BUILDING CONSTRUCTION
Volume 1

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BUILDING CONSTRUCTION

Volume 1

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INTRODUCTION

This text was written to bring together all those topics included in the syllabus for BUILDING CONSTRUCTION 1B, under the one cover.

Not all students will have the same basic knowledge of the building industry, and therefore some student may have to refer to other reference texts to obtain the knowledge required.

As new ideas, materials and construction methods are introduced into the industry all the time, it must be understood that a text such as this can never be completely up to date.

It is partly up to the student to obtain any information on new ideas within the building industry and to incorporate these into his study material.

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1.1 SITE SELECTION CONSIDERATIONS

The decision to purchase a particular housing lot is one of the most important decisions a person may have to make in his or her life. This decision should be made only after a careful consideration of all the factors which may affect the suitability of the site. Many people make the mistake of selecting their home before selecting the site and have to "fit" their house to suit their site. This usually results in the house not being situated so as to get the full benefit of thoughtful design, and the site not being developed to take advantage of natural falls, views and weather.

Factors which need to be considered when selecting a site for residential development include the following.

PREVAILING WEATHER

(a) From which direction does the main winter rain come?

(b) Are there any cooling summer breezes? From which direction do they mainly come? Are they likely to be blocked by further development?

(c) Can one take advantage of the winter sun to warm up the house? In the southern hemisphere the winter sun bathes the northern side of buildings. By keeping the northern side away from boundaries and adjacent buildings, the sun can penetrate the site and the house.
(d) Is it possible to restrict the amount of summer sun—particularly on the western face of the buildings entering and over-heating the house?

The prevailing weather is one of the prime considerations when selecting a site. We cannot change the weather, so we have to plan to use it to advantage. Careful design of a building can result in a summer-cool, winter-warm house, with minimal heating and cooling costs.

CONDITION OF SITE

The various types of foundations are discussed in great detail further on in this text. However, it is necessary to say that most soils can be built upon. Unfortunately, some types of soils will be more expensive to prepare for footings than others.

What should one look for when selecting a site?

(a) The least expensive site to prepare for building is a flat and level one with few trees or shrubs to be removed from the actual house position, and a soil—such as sand—which will allow natural drainage. Of course, this site may have little to offer those who wish to be creative with their house and land.

(b) Sloping sites may allow for design flexibility such as split levels and underground car parking, but these building techniques add cost to the project. A common trend nowadays is to fill sloping sites with sand to establish a flat level surface for the building. This is known locally as a sand pad.

(c) Wet sites pose a particular problem that must be overcome prior to development. It will be necessary to provide sub-soil drainage to remove excessive dampness from the building area. Details of this technique are given in Chapter 3 which deals with site preparation.

(d) Foundation material will influence the "site costs" associated with residential developments. Metropolitan sand with little or no clay content is the least expensive foundation to prepare, needing only to be levelled and compacted prior to building works starting.

Gravel and gravel with a small amount of clay content requires only a slight modification to the normal footing used in domestic construction. However, some developers prefer to put a sand pad down over the gravel or clay and build on the pad in the same way as they would for sand foundation. Of course, the supply and compaction of the sand pad adds to the cost of construction.

Where clay soil occurs, it may be necessary to use special footings which penetrate a certain distance below ground level into stable soil. This method is costly and a less expensive sand pad could be used as an alternative.
Whatever the foundation soil type existing on the site, providing that it is not unsuitable because of health reasons such as flooding or sanitary fill, the apparent unsuitability can be overcome in nearly all cases, but this usually involves extra outlay which then adds to the cost of construction.

ASPECT

Brief attention has already been paid to selecting a site because of its view. Many homes have been built on sites to capitalize on the view or aspect. While this practice will undoubtedly add to the character and value of the house when done tastefully, it must be emphasised that the house needs to be designed to benefit fully from the aspect.

Many sites have no predominant aspect; some are even sited below the road level. When building on a site such as this is contemplated, consideration must be given to ways of raising the floor level either by filling the site or perhaps by placing a garage below the floor of the house.

Aspect is also taken to mean the direction and the way the building faces. A building described as having a sunny aspect would be facing the sun so that it basks in the sun and reflects warmth.

The careful selection of a site can take advantage of a particular aspect.

SERVICES

The necessary services for domestic buildings are electricity for lighting and power, water to bathrooms, kitchen and laundry, and sanitary services (either sewerage or septic installations). Optional services include gas for cooking, home heating and water heating. The telephone is another optional service.

The availability of services will influence the selection of a site but this, of course, will depend on the purchaser's lifestyle. For example, the availability of gas may not be important to a person who plans to have an "all-electric" home.

The telephone, too, may not be regarded as an essential service by some.

A building site must have some sanitary service. Where the sewerage system is not provided, a septic tank system must be installed. Many sites are unsewered but often plans are made by the appropriate authority for sewerage to be provided in the near future. This could affect the suitability of a site. The initial installation of the septic tank must be added to the building costs and, when the sewer is eventually connected, the householder must also pay for this service.

Services are also taken to include footpaths, bus services, the provision of schools, shopping centres, hotels, cinemas, etc. Obviously, some of these are essential while others are merely advantageous.
1.2 TOWN PLANNING

TOWN PLANNING SCHEMES AND THE TOWN PLANNING BOARD

Town planning schemes provide for the orderly growth of cities and towns; they also help to preserve the countryside. Schemes give local councils powers to prepare detailed plans for land use and development.

The most important type of town planning scheme is the zoning scheme, which classifies or zones land into different categories of use such as housing (residential), industrial, commercial, roads, schools, public open space and so on.

These zoning schemes are usually prepared by council staff or a consultant town planner, and a good deal of survey and research is necessary before actual planning begins.

- What are the shopping requirements of the area?
- Should industry be allowed here?
- Is there enough public open space?
- How many kindergartens and schools are required?
- Should the highway be widened to permit more traffic?
- Where should residential flats be encouraged?

These are typical questions which come out of the survey, but there may be many others. In its final form this scheme represents an attempt to rationalize all competing claims but, of course, it is impossible to satisfy everyone.

The principal town planning scheme in Perth is the Metropolitan Region Scheme which became operative in 1963. This scheme sets out a broad framework for the future growth of Perth. Town planning legislation provides however, that each of the 26 councils within the Metropolitan Region must prepare a detailed town planning scheme for its municipal district. These schemes must be consistent with the proposals shown in the Region Scheme. Most councils have either had schemes approved or have schemes in an advanced stage of preparation.

