified as square-groove, V-groove, bevel-groove, U-groove, J-groove, flare-V-groove and flare-bevel-groove depending on the edge preparation performed. Joint penetration in a groove weld is determined by the distance between the joint members, the thickness of the joint member and the edge preparation.

Edge preparation permits a greater amount of joint penetration and fusion of filler and base metal. This results in greater strength of the joint when compared with the square-groove weld.

Fusion
Fusion is the melting together of filler metal and base metal. The welding process used is also a factor to consider when deciding which groove weld type is best suited for the joint. For example, submerged arc welding (SAW) has greater joint penetrating characteristics than shielded metal arc welding (SMAW).

Joints welded using submerged arc welding require less edge preparation than joints welded with shielded metal arc welding.

- **Fillet welds**

A fillet weld is a weld type in the cross-sectional shape of a triangle. Fillet welds can be used on joint members of right-angle welds such as T-joints and lap joints. A fillet weld without additional information positions the joint members at 90°. Weld joints requiring more or less than 90° must be specified on the print.

Fillet welds are the most popular type of weld. They require little or no edge preparation.

Single-fillet welds
Single-fillet welds are fillet welds that have filler metal deposited on one side. They are limited to smaller loads than double-fillet welds.

Double-fillet welds
Double-fillet welds are fillet welds that have filler metal deposited on both sides. The weld on both sides provides additional strength. **Figure 10.11** shows a fillet weld that is triangular in cross-sectional shape. Fillet welds transfer loads to joint members that are positioned at 90° to each other.

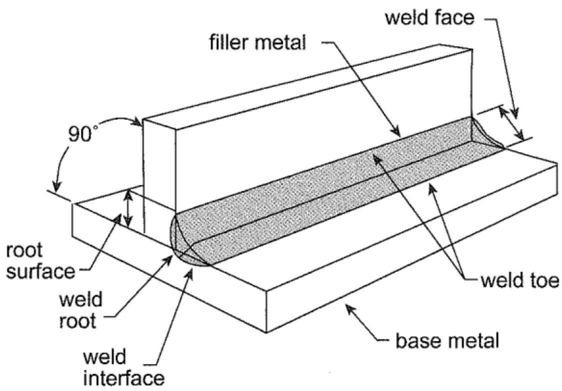


Figure 10.11 Elements of a fillet weld

- **Plug welds and slot welds**

A plug weld is a weld type in the cross-sectional shape of a hole in one of the joint members. A slot weld is a weld type in the cross-sectional shape of a slot (elongated hole) in one of the joint members.

These welds are made through the opening of the hole or slot to the other joint member. The round hole, which is filled or partially filled with filler metal during the welding operation, becomes the plug weld. The elongated hole, which is filled or partially filled with filler metal during the welding operation, becomes the slot weld.

Plug welds and slot welds are used for similar applications as the lap joint, except when the edges of the joint members cannot be welded. Slot welds are stronger than plug welds because of the larger weld surface area. Plug welds and slot welds are not to be confused with the fillet weld as the base of the hole or slot is filled.

A fillet weld would only deposit weld material in a triangular shape on the perimeter of the hole or slot. **Figure 10.12** illustrates the plug weld and the slot weld, which provide strength without affecting the edges of the joint members.

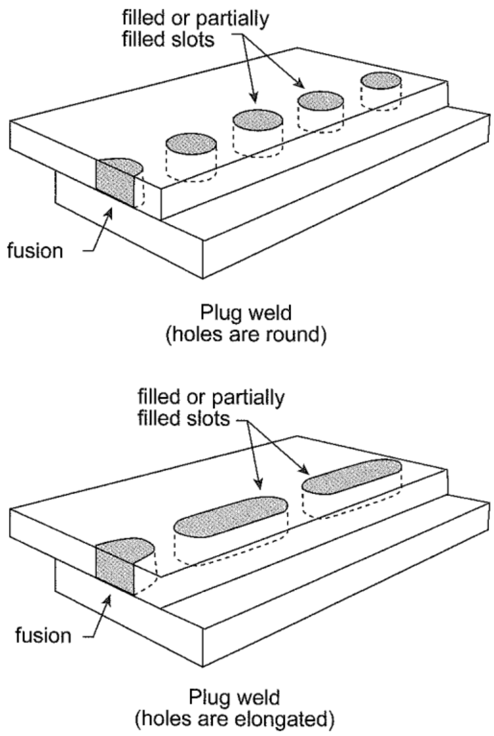


Figure 10.12 Plug weld and slot weld

- **Stud weld**

A stud weld is a weld type produced by joining threaded studs with other parts using heat and pressure.

Part of the stud is melted during the welding process, providing weld reinforcement at the base of the stud. After welding, the stud is permanently joined to the part, as shown in **Figure 10.13**.

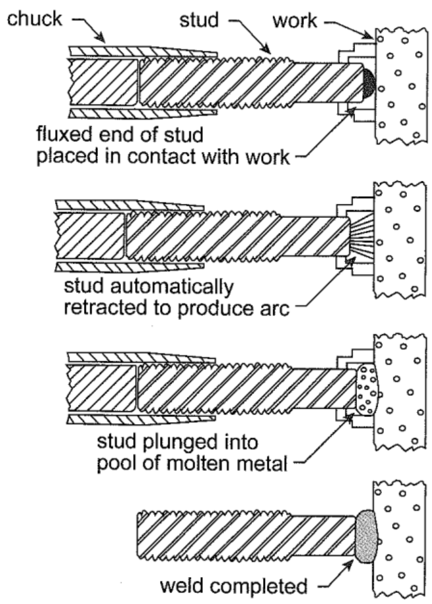


Figure 10.13 Stud welds permanently join threaded fasteners to parts using heat and pressure

- **Spot, projection and seam welds**

Spot, projection and seam welds are welds produced by confining the fusion of molten base metal using heat and pressure. A weld nugget is formed where the fusion occurs. Electric current directed through the joint members is commonly used to produce the heat required.

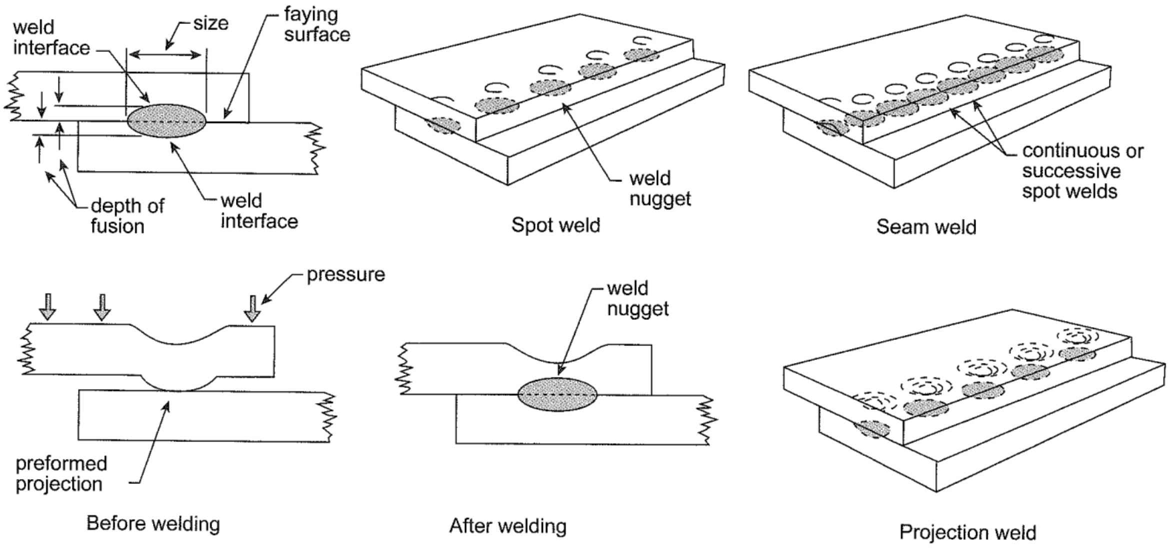


Figure 10.14 Spot, projection and seam welds

Figure 10.14 shows that the size of the spot, projection and seam welds is the diameter of the weld nugget. The length of the weld is also illustrated.

Spot weld

A spot weld is a weld type produced by confining the fusion of molten base metal using heat and pressure without preparation to the joint members. Joint members are in contact at the faying surface prior to welding.

The faying surface is the part of the joint member that is in full contact prior to welding.

Projection weld

A projection weld is a weld type produced by confining the fusion of molten base metal using heat and pressure with a preformed dimple or projection in one of the joint members prior to welding.

The joint members are in contact at the projection of the joint member prior to welding. The projection is melted during welding and becomes part of the weld nugget.

Seam weld

A seam weld is a weld type produced by confining the fusion of molten base metal using heat and pressure for a series of continuous or overlapping successive spot welds on the joint members. Continuous spot welds are made using rotary electrodes. Overlapping successive spot welds are made using conventional spot-welding equipment.

- **Back welds and backing welds**

A back or backing weld is a weld deposited in the weld root opposite the face of the weld on the other side of the joint member. The difference between these two welds is based on when the weld is deposited.

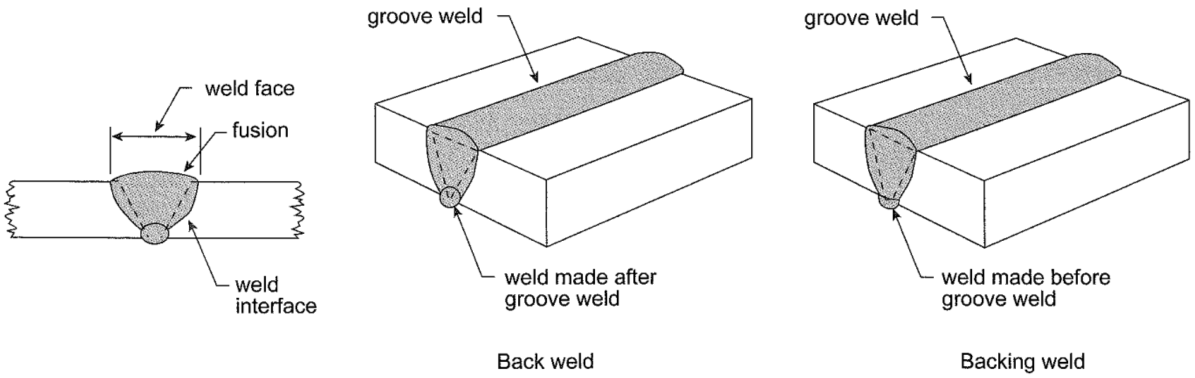


Figure 10.15 Back welds and backing welds

Back welds are deposited after the weld on the opposite side of the part and backing welds are deposited before the weld on the opposite side of the part, as was seen in **Figure 10.15**.

- **Surfacing welds**

A surfacing weld is a weld type in which weld beads are deposited on a surface to increase the dimensions of the part. Successive overlapping beads are deposited to form a layer of filler metal on the base metal.

The filler metal can have the same or different characteristics as the base metal depending on the application. Surfacing welds are commonly used for building up worn parts or depositing abrasive-resistant metals.

Layers of filler metal are deposited with additional layers deposited at 90° to the previous layer, as shown in **Figure 10.16.**

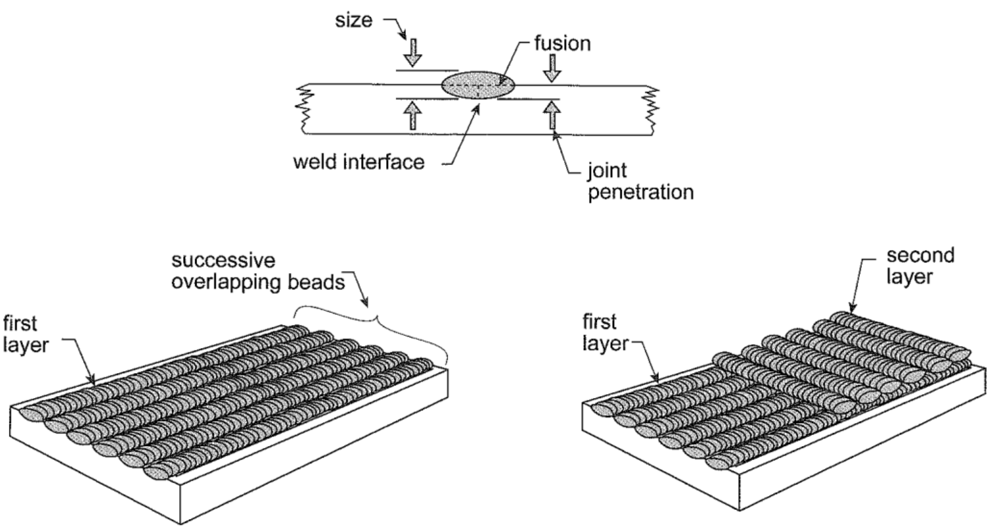


Figure 10.16 Surfacing welds are commonly used to build up worn parts.

- **Flange welds**

A flange weld is a weld type of light-gauge metal with one or both of the joint members bent at approximately 90°. An edge flange weld is a flange weld with both joint members bent.

A corner-flange weld is a flange weld with one joint member bent.
In some instances, part of the joint members may be melted and become part of the filler metal. This allows joining of the two joint members without the addition of filler metal.

As shown in **Figure 10.17**, flange welds are commonly used on thin materials where filler metal is not required.

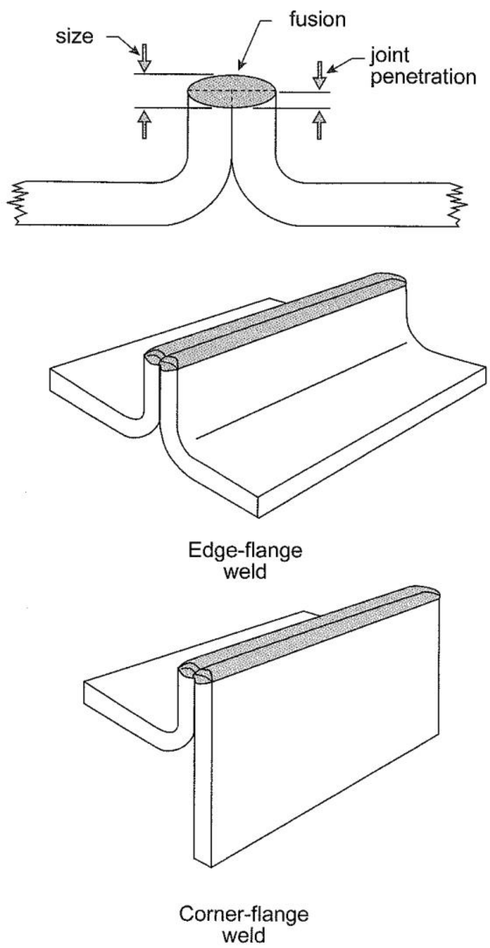


Figure 10.17 Flange welds

10.3 Bolts in structural steelwork

One of the most common methods of joining one component to another in structural steelwork is bolting. It may be used either in the workshop or on site, and has the advantage that the components can be separated easily should this become necessary for any reason.

Most fabricators prefer to use welding for shop connections, but where workshops are equipped with automated punching and drilling machines, shop bolting is generally found to be quicker and cheaper.

For site connections, however, bolting is virtually the universal medium of connection. Welding is only undertaken on site in very special circumstances in view of the higher cost and greater inconvenience.

Connections join individual elements together to form a structural frame. For example, floor beams are connected to columns in a building. Today, bolts and welding are mostly used to make connections, with riveted connections being virtually obsolete.

The function of a bolt is not only to attach one member or component to another, but also to transmit a force from that member or component to the other.

For example, if bolts are used to connect a beam to a column in a building, their purpose is not only to hold the beam in relation to the column (and thus prevent the building from falling apart), but also to transfer the load (in other words, the end shear in the beam) to the column.

Similarly, when a bracing member is bolted to a gusset, the bolts will transmit the axial force in the bracing (whether tensile or compressive) into the gusset.

10.3.1 Different types of bolts

All bolts have hexagonal heads and nuts, and parallel shanks with threads cut or rolled into them, as seen in **Figure 10.18**. Bolts come in standard shank diameters of 12 mm, 16 mm, 20 mm and 24 mm, in a large range of lengths and in various grades of strength.

Figure 10.18 Structural fastener: bolt, nut and washer

Bolts are designated by size (in other words, the nominal diameter of the shank and thread) and by length (that is, the total length of the shank, including thread, up to the underside of the head). The bolt sizes mentioned above are designated M12, M16, M20 and M24, the M meaning 'metric'.

The three most commonly used types of bolts are the following:

- Grade 4.8 ordinary bolts (also known as black bolts),
- Grade 8.8 precision bolts (also known as close-tolerance bolts), and
- HSFG bolts (also known as high-strength friction-grip bolts).

Grade 4.8 ordinary bolts are manufactured from rolled bars. These bolts are used in holes of 2 mm clearance for bolts up to 24 mm diameter and 3 mm clearance for larger bolts. Commercial bolts are made of low-carbon steel with mechanical properties similar to that of Grade 250 material.

Grade 8.8 precision bolts and HSFG bolts are manufactured from high-strength steel. High-strength structural bolts are made by heat-treating, quenching and tempering medium-carbon steel.

As a result, heating or welding a commercial bolt will cause no significant change in its properties. However, both processes will cause a significant degradation in the mechanical properties of high strength structural bolts.

10.3.2 Uses of different bolts

This section considers the different types of bolts used in structural steelwork connections. Only a limited range of sizes of these bolts is used in structural engineering. **Figure 10.19** shows the typical application of bolted connections.

The commercial bolt is commonly used in the following diameters:

- M12 (purlin and girt applications),
- M16 (relatively lightly loaded cleats and brackets),
- M20 (general structural connections and holding-down bolts),
- M24 (general structural connections and holding-down bolts),
- M30 (holding-down bolts), and
- M36 (holding-down bolts).

The HSFG bolt is most commonly used in the following diameters:

- M16 (designed connections in small members),
- M20 (flexible connections and rigid connections),
- M24 (flexible connections and rigid connections), and
- M30 and M36 (designed connections in very large members).

Important

Note that larger sizes (M30 and M36) of the HSFG bolt should be avoided when full tensioning is required, since on-site tensioning can be difficult and requires special equipment.

Figure 10.19 Typical application of bolted connections

10.3.3 Economy of bolts
The cost of a bolted connection is made up of the following components:

- the cost of the bolts themselves, and
- the cost of forming the holes for the bolts.

The following three types of bolts are the most common bolts used in the South African steelwork industry:

- the Class 4.8 ordinary bolt, used in shear or bearing,
- the Class 8.8 ordinary bolt, used in shear or bearing and in direct tension, and
- the Class 10.9S bolt, used in friction-grip connections and also in direct tension.

Although fabricators should check current prices for a more accurate comparison, the relative price ratios of these three types of bolt per kilogram are approximately as given below:

- Class 4.8: 1,0,
- Class 8.8: 1,2, and
- Class 10.9S: 2,8.

The following points need to be considered:

- The Class 8.8 bolt has factored shear and direct tension resistances almost twice that of a Class 4.8 bolt. It is therefore the most efficient fastener on an installed-cost basis and would be a suitable choice for a job with a high proportion of large, fully stressed connections.

In most structures, however, many of the connections contain only two or three bolts. It is obviously not possible to halve their number since two is the minimum number used for practical reasons. Discretion must therefore be used in deciding on the bolt class for a particular job.

- The Class 10.9S bolt is relatively expensive. The purchase price of the bolt is high, and the specialised installation procedure (involving turn-of-the-nut procedures or torquing) and the need for subsequent inspection add to the cost.

  These bolts are only specified when their use is clearly necessary, such as in slip-resistant (in other words, friction-grip) connections and in connections where large direct-tension forces are induced in the bolts.

Ideally, all the bolts on one job should be of the same class and diameter so as to avoid the use of the wrong bolts in a particular joint. This is especially desirable on sites where the level of supervision is low.

As far as possible, Class 8.8 M20 bolts should be used for all structural applications, while Class 4.8 M12 and M16 bolts should be used for small profiles as well as for purlins and girts.

- **Ordinary bolts (Grade 4.8)**

Ordinary bolts are used for the great majority of connections, especially where force transfer is by shear and bearing. They are manufactured to SANS 135.

- **Precision bolts (Grade 8.8)**

Precision bolts have a much higher strength grading and are manufactured to a closer dimensional tolerance than ordinary bolts. Since they are more expensive, precision bolts are used sparingly. Force transfer is by shear, bearing and tension. Precision bolts are manufactured to SANS 136.

The information given in **Table 10.12** should be used to choose the length of fastener appropriate to the grip (the total thickness of the material kept together by the bolt).

The table conforms to the requirements of Clause 4.5.1.3 of SANS 2001-CS1.

Minimum and maximum grip lengths for preferred bolts								
Bolt length	30		50		70		90	
Max. or min. grip	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Grip (mm) without washers								
M12	0	17	15	37				
M16	0	14	13	34				
M20			10	30	30	50	50	70
Grip (mm) with one washer								
M12	0	15	13	35				
M16								
M20								
Notes: 1. Only preferred combinations of class, diameter and length are shown in this table. 2. The bolts are to be fully threaded. 3. The table does not apply to HSFG bolts.								

Table 10.12 Minimum and maximum grip lengths for preferred bolts

The nuts that are commonly available on the South African market are made to different standards. The protrusion of the bolt from the face of the nut may be slightly outside the specified parameters for some nuts.

It should be appreciated, however, that slight deviations are not detrimental to the strength or performance of a bolted connection.

It is recommended that 30-mm long fully threaded (so-called ‘set screws’) Class 4.8 M16 bolts be used for purlins and girts, and 50-mm long M20 Class 8.8 bolts be used for all structural connections, except where that is not practical.

- **High-strength friction-grip bolts (HSFG bolts)**

The grade generally used is 8.8S, but a higher grade, 10.9S, is also available. These bolts are used for force transfer by friction between the connected parts and comply with SANS 1282.

They may also be used for the transfer of tensile force because of their high strength. They are more expensive than Grade 8.8 precision bolts.

The class designations have the following significance:

- o The first number multiplied by 100 is the approximate nominal tensile strength of the bolt material in MPa.
- o The second number divided by 10 is the approximate ratio of the yield stress or proof stress to the tensile strength.

Thus a Class 8.8 bolt has a nominal tensile strength of 800 MPa and a yield stress of 0,8 □ 800 = 640 MPa. A Class 4.8 bolt has a nominal tensile strength of 400 MPa and a yield stress of 320 MPa.

- **Holding-down (HD) bolts**

All columns require a base plate at their lower end to provide the necessary attachment to the concrete foundation and to transmit the load (and possibly the moment) in the column shaft into the foundation of the structure.

It is standard practice for the designer to provide full details of the bases, including the layout and sizes of the HD bolts.

Bases may vary from a simple slab for columns carrying an axial load only to a complex built-up base for columns subjected to a large base moment in addition to an axial load. Examples are shown in **Figure 10.20**.

The general design of the base will have been done by the engineer, but the detailer may have to attend to the final dimensioning, the sizing of some of the smaller components and the welding. Grout thicknesses may also have to be specified.

There needs to be proper contact at the interface for a satisfactory transfer of the compressive load in the column shaft to the base plate. Accurate saw-cutting is usually specified to ensure a flat, smooth end to the shaft.

Base plates up to 50 mm thick have surfaces that are sufficiently smooth. For greater plate thicknesses, the usual procedure is to use a thicker plate than the minimum required and to machine it down to the required thickness.

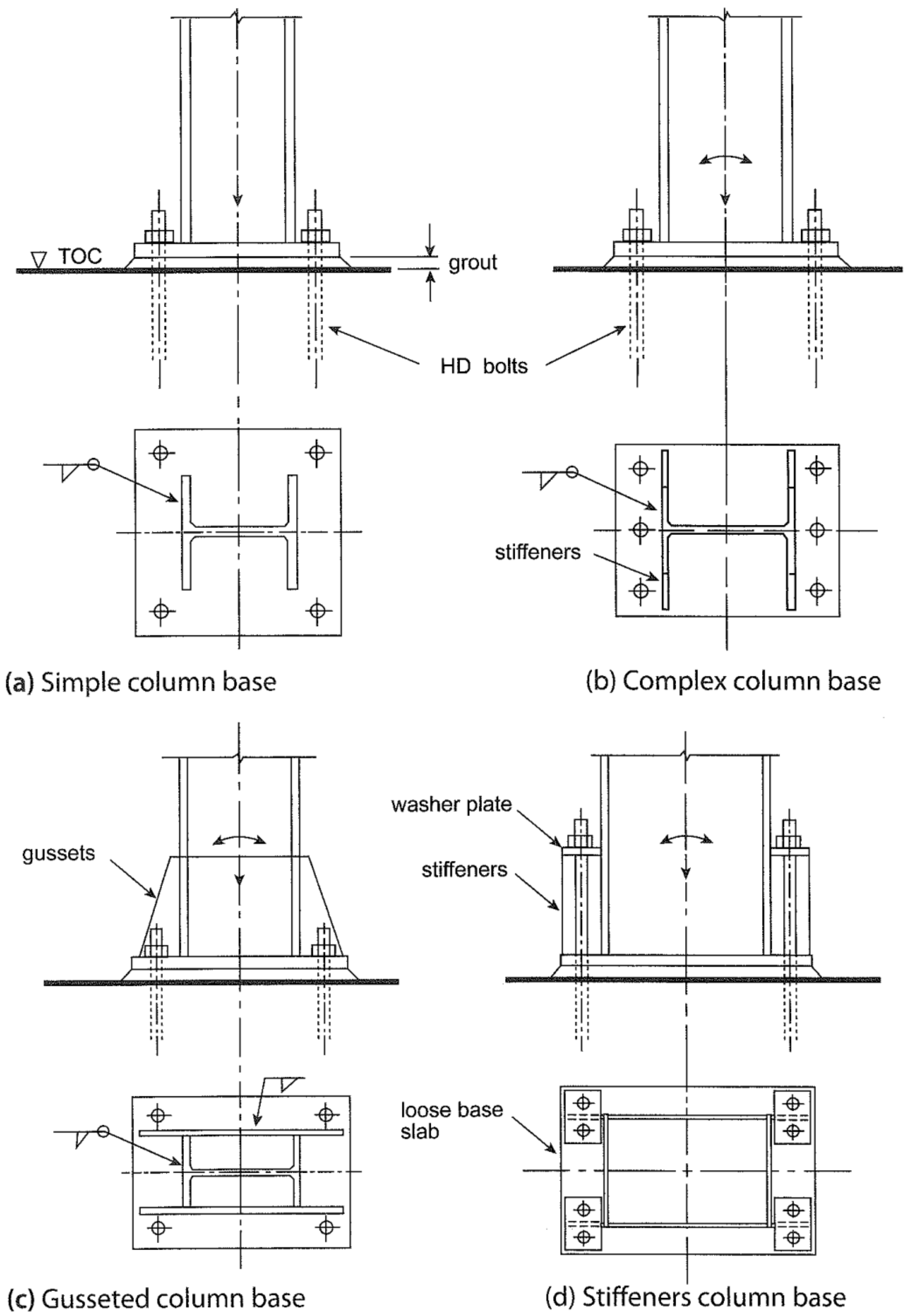


Figure 10.20 Column bases fixed down to the concrete foundation by means of HD bolts

The machining need only be done in a strip slightly wider than the column shaft and extending across the narrower plan width of the base plate.

Every column base plate requires at least two and possibly as many as eight HD bolts to attach it to the concrete foundation. The purpose of the bolts is to position the column base accurately. Bolts also transfer axial forces (uplift) and moment from the base into the foundation.

Although HD bolts are set in the concrete by the civil contractor, it is usual practice for the bolts to be detailed and supplied by the steelwork contractor. Their number, location, diameter and bond length should always be decided by the designer.

An example of a typical HD bolt is shown in **Figure 10.21**.