The survey and preparation of a scheme may take many months. When the council is satisfied with it, the scheme is sent to the Town Planning Board which advises the Minister for Town Planning. If the Board so recommends, the Minister may give the scheme 'preliminary approval', whereupon it is advertised and made available for public inspection for a period of three months. (He may refuse preliminary approval, in which case the scheme proceeds no further.)

The three months constitute the 'representation period' in which the public is invited to make submissions. At the end of this period, the council examines submissions and, if deemed necessary, may recommend amendments to the scheme when forwarding it, with copies of the submissions, to the Minister - through the Town Planning Board - for final approval.

When the Minister is satisfied that all submissions have been considered and correctly determined, he gives his final approval, which is announced in the Government Gazette and local newspapers circulating in the area of the scheme.
After this date, any person wishing to develop land - such as the construction of a house, a flat or a shop - may only do so if the proposed building or proposed use fits into the zone shown on the town planning scheme map, or any other scheme provision.

Apart from the map or maps, there is also a scheme text and an accompanying report. These describe the area of the scheme, the manner in which it will be administered, and sets out the areas permitted in the various zones. The text also sets standards of development, such as the car parking requirements for new shopping areas, the set back distances for office buildings, and so forth.

Sometimes land is reserved in a town planning scheme for a particular public purpose. If such land is still privately owned, its reservation in the scheme is an indication that the land will eventually be required for some public purpose such as a road or recreation area. Compensation may be involved here, and the scheme text describes the procedure to be followed.

Outside the Metropolitan Region most of the larger country centres in Western Australia have town planning schemes. These schemes provide for the orderly growth of the town and are generally similar in operation to those administered by local councils in the Perth Region.

Apart from zoning schemes, there are also other types of schemes which may provide for the subdivision - or re-subdivision - of the land for specific scheme works such as comprehensive drainage, provision of deep sewerage, and so on. This type of scheme is usually initiated by a private developer, or a local council where an area needs extensive planning or re-planning, and where it would otherwise be difficult to achieve the best results because of the large number of individual owners.

The development scheme, as it has become known, ensures that the costs of scheme work are shared fairly among owners, and that each owner gets his fair share of the benefit resulting from the scheme. Some development schemes provide for the local council to acquire all the land in the scheme area, subdivide it, carry out the necessary works, and then allocate fully serviced lots to the original owners, less the costs of the scheme works. The M.R.P.A. has the power to act in a similar way under what is known as an Improvement Plan whereby land in multiple ownership can be acquired, consolidated, serviced and made available for industry, housing or other purposes.

Other development schemes are less involved and may set down guidelines for a subdivision pattern with which individual owners must comply when subdividing but which, again, ensures that there is a fair distribution of scheme costs, including the distribution of public open space.

This type of scheme is required to have the approval of the Minister and to follow the same administrative procedures as the zoning schemes outlined above.

ZONES

Zones as defined by the Town Planning Regulations mean a portion of the scheme area shown on the map by distinctive colouring, hatching, or edging for the purpose of indicating the restrictions imposed by the planning scheme on the erection and use of buildings or for the use of land, but do not include land reserved.
There are seven main zones, each of which is further divided to distinguish between types of uses within a given zone. For example, industrial zones are divided into:

- service industry
- light industry
- general industry
- noxious industry
- hazardous industry
- extra-active industry.

The main zones are:

1. **PRIVATE CLUBS AND INSTITUTIONS**, which include: golf clubs, bowling clubs, private schools, religious institutions.

2. **PLACE OF PUBLIC ASSEMBLY**, which includes: places of public worship, cinema, indoor games, theatres.

3. **RESIDENTIAL ZONES**, which include: urban deferred, residential 1, residential 2, residential 3, general residential 4, general residential 5, general residential 6.

4. **COMMERCIAL ZONES**, which include: local shopping, district shopping, special business, offices, other commercial uses.

5. **INDUSTRIAL ZONES**.

6. **RURAL ZONES**, which include: rural, intensive rural, other rural use.

7. **SPECIAL ZONES**, which include: hotels, motels, fuel depots, service stations, drive-in theatres, undertaker's premises, underdeveloped land.

The concept of zoning is to regulate the establishment of specific areas for a definite purpose. This has the advantage that it protects the individual land owner and ensures that noxious industries for example, cannot be established in the same area as a residential development.

Further information regarding any aspects of town planning, development, zoning, etc., is fully given by the Town Planning Department in Perth.

1.3 **LOCAL AUTHORITIES**

Local authorities or councils can influence the proposed building by zoning requirements and by classification by occupancy regulations. They are assisted in this by the Uniform Building By-laws as well as their own adopted by-laws and planning schemes.

Uniform Building By-laws in most cases only indicate the minimum requirements, and local authorities can upgrade or change these to suit their own requirements.
BY-LAWS

There has always been a certain amount of confusion in the mind of the public, about by-laws, their use and when they apply. In general, planning by-laws are used as a temporary measure of zoning control pending the adoption of a town planning scheme.

Planning by-laws assist local authorities or councils to achieve the aims of a town planning scheme, but are less sophisticated in their application. Quite often they relate to a small part of the entire council area, or even merely to a few lots.

Planning by-laws can cover many aspects apart from zoning, such as set-backs in the case of proposed road widenings, restrictions on the height of fences at street corners, and similar matters considered essential for the orderly development of a district.

Zoning by-laws are made by local councils under the Local Government Act and need the approval of the Minister for Local Government. The use of zoning by-laws has become less frequent as councils have completed town planning schemes, but there are still a few councils which operate under zoning by-laws.

Other related by-laws that affect the public are health and building by-laws which will be considered separately in further chapters of this text.

SUB-SOIL AND SUB-SOIL WATER

In areas where there is a high water table, the local authority may insist that a minimum height of floor level above natural ground be established. This can be obtained by way of a sand pad or a footing wall of brick up to floor level. The important consideration is that where it is proposed to install a septic tank system in such ground conditions, the tanks and disposal mediums must be above the high water table which then dictate that the floor level needs to be a corresponding height above the system. Where there is doubt as to the exact requirements for floor level, the local authority should be contacted at the planning stage.

Land that is damp and has poor natural drainage may need to be kept dry by installed drainage systems. The simplest system is to have an open ditch around the sides of the site allowing the moisture to permeate to the trenches. However, this is often hazardous to children in built-up areas; it is also unsightly and a breeding place for mosquitoes and the like. A more suitable alternative is to employ sub-soil drainage. (See Fig. 1.1)

Two methods of applying sub-soil drains are:

(a) rubble drains (see Fig. 1.2 (a));

(b) drainage pipes (see Fig. 1.2 (b)).

A rubble drain is a small, shallow trench which is dug by hand or machine and is then trimmed to the required gradient and filled with coarse rubble, clinker or similar material. If the drain is to be used to remove surface as well as sub-surface water it should be filled to the top with the coarse drainage material; otherwise, an earth backfill can be used for the top layer.

Rubble drains have a disadvantage in that over a period of time they become clogged with silt. This clogging can be reduced by using layers of well compacted and graded aggregate to fill the trench.
There is available a range of drainage pipes which allows water to pass through the walls of the pipes and then delivers the trapped water to a common sump. Open-ended clay and concrete pipes can be used and there is now a polyethylene corrugated drainage pipe which is light and flexible which can be laid in trenches to carry away sub-soil water. The polyethylene pipe has fine holes to allow the permeation of water and small corrugations to give it cross-sectional strength. It is available in 50, 65 and 100 mm diameters and in coils up to 100 metres in length. The trenches are constructed in a similar way to the rubble drains, with the pipe located about 75 mm from the bottom of the trench. This will allow for the collection of silt deposits significantly reducing clogging of the pipe.

The position and number of drains to be placed is determined by the nature of the soil. Soils such as clay or those with a high clay content are difficult to drain, and the lines of drains need to be placed close together and fairly shallow. Table 1.1 shows the recommended spacings and depths for drainage lines or laterals.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Depth of line</th>
<th>Spacing of lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1.0 to 1.5 m</td>
<td>45 to 90 m</td>
</tr>
<tr>
<td>Sand/loam</td>
<td>0.9 to 1.2 m</td>
<td>30 to 37.5 m</td>
</tr>
<tr>
<td>Clay/loam</td>
<td>0.9 to 1.2 m</td>
<td>12 to 18 m</td>
</tr>
<tr>
<td>Clay</td>
<td>0.6 to 0.9 m</td>
<td>7.5 to 10.5 m</td>
</tr>
</tbody>
</table>

**TABLE 1.1**

Two methods of draining large areas are: to set the lines in parallel runs which intersect a main at right angles; or the line may be angled towards the central main. (See Fig. 1.1)
The choice of the system will depend on the topography. If there is a need to incorporate bends, these must be kept to a minimum and laid in long sweeping curves.

Further reading and information regarding 'Sub-Surface Drainage' can be obtained from the

NOTES ON THE SCIENCE OF BUILDING, No. 89 'Sub-Surface Drainage'.

These technical information sheets are available from:

The Department of Works,
Commonwealth Experimental Building Station,
P.O. Box 30,
Chatswood, N S W 2067

and, from the

Department of Housing and Construction,
2nd floor, Sheraton Court,
207 Adelaide Terrace,
PERTH.

1.4 RESTRICTIONS ON TITLES

Encumbrances are restrictive conditions registered on the title of the land. These encumbrances may restrict the building to a certain height or a certain type of material, or they might restrict the number of buildings allowable on the lot (e.g. prohibit duplex development). A title search at the Land Title Office is a sure way to establish the existence of any encumbrances. Searches can be carried out by any individual (all you need to supply is the lot number and location number), or the services of a lawyer or land settlement agency can be utilized.
CHAPTER TWO - FOUNDATIONS

2.1 FOUNDATION TYPES

ROCK
GRAVELS
SANDS
PLASTIC SOILS

2.2 SITE INVESTIGATION

INTRODUCTION
INVESTIGATION
TESTING

2.1 FOUNDATION TYPES

In building, the term foundation is very often confused with the term footing, but for clarity we will refer to the Uniform Building By-Laws which give the definition as: "the foundation means the ground that supports the building".

There are four basic foundation groups.

ROCK

Sound, unweathered rock, whatever its origin, suffers negligible deformation under normal loads from light buildings. The commonly accepted safe bearing values for rocks in Australia, excepting shales and limestones, are usually much lower than results derived from tests. (See Table 2.1 for allowable pressures on rock foundations.)

On exposure to water and air some friable, weathered shales may soften appreciably and the value given in Table 2.1 could be too high. Values of 0.425 MPa to 0.525 MPa may be more acceptable; however, if there is some doubt as to the safe bearing capacity of weathered shale, either laboratory tests can be carried out on sample cores of the rock, or the excavations should be deepened and the footings placed on sound material.

The safe bearing capacity of limestone can vary considerably more than these values. Customary values for safe bearing values are given in Table 2.1. Again, where footings are to be placed on a doubtful type of rock, laboratory tests may be needed to obtain reliable values.

GRAVELS

Under commonly accepted definitions, hard gritty material above 2 mm in diameter is classified as gravel.
ALLOWABLE Pressures ON Rock Foundations

<table>
<thead>
<tr>
<th>Kind of Rock</th>
<th>Loading MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft shales and soft mudstones.</td>
<td>0.85</td>
</tr>
<tr>
<td>Soft sandstones (free from seams greater than 20 mm thick to a depth of 900 mm below level of footing).</td>
<td>1.30</td>
</tr>
<tr>
<td>Medium sandstones (free from seams greater than 20 mm thick to a depth of 1200 mm below level of footing).</td>
<td>2.125</td>
</tr>
<tr>
<td>Hard sandstone (free from seams greater than 20 mm thick to a depth of 1800 mm below level of footing).</td>
<td>3.25</td>
</tr>
<tr>
<td>Hard igneous rock, such as basalt containing no gas holes, diabase, dolerite and granite.</td>
<td>4.3</td>
</tr>
<tr>
<td>Limestone in solid layers.</td>
<td>variable</td>
</tr>
</tbody>
</table>

**Table 2.1**

SANDS

Material from 2 mm to 0.02 mm in diameter is classified as sand.

Gravel and sand may occur together, or mixed with finer material. The usual type of failure occurring in an over-loaded compact sand or gravel foundation is known as a general shear failure. General shear failure occurs when the soil slips sideways and upwards allowing the footings to settle because of displacement of the foundation material. Figure 2.1 illustrates this type of displacement; the soil slipping along the lower dotted lines.

General shear failure is so called because failure occurs as a result of shearing over a considerable surface of material. It is important to note that the material is not compressed but displaced, and that such a failure allows a fairly marked settlement of the footing. As compact sands and gravels are relatively incompressible, the most important property to be considered in designing footings on them is the resistance of the material to shear failure. The resistance to such failure increases rapidly with the depth of the footings, since the deeper the footings the greater the volume of foundation material to be moved in a general shear failure.