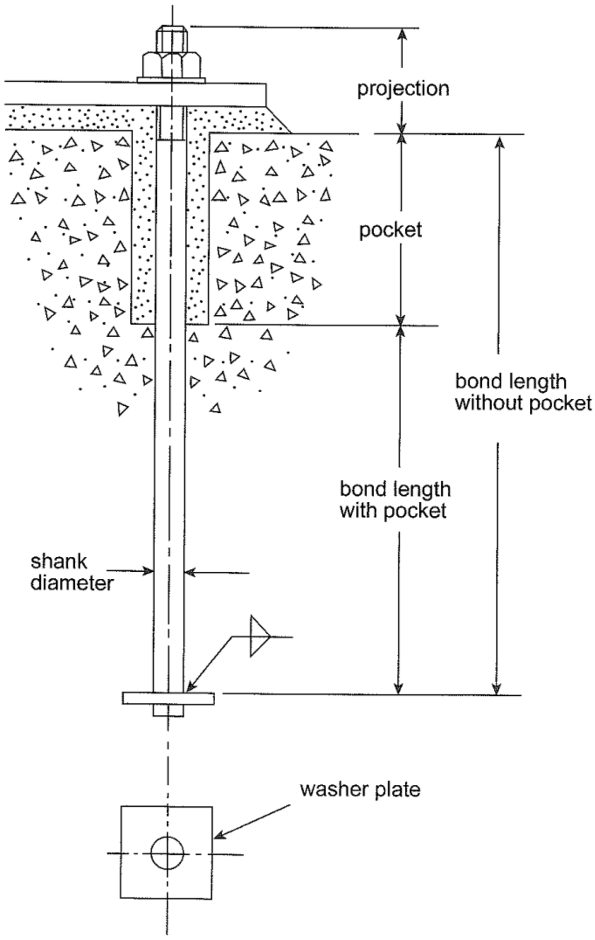


Figure 10.21 Details of the HD bolt

A pocket is often provided around the upper part of the bolt to permit it to be bent sideways if necessary to allow for inaccuracies in its setting in the concrete.

The projection length of the bolt is usually calculated by the detailer from their knowledge of the grout and base-plate thicknesses. Allowance should be made for a fairly generous protrusion of the bolt thread above the nut.

The configuration of HD bolts should preferably be such that the bolts are symmetrical about both centre lines or that the dimensions are sufficiently different as to be visually discernable.

HD bolts are usually made by cutting a standard metric bolt thread on the end of a Grade 43 round bar. The standard diameters of bar are 20 mm, 24 mm and 30 mm, and then upwards in increments of 5 mm.

Only the first three sizes match standard nut sizes. For nut sizes of M36, M42, M48, M56, M64 and M72, round bars of the next larger standard size have to be used and the shanks are turned down to the required thread diameter.

The holes for the HD bolts in the base plate should be made considerably larger than the bolt diameter to allow for inaccuracies in bolt setting. Suitable hole sizes for the various bolt diameters are given in **Table 10.13**.

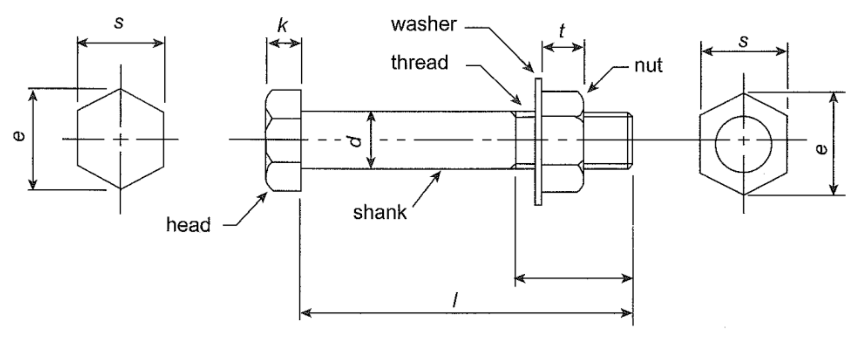
Drilled holes for holding-down bolts	
HD bolt size	Drilled hole diameter
M20	26
M24	30
M30	40
M36	46
M42	55
M48	60
M56	70
M64	80
M72	90

Table 10.13 Drilled holes for HD bolts

For bolts with long projections, as required in detail (d) of **Figure 10.22**, the shank and not the threaded part passes through the plate. The hole diameter should be increased accordingly for bolts from M36 upwards.

10.3.4 Drawings of structural bolts

Figure 10.22 illustrates a typical structural bolt, nut and washer assembly, and gives the associated terminology.



Key

l = Bolt length
lt = Thread length
d = Diameter of shank
k = Thickness of bolt head
t = Thickness of nut
s = Distance across the flats (A/F)
e = Distance across the corners (A/C)

Figure 10.22 Details of a structural bolt

- **Conventional representation of structural bolts and nuts**

Figure 10.23 (a) and **(b)** shows the approximate proportions used to construct and produce a detailed drawing of a hexagonal bolt and nut, and a square-head bolt and nut.

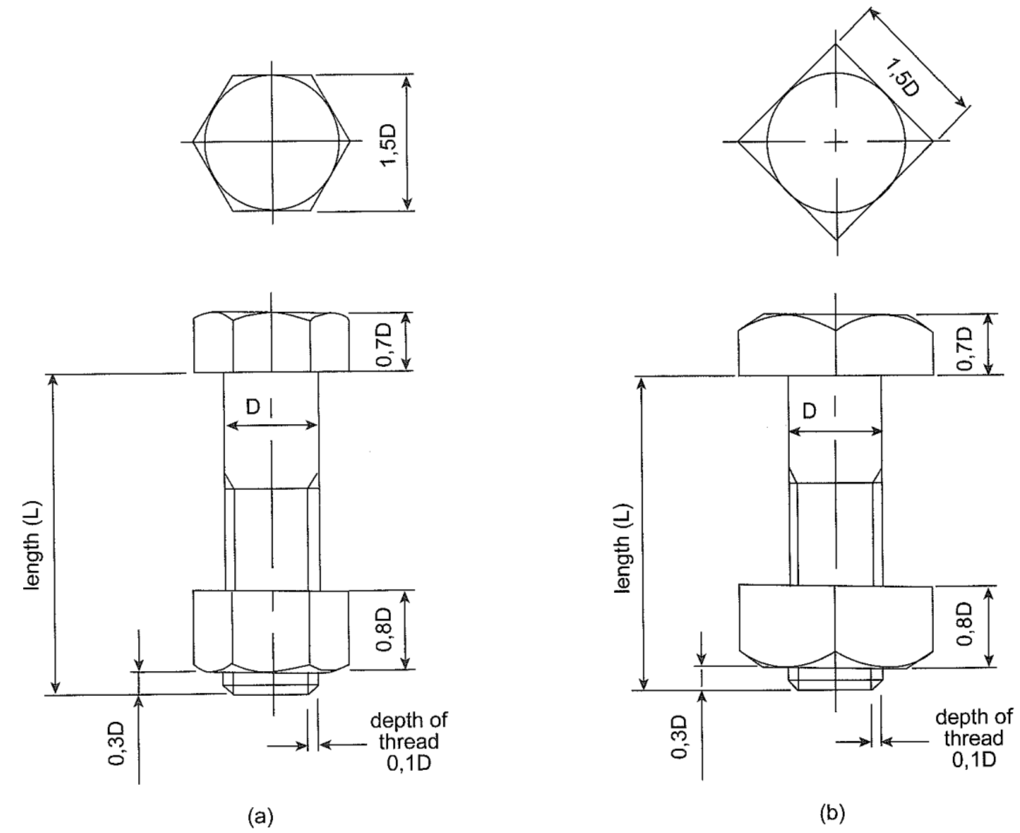
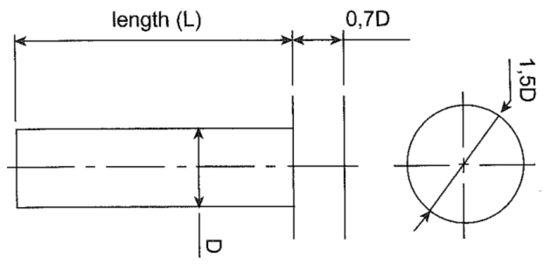


Figure 10.23 (a) A hexagonal bolt and nut and (b) a square-head bolt and nut

- **Construction method used to draw a structural bolt**

Follow the steps and diagrams in **Table 10.14** below to produce a detailed drawing of a structural bolt.

Construction method used to draw a structural bolt	
Step 1 • Draw the centre lines. • Draw the diameter of the bolt (nominal size), say M30. • Draw the thickness of the bolt head as 0,7D and the diameter as I,SD. • Draw the thickness of the nut as 0,8D.	
Step 2 • Draw the hexagonal head around the diameter of 1,5D at 60° angles and project the head to the front	

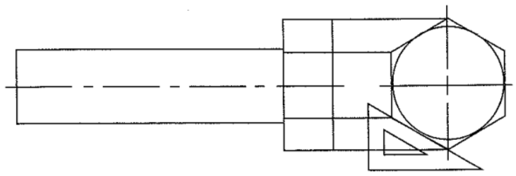
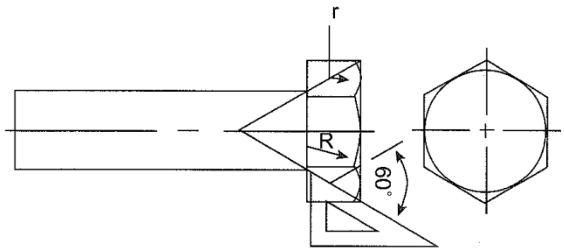
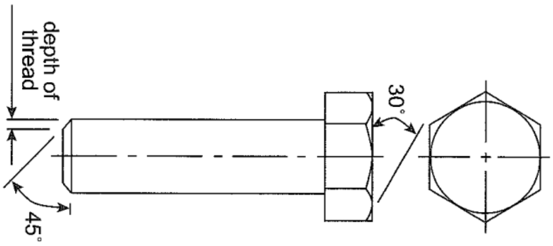
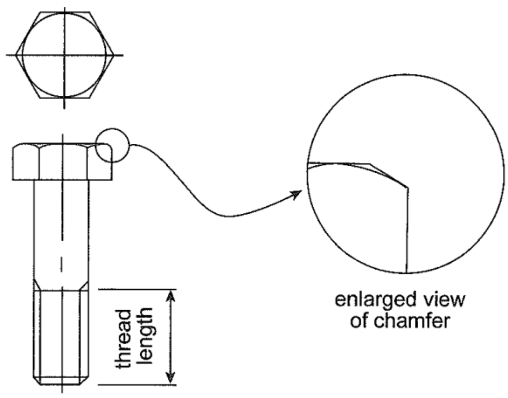
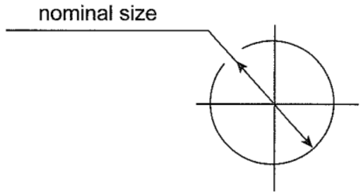
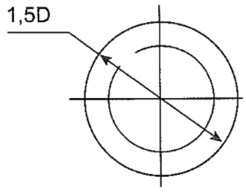
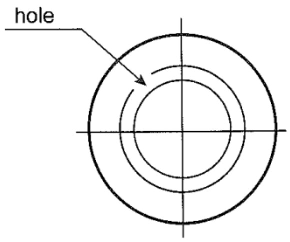
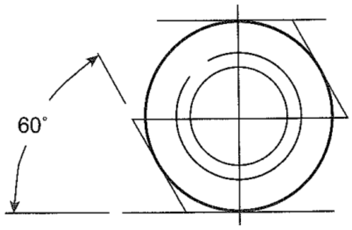
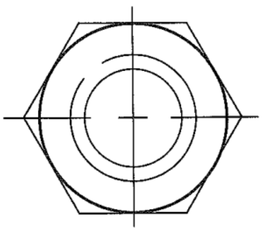
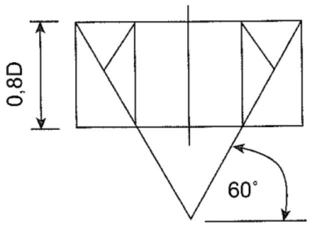
view.	
Step 3 • Locate the centres for chamfer arcs in the front view. • For the four smaller arcs, project lines at a 60° angle with the horizontal down from the top edges of the two outside faces of the head. • For the two larger arcs, project lines at a 60° angle with the horizontal down from the outer edges of the bolt head.	
Step 4 • Complete the drawing of the hexagonal bolt head by drawing a 30° chamfer line on the upper outside corners in the front view.	
Step 5 • Draw all the **full** lines needed to complete the drawing.	

Table 10.14 Construction method used to draw a structural bolt

- **Construction method used to draw a structural nut**

Follow the steps and diagrams in **Table 10.15** below to produce a detailed drawing of a structural nut.

Construction method used to draw a structural nut	
Step 1 • Draw the two centre lines. • Draw the nominal size (diameter) of	

the screw thread as a circle using a thin line.	
Step 2 • Draw the large chamfer circle to the proportion of 1,5D.	
Step 3 • Represent the drilled hole with a full line circle. • Draw the diameter of the hole in good proportion to the nominal size. • Draw the depth of the thread a distance of 0,1D outside the drilled hole using a thin line.	
Step 4 • Draw light horizontal construction lines at the top and the bottom of the large circle. • Draw the sides of the hexagon as full lines and tangents at an angle of 60° to the circle.	
Step 5 • Complete the sides. • Always draw the view as shown on the right because the sizes for the other views will be obtained from this view. In this case, the view will be the top view.	
Step 6 • Mark the thickness (0,8 x nominal size of screw thread) of the nut on the drawing. • Project the corners of the nut from the top view to the front view. • Obtain the centre points for the arcs by lightly drawing 60° construction lines.	
Step 7 • Draw the arcs as full lines • Omit the 30 chamfer for small- or	

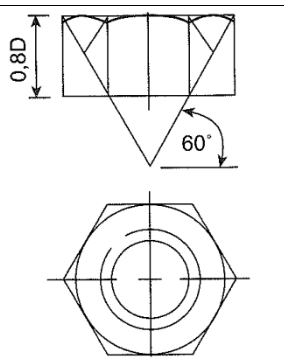
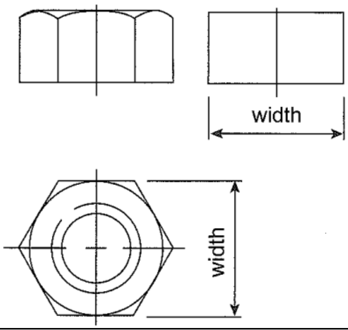
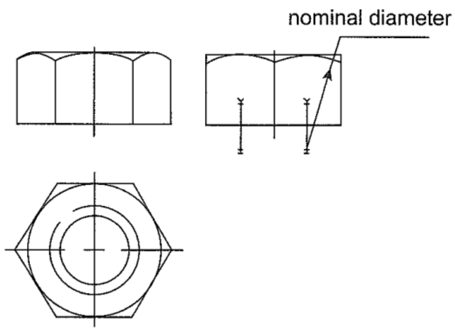
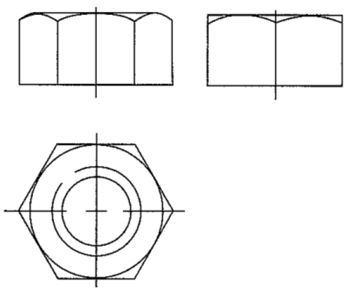
medium-sized nuts because it is barely visible.	
Step 8 • Complete the front view and draw the vertical centre line for the left view. • Mark its width and draw the light construction lines for this view.	
Step 9 • Bisect the two planes in the horizontal direction and draw the two arcs (full lines), using the bisecting lines as centre lines and the radius equal to the nominal size.	
Step 10 • Draw all the full lines needed to complete the drawing.	

Table 10.15 Construction method used to draw a structural nut

10.3.5 Bolt holes
The holes for the bolts are usually punched or drilled. They should have a diameter 2 mm larger than the bolt shank diameter for bolt sizes up to 24 mm diameter and 3 mm larger for bolts of greater diameter.

These holes are called clearance holes. They facilitate the assembly of components by making allowance for slight inaccuracies in fabrication of the steelwork.

The holes may be punched full size through material not thicker than 12 mm or the diameter of the hole. For greater thicknesses, the holes are drilled full size or sub-punched to a diameter not more than 4 mm less than the finished diameter, and then reamed or drilled to the full size.

Holes for fitted (close-tolerance) bolts and for all bolts in members subject to dynamic loading must be drilled, or be sub-punched and reamed. The clearance on these holes can be 0 to 0,50 mm depending on the application.

Figure 10.24 (b) shows a black bolt and a turned barrel bolt, each of which has a flat washer in position underneath, the nut and taper washer in position between the head and the tapering inside surface of a joist or channel flange.

The flat washer is placed under the nut to ensure that no part of the thread of the bolt shall be in the holes in the steel parts being bolted together.

Holes for black bolts are usually made 1,5 mm larger than the diameter of the bolts. Turned barrel bolts are turned 0,125 mm less than the clearance size of holes drilled for black bolts and rivets.

The thread and the nut are of standard size, but the shank is oversize. In sub-drilling parts, the holes are reamed after assembling for making suitable holes for turned barrel bolts.

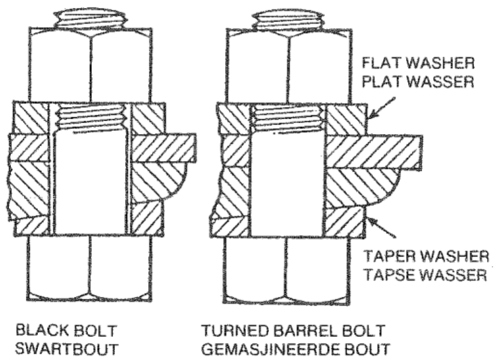


Figure 10.24 (b) Black and turned barrel bolt

10.3.6 The strength or resistance of bolts

The ability of a bolt to transfer an applied force (in other words, its ability to withstand this force) is called its resistance.
The resistance of a bolt is dependent on three main components:

- the area over which the force is applied,

- the strength of the bolt material, and
- the resistance factor, which is a factor that allows for variability of material properties, workmanship and so on that might be present in any connection and that might have a detrimental effect on its performance.

When these three components are multiplied together, they give the factored resistance of the particular bolt under consideration.

A transfer of force is involved in all bolted connections. In nearly all cases, the transfer is by one or more of the following modes:

- by shear in the bolt shank,
- by bearing of the bolt shank against the holes in the two components,
- by friction between the parts when the bolt is tightened to clamp the parts firmly together, and
- by tension when the load is applied in the axial direction of the bolt.

The first two modes, shear and bearing, usually occur simultaneously. The reason for this is that as the load is applied, the two parts slip (since the hole diameter is larger than the bolt diameter) until the bolt bears against the sides of the hole. The bolt then transmits the load by combined shearing and bearing action.

It is necessary for the steelwork detailer to have a clear understanding of how bolts work and to be able to select a suitable group of bolts to transmit the forces specified on the engineer's drawings.

- **Bolted-joint resistances**

Table 10.16 lists the resistances of bolts under single or combined forces.

Factored resistance of various bolts in bearing-type connections				
Class 4.8 bolts				
Size	Factored resistance (kN/bolt)			
	Tension T_r	Shear V_r		Bearing B_r per mm of plate thickness
		Single	Double	
M12	28,5	16,0	32	11,6
M16	50,7	28,4	57	15,4
M20	79,2	44,3	89	19,3
M24	114	63,8	128	23,2
M30	178	99,8	200	28,9
M36	257	144	287	34,7
Class 8.8 bolts				
Size	Factored resistance (kN/bolt)			
	Tension T_r	Shear V_r		Bearing B_r per

		Single	Double	mm of plate thickness
M16	95,5	54,0	108	15,4
M20	156	87,6	175	19,3
M24	225	126	252	23,2
M30	352	197	394	28,9
M36	507	284	568	34,7
Class 10.9 bolts				
Size	Factored resistance (kN/bolt)			
	Tension T_r	Shear V_r		Bearing B_r per mm of plate thickness
		Single	Double	
M16	125	70,3	141	15,4
M20	196	110	220	19,3
M24	282	158	316	23,2
M30	441	247	494	28,9
M36	635	356	711	34,7

Table 10.16 Factored resistance of various bolts in bearing-type connections

- **Bolts in shear and bearing**

Figure 10.25 shows a bolt passing through two plates. The plates are loaded in tension as shown.

Because the nut is only hand-tightened (using an ordinary spanner or wrench), little friction will be developed between the contact or faying surfaces of the plates. Under the action of force P, one plate will slip in relation to the other plate until the clearance in the holes is taken up and the bolt bears against the sides of the two holes, as shown.

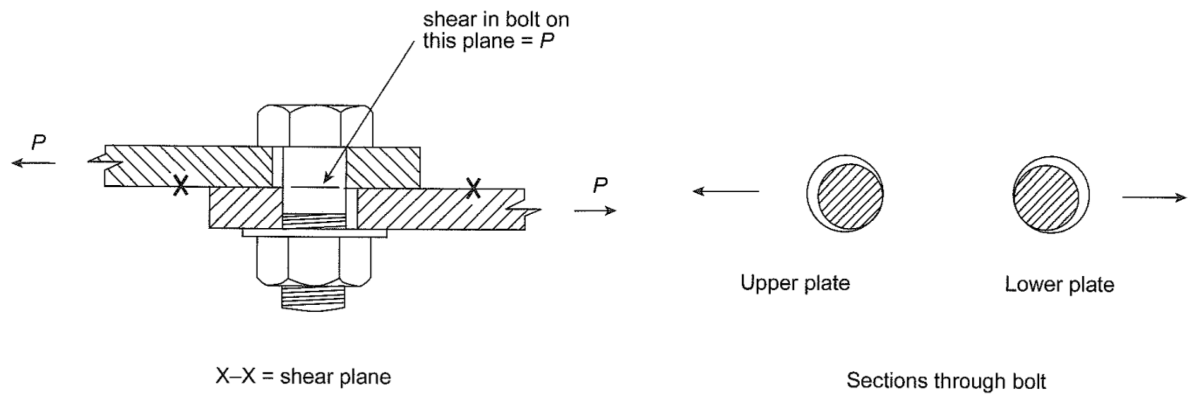


Figure 10.25 Bolt in single shear

Consequently, the bolt is subject to a shear force across its shank in the plane of the interface between the plates. Since the bolt is required to transfer the force P from one plate to the other plate, the force acting in shear across the shank of the bolt must also be *P*. If there were more than one bolt in the connection, the force in each bolt would be *P* divided by the number of bolts.

At the same time, the bolt is bearing against the sides of the holes, so the mode of force transfer is called shear or bearing. Two requirements must be fulfilled to ensure the safe transfer of the force *P*: the bolt must be strong enough to resist the shear force and the plates must have sufficient strength to resist the bearing force.

If the plates were loaded in compression, the forces *P* would act in the opposite directions to those shown and the slipping of the plates would also be in the opposite direction. However, the strength requirements for the bolt and the plates would be exactly as stated above.

The factored shear resistance of a bolt is dependent on its material class and its cross-sectional area on the shear plane.

However, the factored bearing resistance is dependent on the diameter of the bolt, the grade of the plate material and the thickness of the plate (on the assumption that it is at an ultimate load; after a certain amount of bedding-in has taken place, the diameter of the bolt will be bearing against the sides of the holes).

Values of the factored bearing and shear resistances per bolt are given in SANS 10162-1. The types of bolts used in shear or bearing mode are the Class 4.8 and Class 8.8 ordinary bolts.

In the above description of bolt-load transfer, the case of two plates having one contact or shear plane has been considered. This is called the single-shear condition.

However, as shown in **Figure 10.26**, there may be more than one contact or shear plane. In detail (a) of the figure, there are clearly two equally loaded shear planes, each subject to a shear force of *P* — 2 .

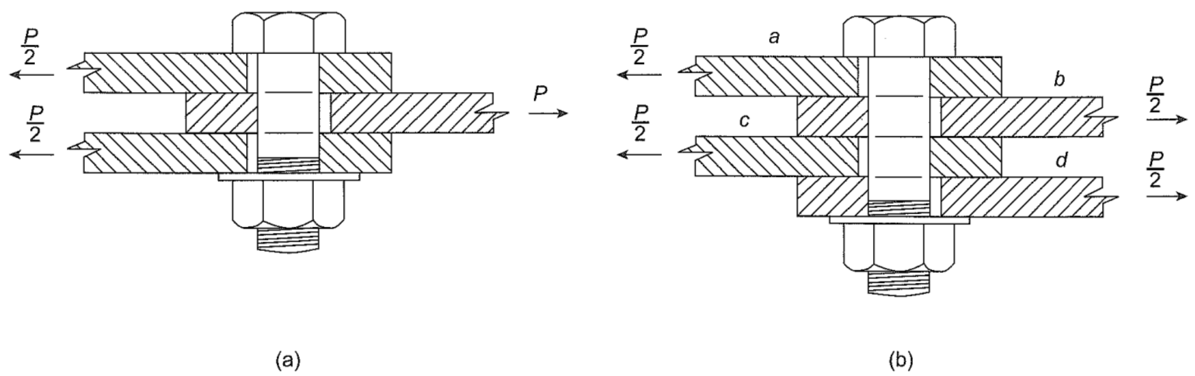


Figure 10.26 Bolts in double shear

This is referred to as the double-shear condition. A study of detail (b) will show that, although there are three planes, shear is transmitted by the bolt at only two of them (between plates *a* and *b*, and between plates *c* and *d*).

This is because the force in plate *a* is balanced by the force in plate *b*, and the force in plate *c* is balanced by the force in plate *d*. There is therefore no transfer of force on the plane between *b* and *c*. Consequently, this is also a double-shear condition, with a shear of *P* — 2 at each of the two loaded planes.

As already stated, a special limiting case applicable to bearing must be allowed for. In a tension connection, the bolt nearest the end of the member may tend to pull out through the end of the member because of the proximity of the hole to the end.

This is illustrated in **Figure 10.27**. The allowable bearing stress used is for a connection where the end distance *a* is sufficient to ensure that this type of failure does not occur (in other words, where the distance *a* is equal to at least three times the bolt diameter).

Where distance *a* in a tension connection is less than 3*d*, the bearing resistance of that bolt is reduced.

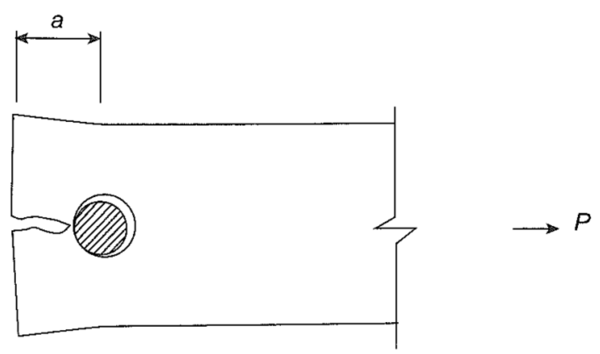


Figure 10.27 Bolt-end distance

- **Friction-grip bolts**

HSFG bolts are used where a slip-resistant connection is required under shear loading (loading in the plane of the connected parts and at right angles to the bolt axes).

On installation, the bolts are pre-tensioned to 0,7 times their full tensile strength and so produce a high clamping force between the plies of the joint. This is the reason why high-strength bolts are used.

The means of force transfer is by friction between the plies. No slipping takes place, so the bolts are not acting in shear or bearing. It is necessary, however, to ensure an adequate frictional resistance between the contact or faying surfaces of the connected parts.

The frictional resistance is therefore dependent on:

- the pre-tension force in the bolt, and
- the coefficient of friction of the contact surfaces.

The means of load transfer is illustrated in **Figure 10.28** on the following page. After initial tightening, the bolt loses some of its pre-tension because of bedding-in of the bolt head and nut and the connected parts, but this is covered by a load factor that makes allowance for this loss, amongst other things.

Since the requirement for a friction-grip connection is that slip of the assembly shall not occur under the forces and moments produced by the serviceability loads, the resistance of the connection is rated at the serviceability and not the ultimate load condition. In addition, the effects of the ultimate loads must not exceed the factored resistances given in Clause 13.12.1.2 of SANS 10162-1.