Most sands and gravels have fairly similar frictional properties, so that safe bearing capacities can be predicted with reasonable accuracy. However, these values are not equal for different types of footings, and so the safe bearing capacities for such different footings will vary. (See Table 2.2)
GENERAL SHEAR FAILURE

FIG. 2.1

PREDICTED BEARING VALUES UNDER VERTICAL STATIC LOADING

<table>
<thead>
<tr>
<th>TYPES OF SOIL</th>
<th>LOADING MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact gravel, or compact sand and gravel.</td>
<td>0.6 MPa</td>
</tr>
<tr>
<td>Medium dense gravel, or medium dense sand and gravel.</td>
<td>0.2 to 0.6 MPa</td>
</tr>
<tr>
<td>Loose gravel or loose sand and gravel.</td>
<td>0.2 MPa</td>
</tr>
<tr>
<td>Compact sand</td>
<td>0.3 MPa</td>
</tr>
<tr>
<td>Medium dense sand</td>
<td>0.1 to 0.3 MPa</td>
</tr>
<tr>
<td>Loose sand</td>
<td>0.1 MPa</td>
</tr>
</tbody>
</table>

TABLE 2.2

PLASTIC SOILS

Any soil that is subject to slow movement such as shrinkage, swelling or consolidation not necessarily connected with a change in foundation loading, may be regarded as plastic. Soils that contain particles of material less than 0.02 mm in diameter will generally exhibit some degree of plasticity. Soils with particles between this diameter and 0.002 mm are generally classed as silt and those with particles under 0.002 mm are generally classed as
clay. The tendency to slow movement increases with a decrease in the size of the particles, and the degree of this movement becomes marked only in the case of clays and the finer silts.

Soils in the plastic state increase in volume with increase in moisture content, and decrease in volume with decrease in moisture content. They may consolidate if subjected to compressive loadings and may expand on release of such loadings. If the compressive loadings are above certain limits, then, depending on the soil's history, the soil will remain almost constant in volume while still loaded, despite other influences (such as seasonal changes) which may act upon it. The time required for loading consolidation to take place under domestic and similar small footings is short, and is usually over by the time the building is finished; it will rarely exceed five years.

A foundation failure in a plastic soil may occur in one or more of three ways outlined below.

(a) Successive expansion and contraction of the soil, caused by the absorption or release of moisture related to the weather.

(b) Settlement of foundations as a result of excessive consolidation (i.e., excessive contraction of the soil) under compressions caused by the load.

(c) General shear failure, in which case the soil is pushed down below the footing, to bulge upwards alongside. Expansion of a soft soil may cause a general shear failure, with the soil bulging alongside the footing without raising the footings; in this case a subsequent decrease of moisture will cause the footing to subside.

The bearing values set out in Table 2.3 are general values for all types of larger footings. It is considered that, because of complex soil phenomena associated with small footings such as those used for domestic and similar work, these values could be increased.

### COMMONLY ACCEPTED SAFE BEARING VALUES FOR PLASTIC SOILS

<table>
<thead>
<tr>
<th>TYPE OF PLASTIC SOIL</th>
<th>LOADING MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial soil</td>
<td>0.06</td>
</tr>
<tr>
<td>Soft clay</td>
<td>0.11</td>
</tr>
<tr>
<td>Ordinary clay</td>
<td>0.21</td>
</tr>
<tr>
<td>Dry (or firm) clay</td>
<td>0.32</td>
</tr>
<tr>
<td>Hard clay</td>
<td>0.43</td>
</tr>
</tbody>
</table>

**TABLE 2.3**
2.2 SITE INVESTIGATION

INTRODUCTION

The object of a site investigation is to assess the general suitability of the foundation for the proposed work, so that an adequate and economic design can be prepared, and any difficulties that may arise during the construction can be foreseen and due allowance made.

On some small jobs, the extent of the site investigation is usually limited by the size of the site and the loads to be applied to the foundations. Many small jobs (such as domestic work) are undertaken after only a visual investigation based on the investigator's personal observations and experience.

Where work is to be undertaken in a location where the individual has had no previous, or very little, experience, he may wish to engage a testing agency to conduct a site investigation.

The following information has been prepared as a guide to builders in ascertaining the suitability of the site for building purposes.

General Information Required Prior to Investigation

- design and loads on footings;
- proposed location of house to be marked on building site;
- depth of footing below existing ground level;
- whether or not the site was filled at an early date.

INVESTIGATION

GENERAL COMMENTS

The investigation should be carried out in two steps:

(i) initial investigation prior to site works and sandfill (if any);

(ii) on completion of site works prior to placement of concrete raft and footings.

The reason for these two steps is to have results of investigation stage (i) available should some modification in design be required. Step (ii) is used to check that any fill placed is satisfactorily compacted.

Stages (i) and (ii) may be combined, if necessary.

Generally, for a normal residence, four test holes to a depth of 900 mm below footings or to rock should be adequate. For residences of larger area, the number shall be nominated by the Engineer.

SAND OR NON-COHESIVE SOIL

Test holes should be taken to a depth of 900 mm, under good conditions, below the footing level and any changes in strata or layers of organic matter should be noted. Test holes must be located as near as possible to the proposed footings and to be spaced so as to produce a representative picture of sub-soil beneath footings carrying major loads.
The *Perth Sand Penetrometer Test* should be carried out in the vicinity of the hole, commencing 150 mm below ground surface and taken to a depth of 900 mm.

If readings from hole to hole vary by more than 2 blows per 300 mm, a grid of 900 x 900 should be tested to isolate any differences. Note should be taken of the natural moisture and classified as:

- dry
- moist
- wet
- saturated.

Samples of material representing each stratum should be taken. A note of the ground water level should also be taken.

A general inspection should be carried out initially to ensure that the soil is uniform or otherwise before holes are located; if non-uniform, holes should be put down in each type of material.

**COHESIVE SOILS**

Because of the active nature of some cohesive soils, initial inspection of the building site before any holes are located is essential.

An initial inspection should be carried out to ensure that the material on which the house is to be built is uniform, as a small band of highly active soil can cause severe problems.

1. The surface layer of soil should be visually investigated to observe any soil types that differ visually by colour, vegetation or other indications.

2. (a) If uniform, locate test holes over the site in footing areas so as to encompass the building.

   (b) If not uniform, locate test holes in the different soil types.

3. Samples of each type of material encountered must be obtained. Undisturbed samples of clays may be desirable for testing at the engineer's discretion.

4. All samples are to be classified according to the classification system of C.P. 2001 - "Site Investigations" - British Standards Institution, London, 1957.