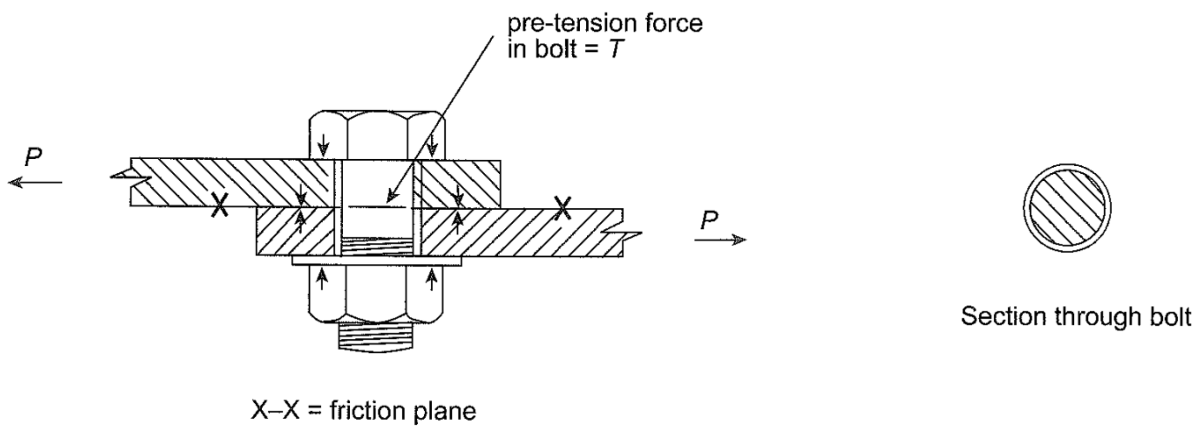


Figure 10.28 Load transfer on an HSFG bolt

The type of HSFG bolt generally used is the Class10.9S, although the Class 8.8S is also available. HSFG bolts have larger heads and nuts than ordinary and precision bolts to allow for the high pre-tension force.

After installation, all HSFG bolts must be checked to ensure that sufficient torque has been applied to the nut to produce the required pre-tension in the shank.

However, several proprietary types of friction-grip fasteners that eliminate the need for checking the torque or tension are available. The most commonly used ones in South Africa are:

- the Huckbolt, and

- the torque-control (TC) Bolt.

The Huckbolt is a direct-tension control fastener. It does not have a conventional nut. Instead, it has an extended tail that is subjected to a high-tensile force by the installation tool whilst a collar is swaged onto the circular (not helical) thread on the bolt shank. The tension is applied until the tail breaks off at its reduced-section neck, thus ensuring that the required tension has been induced.

The TC bolt has an extended torque-control spline with a reduced-section neck. The tension is induced by a torque applied to the nut and resisted by the spline. The torque is applied until the spline shears off at the neck. Thus the torque is accurately monitored and no further inspection is required.

- **Bolts in tension**

Figure 10.29 shows how bolts may be loaded in tension. In this type of loading, the force in each bolt is *P* divided by the number of bolts in the connection (in this case, two). The force acts axially in each bolt.

There is no slip in the connection, so the bolts do not act in shear or bearing. The force is transmitted by the cross-sectional area of the threaded part of the bolt. The factored tensile resistance of each bolt at the ultimate limit state is given by Clause 13.12.1.3 of SANS 10162-1.

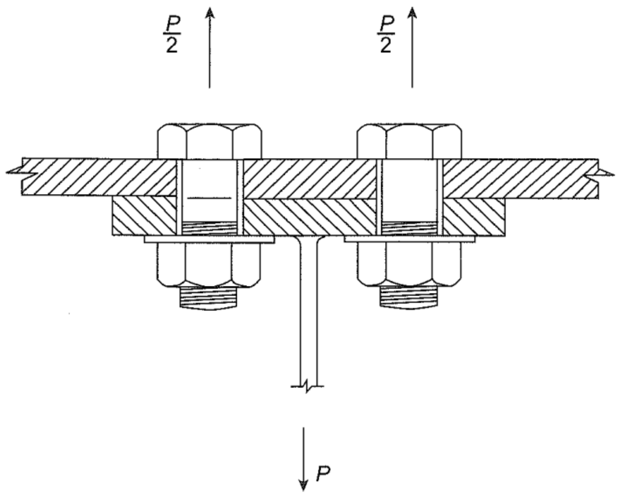


Figure 10.29 Bolts in tension

Any class of bolt may be used to transmit tensile force, but use of Class 4.8 should be limited to minor connections subject to low loads. Class 8.8S and 10.9S bolts, with their high strength and larger heads and nuts, are especially suited to high-tensile loading. An added advantage is that they can be pre-tensioned (as when used in friction-grip connections) to ensure that the nut will not work loose under repetitive loading.

The plate and the flange through which the bolts pass in **Figure 10.29** are relatively thick, so these elements will not bend under the tensile load.

However, where thinner elements are used, bending will take place and a phenomenon called 'prying action' will occur, resulting in an increase in the tensile force in the bolts. A typical example of prying action is where a crawl beam is suspended through its top flange by tension bolts from an overhead beam.

10.3.7 Recommended gauges and back marks on steel profiles

The arrangement of the bolt holes on steel profiles usually follows a rectangular pattern. In other words, the holes are in rows. The holes in one row are in line with the holes in the other rows, as shown in **Figure 10.30** on the following page. This makes for easier setting out and a neat appearance.

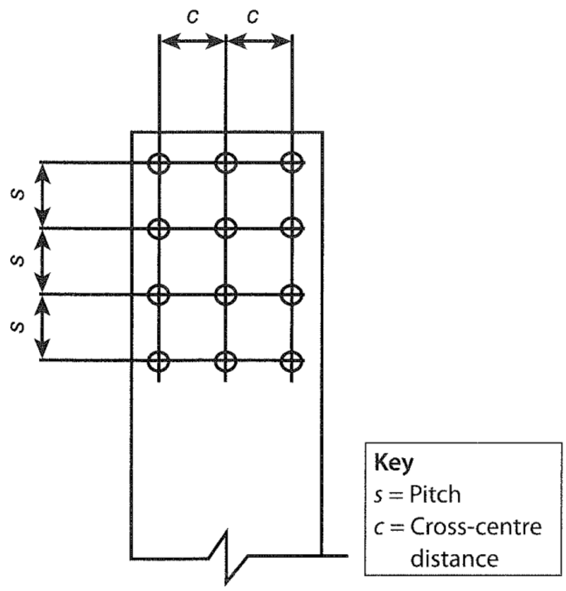


Figure 10.30 Rectangular layout of bolts

The spacing between bolts in the longitudinal direction of a member is called the pitch. The spacing at right angles to this is called the cross-centre distance. The minimum and maximum pitches and cross-centres allowed from a design point of view are laid down in SANS 10162-1, but minimum spacings are also controlled by the clearance required between the head of the spanner or wrench and the nearest bolt already installed.

When the bolts in alternate rows are offset from those in intermediate rows, they are said to be in a staggered pattern, as shown in **Figure 10.31** This pattern is used when a large number of bolts are to be fitted into a limited width, since the zigzag arrangement allows the bolts to be more closely nestled whilst still maintaining the required minimum centre-to-centre distance, *d*.

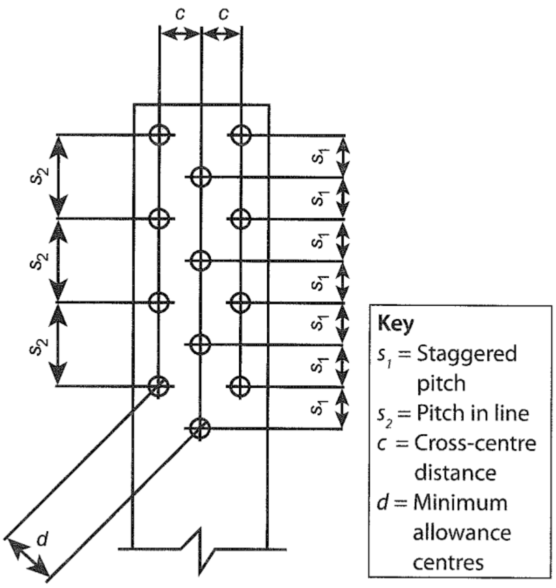


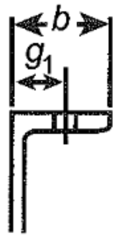
Figure 10.31 Staggered layout of bolts

However, the length of the bolt group is increased. It should also be noted that, for quality-control reasons, this staggered pattern is not recommended.

Holes in the flanges of I- and H-sections and channels and the legs of angles are usually placed on the centre lines at a set distance from the backs of channels or angles (gauge lines or back mark lines) or from the web centres of I- and H-sections (gauge lines or cross-centre lines).

Table 10.17 shows the recommended gauges and back marks for channel sections. It also gives the maximum hole diameter that should be used for each section flange width.

Recommended gauges and back marks for channel sections



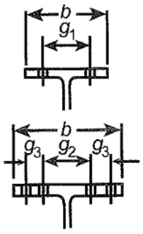
b (mm)	g_1 (mm)	Ø max. (mm)
38	22	8
45	25	10
50	28	12
54,55	28	16
60	35	16
64,65	35	20
70	40	20

75-85	45	20
90	50	24
95-110	55	24

Table 10.17 Recommended gauges and back marks for channel sections

Table 10.18 shows the recommended gauges and back marks for I- and H-sections. It also gives the maximum hole diameter that should be used for each section flange width.

Recommended gauges and back marks for I- and H-sections

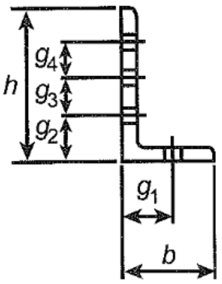


b (mm)	Gauge (mm)			Ø max. (mm)
	g_1	g_2	g_3	
64	32			12
73-82	40			12
89-91	50			12
102	54			16
133-146	70			20
152	90			20
165-191	90			24
203-254	140			24
305	140	120	60	24
368-406	140	140	75	24

Table 10.18 Recommended gauges and back marks for 1- and H-sections

Table 10.19 shows the recommended gauges and back marks for angles. It also gives the maximum hole diameter that should be used for each section flange width.

Recommended gauges and back marks for angles



h or *b* (mm)	Back mark g_1 (mm)	Ø max. (mm)	*h* or *b* (mm)	Back mark (mm)				*h* or *b* (mm)
				g_1	g_2	g_3	g_4	
25	15		90	50				24
30	17		100	50				24
35	20		120	60				24
40	22	8	120		45	45		16
45	25	10	125	65				24
50	28	12	125		45	45		20
60	35	16	150	75				24
65	35	20	150		55	55		20
70	40	20	200		75	75		24
75	45	20	200		55	55	55	20
80	45	20	200					

Table 10.19 Recommended gauges and back marks for angles

The distances for the back marks are illustrated in details (a) to (c) of **Figure 10.32**. The set distances vary according to the size of the particular section, but are standard for each size of section.

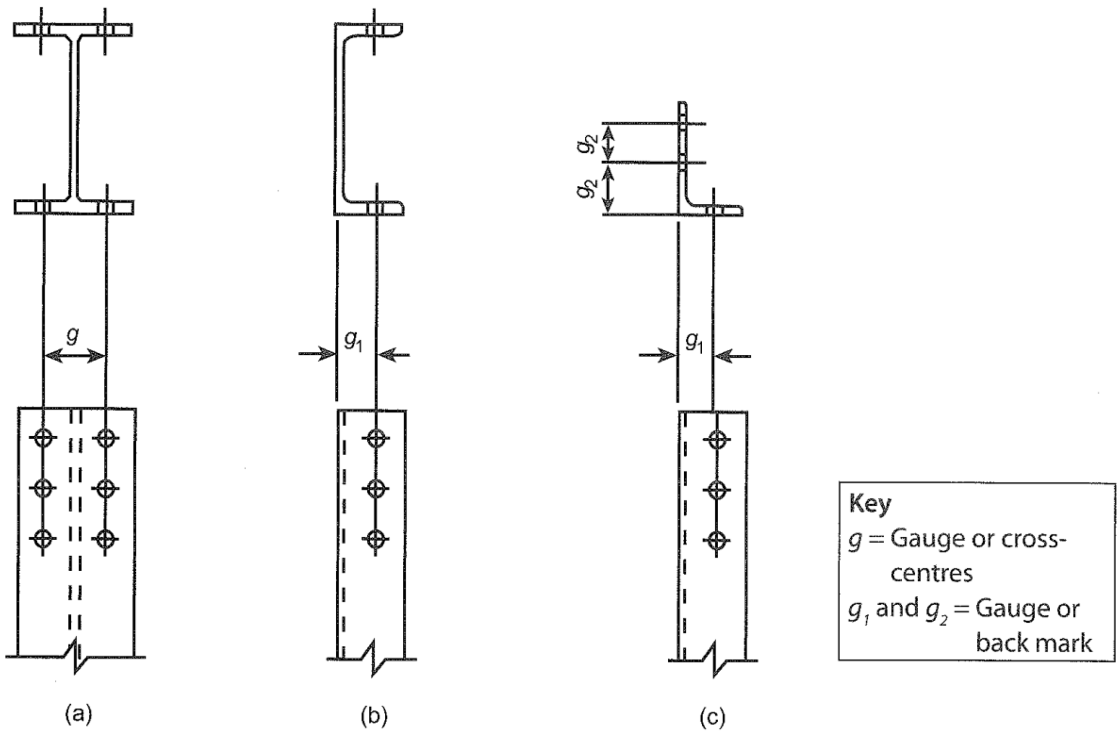


Figure 10.32 Layout of bolts

Another limitation on bolt placement is the distance of a hole from the edge of the plate or member. This is called the edge distance. When it is measured to the end and not the side of the member, it is called the end distance. Minimum limits are placed on this dimension to prevent tear-out of the plate edge when the shear force in the bolts is directed towards the edge.

These limits are specified in SANS 10162-1. Holes in the flanges of I- and H-sections are usually placed at a set distance from the web centres (gauge lines or cross-centre lines) or at a set distance from the backs of channels or angles (gauge lines or back mark lines). We refer to this set distance as the gauge distance.

10.4 Steel floor layout drawn from a given line diagram

In most structures containing suspended floors the beams or girders represent a significant proportion of the total steel content and for this reason special attention needs to be given to their cost-effective application. **Figure 10.33** shows a typical steel framed building. The front and part of the end elevation is shown as well as the first floor plan layout.

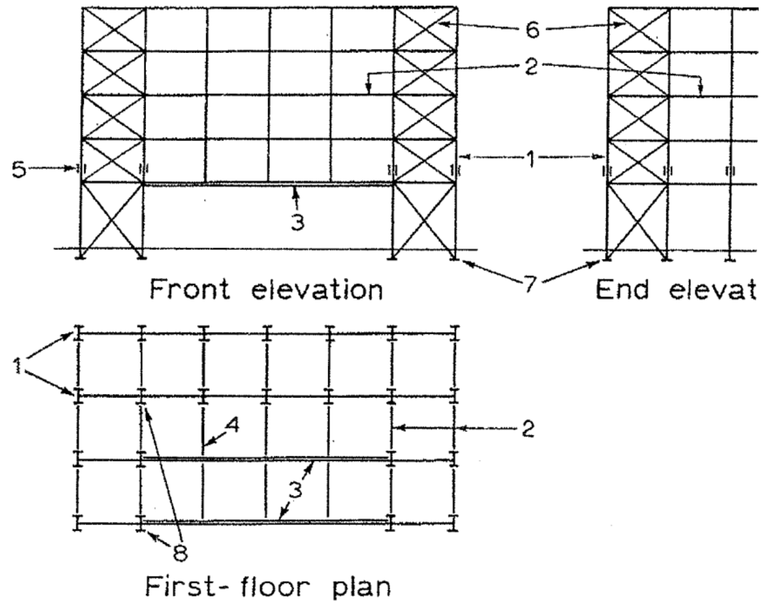


Figure 10.33 Typical Steel Framed Building

Steel-frame buildings consist of a skeletal framework which carries all the loads to which the building is subjected. The steel members are used to carry lateral loads when acting as beams and girders, and axial loads when acting as stanchions, struts and ties.

Internally the structure is covered with floor plates and slabs to carry floor loads. Externally, sheeting and glazing form the cladding for the framework and carry wind and snow loads on the roof and walls. Internal partitions in this type of building are generally non-load-bearing.

The plate elements collect the imposed loads from the floors, and the wind and snow loads from the roof and walls, and transmit them to the steel frame.

The steel frame is made up of the following load-bearing structural elements: beams, girders, trusses, columns /stanchions and bracing.

Connections join individual members to form some of the elements as well as joining the elements together to form the frame. Columns / stanchion bases transmit the building loads to the foundations.

The structural elements are fabricated in shops where working conditions can be carefully controlled. The frame is broken down into arts of suitable size for the method of transport and erection to be used. The members stack together occupying little volume for transport to site.

The designer must have an appreciation of the methods of fabrication and erection, as well as the problems of transport, in order to set the size of the separate members and design and detail suitable connections.

Before we commence with detailing or drawing up a floor layout we will need to, first understand the grid lines and marking plans of a building.

10.4.1 Grid lines and marking plans

Marking plans for single-storey buildings present no difficulty. Members are marked in sequences as follows:

- Columns - AI, A2, and so on;
- Trusses - T1, T2;
- Crane girders CG 1, CG2;
- Purlins P1, P2;
- Sheeting rails SR 1, SR2;
- Bracing B 1, B2;
- Gable columns / stanchions GS1, GS2;

Various numbering systems are used to locate beams and stanchions in multi-storey buildings. Two types an outlined below:

- In plan, the column / stanchion grid is marked A, B, C in one direction and 1, 2, 3 in the direction at right angles. Columns / stanchions are located AI, C2, and so on.
- Floors are numbered A, B, C for ground, first, second respectively.
- Floor beams, for example, on the second floor are numbered BI, B2, and so on
- Column / stanchion lengths are identified, for example, A4-B is the column / stanchion on grid intersection A4, length between second and third floors.

In Type 1 the beams are numbered or marked consecutively as indicated in **Figure 10.34**.

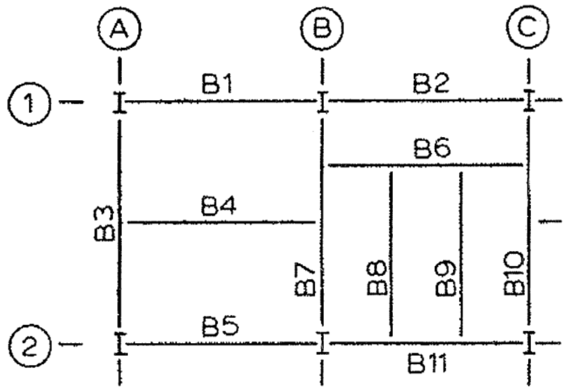


Figure 10.34 First floor layout – Type 1

In Type 2 the beams are numbered or marked on grid lines, for example, line 1 – 1a, 1b and so on. The first floor requires prefix B, for example B-1a, as shown in **Figure 10.35**.

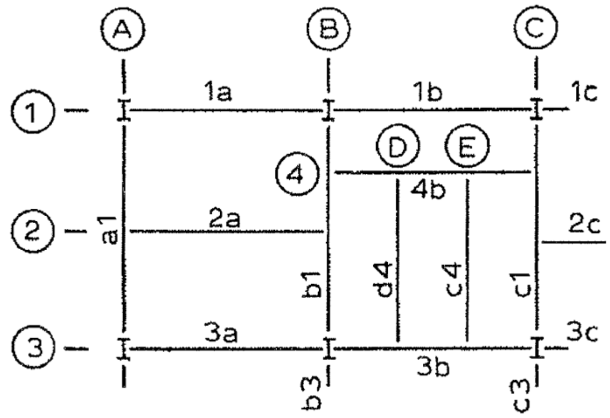


Figure 10.35 First floor layout – Type 2

We are now going to discuss the guidelines to follow when drawing a floor layout from a single line diagram.

It is expected of you to show the following on floor layouts:

- Main centre lines;
- Columns in section;
- Flange widths;
- End reactions;
- Dimensions;
- Tile and scale
- Section size of each beam and column;
- True north;
- A separate piece mark for each item on the floor.

10.5 Number of bolts required for end plate/ cleat connections

When we are required to select a suitable end connection for an end plate or cleat connection we will refer to the factored resistance of bolts in bearing type connections.

To calculate the number of bolts (for each connection), use the follow formula:

$$\text{Number of bolts required (n)} = \frac{\text{End reaction (kN)}}{\text{Factored resistance per bolt (in single shear or double shear - kN)}}$$

Important: Note that the number of bolts will always be in pairs. For example, if your answer is 3, 45 bolts; then you will make it 4 bolts and so on.

Factored resistance per bolt is given in the **Table 10.20** below. Select the size of the bolt and then reference either single shear or double shear. This is then inserted into the above formula to calculate the number of bolts per connection.

Important: Note that **Table 10.20** must be used to select the factored resistance per bolt (in single shear or double shear - kN) when calculating the number of bolts needed for the end connections of beams.

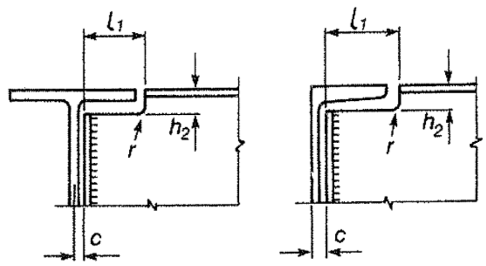
Factored resistance of bolts in bearing-type connections				
Class 4.8 bolts				
Size of bolt	Factored resistance			
	Tension TR	Shear Vr		Bearing Br per mm of plate thickness
		Single	Double	
M12	28,5	16,0	32	11,6
M16	50,7	28,4	57	15,4
M20	79,2	44,3	89	19,3
M24	114	63,8	128	23,2
M30	178	99,8	200	28,9
M36	257	144	287	34,7
Class 8.8				
Size of bolt	Factored resistance			
	Tension TR	Shear Vr		Bearing Br per mm of plate thickness
		Single	Double	
M16	96,5	54,0	108	15,4
M20	156	87,6	175	19,3
M24	225	126	252	23,2
M30	352	197	394	28,9
M36	507	284	568	34,7
Class 10.9 bolts				
Size of bolt	Factored resistance			
	Tension TR	Shear Vr		Bearing Br per mm of plate thickness
		Single	Double	
M16	125	70,3	141	15,4
M20	196	110	220	19,3
M24	282	158	316	23,2
M30	441	247	496	28,9
M36	635	356	711	34,7

Table 10.20 A standard table of the factored resistance for grade (Class) 4.8, 8.8 and 10.9 bolts.

10.6 Notching of steel members

When connecting a beam to a beam, the flange of the one beam may have to be notched to allow for the flanges of the beams to be flush. Sufficient clearance is allowed around the flange to ensure that the flange does not foul it.

The dimensioning of flange notches is illustrated in **Table 10.21** on the following page.



Dimension c is to face of end plate or angle cleat.
r = 10mm minimum.
Dimensions are in mm.

	Section	c	Notch l_1	Notch h_2		Section	c	Notch l_1	Notch h_2
I-Sections (parallel flange)	100 x 55 x 8	4	33	15	I-Sections (parallel flange)	533 x 210 x 82	7	113	30
	120 x 64 x 19	4	37	15		93	7	113	35
	140 x 73 x 13	4	42	20		101	7	113	35
	160 x 82 x 16	5	47	20		109	8	113	35
	180 x 91 x 19	5	51	20		122	8	113	40
	200 x 100 x 22	5	56	25		610 x 229 x 101	7	122	35
	203 x 133 x 25	5	74	20		113	7	122	35
	30	5	74	20		125	8	122	40
	254 x 146 x 31	5	81	20		140	8	122	40
	37	5	81	25	I-Sections (taper flange)	127 x 76 x 13	4	44	20
	43	6	81	25		152 x 89 x 17	4	50	20
	305 x 102 x 25	5	57	25		178 x 102 x 22	4	57	25
	29	5	57	20		203 x 102 x 25	5	57	25
	33	5	57	20		52	6	82	35
	41	5	91	25		254 x 152 x 59	6	82	35
	46	5	91	25		305 x 152 x 66	7	82	35
	54	6	91	25	Channels	100 x 50 x 11	8	51	20
	356 x 171 x 45	5	94	25		120 x 55 x 13	9	55	25
	51	5	94	25		140 x 60 x 16	9	60	25
	57	6	94	30		160 x 65 x 19	9	65	25
	67	7	94	30		180 x 70 x 22	10	70	30
	406 x 140 x 39	5	78	25		200 x 75 x 25	10	75	30
	46	5	78	25		220 x 80 x 29	11	80	30
	54	6	97	25		240 x 85 x 32	11	85	30
	60	6	97	30		260 x 90 x 38	12	88	35
	67	6	97	30		280 x 95 x 42	12	95	35
	457 x 191 x 67	6	103	25		300 x 100 x 46	12	100	40
	75	7	103	30		76 x 38 x 7	7	40	20
	82	7	103	30		127 x 64 x 15	8	65	25
	90	7	103	30		152 x 76 x 18	8	78	30
	98	8	103	35		178 x 54 x 15	8	55	20
H-Sections	152 x 152 x 23	5	84	20		381 x 102 x 55	12	100	40
	30	5	84	20	H-Sections	254 x 254 x 107	8	138	40
	37	6	84	20		132	10	138	40
	203 x 203 x 45	6	111	25		167	12	138	50
	52	6	111	25		305 x 305 x 97	7	165	35
	60	7	111	30		118	8	165	40
	72	7	111	30		137	9	165	40
	86	8	111	35		158	10	165	45
	254 x 254 x 73	6	138	30		198	12	165	50
	89	7	138	35		240	13	165	55

Table 10.21 Dimensions of beam notches

We will now review the notching of beams with application to the detailing of beams and plate girders. **Figure 10.36** shows two beams with a smaller beam spanning between them.

The top of the beams are all at the same level. In order to connect the smaller beam to the webs of the larger beams it is necessary to notch the top flange of the smaller beam.

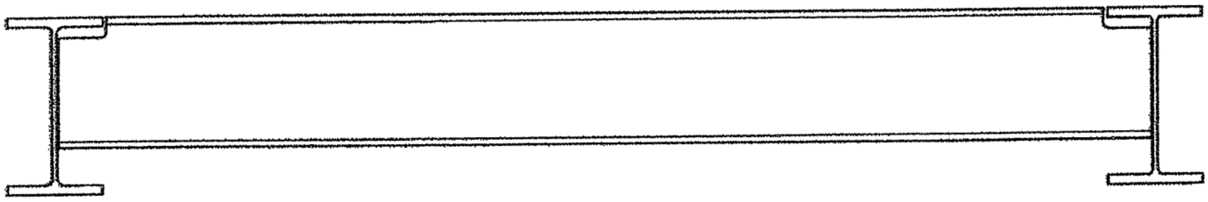


Figure 10.36 Two beams connected by a smaller beam spanning between them

Figure 10.37 is an enlarged view of the notch in the top flange of the smaller beam. There are several rules that apply to the notching of flanges in beams.

The corner of the notch should never be square. It should always be radiused, as seen in **Figure 10.37**. Generally the corner radius is 9 mm for the lighter sections and up to 12 mm for the heavier sections.

Important: Note that the corner of the notch should never be square. A squarely notched corner is a weak point in the steel, from which a tear can originate.

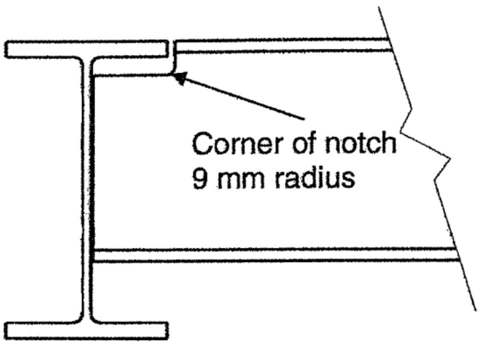


Figure 10.37 Enlarged view of notching of the top flange

Furthermore, the corner should not be formed with a cutting torch. The correct method is to drill a hole located at the corner of the notch, and then gas-cut away from the hole, not towards it, as seen in **Figure 10.38** on the following page.

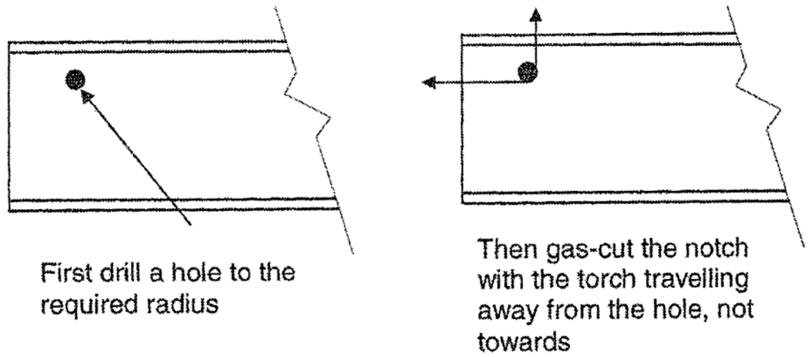


Figure 10.38 Notch preparation

Figure 10.39 indicates that the notch must be at least deep enough to avoid interference with the internal radius of the web fillet of the larger beam, plus an additional 2 or 3 mm.

In general a notch depth of 35 mm is used for connection to the larger beams, as seen in **Figure 10.39**, dimension "a".

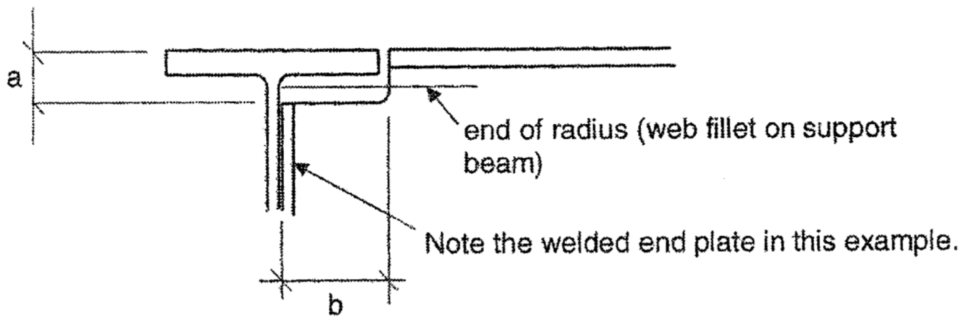


Figure 10.39 Notch details

Where only one flange at the end of a beam is required to be notched as shown in **Figure 10.39** above, the maximum length of the "single notch" (**Figure 10.39**, dimension "b") should never exceed 22 x web-thickness of the notched beam, unless additional stiffening is added to the notched web.

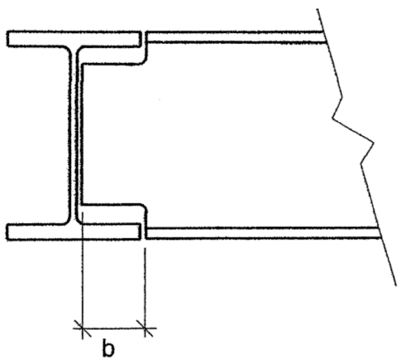


Figure 10.40 Double flange notching

Where both flanges are notched at the end of a beam as in **Figure 10.41**, the maximum length of the "double notch" (**Figure 10.41** dimension "b") should not be more than 14 x the web-thickness of the notched beam unless additional stiffening is added to the notched web.

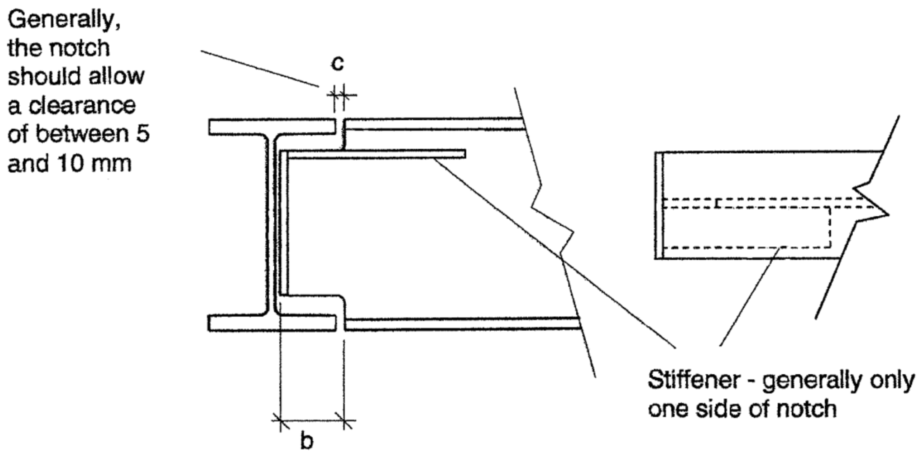


Figure 10.41 Double notch with a stiffener

Figure 10.41 shows a beam with a double notch and both notches are quite long. In other words if we assume that the notch length "b" is greater than 14 x the web-thickness of the notched beam, then additional stiffening as shown in **Figure 10.41** will be required where the beam is carrying a heavy load. Occasionally stiffening may also be required to the bottom tension portion of the notch.

Where large notches are required that may need stiffening they should always be discussed with the design engineer. The stiffener normally extends beyond the notch by at least 150 to 200 mm.

Important: Note that the recommended way for the detailer to calculate the length of the notch is as follows.

First, ensure that the beam length allows for 2 mm tolerance at each end.

Then calculate the length "b" of the notch as follows:

b = (flange-width of support beam / 2) - (web-thickness of support beam */2)* + (say 7 mm).

This method will ensure that dimension "c" (**Figure 10.41**) is between 5 and 10 mm, which are considered good practice.

10.7 Beam end connections

Usually a beam is supported at its ends on either a column or another beam (or girder). Examples of end connections are shown in **Figure 2.10**, with isometric views of some of them in **Figure 2.17**.

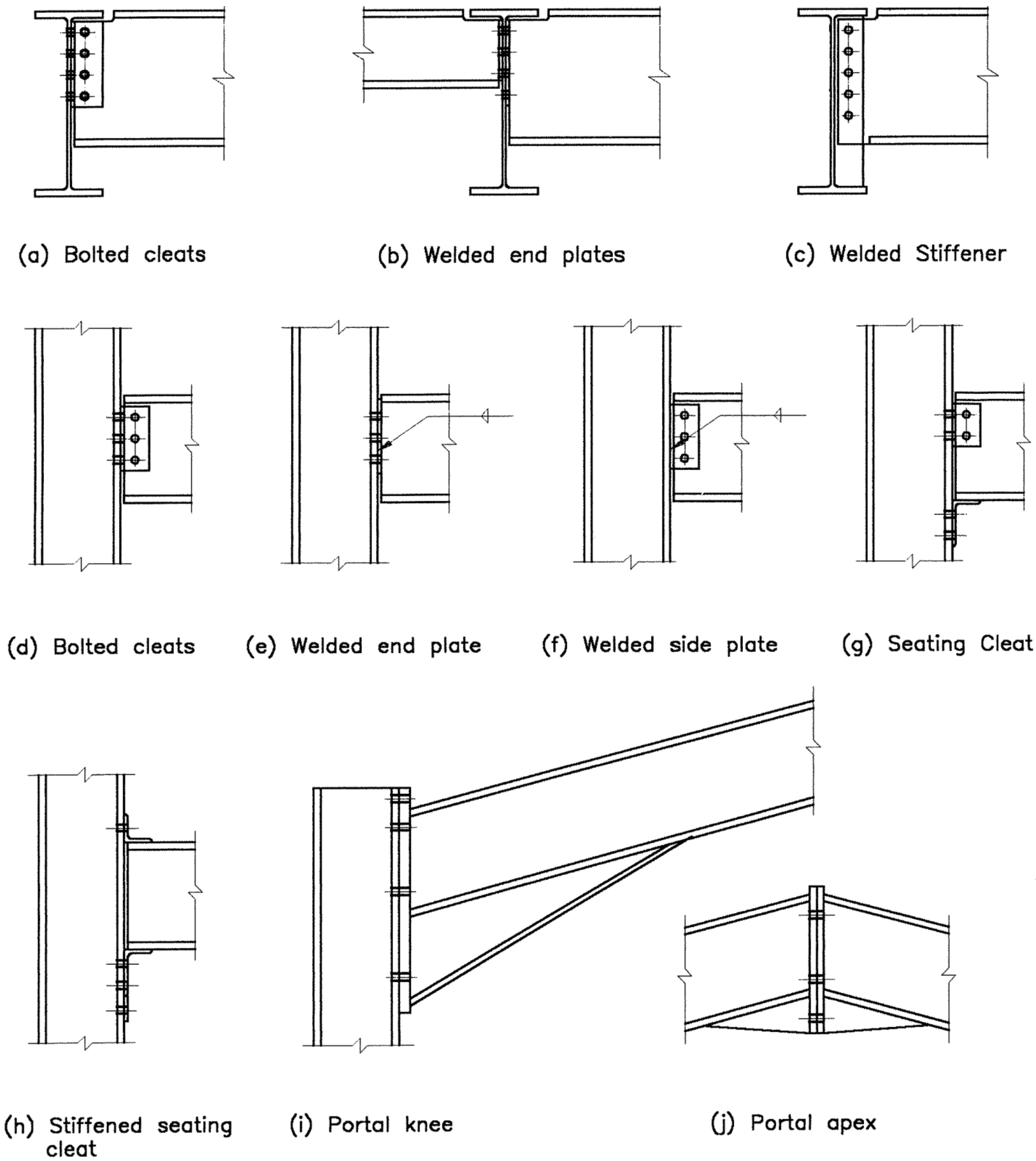


Figure 10.42 Beam end connections

Figure 10.42 to **Figure 10.49**, on the following pages, shows further examples of drawings of various end connections for beams.

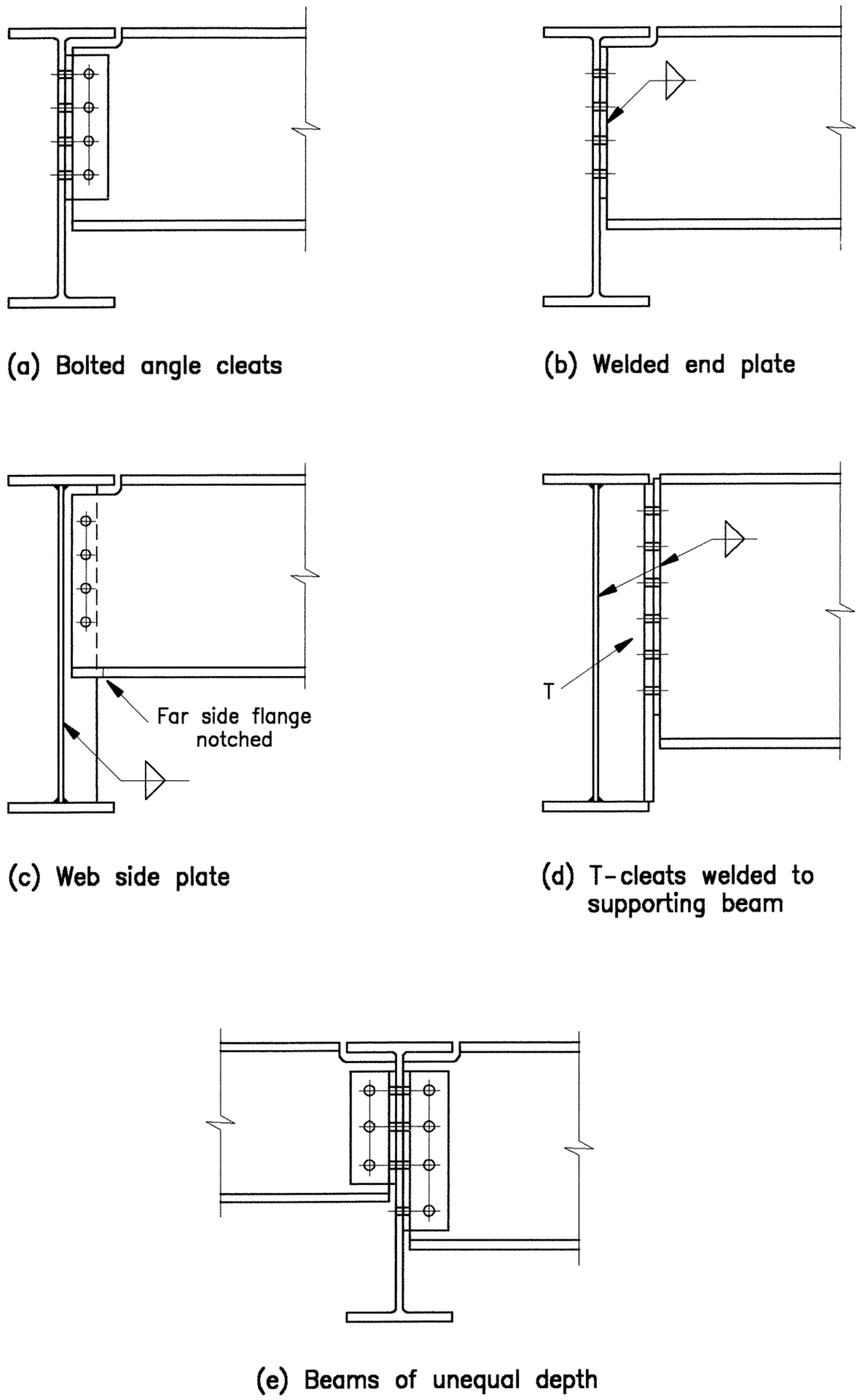


Figure 10.43 Beam-to-beam connections - shear only

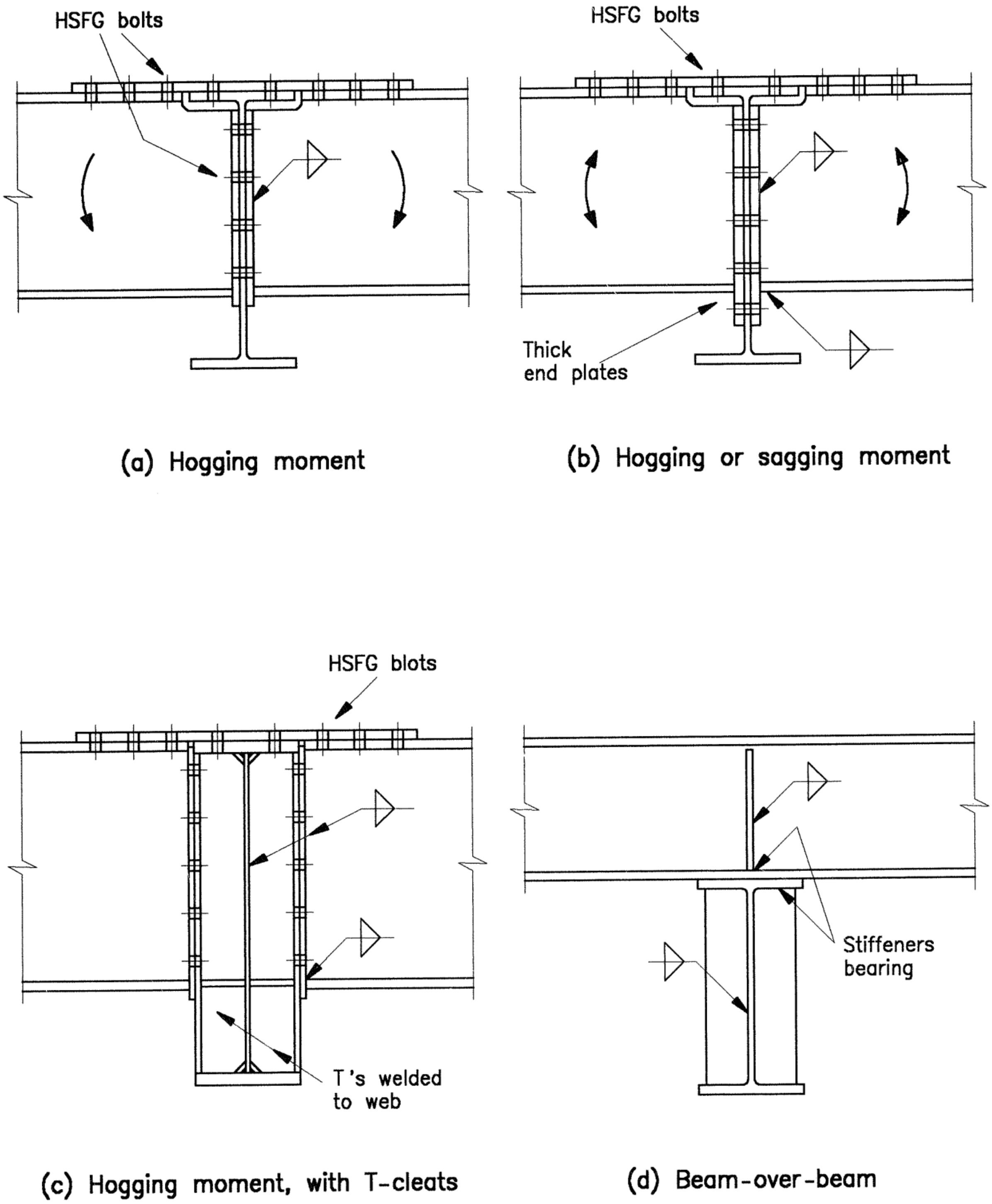


Figure 10.44 Beam-to-beam connections - continuous

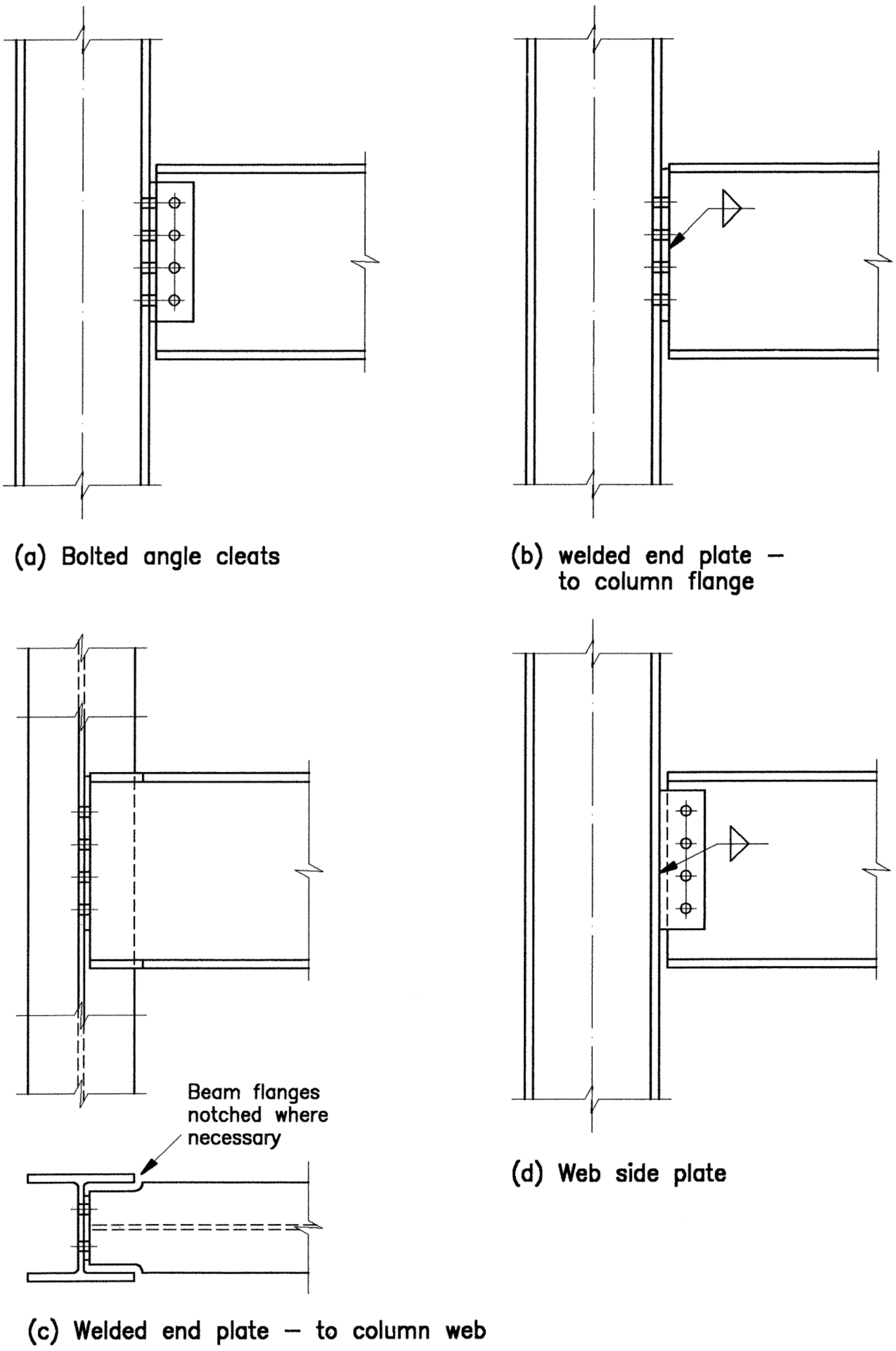


Figure 10.45 Beam-to-column connections – flexible

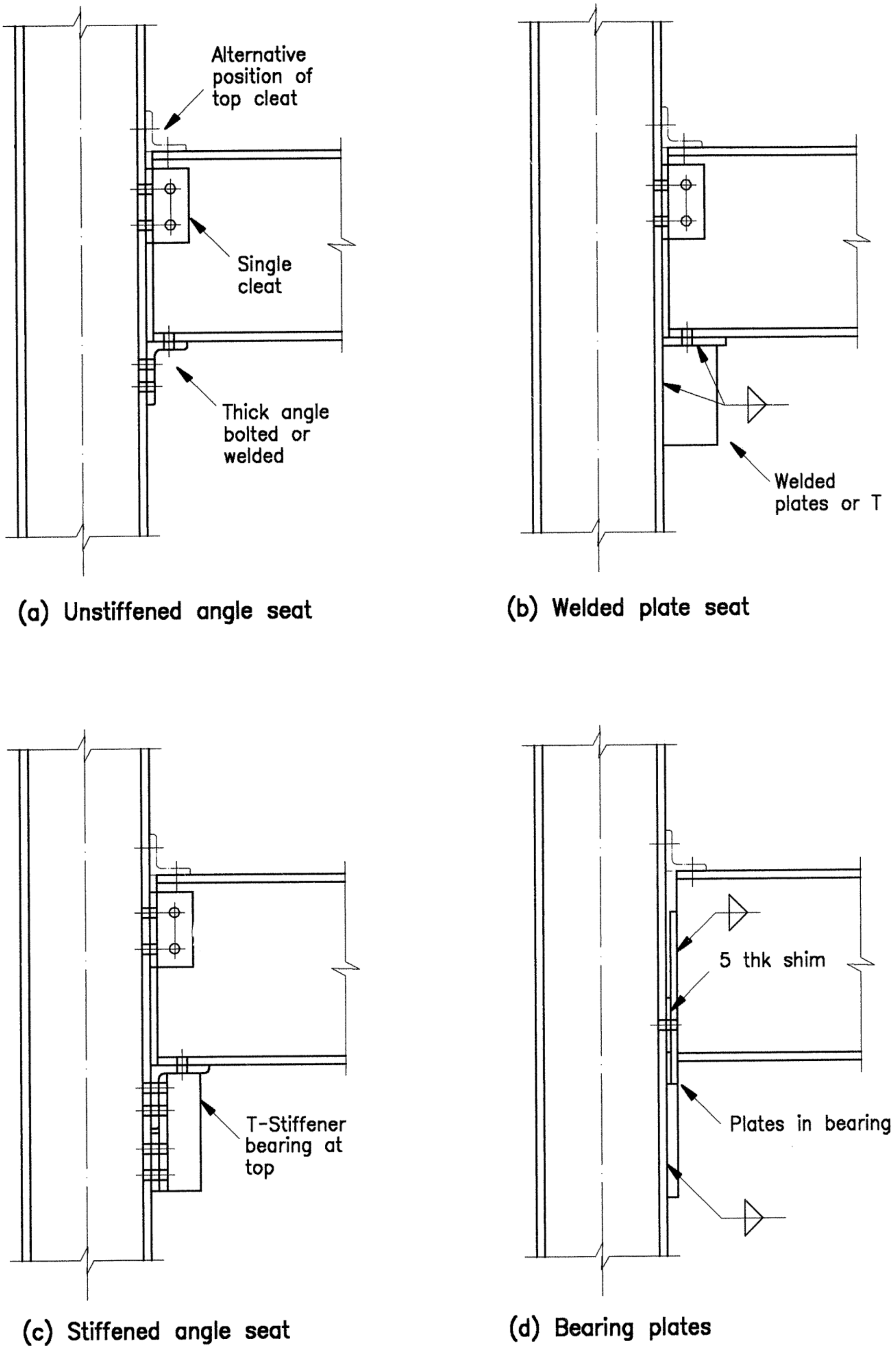


Figure 10.46 Beam-to-column connections – flexible (continued)