5. Water levels are to be taken if water is present:

   (a) at the depth encountered;

   (b) at the depth after a period of time (that is, if the water level has risen or fallen).
ROCK

Where a site has rock of a solid nature and if the rock is encountered in the form of boulders or cobbles, the nature of the surrounding soil should be investigated and an estimate of the size of rock made.

FILLED SITES

Filled sites generally require more attention and, because of their nature, should be investigated more thoroughly.

Test holes should go to the full depth of fill where possible.

A qualified person should head a thorough investigation on fill sites containing rubble and boulders; excavation may be necessary in these cases.

TESTING

Perth Sand Penetrometer testing is a good guide to compaction of sand only and should not be used in cohesive materials or materials containing stone or coarse particles.

The tests most applicable to cohesive materials are the Plasticity Index and the Linear Shrinkage as a guide to the activity of the soil, and Triaxial Shear Tests or Consolidation Tests on undisturbed samples.

NOTE: All tests should be carried out by an experienced operator and the results should be interpreted by a qualified engineer.

Description of Materials - shall be based on C.P. 2001.

SANDS AND GRAVELS - NON-COHESIVE

Density, Colour, Grading, Soil e.g. Medium density, brown, well-graded, gravelly sand.

COHESIVE SOIL

Consistency, Colour, Soil e.g. Soft, grey, sandy clay or Firm mottled red and yellow clay.

It is important that all information on materials and water levels is logged and produced on a final schedule showing all details. Accurate notes of locations of the test holes should be supplied with the logged results of site investigation.

For further reading on this topic, it is suggested that the following NOTES ON THE SCIENCE OF BUILDING be obtained.

No. 2, 'Footings for Small Masonry Buildings on Sand, Gravel or Rock',
No. 6, 'Footings for Small Masonry Buildings on Plastic Soils'.
No. 89, 'Sub-Surface Drainage',
No. 110, 'Site Investigation of Foundations',
No. 113, 'Foundation Movement'.

2.7
These publications can be purchased from:
The Department of Housing and Construction,
2nd floor, Sheraton Court,
207 Adelaide Terrace,
Perth
or by mail from:
The Department of Housing and Construction,
Experimental Building Station,
P.O. Box 30,
Chatswood, N S W 2067.
CHAPTER THREE - SITE PREPARATIONS

3.1 STATUTORY REQUIREMENTS
   LOCAL COUNCIL
   WATER AUTHORITY
   OTHERS

3.2 SITE CLEARING AND EARTHWORKS

3.3 SETTING OUT
   METHOD

3.4 TIMBERING IN EXCAVATIONS
   THE NEED FOR TIMBERING
   TYPES OF TIMBERING

3.1 STATUTORY REQUIREMENTS

After selection of the site has been made (with due consideration to the factors discussed in Chapter 1), the building is designed and working drawings are prepared to standards which comply with the Uniform Building By-laws.

LOCAL COUNCIL

Two copies of the drawings and a copy of the specifications are presented to the Local Authority - that is, shire, town, or city municipality, etc - for approval. The local authority will inspect the plans and specifications to ensure that the building will be built in accordance with the standards set down in the Uniform Building By-laws. Also, at the offices of the local authority is a health inspector who will inspect the plans to see that the building conforms with regulations set out in the Health Act. The health surveyor is particularly interested in the location of septic tanks (if used) and in the provision of lighting and ventilation to all rooms - particularly bathrooms, water closets and the like.

Once the drawings are approved, the builder pays for the inspection and approval. This cost is passed on to the client as a preliminary to construction.

Often approval is given conditional to an amendment of the plans. These conditions - plus the standard conditions such as notice being required in advance prior to pouring concrete - are clearly listed on the approval certificate which is fixed to the stamped and dated working drawings.
WATER AUTHORITY

One such important condition to approval by the local authority is that approval for the works be obtained from the Metropolitan Water Authority - which was called the Metropolitan Water Supply Sewerage and Drainage Board (M.W.S.S. & D.B.). The W.A.W.A. will inspect the drawings to ensure that the building is not being built too close to or over existing or planned drainage, water supply or sewerage lines. A fee is payable to the W.A.W.A. based upon the number of fixtures in the building and the value of the works.

The W.A.W.A. will issue an assessment number and a "flimsy" which is a photocopy of their drawing showing the position of main drainage and sewerage lines, as well as the connection point for the house drainage system to the sewer main. This assessment number and "flimsy" should be handed to the plumber engaged to do the plumbing work who will submit notice of intention to do work to the W.A.W.A.

OTHERS

Tabled below is a comprehensive list of the various authorities that are involved in building and/or building approvals in Western Australia. (See Table 3.1)

It is important to note that not all of these authorities need to be notified or applied to, before or during construction. This list is a guide to the bodies which have some authority over some aspect of buildings or building works.

After W.A.W.A. (M.W.S.S. & D.B.) approval has been obtained, it is important that the builder place on the site a sign noting the lot number and indicating the position of the water meter. The water will be connected to this point by the W.A.W.A.
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>GENERAL</th>
<th>Sewered areas</th>
<th>Non Sewered areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uniform Building By-laws (1979) Septic tank Regs - Ventilation Regs Town Planning and Zoning Regulations S.E.C. Regs</td>
<td>S.A.A. Lift Code</td>
<td>Septic Tank Regs</td>
</tr>
</tbody>
</table>