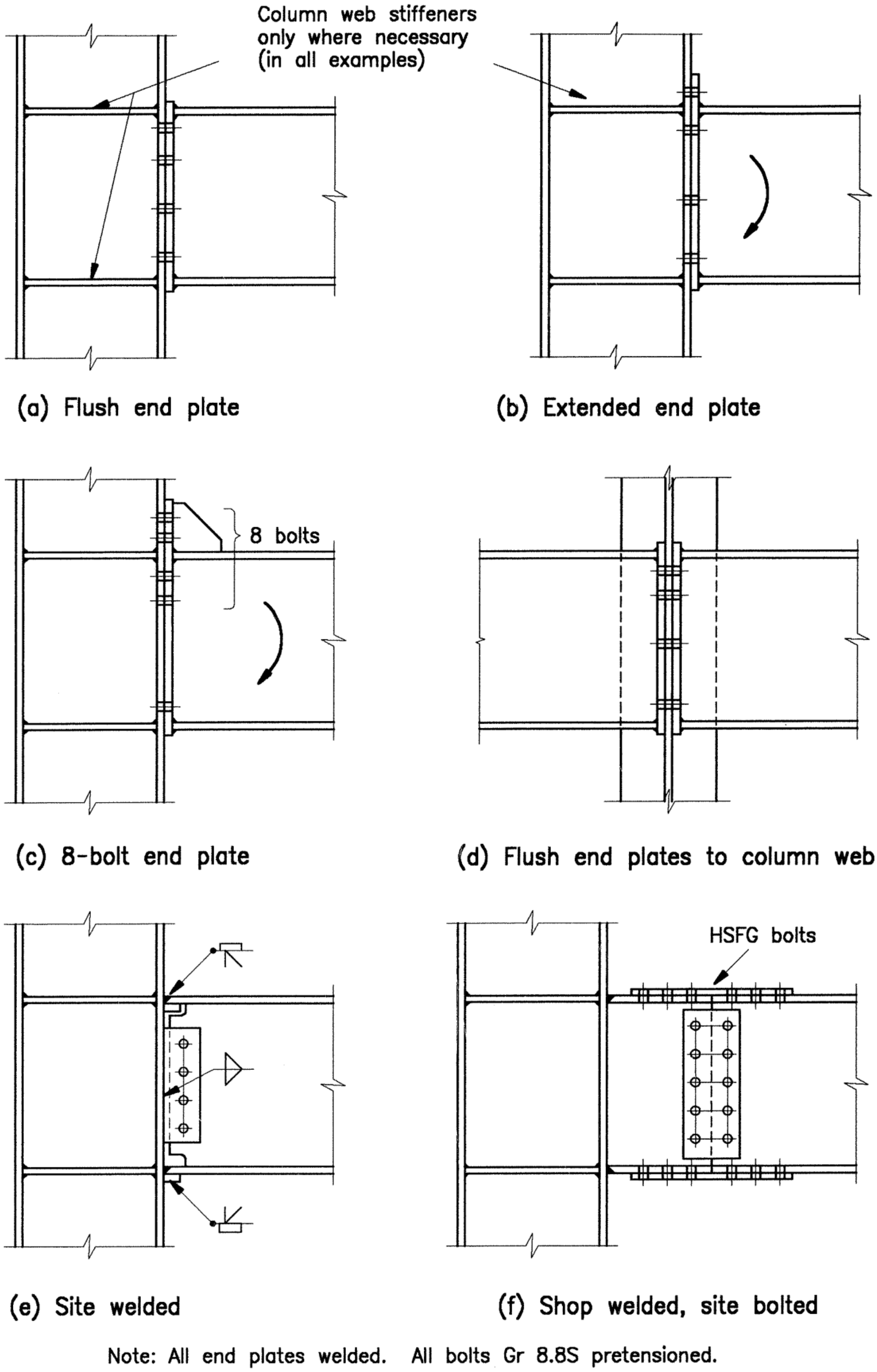


Figure 10.47 Beam-to-column connections - moment

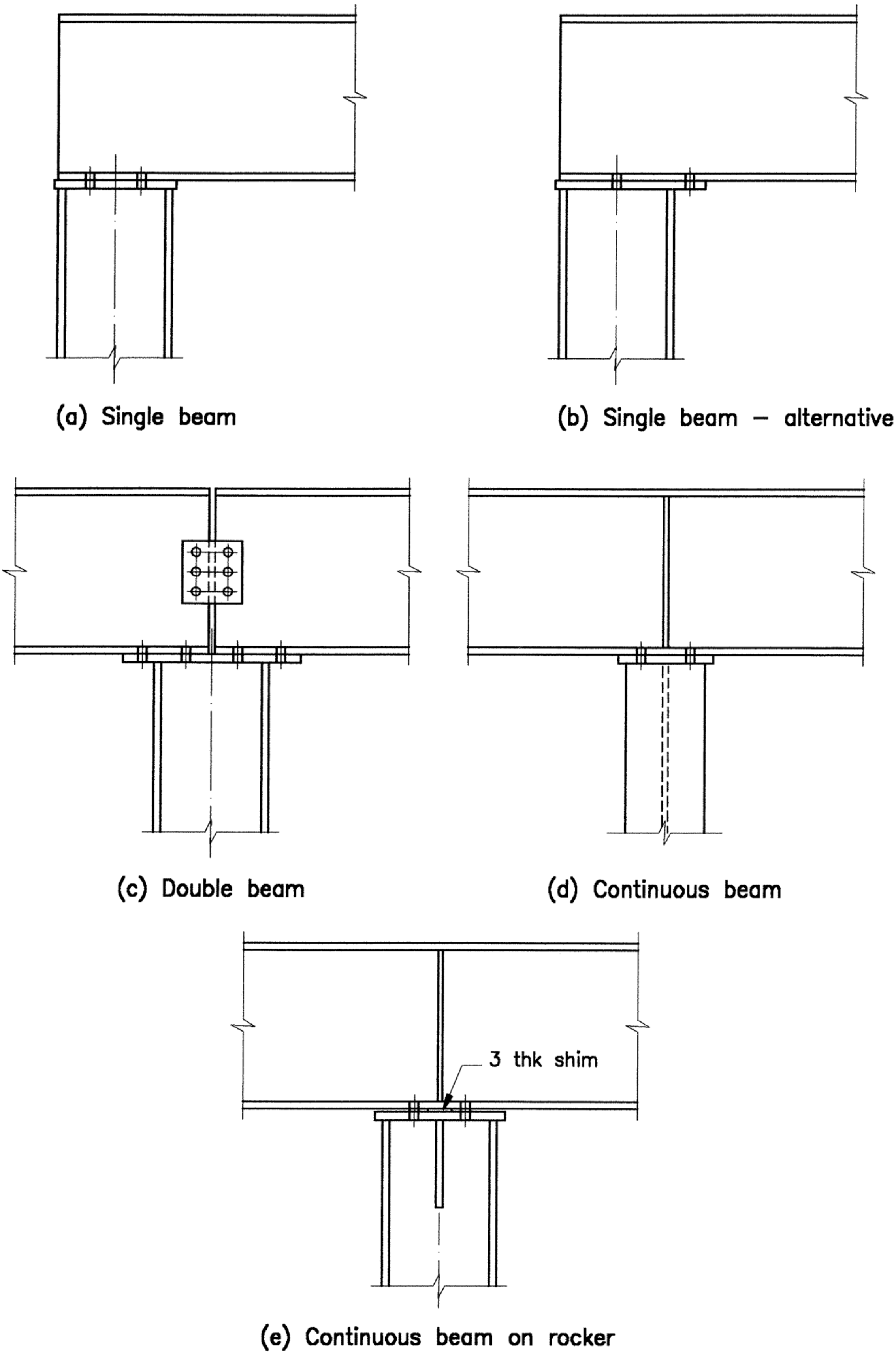


Figure 10.48 Beam-to-column cap connections – flexible

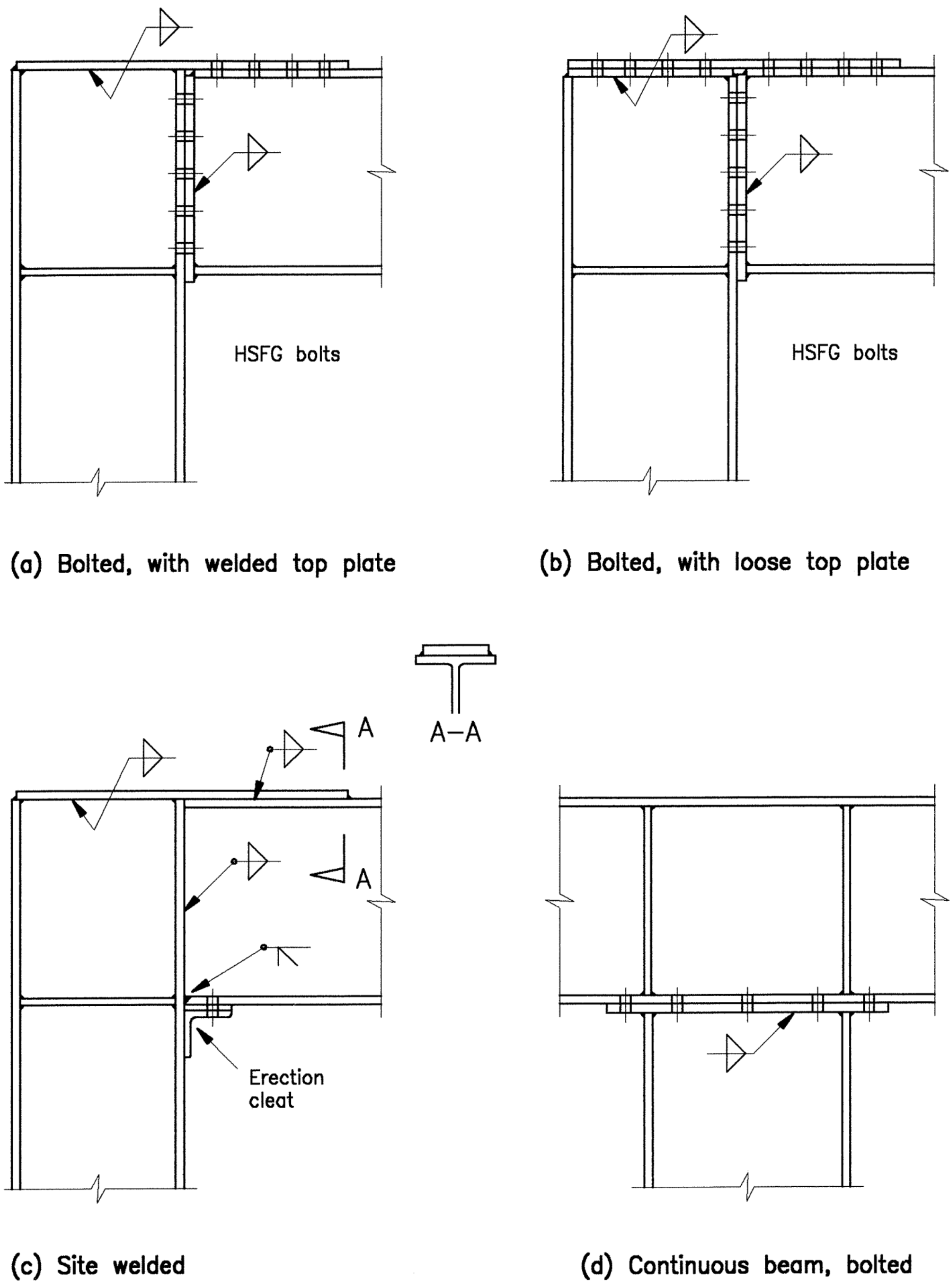


Figure 10.49 Beam-to-column cap connections - moment

The following points should be noted:

- In the beam-to-column and the beam-to-beam connections the connecting elements can be bolted angle cleats, welded end plates or plates welded to the supporting members.

- In beam-to-column connections a further type of connection, the angle seat, can be used, but must be accompanied by a steadying cleat at or near the top of the beam.

- In the beam-to-beam connections the top flange of the supported beam is cut back or notched to clear the top flange of the supporting beam.

- The choice of whether to use bolted angle cleats or welded end plates is usually left to the fabricating company and is dependent on workshop preferences. If appearance is important the designer may specify welded end plates rather than bolted angles.

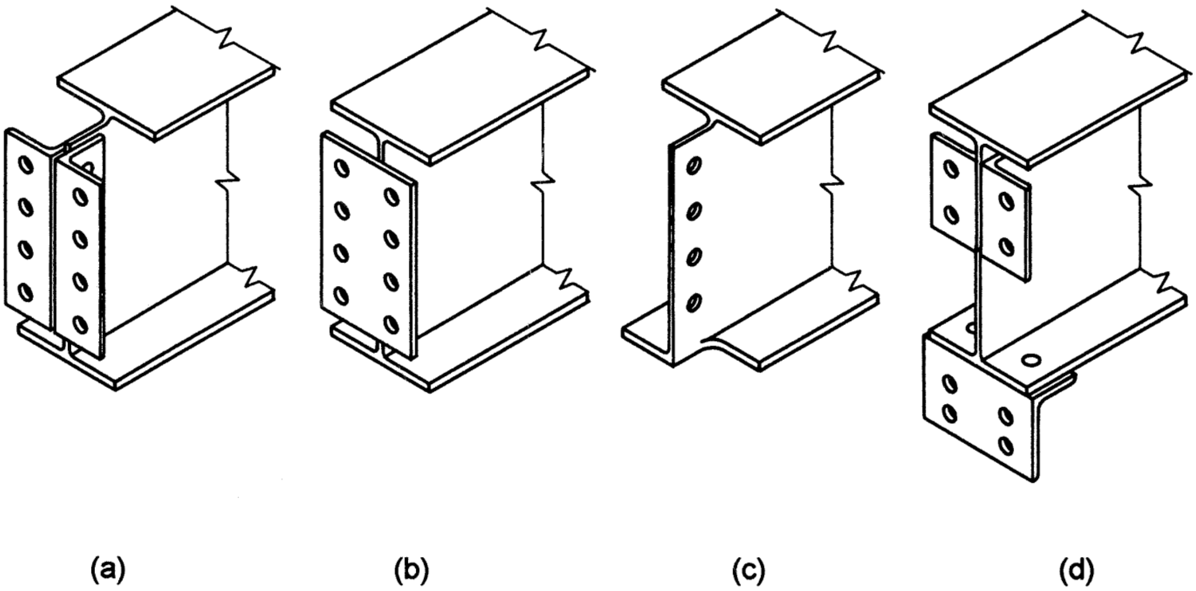


Figure 10.50 Beam end connections

It is not intended here to go into the detail of how the elements of the connections are designed, since the detailer is able to select the appropriate connection from the pre-designed standard types given in the tables.

However, in order that the detailer may have an understanding of how the tabulated factored resistances are calculated, the following list of design steps is given:

- The number of bolts is arrived at on the basis of their single or double shear resistance, with threads in the shear plane.

- The size and, amount of welding is based on the shear resistance of the welds.
- The minimum required thicknesses of angle cleats and end plates in the tables are based on the shear strength of these elements and also on their bolt bearing resistance, assuming the bolts are fully stressed in shear.
- The minimum required thicknesses of the supporting members (ie column flange. or web, or supporting beam web) are based on the bolt bearing resistance, assuming the bolts are fully stressed in shear.

In **Table 10.20**, if the actual thicknesses of the supported beam or supporting member elements are less than those tabulated the resistance of the connection is reduced in proportion to the actual-to-required thicknesses. Likewise, if the actual beam end reaction is less than the connection resistance, the minimum required thicknesses of the elements can be reduced pro rata.

The values given in the tables are called the *factored resistances* of the connections and are in kilonewtons (kN). By resistance is meant the ability or capacity of the connection to resist the force, but this in tum implies its ability to *transmit* the force to the supporting member.

Thus, for any beam end reaction shown on the engineer's drawing, it is the detailer's duty to select a particular connection from the tables having a resistance equal to or greater than the specified end reaction.

In certain cases, and especially where small beams or low loads are involved, the designer may not specify the end reactions, but simply state on his drawing; 'Where beam end reactions are not given, connections to be designed for reaction of 140 kN'. The detailer is then required to select a standard end connection having a resistance at least equal to that end reaction.

Worked Example 10.1

To illustrate how the detailer selects suitable standard end connections, the beam marked **B15** in **Figure 10.51** will be considered.

It is obvious that before the beam can be detailed the particulars of the required end connections must be known.

Figure 10.51 represents part of an engineer's floor layout drawing and shows how all the information needed to detail the beams is provided in a way that is both concise and clear.

Note that the top-of-steel (TOS) level is given as+ 13 000 (i.e. 13,0 m above datum), unless otherwise noted (uon); this means that the top flanges of all beams in the floor are flush, i.e. at the same level, except for Beam **B 17**, which is 80 mm above the general level.

We may now proceed with the selection of end connections for the beam in question. Note that it is stated in **Figure 10.51** that the steel grade is 300W and that M20 Grade 4.8 bolts are to be used.

It will be assumed that the fabricator would prefer to use the bolted double-angle connection rather than the welded plate type, so **Table 10.22** will be used.

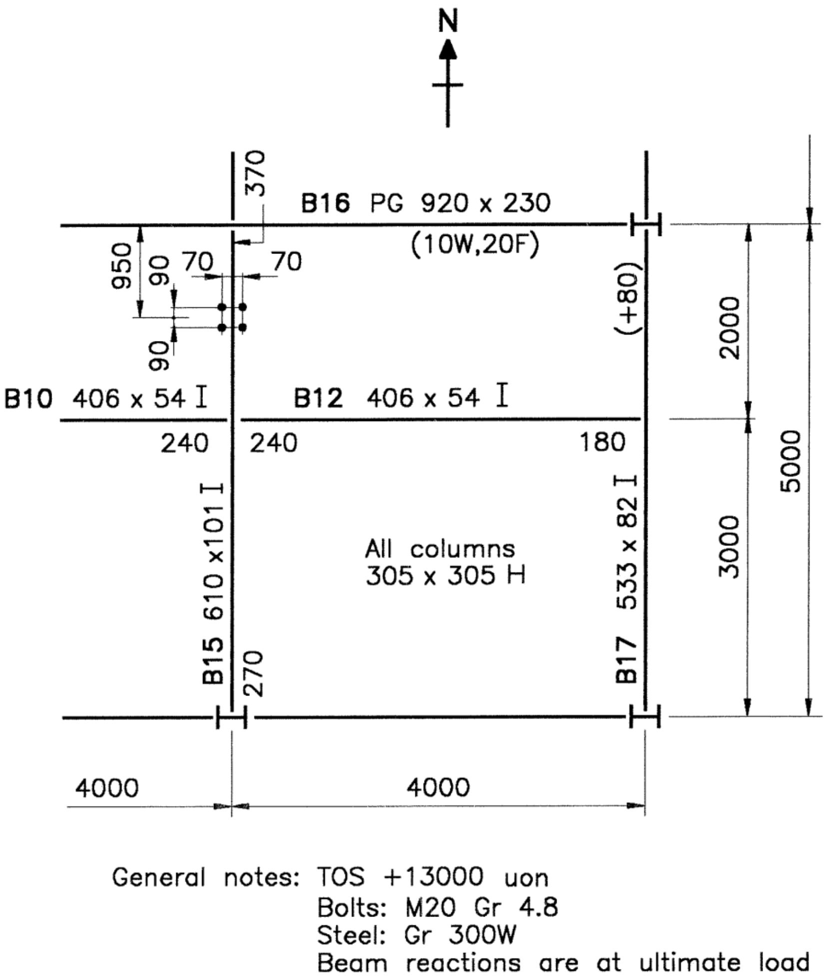


Figure 10.51 Partial floor layout

The selection procedure is given below and the actual details of the connections adopted are given on the final beam details in **Figure 10.52**.

Beam B15, north end

End reaction = 370 kN. Beam section = 610 x 229 x 101 I.
The tops of **B15** and **B16** are at the same level, therefore the top flange of **B15** will have to be notched to clear the flange of **B16**.

See **Table 10.22** Bolted double-angle beam connections.

In the column headed '1-Notch' select a connection for a 610 x 229 x 101 I having a resistance at least equal to 370 kN.

In this case, it is a ten-bolt connection (i.e. n = 5) having a resistance (governed by the bolts) of 379 kN. This exceeds the reaction of 370 Kn, so is satisfactory.

The bearing resistance of the bolts on the 10 mm web of the supporting beam B16 must now be checked. The force per bolt is 370/10 = 37 kN. The bearing resistance per bolt is 10 mm x 18,1 kN/mm = 181 kN, which is satisfactory.

Beam B15, south end

End reaction = 270 kN.

The beam end frames into the web of the 305 x 305 H column, so no notching of the beam flanges is necessary.

The end reaction is less than at the north end. Use the same size of angle cleat connection.

Connection of B10 and B12 to B15

End reaction from **B10** and **B12** = 240 kN each.

Beam sections = 406 x 178 x 54 I.

Steel: Grade 300W Bolts: Grade 4.8, M20

Beam section	Unnotched			1-Notch					2-Notch				
		Resistance			Resistance		Notch len. (mm)			Resistance		Notch len. (mm)	
	n	Bolts	Web V_r	n	Bolts	Web V_r	ℓ_1	ℓ_2	n	Bolts	Web V_r	ℓ_1	ℓ_2
I-Sections (cont.)													
406 × 178 × 75	3	227	407	3	227	336	263	213	3	227	336	186	136
	4	303	497	4	303	426	263	213	4	303	395	169	136
	5	379	577	5	379	483	254	213					
457 × 191 × 67	3	227	354	3	227	294	237	187	3	227	294	169	119
	4	303	435	4	303	373	237	187	4	303	373	169	119
	5	379	515	5	379	452	237	187	5	379	387	149	119
75	3	227	379	3	227	315	250	200	3	227	315	177	127
	4	303	466	4	303	400	250	200	4	303	400	177	127
	5	379	551	5	379	484	250	200	5	379	418	162	127
82	3	227	413	3	227	343	268	218	3	227	343	189	139
	4	303	507	4	303	435	268	218	4	303	435	189	139
	5	379	599	5	379	527	268	218	5	379	458	179	139
90	3	227	442	3	227	367	283	233	3	227	367	198	148
	4	303	543	4	303	466	283	233	4	303	466	198	148
	5	379	642	5	379	564	283	233	5	379	495	195	148
98	3	227	475	3	227	394	301	251	3	227	394	210	160
	4	303	584	4	303	501	301	251	4	303	501	210	160
	5	379	690	5	379	607	301	251	5	379	538	209	160
533 × 210 × 82	4	303	492	4	303	422	261	211	4	303	422	184	134
	5	379	581	5	379	511	261	211	5	379	511	184	134
	6	454	671	6	454	600	261	211	6	454	522	184	134
93	4	303	523	4	303	448	274	224	4	303	448	192	143
	5	379	618	5	379	543	274	224	5	379	543	192	143
	6	454	713	6	454	638	274	224	6	454	561	192	143
101	4	303	559	4	303	479	290	240	4	303	479	203	153
	5	379	660	5	379	580	290	240	5	379	580	203	153
	6	454	762	6	454	682	290	240	6	454	604	203	153
109	4	303	594	4	303	509	305	255	4	303	509	212	162
	5	379	702	5	379	618	305	255	5	379	618	212	162
	6	454	811	6	454	726	305	255	6	454	647	212	162
122	4	303	656	4	303	562	332	282	4	303	562	229	179
	5	379	775	5	379	681	332	282	5	379	681	229	179
	6	454	894	6	454	801	332	282	6	454	721	229	179
610 × 229 × 101	4	303	541	4	303	466	283	233	4	303	466	198	148
	5	379	642	5	379	564	283	233	5	379	564	198	148
	6	454	741	6	454	663	283	233	6	454	663	198	148
	7	530	839	7	530	762	283	233	7	530	670	198	148
113	4	303	571	4	303	492	296	246	4	303	492	207	157
	5	379	678	5	379	596	296	246	5	379	596	207	157
	6	454	783	6	454	701	296	246	6	454	701	207	157
	7	530	887	7	530	805	296	246	7	530	714	207	157

Table 10.22 Bolted double-angle beam connections

Select a 1-Notch connection for a 406 x 54 I with eight bolts (i.e. n = 4); this has a resistance of 303 kN (governed by the bolts). This exceeds the reaction of 240 Kn, so is satisfactory.

Checking the bearing resistance of the bolts in the web of **B15**, the force per bolt is 2 x 240/6 = 80 kN. The bearing resistance per bolt is 11,9mm x 18,1 kN/mm = 215 kN, which exceeds 80 kN.

The details of the end cleats to 815 are shown in **Figure 10.52** below**.**

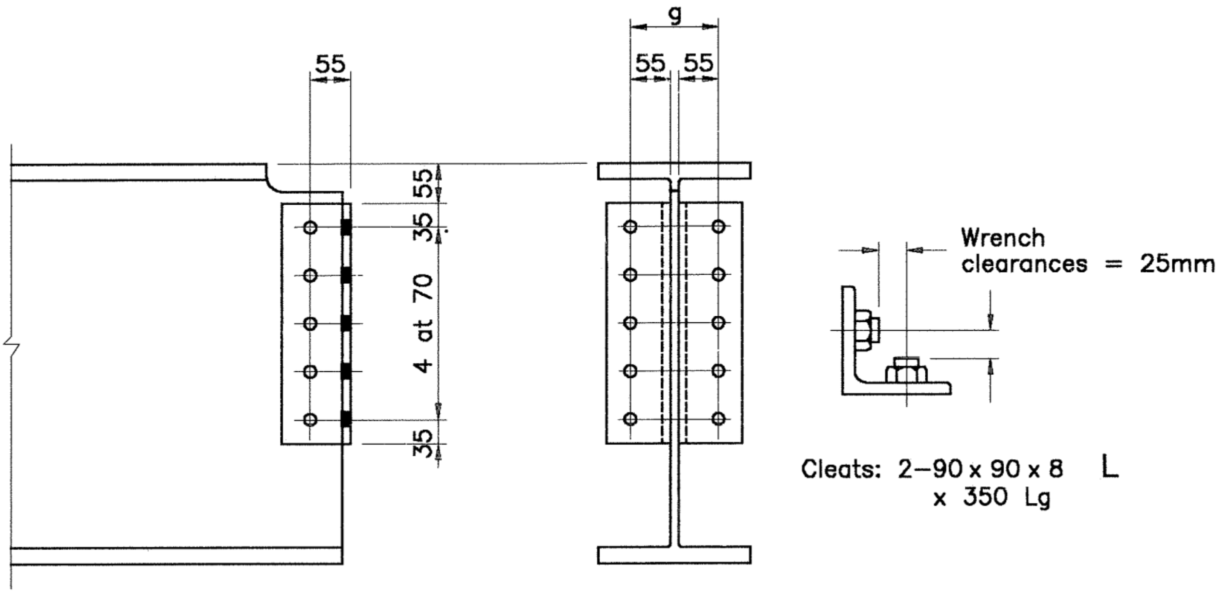


Figure 10.52 Beam **B15** - angle cleats

Comments on end connections

- The angle cleats will have the following particulars:

  Size : 90 x 90 8 L

  Bolt size : M20

  Hole diameter : 22 mm

  Pitch: 70 mm

  End distance : 35 mm, top and bottom

  Backmark : 55 mm in both legs

  Cross-centres of holes in supporting beam or column : 120 mm

- Note that the backmark is the same in both legs of each angle; this is to enable either leg of the angle to be attached to the beam web. The cross-centre distance, g, in the outstanding legs of the angles will vary slightly, depending on the thickness of the beam web between the two angles, but if g is made 120 mm in the supporting beam **B16** and the column web, the clearance between the bolts and the holes will allow for the small differences.

  The round dimension of 120 mm is chosen to simplify the holing in the supporting members.

- For both bolted angles and welded end plates the ratio of the cross-centre distance or gauge, g, to the thickness, t, of the angle or plate should lie within the limits of 10 and 18.

  A higher value of g/t will result in too flexible a connection, whereas a lower value will produce undue stiffness, that will not allow the beam end to rotate freely when under load and induce a moment into the connection. Thus for g = 120 mm the thickness of the cleats or plates should be 7 mm to 12 mm; in this case it is 8 mm.

- The depth of the connection, i.e. the length of the angles or the end plate, should be made at least half of the overall depth of the beam. This is partly for the sake of good appearance, but also to avoid an unduly small end connection in the case of beams having small end reactions.

  If extra length is required to meet this requirement, the bolt pitches can be increased. It is, however, preferable to maintain the standard pitch and to add extra rows of bolts.

- To facilitate erection, a clearance must be allowed between the face of the angle cleats and the face of the supporting members. The clearance usually allowed is 2 mm at each end of the beam, as shown in dimension, a, in **Figure 10.53** on the following page**.** Thus the beam is detailed with an overall length (i.e. over end cleats) equal to the clear distance between supports minus 4 mm.

- Furthermore, the end of the beam itself (i.e. the I-section) is set back from the outer face of the cleats. This is shown as dimension, d, in **Figure 10.53** on the following page**.**

  The usual allowance is 8 mm to 15 mm, but when necessary a minimum allowance of 5 mm is permitted. The net cut length of the beam section is then the clear distance between supports minus (a+ d) at each end.

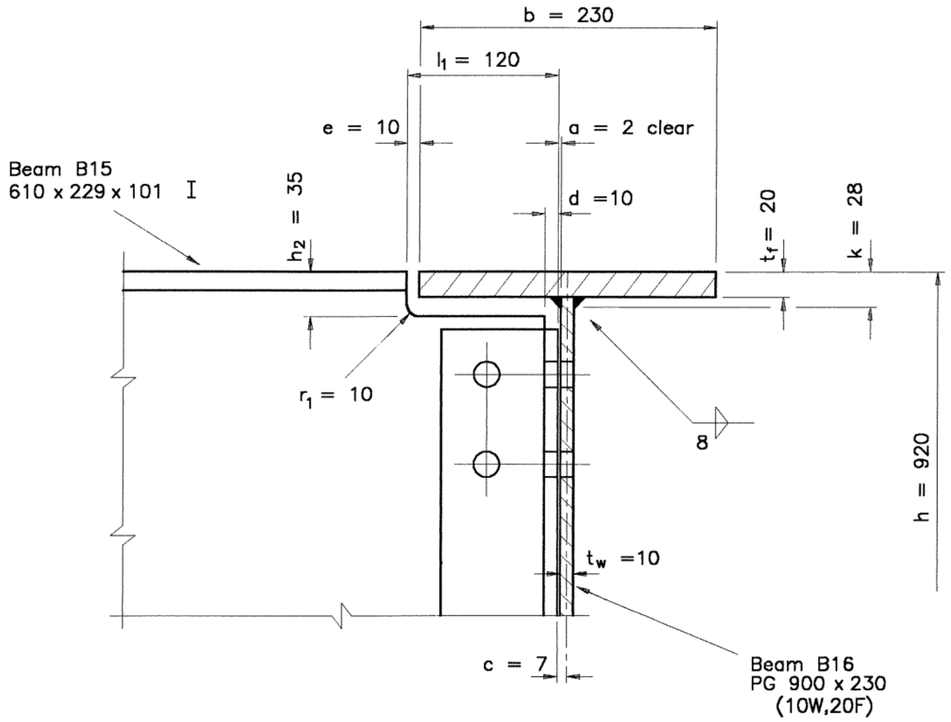


Figure 10.53 Top flange notch

Activity 10.1

1. Name three basic weld symbols.
2. What information can a welding symbol present?
3. Name the parts of a welding symbol.
4. Make a neat drawing of a welding symbol that shows all the welding-symbol elements.
5. What are supplementary symbols?
6. Make a neat drawing of the supplementary welding symbols.

Activity 10.2

Indicate whether the following statements are true or false. Choose the answer and write only 'true' or 'false' next to the question number (1–8) in your answer book.

1. Welding symbols are developed by the Institute of Welding.
2. The reference line of the welding symbol identifies the side of the joint to be welded.
3. Weld symbols with a vertical line always show the vertical line on the right side.
4. If no length dimension is specified on the welding symbol, the welder may make the weld any length desired.
5. Welding and allied processes are abbreviated in the tail with letter

designations.
6. The melt-through symbol is a supplementary symbol.
7. The arrow of the welding symbol always points to the joint member to be prepared if edge preparation is indicated.
8. Brazing symbols are similar to welding symbols.

Activity 10.3

Four options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the question number (1–3) in your answer book.

1. The site-weld symbol is a supplementary symbol indicated by a ________.

A triangular shape
B black dot
C circle
D semi-circle

2. The arrow of the welding symbol identifies the ________ where the welding operation is to be performed.

A location
B position
C Both A and B
D Neither A nor B

3. The fillet-weld symbol is indicated on the reference line by a ________ on the opposite side of a groove weld.

A triangle
B circle
C square
D rectangle

Activity 10.4

Complete the table below by means of a drawing that matches each description. Write only the question number (1–8) next to your drawing in your answer book.

Description	Drawing	Description	Drawing
1. V-groove weld with a flat contour		5. Slot weld	
2. Fillet weld		6. Seam weld	
3. Fillet weld on		7. Stud weld	

the other side			
4. Site weld		8. Square-groove weld on the arrow side.	

Activity 10.5

Indicate whether the following statements are true or false. Choose the answer and write only ‘true’ or ‘false’ next to the question number (1–12) in your answer book.

1. Joint penetration and the strength of the filler metal determine the strength of a weld joint.
2. A butt joint is generally stronger than a lap joint.
3. The weld type is shown on detail drawings by the description of the object.
4. The weld toe is the intersection of the base metal and the weld face.
5. A fillet weld without additional information positions the joint members at 90°.
6. Slot welds are stronger than plug welds.
7. Back welds are deposited before the weld on the opposite side of the part.
8. Edge joints are commonly used to join support structures and short lengths of structural steel.
9. The weld root is the exposed surface of the weld.
10. Fillet welds are the most popular type of weld.
11. Flange welds are commonly made on material over 150 mm thick.
12. Surfacing welds are commonly used to build up worn parts.

Activity 10.6

Four options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the question number (1–7) in your answer book.

1. ________ metal is the material to be welded.

A Filler
B Base
C Both A and B
D Neither A nor B

2. A fillet weld is a weld type in the cross-sectional shape of a ________.

A square
B circle

C triangle
D rectangle

3. A plug weld is a weld type in the cross-sectional shape of a ________.
A butt
B lap
C edge
D corner

4. Surfacing welds are commonly used for ________.
A joining two edges together
B appearance over the weld
C increasing the thickness of a part
D None of the above

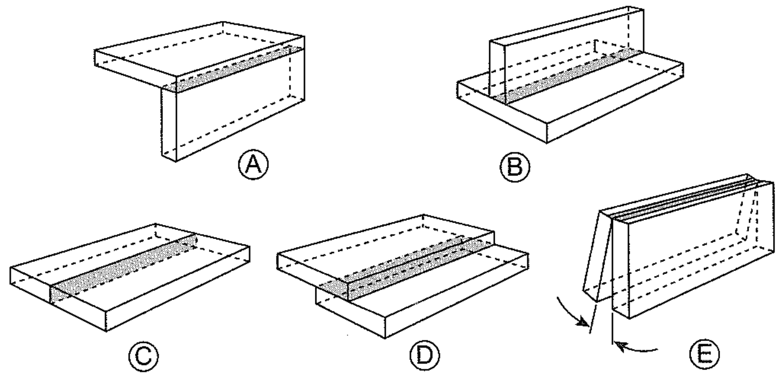
5. ________ reinforcement is filler material that extends above the surface of the joint member on the side of the joint on which welding was done.
A Face
B Root
C Crown
D None of the above

6. Joint penetration in a groove weld is determined by the distance between the joint members and the joint ________.
A thickness
B edge preparation
C Both A and B
D Neither A nor B

7. Lap joints are commonly welded on ________.
A one side
B both sides
C all surfaces
D None of the above

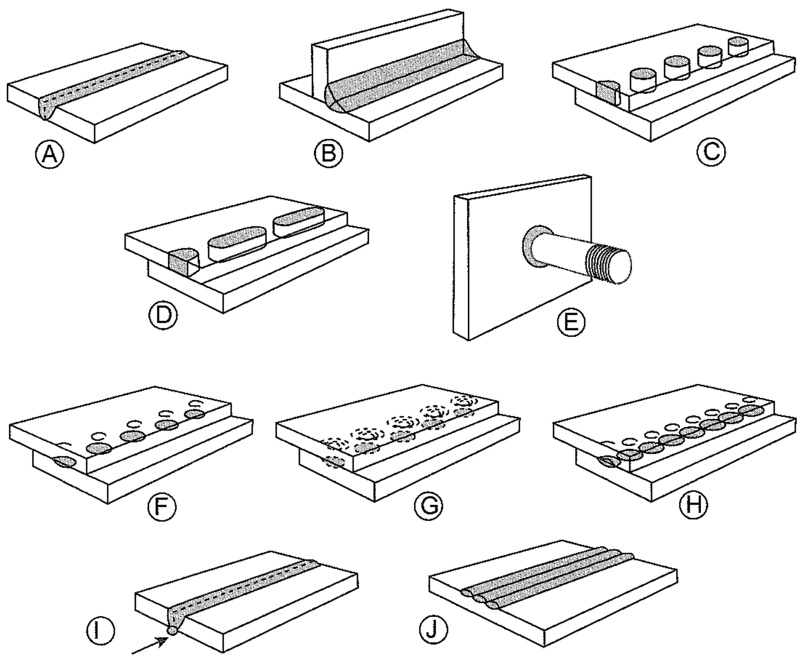
Activity 10.7

Match the weld joints in Column A with the drawings in Column B. Write only the letter (A–E) of the correct drawing next to the question number (1–5) in your answer book.

Column A	Column B
1. T-joint	
2. Edge joint	
3. Lap joint	
4. Corner joint	
5. Butt joint	

Activity 10.8

Match the weld types in Column A with the drawings in Column B. Write only the letter (A–J) of the correct drawing next to the question number (1–10) in your answer book.

Column A	Column B
1. Back weld	
2. Seam	
3. Fillet	
4. Slot	
5. Stud	
6. Plug	
7. Groove	
8. Projection	
9. Spot	
10. Surfacing	

Activity 10.9

1. Indicate whether the following statements are true or false. Choose the answer and write only 'true' or 'false' next to the question number (1.1–1. 5) in your answer book.

1.1 The abbreviation SANS stands for South African Neutral Standards.
1.2 A butt joint is a type of plumbing pipe joint.
1.3 The root surface is the surface of the weld on the opposite side of the joint on which welding was done.
1.4 A triangle is a four-sided plane figure.
1.5 The base metal is the material that is to be welded.

2. Three options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–C) next to the question number (2.1–2.3) in your answer book.
2.1 A corner-joint weld is a weld joint formed when the edges of __________ joint members are joined.
A two
B three
C four

2.2 Fusion is the __________ together of filler metal and base metal.
A crushing
B melting
C dissolving

2.3 A flange weld is a weld type of light-gauge metal with one or both of the joint members bent at approximately:

A 45°.
B 60°.
C 90°.

3. Define the following terms:

3.1 symbol
3.2 weld
3.3 concave
3.4 filler

4. Name two types of welding joints.

5. Explain the following:

5.1 Explain the difference between plug welds and slot welds, and list their

uses in welding.
5.2 Explain what a welding symbol is.

Activity 10.10

Indicate whether the following statements are true or false. Choose the answer and write only 'true' or 'false' next to the question number (1–10) in your answer book.

1. Most fabricators prefer to use welding for shop connections, but where workshops are equipped with automated punching and drilling machines, shop bolting is generally found to be quicker and cheaper.
2. Welding is only undertaken on site in very special circumstances in view of the higher cost and greater inconvenience.
3. Today, bolts and welding are mostly used to make connections, with riveted connections being virtually obsolete.
4. The function of a bolt is to attach one member or component to another without transmitting a force from that member or component to the other.
5. All bolts have hexagonal heads and nuts, and parallel shanks with threads cut or rolled into them.
6. Bolts are designated by size (in other words, the nominal diameter of the shank and thread) and by length (that is, the total length of the shank, including thread, up to the underside of the head).
7. Heating or welding a commercial bolt will cause no significant change in its properties, but both processes will cause a significant degradation in the mechanical properties of high-strength structural bolts.
8. Commercial bolts are made of low-carbon steel with mechanical properties similar to that of Grade 250 material.
9. Ordinary bolts (Grade 4.6) are not used for the great majority of connections.
10. Precision bolts (Grade 8.8) have a much higher strength grading and are manufactured to a closer dimensional tolerance than ordinary bolts.

Activity 10.11

1. Identify different types of bolts used in structural steelwork connections.
2. List the three most commonly used bolts in structural steelwork connections.
3. Describe the uses of different bolts.
4. What is a high-strength friction-grip bolt (HSFG bolt)?

Activity 10.12

1. **Figure 10.54** below shows a pictorial view of a built-up purlin cleat. The bolts and nuts have been omitted. Make full-size drawings (scale of 1:1) in third-angle orthographic projection of the following views with the bolts and nuts secured in position:

- a full-sectional front view with bolt heads on the outside and the nuts on the inside
- a right view

Insert all the dimensions

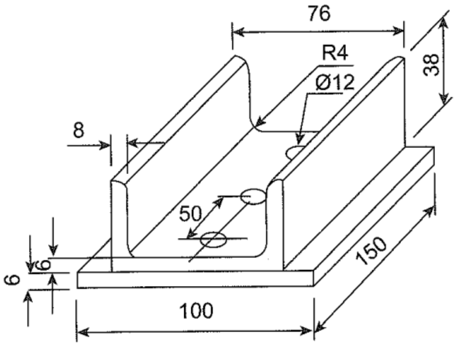


Figure 10.54 Pictorial view of a built-up purlin cleat

2. **Figure 10.55** shows a built-up cleat used on a roof construction. Draw the given view freehand and full size (scale of 1:1). Show the bolt head on the right side and the nut on the left-hand side of the upright. At the base, show the bolt head on the top and the nut below. Insert all the dimensions.

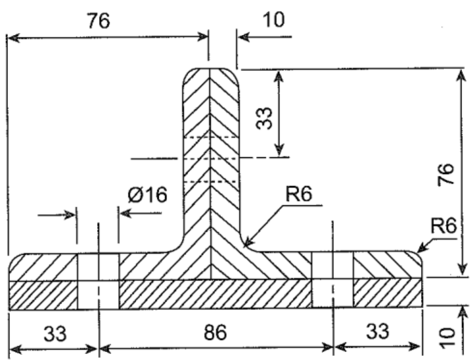


Figure 10.55 Built-up cleat

3. Use a scale of 1:1 and copy the given front view of the built-up beam profile as shown in **Figure 10.56**. At the top of the beam, show the bolt heads. Show the nuts on both sides and at the base of the beam. Insert all the dimensions.

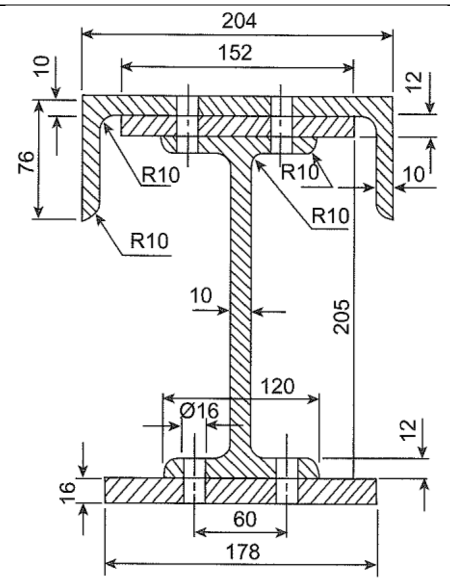


Figure 10.56 Built-up beam profile

Activity 10.13

Figure 10.57 shows a plan layout of a steelwork floor for a small factory.

Draw to scale 1:20, a general arrangement of the steelwork floor.

It is expected of you to show the following:

- Main centre lines;
- Columns in section;
- Flange widths;
- End reactions;
- Dimensions;
- Tile and scale;
- Section size of each beam and column;
- True north;
- A separate piece mark for each item on the floor.

Specifications:

- Beams, B1 to B6 = I-section 254 x 146 x 31 kg/m.
- Beams, B7 to B11 = I-section 356 x 171 x 45 kg/m.
- Beam B9 = I-section 305 x 165 x 40 kg/m.
- All columns = H-section 305 x 305 x 97 kg/m.
- All end plates = 10mm thick.
- All bolts = M20 black bolts.
- All figures in brackets represent end-loads of beams in kN
- All welds to be 6 mm continues fillet weld.

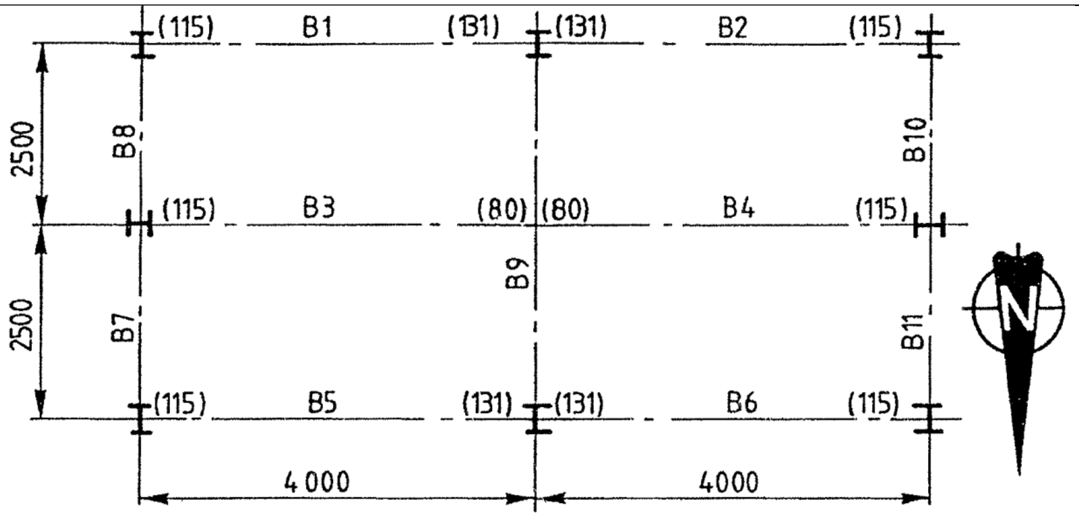


Figure 10.57 Plan layout of a steelwork floor for a small factory

Activity 10.14

Four options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the question number (1–8) in your answer book.

1. The ability of a bolt to transfer an applied force, in other words, its ability to withstand this force, is called its ________.
A area
B resistance
C strength
D tension

2. The resistance of bolts is dependent on the ________ over which the force is applied.
A area
B surface
C A and B
D Neither A nor B

3. The resistance of bolts is dependent on the ________ of the bolt material.
A cross-sectional area
B strength
C thread
D Neither A, B nor C

4. The resistance of bolts is dependent on the ________, which allows for variability of material properties, workmanship and so on that might be

present in any connection and that might have a detrimental effect on its performance.
A resistance factor
B stress factor
C A and B
D Neither A or B

5. HSFG bolts are used where a ________ connection is required under shear loading, in other words, loading in the plane of the connected parts and at right angles to the bolt axes.
A slip-resistant
B non-slip resistance
C friction-resistant
D Neither A, B nor C

6. In all bolted connections, a ________ is involved.
A transfer of force
B transfer of load
C A and B
D Neither A nor B

7. The plate and the flange through which the bolts pass are relatively ________, so these elements will not bend under the tensile load.
A thick
B thin
C hard
D soft

8. It is necessary for the steelwork detailer to have a clear understanding of how bolts work and to be able to select a suitable group of bolts to ________ specified on the engineer's drawings.
A transmit the forces
B transmit loads
C A and B
D Neither A nor B

Activity 10.15

1. Indicate whether the following statements are true or false. Choose the answer and write only 'true' or 'false' next to the question number (1.1–1.5) in your answer book.

1.1 The abbreviation 'Mpa' is a metric unit of measurement used to measure weight.

1.2 There are three main commonly used bolts in civil and structural detailing.

1.3 M48 is a type of holding-down bolt.

1.4 Precision bolts have a grade rating of 10.2.

1.5 The shaft of a bolt is called the shank.

2. Three options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–C) next to the question number (2.1–2.3) in your answer book.

2.1 The Class 4.8 ordinary bolt is used in:

A shear or bearing.
B shear or bearing and direct tension.
C shear or bearing, friction-gripping and direct tension.

2.2 Commercial bolts are made from:

A low-carbon steel.
B low-carbon aluminium.
C low-carbon iron.

2.3 Bolt holes usually have a diameter ________ larger than the bolt shank diameter for sizes up to 24 mm diameter.

A 2 mm
B 3 mm
C 4 mm

3. Define the following terms:

3.1 force

3.2 HSFG bolt

3.3 shank

3.4 load

4. Name two HSFG bolts.
5. Explain the steps to follow when constructing a detailed drawing of a structural steel bolt.
6. Name one common friction-grip fastener used in South Africa.

Self-Check		
I am able to:	**Yes**	**No**
• Identify welding symbols		
• Identify types of bolts and rivets		
• Describe column bases and column caps for		
o universal columns		
o columns with lattice beams		
• Explain intersections at		
o Beams and columns		
o Beams and beams		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Past Examination Papers

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NOVEMBER 2009

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N4

(**4090034**)

23 November (X-Paper)
09:00 – 13:00

This question paper consists of 4 pages and a diagram sheet

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.

2. Read ALL the questions carefully.

3. Number the answers correctly according to the numbering system used in this question paper.

4. Write neatly and legibly.

QUESTION 1

1.1 Draw to scale 1:10, the front view of a two-ring rough segmental arch. The arch spans 1 200mmand the rise is one-sixth of the span. Half of the brickwork in the arch must be show with only the construction method clearly illustrated in the remaining half of the arch. No surrounding brick need to be shown. (15)

1.2 Describe the purpose of a wall plate. (3)

1.3 State TWO advantages of using clear sheet glass. (2)

[20]

QUESTION 2

Your father is a do-it-yourself (D.I.Y) fanatic. He wants to build in a steel door frame which will take him more than one day to finish

Explain or describe to him how to do the following.

2.1 Briefly explain or describe how he would set up a steel door frame in position to ensure that it is plumb-level and in line with the wall State also how he will secure it temporarily in position until it is built. (5)

2.2 By means of drawing, explain to him the TWO ways of later joining unfinished brickwork (raking back and toothing):

2.2.1 Raking Back. (3)

2.2.2 Toothing. (3)

2.3 Draw to scale 1:5, a vertical section through a door opening with a double-rebated steel door frame suitable for a one-and -a-half brick wall. Include dimensions and label the drawing. (9)

[20]

QUESTION 3

3.1 Your father is thinking of building an arch between the dining room and the kitchen at your house. He does not know how to temporarily support the arch structure while he is busy building.

Show him by means of a drawing and name ALL the components of a temporary structure that he can use (telescopic metal struts). (15)

3.2 Draw to scale 1:10, the alternate plan courses of a T-junction, built in English bond, with two-brick external wall and a one-and-a-half brick internal wall, approximately 1 000mm and 660mm in length respectively. No stopped ends need to be shown. (10)

[25]

QUESTION 4
A steel roof truss is built to 50mm x 50mm x 5mm angle iron sections and 5mm thick gusset plates.

Draw to scale 1:20, a detailed elevation at the riveted connections and show the following positions.

4.1 Where a strut forms a 90^{o} to the rafter.

4.2 Where TWO struts are connected to the tie beam (each forms a 60^{o} angle to the tie beam) at the same point on the tie beam. **[10]**

QUESTION 5
FIGURE 1, DIAGRAM SHEET (attached), shows an isometric view of a welded construction column beam cleat. The cleat plate and cleat site plate must be welded in the workshop by means of a half-round arc weld. The cleat side plate is welded to the H-profile (parallel flange) 254mm x 254mm x 88.9kg/m column all around with corner fillet with leg length of 8mm x 8mm

Draw the following to scale 1:10:

5.1 The view of the column beam cleat indicate by arrow 'F'. (10)

5.2 The top view. (10)

Insert ALL the dimensions and appropriate welding symbols.

[15]

TOTAL: 100

DIAGRAM SHEET

QUESTION 5

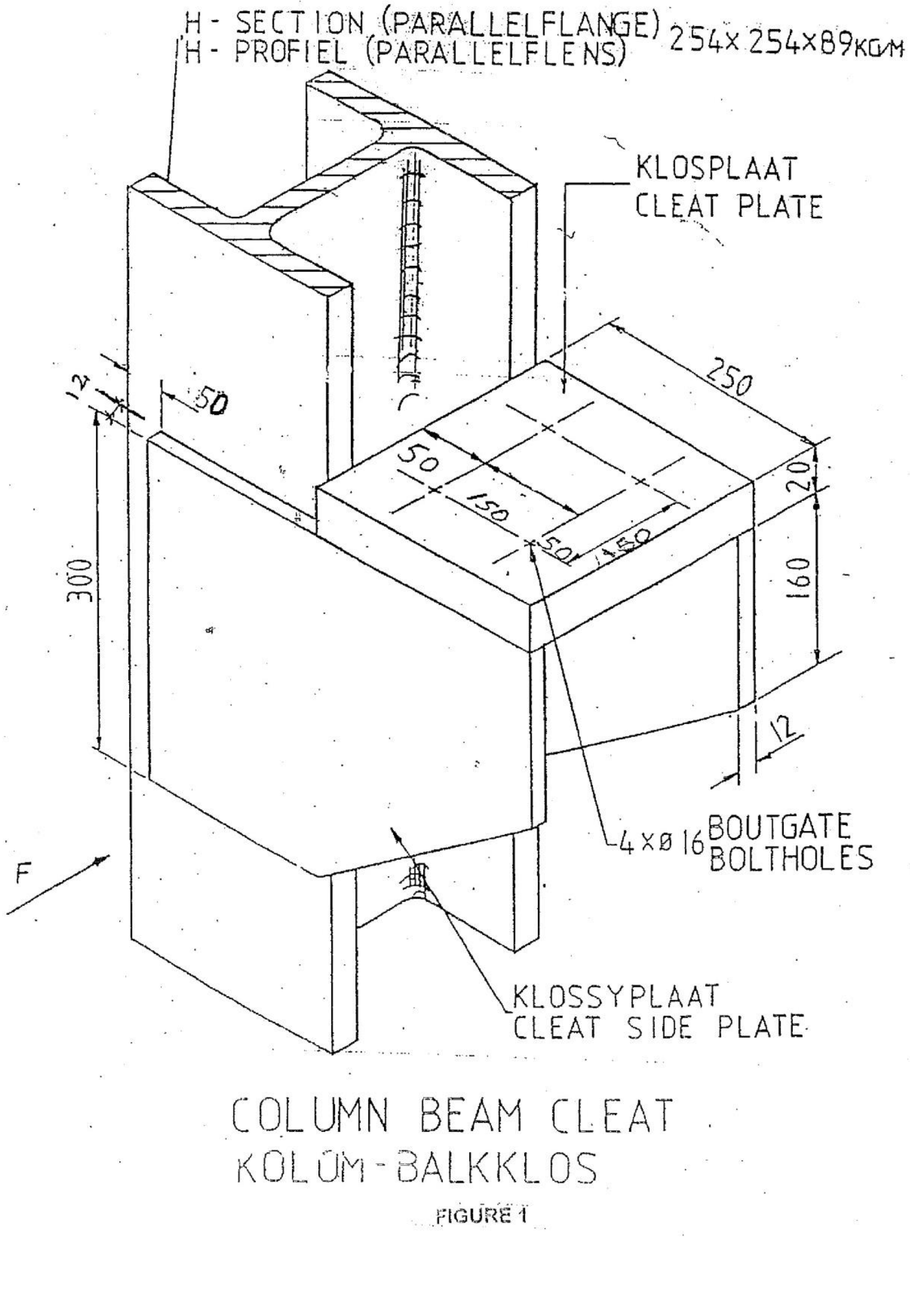


FIGURE 1

Marking Guidelines

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

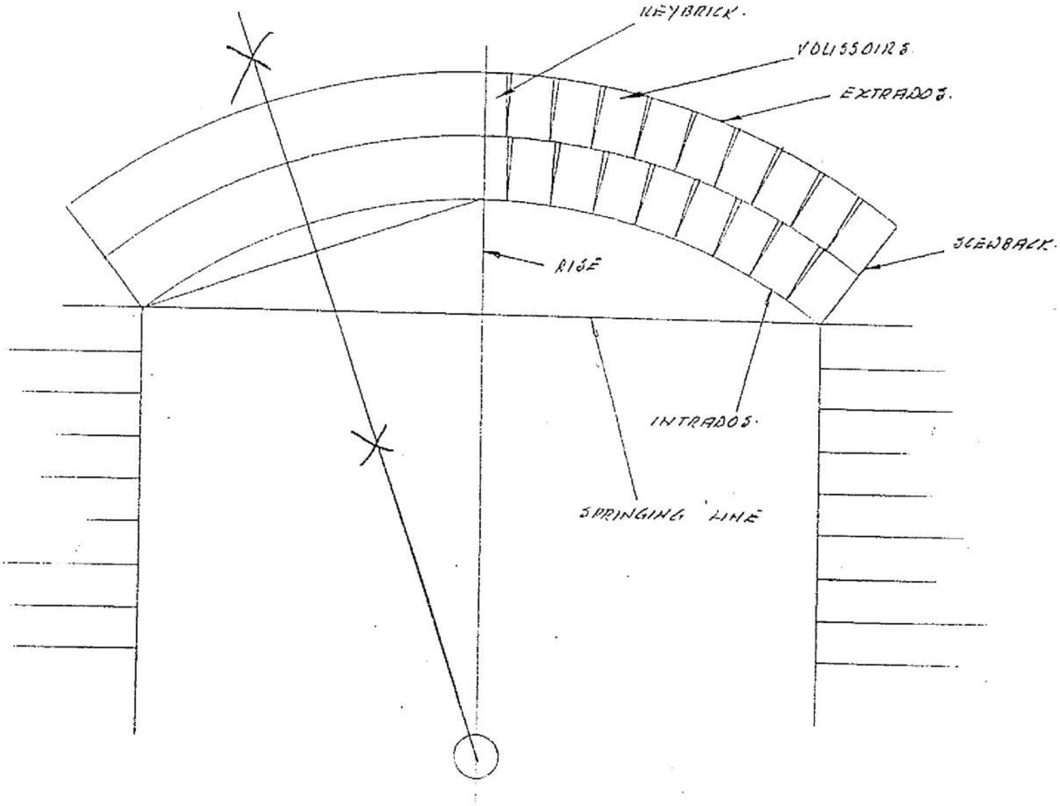
NOVEMBER 2009

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N4

(4090034)

QUESTION 1



<u>Segmental Arch</u>
<u>Scale1:10</u>

(15)

1.2

1.2.1 The purpose of a wall plate is to insure an even distribution of the force acting on the wall, due to roof construction. (3)

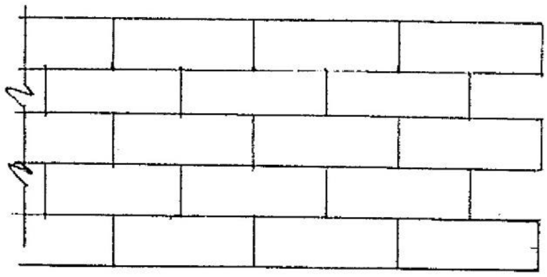
1.2.2 Advantage of clear sheet glass,(a)cheap (b) easy to cut (2)

QUESTION 2

2.1 The frame is to be place in line with the brickwork, with bottom propped to allow for D.P.C and window sill, and checked for plumb and level, by means of a spirit level at the top and at both sides for any possible twist in the frame. The frame must be checked for squareness and symmetry. (5)

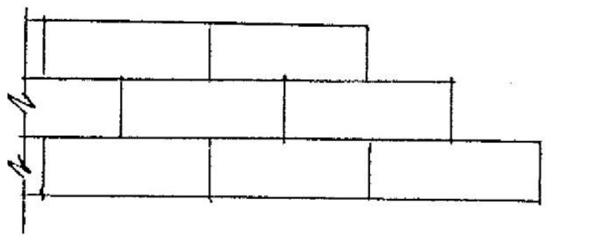
2.2 Costing: The science of investigating, calculating.