.../2
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>ADMINISTRATIVE AUTHORITY</th>
<th>CONTROLLING ACT</th>
<th>REGULATIONS, ORDINANCES, &amp; BY-LAWS MADE UNDER THE CONTROLLING ACT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Country Water Supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Country Town Sewerage Dept.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.E.C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPECIAL BUILDINGS as for general plus the following</td>
<td>Department of Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airports</td>
<td>Air Transport Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caravan Parks</td>
<td>Local Authorities</td>
<td>Health Act</td>
<td>SAA Wiring rules. Codes of practice for L.P. gas installation</td>
</tr>
<tr>
<td>Dairies, Milk Plants &amp; Depots</td>
<td>Milk Board of W.A.</td>
<td>Dairy Industry Act</td>
<td>Commonwealth Legislation</td>
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<tr>
<td>Factories, Shops</td>
<td>Dept. of Labour</td>
<td>Factories &amp; Shops Act</td>
<td>Model By-laws</td>
</tr>
<tr>
<td>Warehouses</td>
<td>Factories Inspection Board</td>
<td></td>
<td>Regulations</td>
</tr>
<tr>
<td></td>
<td>Inspection of Machinery</td>
<td></td>
<td>Factories &amp; Shops Regs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Machinery Regulations</td>
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<td></td>
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<td>.../3</td>
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<td>SUBJECT</td>
<td>ADMINISTRATIVE AUTHORITY</td>
<td>CONTROLLING ACT</td>
<td>REGULATIONS, ORDINANCES, &amp; BY-LAWS MADE UNDER THE CONTROLLING ACT</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>---------------------------------------------</td>
<td>--------------------------------------</td>
<td>-------------------------------------------------------------------</td>
</tr>
<tr>
<td>Food Processing</td>
<td>Dept. of Primary Industry</td>
<td>Commonwealth Health Act</td>
<td>Public Building Regs</td>
</tr>
<tr>
<td></td>
<td>Public Works Dept.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitals</td>
<td>Public Health Dept.</td>
<td>Health Act</td>
<td>Public Building Regs</td>
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<td>Public Works Dept.</td>
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<tr>
<td>Hotels</td>
<td>Licensing Court</td>
<td>Licensing Act</td>
<td>Factories &amp; Shops Regs</td>
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<td>Public Health Dept.</td>
<td>Health Act</td>
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<td>Inflammable Goods Stores</td>
<td>Mines Dept.</td>
<td>Explosives Act</td>
<td>Storage of Flammable material</td>
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<td></td>
<td>Explosives Branch</td>
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<tr>
<td>Motels</td>
<td>Local Authority</td>
<td>Model By-laws</td>
<td>Regulation Code</td>
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<td>Offices</td>
<td>Inspector of Machinery</td>
<td>Inspection of Machinery Act</td>
<td>S.A.A. Lift Code</td>
</tr>
<tr>
<td>Public Buildings, Halls and Restaurants Theatres</td>
<td>Public Health Department</td>
<td>Health Act</td>
<td>Public Building Regs</td>
</tr>
<tr>
<td>Pharmacies</td>
<td>Pharmacy Board</td>
<td>Pharmacy Act</td>
<td>Health By-laws</td>
</tr>
<tr>
<td>Parking</td>
<td>Local Authority</td>
<td>Town Planning Act</td>
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<tr>
<td>Schools</td>
<td>Public Works Dept.</td>
<td></td>
<td>Town Planning Regulations</td>
</tr>
<tr>
<td></td>
<td>Education Dept.</td>
<td></td>
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</tbody>
</table>

.../4
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>ADMINISTRATIVE AUTHORITY</th>
<th>CONTROLLING ACT</th>
<th>REGULATIONS, ORDINANCES, &amp; BY-LAWS MADE UNDER THE CONTROLLING ACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers and War Service Homes</td>
<td>Commonwealth Department of Housing and Construction; State Housing Commission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICES TO BUILDINGS</td>
<td>Fire Brigades Board Fire &amp; Accident Underwriters Association Bush Fires Board (unoccupied land)</td>
<td></td>
<td>Uniform Building By-laws</td>
</tr>
<tr>
<td>Fire Precaution</td>
<td>S.E.C.</td>
<td></td>
<td>Uniform Building By-laws</td>
</tr>
<tr>
<td>Gas</td>
<td>S.E.C.</td>
<td></td>
<td>Code of practice for gas installation</td>
</tr>
<tr>
<td>Electricity</td>
<td>S.E.C.</td>
<td></td>
<td>Code of practice for L.P. gas installation</td>
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<tr>
<td>Telephones</td>
<td>Telecom</td>
<td>Commonwealth Act</td>
<td>Telecom, Radio Regulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.../5</td>
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<tr>
<td>SUBJECT</td>
<td>ADMINISTRATIVE AUTHORITY</td>
<td>CONTROLLING ACT</td>
<td>REGULATIONS, ORDINANCES, &amp; BY-LAWS MADE UNDER THE CONTROLLING ACT</td>
</tr>
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<td>------------------------------------------</td>
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</tr>
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<td>Main Roads</td>
<td>Main Roads Dept.</td>
<td>Public Works Act</td>
<td>Roads, Reserves, etc. Freeway Construction Design</td>
</tr>
<tr>
<td>Town Planning</td>
<td>Town Planning Board</td>
<td>Town Planning Act</td>
<td>Regulations</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Planning Authority</td>
<td></td>
<td>Town Planning Schemes</td>
</tr>
<tr>
<td>Land Titles - reserves, land and surveys</td>
<td>Titles Office</td>
<td>Lands and Surveys Act</td>
<td>Metropolitan Regional Plan and Regulations</td>
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<td>Swan River</td>
<td>Swan River Conservation Board</td>
<td>Swan River Conservation Act</td>
<td>Titles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Road reserves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recreation Reserves</td>
</tr>
</tbody>
</table>
3.2 SITE CLEARING AND EARTHWORKS

Before any materials or temporary services are connected to the site, clearing of the site should be undertaken. It is important to note any trees or shrubs that need to be left standing. Where these are indicated on the site plan or nominated on site by the owner or architect, they should be clearly marked on site. A usual method is to fix a wide (about 100 mm) brightly coloured band of tape or cloth around the trunk of the tree or foliage of the shrub.

Clearing may involve only the removal of vegetable matter and a small amount of top soil over the actual site coverage, plus an allowance of about 3 m beyond. This operation can usually be performed by a small bulldozer or front-end loader. Where removal of growth and top soil has taken place and given floor levels are to be maintained, it may be necessary to replace the removed soil with clean fill which would need to be compacted with a mechanical compaction machine.

On sites that are not readily suitable for building on directly, a sand pad may be needed to act as a cushion to compensate for plastic foundations, or to maintain a height above a high water table. This pad needs to be placed and compacted in layers, usually not exceeding 600 mm. Sand pads are most suitable for receiving slab-on-ground footings; the advantages of this type of footing will be discussed in more detail later in the text.

When placing the sand pad or, in fact, when doing any site preparation, consideration must be given to the finished floor level. The finished floor level and a datum reference can usually be found on the block plan along with any other notations and contour lines giving information regarding the shape and slope of the site.

Datums are arbitrary reference points to which heights can be referred. They should be permanent objects not subject to movement or damage. For example:

- crowns of roads
- sewer manhole covers
- kerbside stormwater grates
- existing buildings.

Reference is usually made that the finished floor level will be so many millimetres above or below the arbitrary datum. (Fig. 3.1)

There are various methods of clearing and preparing sites. A lot will depend upon the vegetation that exists on the site; the size of the site; the type and volume of earth to be moved; the slope of the site; and whether it is to be cut and removed, cut and filled or filled only.