2.2.1



Toothing (3)

2.2.2



Racking Back

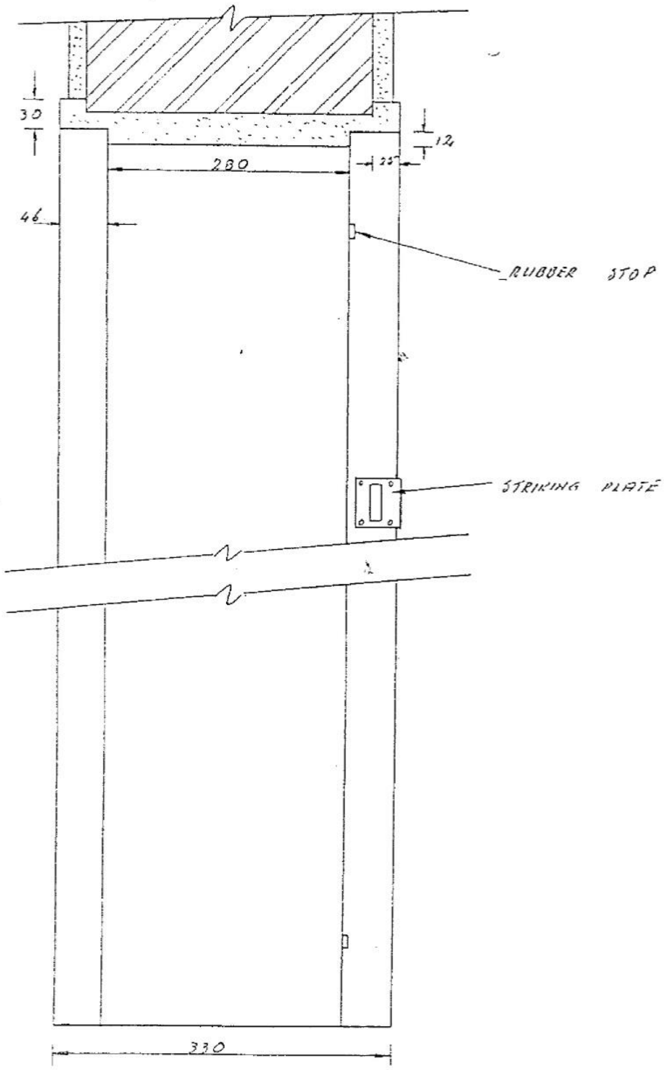
(3)

[10]

2.2.1 Toothing is done when provision must be made for a completed wall to be extended at a
Builders who specialize in alteration and extensions normally find work by this manner. (2)

2.2.2 Raking back is done when a straight piece of wall is built halfway from its end, so that the remainder piece can join into the existing and the bond maintained.

2.3

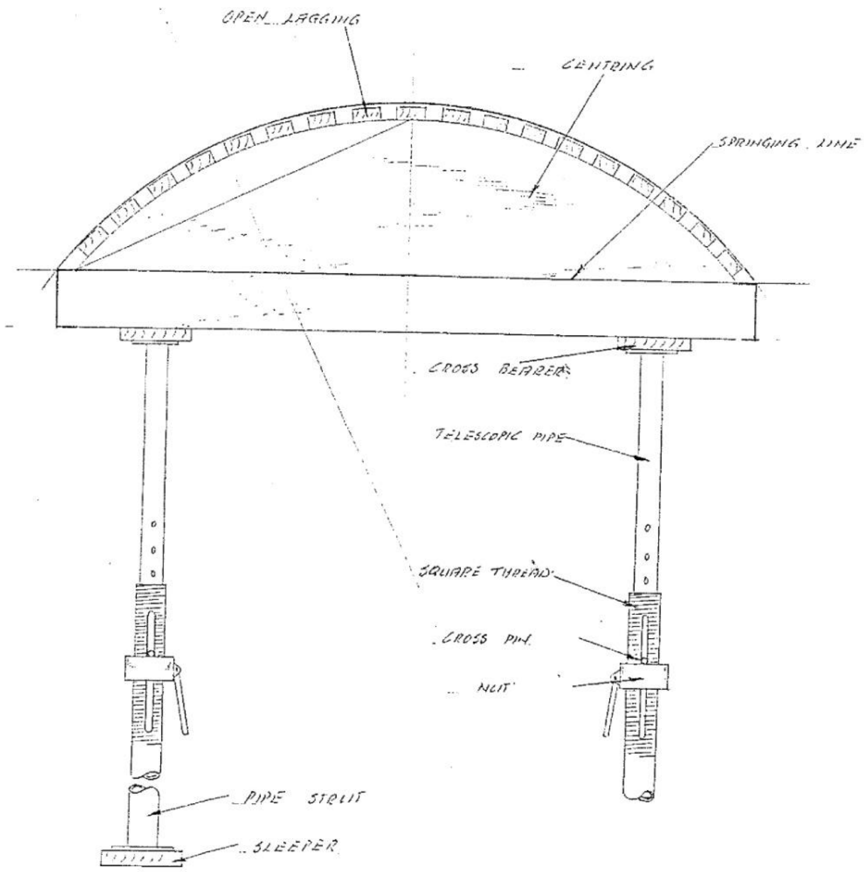


STEEL DOOR FRAME

(11)

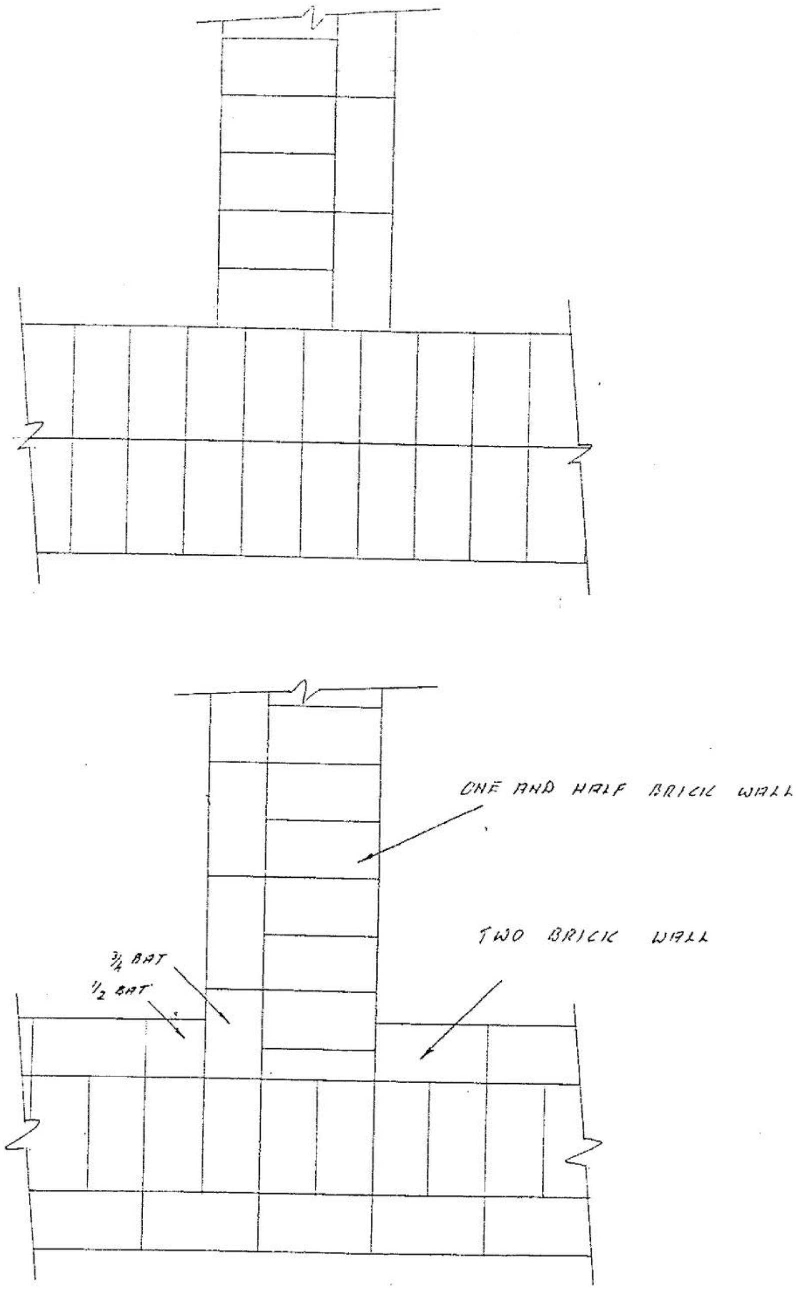
QUESTION 3

3.1



CENTERING FOR ARCH
SCALE 1:10

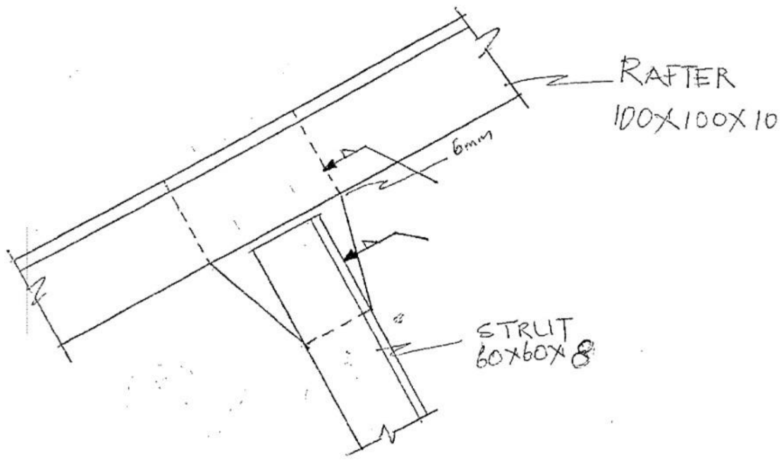
3.2



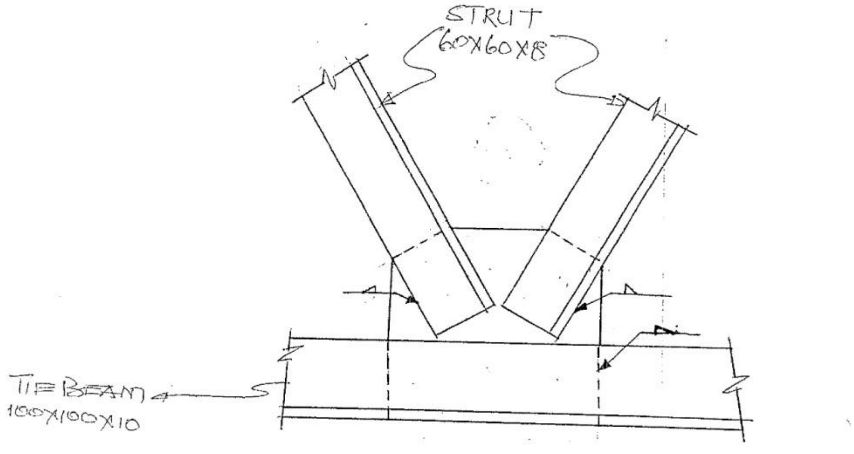
T JUNCTION ENGLISH BOND
SCALE 1:10

QUESTION 4

4.1

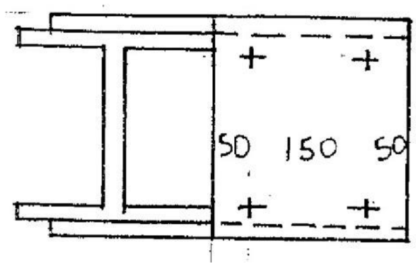


4.2



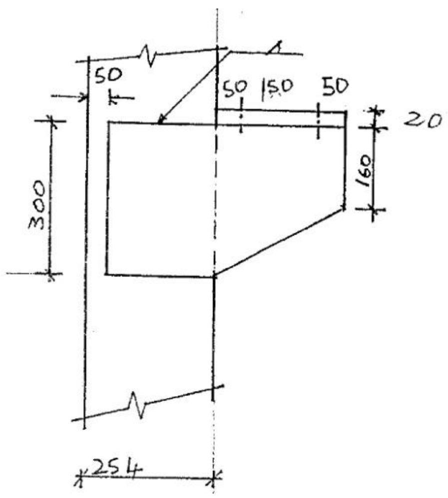
QUESTION 5

5.1 Top View
Scale1:10



(10)

5.2 Front View
Scale 1:10



(10)

TOTAL: 100

Past Examination Papers

higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NOVEMBER 2011

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N4

(4090034)

21 November (X-Paper)
09:00 – 13:00

REQUIREMENTS: ONE A2 drawing paper
Standard hot-rolled structural steel section tables
(BOE8/2)

This question paper consists of 4pages

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers correctly according to the numbering system used in this question paper.
4. ALL the calculations must fulfill the new building regulations
5. ALL the calculations must be shown.
6 Refer to the code reference.
7. 100 marks:100%
8. Write neatly and legibly.

QUESTION 1

The roof covering consists of IBR roof sheeting and a galvanized ridge plate. The roof has a 300mm overhang and is finished off with a square gutter and Ø 75mm water downpipe. It is supported by a 220 mm external wall.
Draw to scale 1:10 a cross section through the eaves and external wall. Use the specifications below:

SPECIFICATIONS:

– Roof covering.	IBR roof sheeting .
– Roof gradient.	30^0 .
– Rafters and tie beams .	114mm x 38mm and 38mm x 38 mm respectively.
– Roof overhang.	500 mm open eaves.
– Fascia boards.	220 x 12 mm fibre cement.

[20]

Question 2

Draw to scale 1:5, an elevation of the foot of a 16 m steel roof truss constructed of 70mm x 70 mm angle iron rafters and tie beams with 80 mm x 60 mm angle iron cleats and 12 mm thick gusset plates. Indicate the positions of the holes to receive mild steel bolts.

[20]

Question 3

Draw to scale 1:10, a front view of a two-ringed rough segmental arch. the arch spans 1 200mm and the rise is one-sixth of the span.
Only half of the brickwork in the arch must be shown with the construction method clearly illustrate in the remaining half of the arch.
NO surrounding brick work needs to be shown.

[10]

Question 4

Draw to scale 1:2 a vertical section through only a bottom section of a steel casement window, set in a one brick face brick wall, plastered on the inside with quarry tile sill and terrazzo window board.
Clearly show the damp-proof course below the frame and also a portion of the clear sheet glass with putty in the steel frame.

[15]

QUESTION 5

5.1 Briefly explain how to set u a steel door frame in position to ensure that it is plum-level and in line with the all. State also how to secure it temporarily in position until it is built. (5)

5.2 By means of sketches not to scale, explain or describe the following TWO ways of later joining unfinished brickwork: (2)

5.2.1 Toothing. (2)

5.2.2 Racking back (3)

[20]

Draw to scale 1:5, a vertical section through a door opening with a double-rebated steel door frame suitable for a one-and-half brick wall Include ALL dimension and label the drawing. (10)

[20]

QUESTION 6

Draw to scale 1:5, a vertical section through the top end of a 26^0 lean-to roof built against a brick wall. Show a 114mm x 38mm rafter supported by a 114 mm x 76 mm wall plate bolted to the wall.

Show the galvanized apron and under flashing for the corrugated roof covering on 51mm x 76mm purlins as well. **[10]**

TOTAL: 100

Marking Guidelines

higher education & training

Department: Higher Education and Training REPUBLIC OF SOUTH AFRICA

NOVEMBER 2011

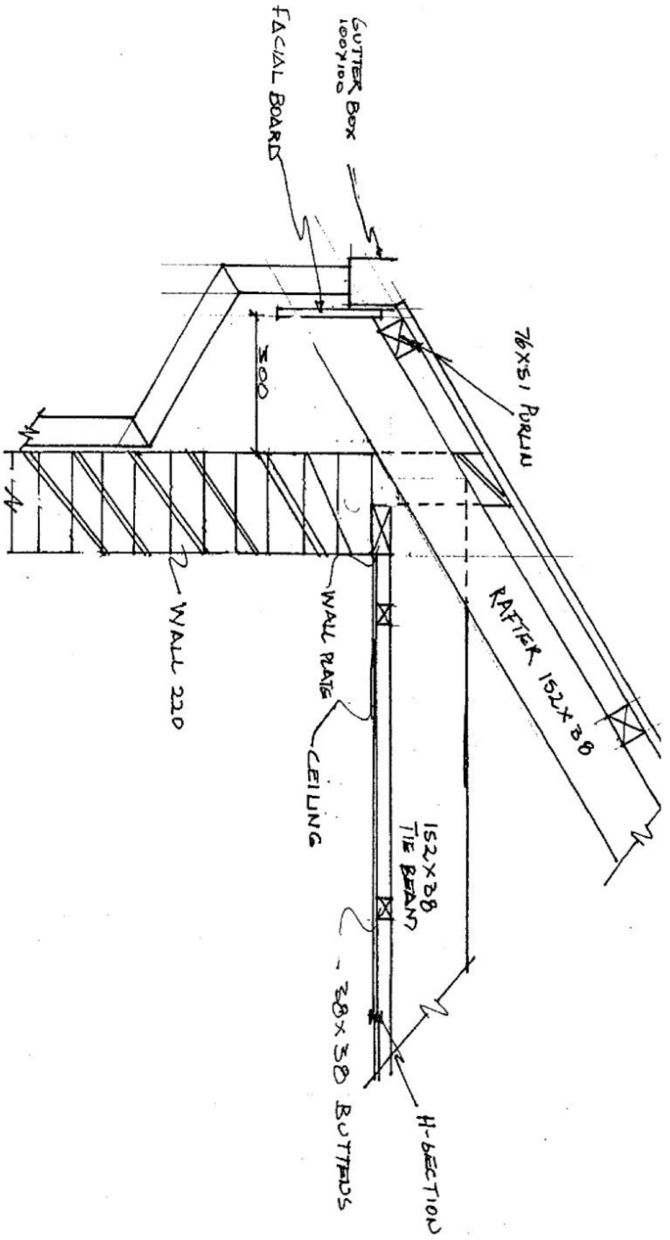
NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N4

(4090034)

QUESTION 1

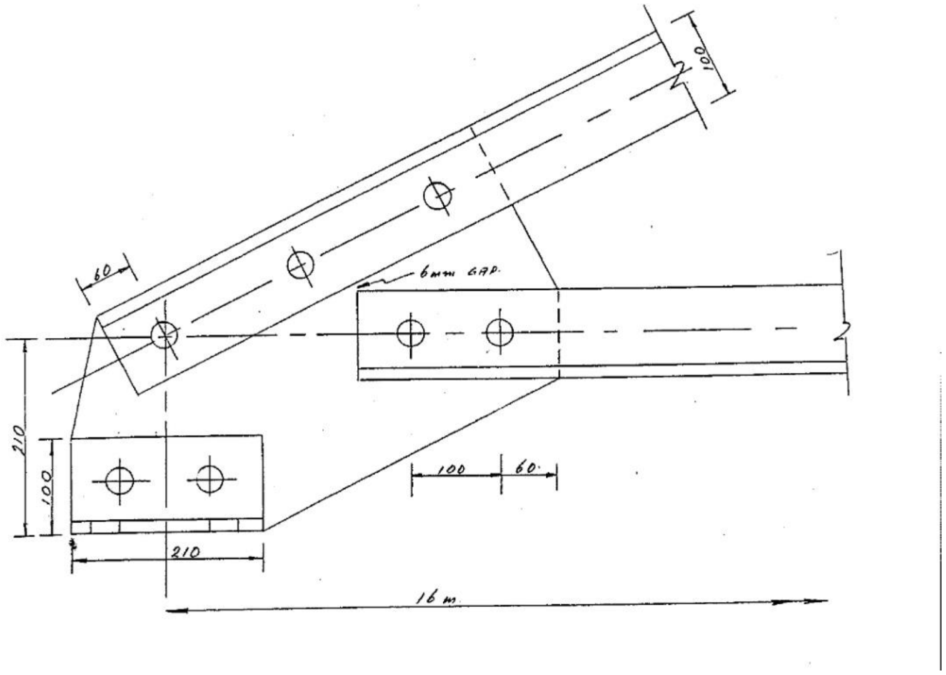
1.1



[20]

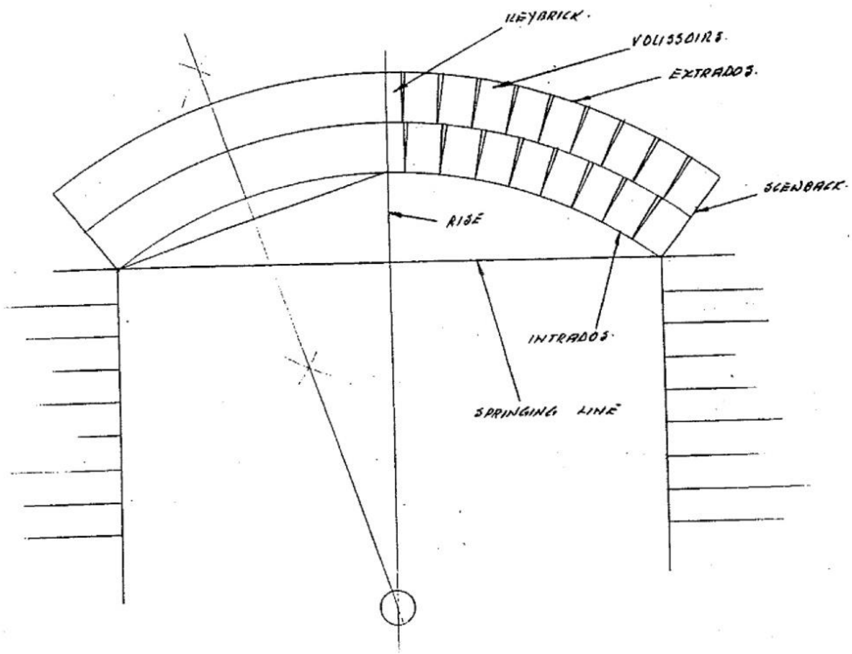
QUESTION 2

(5)



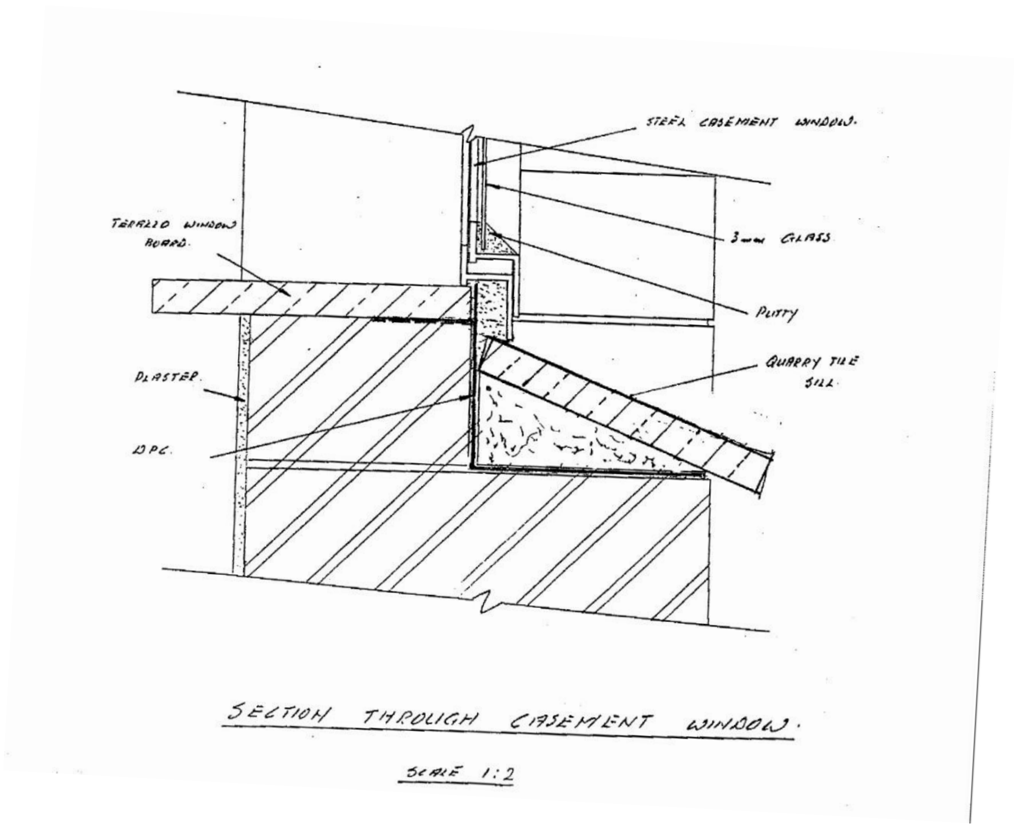
STEEL ROOF TRUSS
SCALE 1:5

QUESTION 3



SEGMENTAL ARCH
SCALE 1:10

QUESTION 4



QUESTION 5

5.1 Building in steel door frame

a. The door frame is set upright in position on top of the d.p.c

b. It is secured in position with temporary supports.

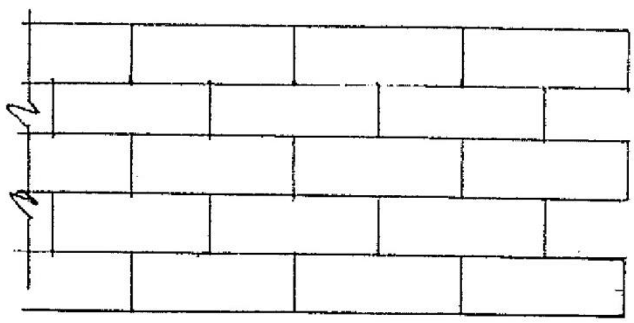
c. The correct height is adjusted b y means of wedges.

d. Set the frame level and plumb.

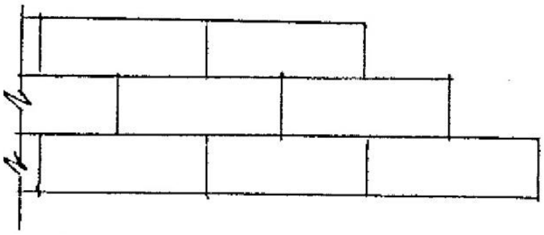
e. Lugs are then build in.

5.2

5.2.1 Toothing is done when provision must be made for a completed wall to be extended at a later stage.

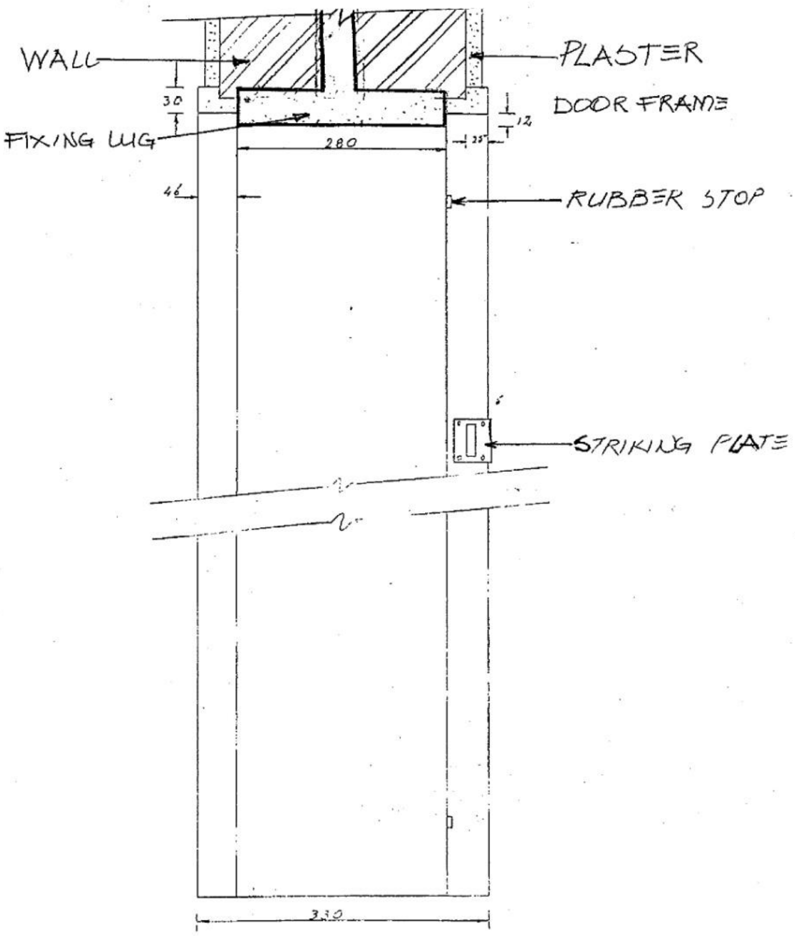


5.2.2 Racking back is done when a straight piece of wall is built halfway from its end, so that the remainder piece can join into the existing bond maintained



Draw to scale 1:5, a vertical section through a door opening with a double-rebated steel door frame suitable for a one-and-half brick wall Include ALL dimension and label the drawing.

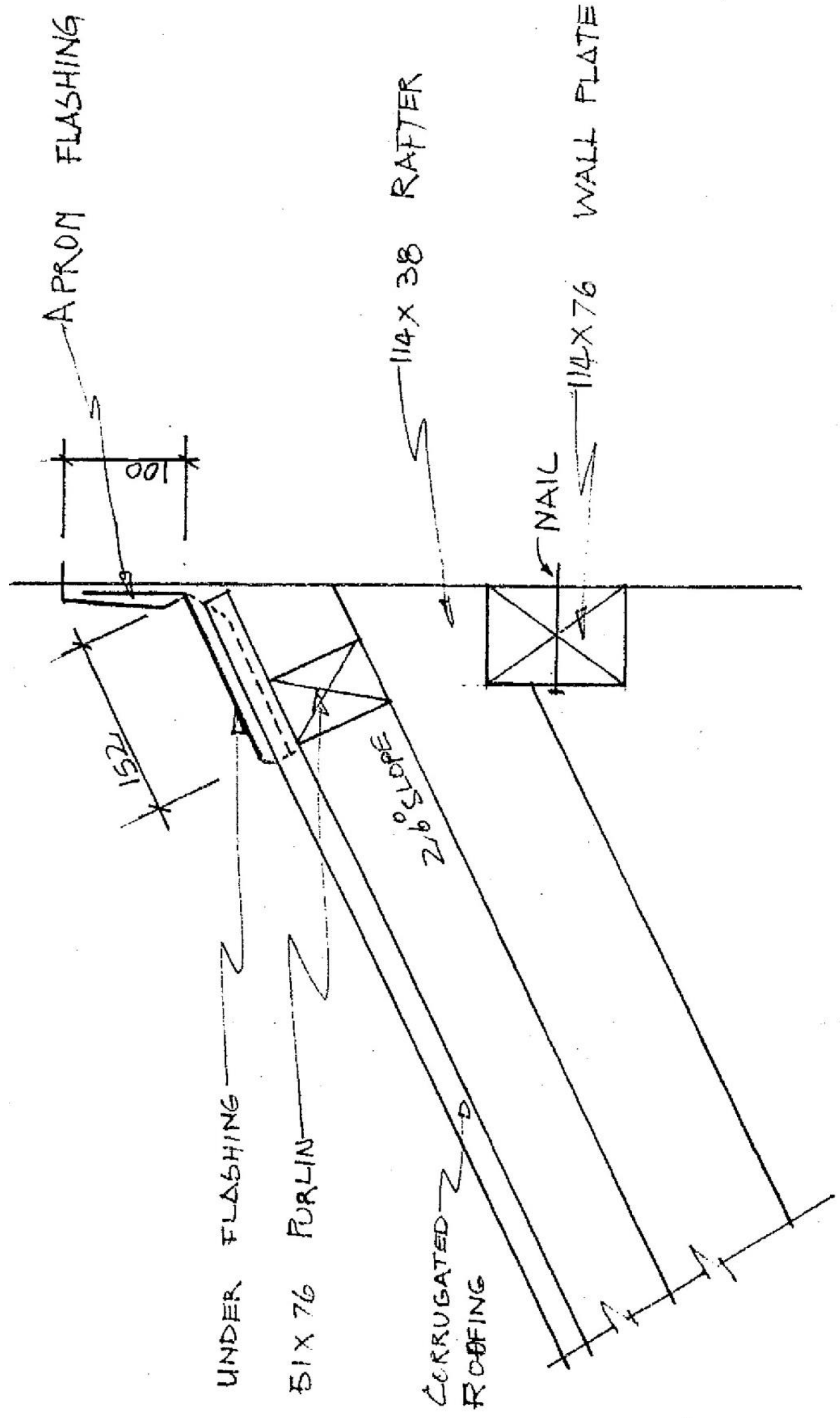
5.3



STEEL DOOR FRAME
SCALE1:5

QUESTION 6

[5]


APRON FLASHING
100
114 x 38 RAFTER
114 x 76 WALL PLATE
NAIL
152
26° SLOPE
UNDER FLASHING
51 x 76 PURLIN
CORRUGATED ROOFING

Past Examination Papers

higher education & training

Department: Higher Education and Training REPUBLIC OF SOUTH AFRICA

NOVEMBER 2012

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N4

(**4090034**)

26 March (X-Paper)
09:00 – 13:00

REQUIREMNTS: ONE A2-drawing paper
Standard hot-rolled structural steel section tables (BOE 8/2)

Candidates may use drawings instruments.

This question paper consists of 4 pages

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers correctly according to the numbering system used in this question paper.
4. Use BOTH sides of the drawing paper.
5. A balanced layout is very important.
6. A 15 mm border must be drawn around the drawing sheet on BOTH sides.
7. ALL the drawing work, including candidate information, must be done in pencil.
8. WHRE no dimensions are given, use your discretion and draw it in good proportion to the drawing.
9. Where no dimensions are given, use your discretion and draw it in good proportion to the drawing.
10. Write neatly and legibly.

QUESTION 1

A 30^0 pitch galvanized corrugated iron roof on 75mm x 50mm purlins is constructed of 114mm x 38 mm rafters, tie beams and plates with an overhang of 300mm. It is supported by a 270mm thick face-brick cavity wall plastered inside. A steel door frame forms part of the cavity wall. The overhang has open eaves with an asbestos ceiling, 228mm x 32mm fascia board and 100mm x 100 mm galvanized gutter in position.

The ceiling is constructed of 1000mm x 400mm x 15mm thick acoustic paneling, secured to the 38mm x 38mm brandering by means of 3mm thick aluminium H-section, finished to the walls with 75mm x 19mm hardwood cornice. The underside of the ceiling is 2800mm from the floor surface. Only two bricks below the wall plate are reduce to 220mm solid wall with plinth in position.

Draw to scale 1:10, a vertical section through the eaves and cavity wall. Do not show the top of the double rebated steel doorframe in position and ceiling construction.

[20]

QUESTION 2

Your FET Manager (Principal) wants to hang a huge board bearing the name of your FET. Advise the Manager (Principal) by means of neat, well-drawn and detailed stanchion that can be used as a pillar to hang the FET name board, using the following specifications.

A 254 mm x 254 mm x 72,9 kg/m H-section, with 8.6mm and 14,2 mm web and flanged thinness respectively is secured to a 1100mm x 1100mm x 450 mm thick chamfered edge concrete foundation through a baseplate of 530mm x 530mm thick, by means of M22 hold-down hook bolts, cast 150mm into the concrete slab. 15mm thick gusset plates and base plates by means of Ø20mm shop driven rivets.

Draw, to scale 1:10, a vertical section through two hold-down bolts, with one column flange facing, and clearly show the method employed to provide for the adjustment of hold-down bolts position during installation.

[20]

QUESTION 3

3.1 Draw to scale 1:10, the front view of a two-ringed segmental arch. The arch spans 1200mm and the rise is one-sixth of the span.

Only half of the brickwork in the arch must be shown with the construction method clearly illustrated in the remaining half of the arch

No surrounding brick work needs to be shown. (15)

3.2 Name ONE advantage and ONE disadvantage of each of the following types

3.2.1 Clear sheet glass. (2)
3.2.2 Laminated glass. (2)
3.2.3 Float glass. (2)

3.3 Explain the following terms with regard to steel door frames:

3.3.1 Catch plate (2)
3.3.2 Transome (2)

QUESTION 4

Draw to scale 1:5 the elevation of the foot of 16m span steel roof truss 30^0 , constructed of 80mm x 80mm x 10mm x11,9kg/m angle iron rafters and tie beams with 80mm x 60mm x 6,37kg/m angle cleats and 12mm thick gusset plate.
Show the position of the holes (20mm) to receive mild steel rivets(18mm) and include the dimensions for these holes positions in the drawing.
(15)

QUESTION 5

5.1 Draw to scale 1:10, the isometric view of a two-brick corner built to English bond. Both projections are to be approximately 1000mm long and the lower projection must be fie courses high.
(10)

5.2 Draw to scale of 1:1, a vertical section through portion of the top, glazing bar and bottom section of a standard section window-frame, and side hung window glazed with clear sheet glass. All brickwork is to be omitted. (10)

TOTAL: 100

Marking Guidelines

higher education & training

Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

26 MARCH 2012

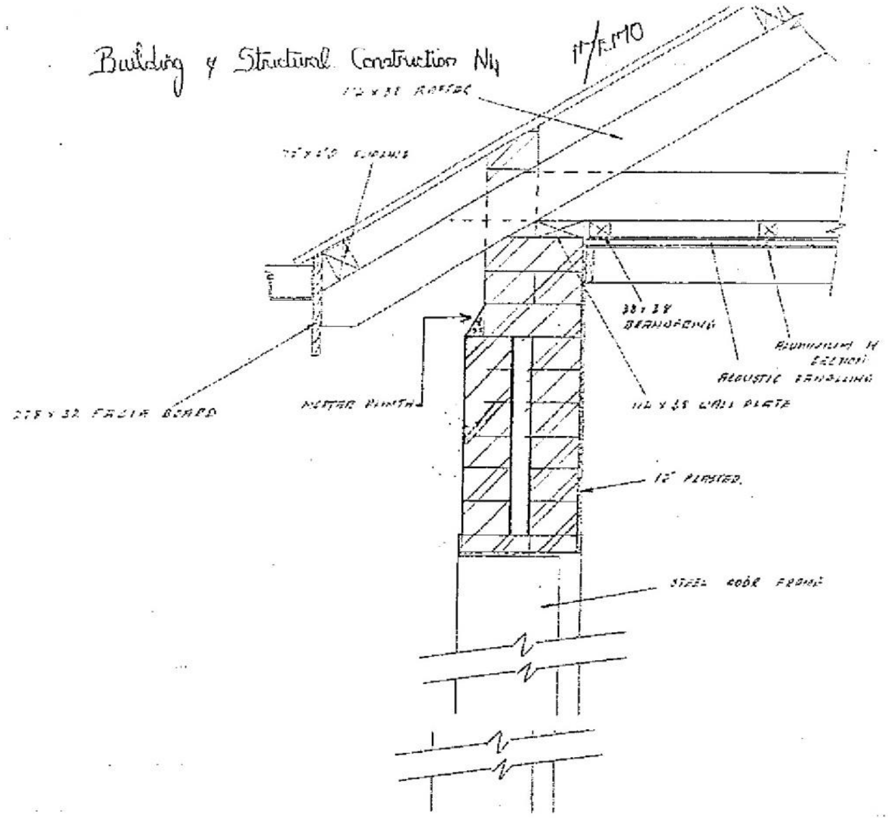
NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N4

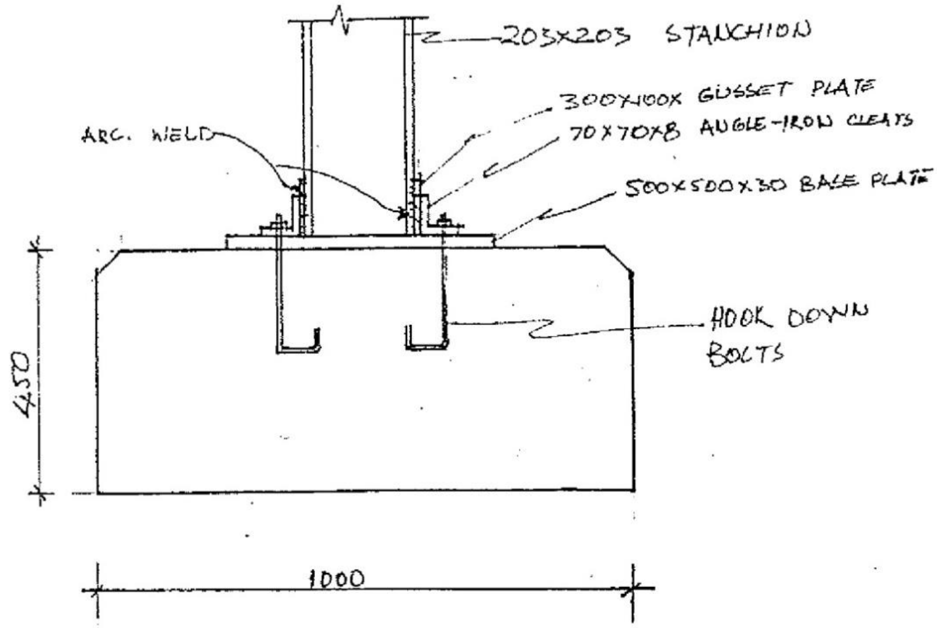
(4090034)

This marking guideline consists of 8 pages

QUESTION 1



QUESTION 2



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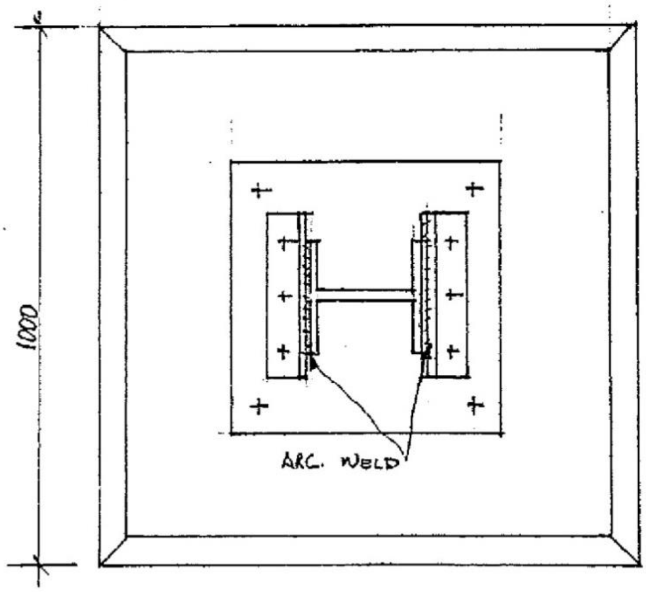
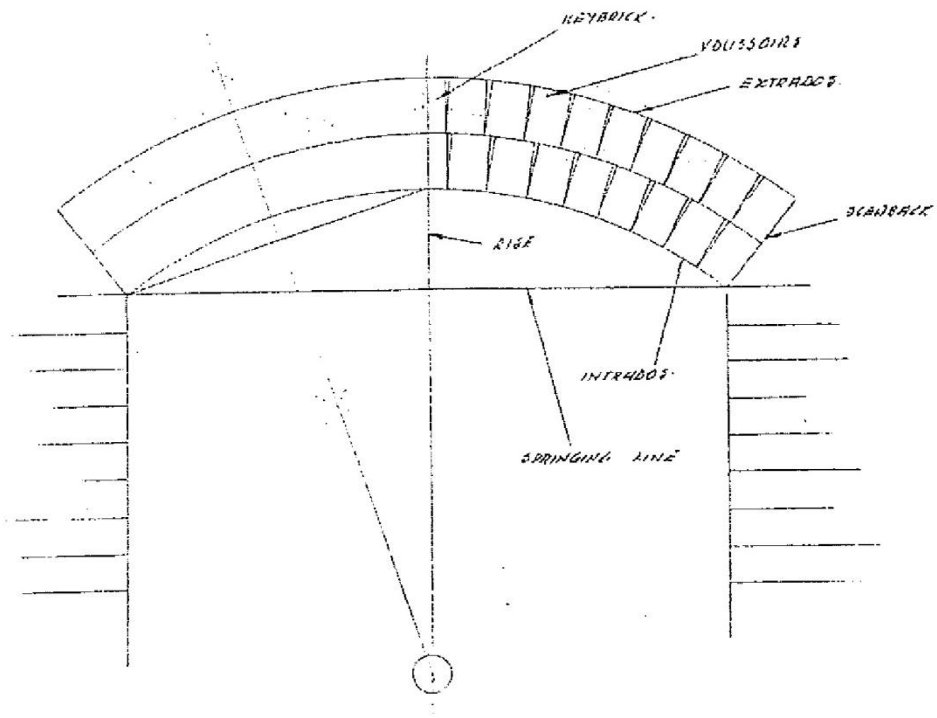


(10)

[20]

QUESTION 3

3.1



<u>SEGMENTAL ARCH</u>
<u>SCALE 1:10</u>

3.2.1 CLEAR SHEET GLASS
Advantages
Cheap
Easy to cut (2)

Disadvantage
Breaks easily
Distorted view (2)

3.2.2 LAMINATED GLASS
Advantages
Strong and durable
Undistorted view (2)

Disadvantages
Expensive
Difficult to cut (2)

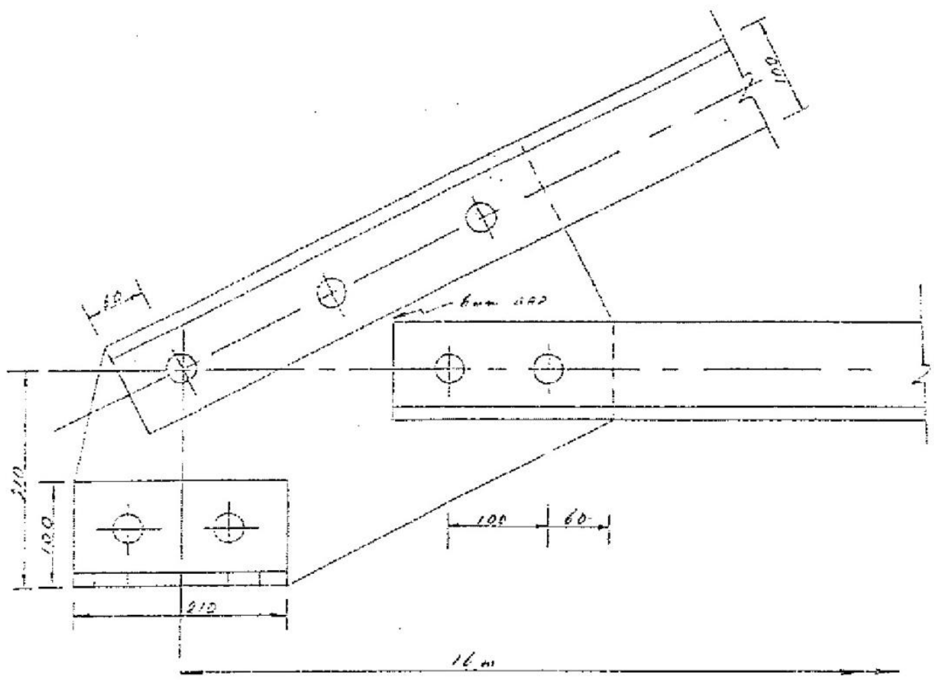
3.2.3 FLOATS GLASS

Advantages
Undistorted view
Easy to cut (2)

Disadvantages
Expensive
Break easily (2)

3.3.1 This is plate is usually fitted to the lock jam to receive the lock and is adjustable (2)
3.3.2 The transom is rail between the fan light and the door. (2)

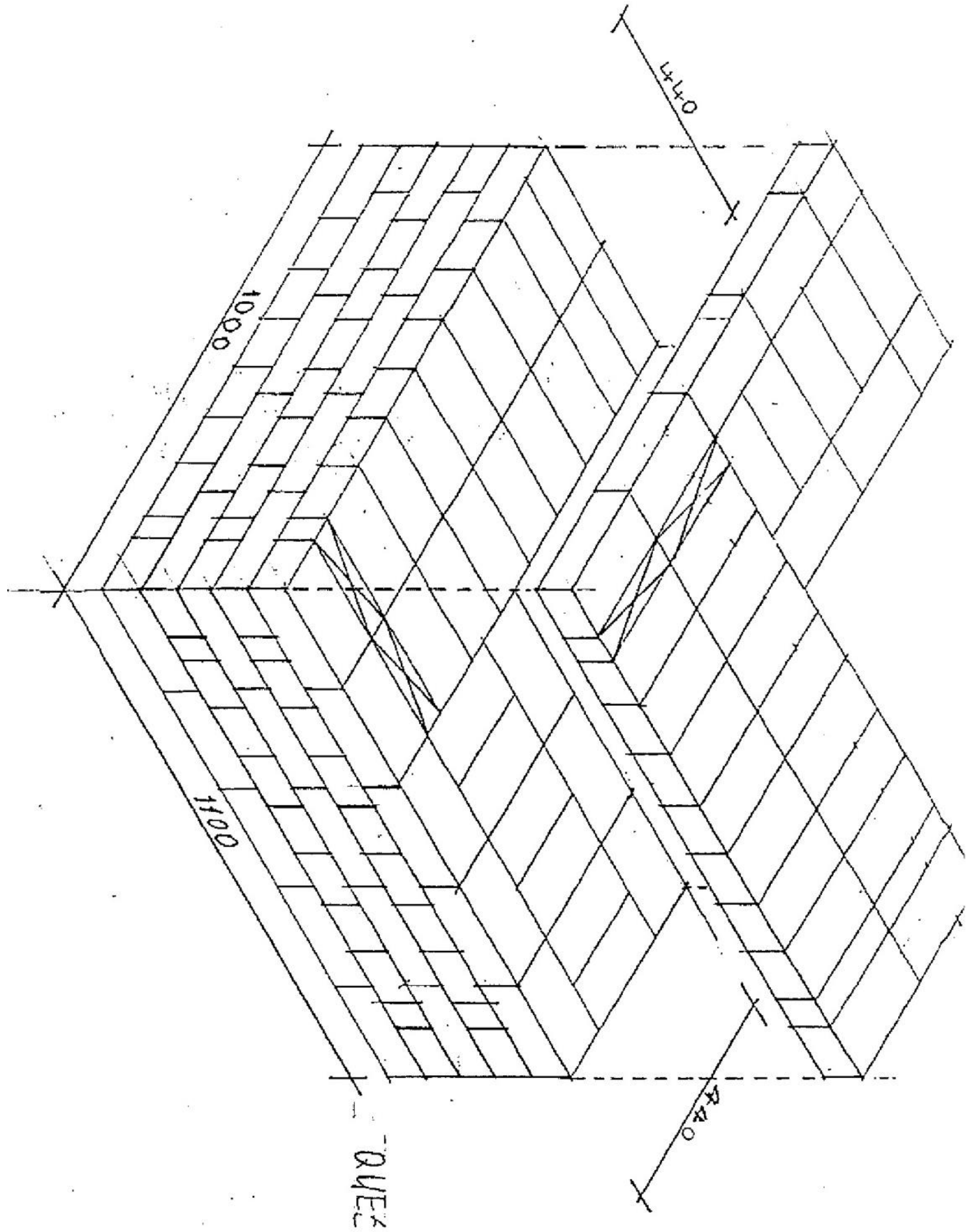
QUESTION 4

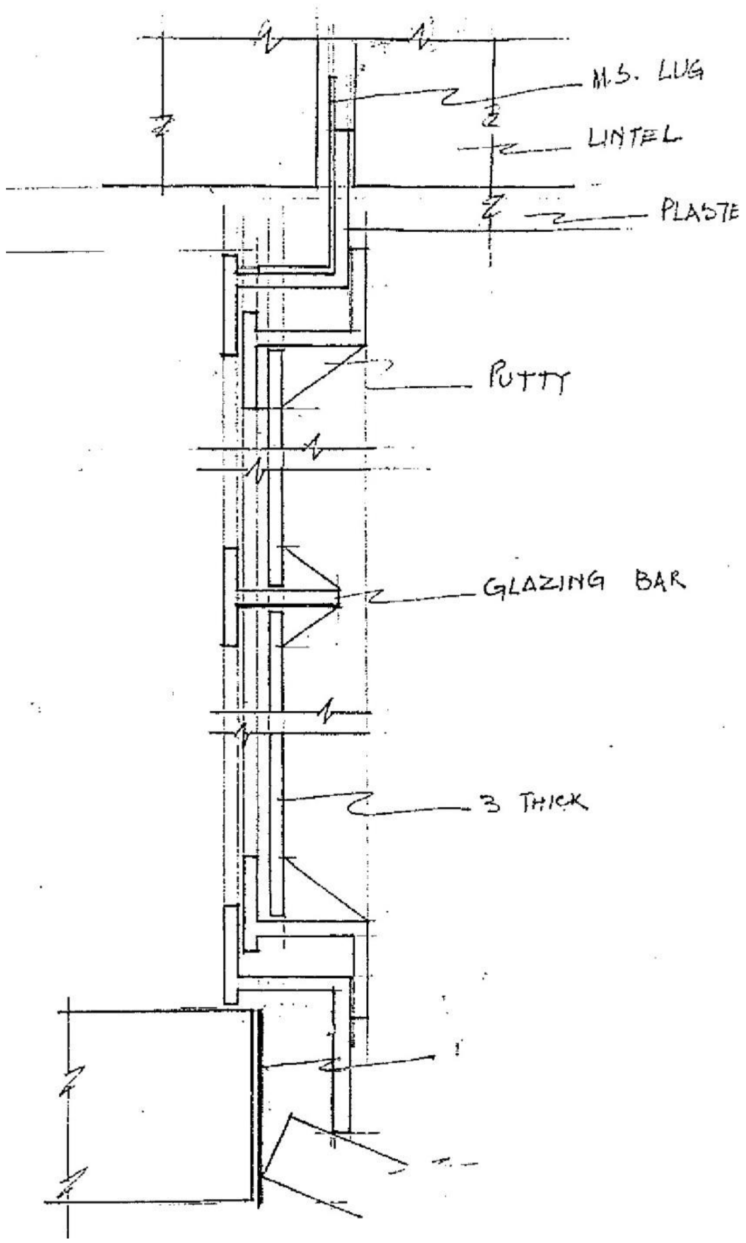


STEEL ROOF TRUSS
SCALE 1:5

QUESTION 5

5.1





TOTAL: 100

N4 Building and Structural Construction is one of many publications introducing the gateways to Civil Engineering Studies. This course is designed to develop the skills for learners that are studying toward an artisanship in the Building and Civil Engineering fields and to assist them to achieve their full potential in a building construction career.

This book, with its modular competence-based approach, is aimed at assisting facilitators and learners alike. With its comprehensive understanding of the engineering construction environment, it assists them to achieve the outcomes set for course.

The subject matter is presented as worked examples in the problem-solving-result methodology sequence, supported by numerous and clear illustrations.

Practical activities are included throughout the book.

The author, Chris Brink is well known and respected in the engineering and related fields. Their extensive experience gives an excellent base for further study, as well as a broad understanding of engineering technology and the knowledge to success.

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