The plant available for this work ranges from small "bobcat" type bucket loaders to large articulated front end loaders and bulldozers. The selection of the plant will depend on the points mentioned previously (Fig. 3.2 shows several methods of site works).
Cross section through site

Plan of site

FIG. 3.1

3.9
3.3 SETTING OUT

The setting out of the building on the site is an operation of the building works that must receive a great deal of care and attention. An incorrectly sited building can prove very expensive to rectify if it encroaches on other sites or is too close to boundaries. A building that is not set out square will create problems for following trades particularly the roof carpenter.

METHOD

Careful and orderly progression of a sequence of setting-out operations will help ensure a correctly sited and true building. The following is one method of setting out. Refer to Fig. 3.3 as you follow the steps.

1. Ensure that you are on the correct site. Check the site plan for means of identification such as:
   . boundaries to observe shape and size of block;
   . street names and lot numbers;
   . adjoining premises if existing;

FIG. 3.2
FIG. 3.3
2. Locate the corner pegs of the site and drive in a long stake, preferably a steel star picket, adjacent to the site peg without disturbing it. This will readily show the boundaries and will also show the pegs to other workers; hopefully, they will not bury, remove or alter their location.

3. String a line across the frontage pegs of the site and from that measure back the "set-back distance". This should be 7.5 m but some local authorities may vary it so observe the distance given on the "approved" copy of the working drawings.

4. After measuring back the set-back distance place in two sets of profiles, set at floor level, and string a line to mark this distance. The line so marked is known as the building line. (See Fig. 3.4 for profile).

![Profile]

FIG. 3.4

5. Check the site plan and select a side of the building to work from as the next step. It is advisable to select the side which has the longest run and the least off-sets. String a line down the side boundary and measure in from that boundary the clearance given on the site plan. Position two sets of profiles, one at each end and accurately mark the distance from the boundary on the profile near the building line. Keep the profiles at least a metre back from the face of the proposed building.

3.12
6. The next step is to square the side line of the building. This can be done with instruments such as the theodolite but these are not usually available on domestic work nor are there always surveyors available for the builder to use when he wants them. The most practical methods are by constructing a large right-angle triangle or by using what is known as the 3-4-5 method.

In a particular right-angled triangle, the sides can be found to be of the ratio of 3:4:5 (See Fig. 3.5). To prove if a triangle is indeed a right-angled triangle, we can square each side (that is, multiply its length by itself: for example, $4 \times 4; 3 \times 3; 5 \times 5$), and then add the squares of the sides making the right angle (the adjacent sides). The sum of these squares of the adjacent sides should equal the square of the hypotenuse (longest side); that is, $5 \times 5$. Thus:

$$(3 \times 3) + (4 \times 4) = 5 \times 5$$
$$9 + 16 = 5^2$$
$$25 = 25$$

So, to construct a timber right-angle square, we can use any multiple of 3:4:5. To check any angle for square, we can multiply each adjacent side by its own length (squaring), add the two together and compare it to the square on the hypotenuse.

![FIG. 3.5](image)

7. Once the side is square, fix the side line to the profile at the end of the side line and re-check for the amount of clearance to the side boundary.

8. We now have a front building line and a side line square to that line. Other sides and lengths can be found by taking measurements from these lines. To position the back line, measure down from the front building line the overall distance of the
building at each end of the building line. When measuring, always keep the tape horizontal and never follow the fall of the ground as that dimension is longer and errors will occur.

Place the profiles in position, then re-measure and mark the position of the back line on the profiles. Because we have kept the back line parallel to the front line, the angle between the back line and the side line should be square. We will be checking this later on in the set out.

9. Measure the overall distance from the side line to position the opposite side of the building. This is done similar to step 8.

10. The job should now be checked to prove that it is square: that is, parallel sides and four right angles. This can be done by measuring the length of the two diagonals. If the job is square, the diagonals will be the same length. If the diagonals are not the same length, re-check the sides for length and correct if necessary. When the sides are the right length but the diagonals do not correspond, recheck the first corner for square and adjust. When 4 sides are true to length and parallel, and one corner is square, the diagonals will be the same length and the job will be square.

11. Now that the job is square and true, offsets and returns can be measured and set out on profiles. By keeping the offset lines parallel to the already existing lines, the offsets should also be square.

12. Once all offsets have been marked on the particular profiles, it is now necessary to position on the profiles all the information needed to construct the footings and walls. See Fig. 3.3 and observe that on the profile is the width of the trench to receive the footings and the width of the wall showing the separate wall and cavity thicknesses. Bear in mind that the profile shown is not the only profile; there are several ways of erecting profiles. Some builders put the horizontal cross piece on the back of the uprights rather than on top of them. Some builders use saw cuts instead of nails to mark the position of footings and walls. Not all string lines are placed around the job at the one time; they are used only as required.

3.4 TIMBERING IN EXCAVATIONS

THE NEED FOR TIMBERING

The importance of having a good knowledge of soil mechanics and the best (yet most economical) method of properly timbering or supporting the sides of trenches, excavated either mechanically or manually, or by both means, cannot be over emphasised. There have been far too many collapses, resulting in injury and death of tradesmen and others, apart from financial losses to contractors and insurance companies, to allow any risks to be taken by contractors.
Very few soils will retain a vertical face when excavated and left exposed to the atmosphere for any length of time. The sides of excavations, therefore, require to be supported, to prevent this falling in. This is done by timbering and strutting. In large cities and towns no excavations should be made (even if the soil itself is stable) without adequate timbering and strutting, in order to prevent any movement of the ground caused by the vibration of traffic and the weight of the surrounding buildings, especially if there is any danger to the public at large. In open country or open sites, where these conditions do not exist, timbering and strutting need not be insisted upon unless workmen safety is an issue.

Experience shows that ground in open excavations tends to move or creep more during the night than during the day; what was a clearly lined trench one day can be a collapsed mess the next, unless proper precautions are taken. Also, the inevitable rainstorm will do enormous damage, and provision needs to be made for such eventualities.

Although the exact figures will depend on different conditions—such as: the geological formations, the nature of surface soils and sub-soils, and the porosity and water content of the ground—the following may be taken as the approximate heights at which the various soils will retain a vertical face for a short time:

- dry sand and gravel 300 mm
- moist sand, ordinary surface soil and peaty soil 300 - 900 mm
- loamy soil 1500 - 3000 mm
- ordinary clay 2100 - 3600 mm
- rock over 3600 mm

**TYPES OF TIMBERING USED**

Although the term timbering is used to describe the supporting of the sides of excavations, materials other than timber and proprietary systems of steel or pre-pact concrete are available and widely used. There are three typical methods of supporting the sides of trenches and open cuttings excavated for foundations, drainage work, pipe lines, etc.

(a) *Firm ground*—consists of the upright timbers, called poling boards, placed against each side of the excavation at intervals between 900 mm and 1800 mm depending on the ground. These boards are kept apart by struts of 100 mm x 100 m cut and driven tightly home. See Fig. 3.6 (a).

(b) *Moderately firm ground*—the second method is adopted where the earth requires to be supported at shorter intervals than the method above and consists of upright poling boards and struts as before but with additional horizontal timber, termed waling pieces. This system is fixed as follows. The cutting is commenced at one end and, as soon as sufficient earth has been excavated, a pair of poling boards is fixed and strutted apart.
Note: This process is repeated along the trench and, when about 3600 mm has been cleared, the waling pieces of 100 x 100 mm timber are fixed and strutted tightly against the poling boards and the temporary struts are then knocked away. (See Fig. 3.6 (b))

(c) Soft or loose earth. In this case, horizontal boards called sheeting support the sides of the excavation. These are supported by upright poling boards tightly strutted. As the width of each poling board is excavated, the lengths of sheeting are fixed and strutted separately. When four or five boards are in position, the poling boards are put in and strutted apart and the temporary struts removed. (See Fig. 3.6 (c))

Proprietary systems are also widely used and Figures 3.7 and 3.8 show the methods of installing systems in non-cohesive soils and free running soils respectively. Excavations can be left open under conditions previously mentioned. Where this is done, consideration must be given to the natural slope of excavated ground. This slope, at which the soil no longer falls or slides down is known as the angle of repose. Listed below are some typical angles of repose. (See Fig. 3.9).

![Diagram with labels: maximum distance 1800, 225 x 38 poling boards, 100 x 100 struts, FIRM GROUND]

**FIG. 3.6 (a)**

3.16
FIG. 3.6 (b)

225 x 38 sheeting

255 x 38 poling board

first board of next system temporarily supported

FIG. 3.6 (c)

MODERATELY FIRM GROUND

100 x 100 waling pieces

100 x 100 struts

2500 max. distance

LOOSE EARTH

225 x 38 poling boards
This system is ideal for supporting trenches in non-cohesive soil — either following the excavator in semi-unstable ground or ahead of excavating in unstable and free-running sand and the like. The following procedure has been developed and proven for speed and safety, for shoring non cohesive trenches following the excavator.

(a) step 1

The Trench Guards following the excavator are toed in below the invert. Guards are easily driven by hand dollys or air-powered hammers.

(b) step 2

Opposite pairs can be toed in and temporarily strutted with the plate head trench jacks if the ground condition is not too unstable or, alternatively, waler hooks can be dropped into the top angle cleat; waler dropped in and trench jacks inserted and extended on the top waler. At this point the trench is supported at intervals by the guards strutted at the top and toed in at the invert, and no man has entered the trench.

(c) step 3 & 4

Additional guards can then be inserted between the trench side and the top waler and toed in as before. The trench is now partly or fully sheathed and supported at the toe and the top. Men can now enter and fit the succeeding lines of walers and trench jacks.

FIG. 3.7

(Adapted from drawings - courtesy of Acrow Australia Limited)
When trenching in unstable ground and free-running sand and the like, it is safest to drive the guards ahead of the excavation. Indeed, sometimes this method is the only practical and safe way of sheathing in these circumstances.

**step 1**
Set up a "guide rig" or platform along the line of the proposed trench and drive the guards into position deeper than the depth required. Guards can be driven at an average speed of 3'0" (0.90m) per minute.

**step 2**
Proceed with the excavation and when the invert level of the trench is below the first cleat, drop the waler hooks in the cleats and fit the first waler and the trench jacks. Excavation can proceed deeper, fitting lower levels of walers and jacks as the angle cleats are uncovered, until the trench is fully excavated.

*FIG. 3.8*
(Adapted from drawings - courtesy of Acrow Australia Limited)
NOTE: All angles taken from the horizontal.

FIG. 3.9
CHAPTER FOUR - SURVEYING AND LEVELLING

4.1 LEVELLING INSTRUMENTS

SPIRIT LEVEL AND STRAIGHT EDGE
BONING RODS
LINE LEVEL
WATER LEVEL
COWLEY AUTOMATIC LEVEL
DUMMY LEVEL
SETTING AND ADJUSTING
STAFF
TILTING LEVEL
THEODOLITE
LASERS

4.2 SQUARING

METHOD
VERNIER SCALES

4.3 LEVELLING

BENCH MARKS

4.4 BOOKING LEVELS

RISE AND FALL METHOD
THE GROUND PROFILE

4.1 LEVELLING INSTRUMENTS

The types of levelling instruments in common use on a building site may be of several types:

- a spirit level and long straight-edge, which may or may not be used in conjunction with a set of boning rods
- boning rods
- line level
- water level
- a Cowley automatic level
- a dumpy level
- the staff
- tilting level
. theodolite
. laser equipment.

SPIRIT LEVEL AND STRAIGHT EDGE

A spirit level and a straight edge (about 3 to 4 m long) may be used for any type of levelling operation of a minor nature or for small jobs. It is a slow method and great care must be taken when any form of packing is used or measurements taken. It should be noted that the long straight-edge must be reversed every time it is moved to a new position. Figure 4.1 illustrates a long straight-edge and level being used to take a level from a fixed peg.

![Figure 4.1: Long straight edge and spirit level](image)

FIG. 4.1

If used in conjunction with a set of boning rods they may be used for levelling trenches, ground work, pavings, etc., but they are more often used for drainage lines or road work. There are three boning rods to a set.

BONING RODS

Two pegs A and C are levelled at about 6 m centres. Then one boning rod is held on each of these pegs and a third boning rod is held on top of the required peg at any portion of the intervening space. The required level can be ascertained by driving the peg in until the top of the boning rod resting on the peg B sinks level with a sight line taken over the top of pegs A and C. (See Fig. 4.2). By the same principle, if peg C were a point lower or higher than peg A, a regular rising or falling line or grade could be equally well produced and extended as in the case of setting drain pipes to a regular fall.

The sight so taken, over the top of the boning rods, is termed "boning". When the rods are used for drain or sewer laying, sight rails are fixed up as shown in Figure 4.3, and a line of sight from one rail to the next will be parallel to the drain and at a distance above it equal to the convenient height of the boning rod which, when sighted, gives the proposed invert of the drain or sewer at the respective position. The invert of the pipe is the lowest point at the bottom of the interior of the pipe and this is the point on which the small metal shoe of the boning rod rests. The sight rails are secured to uprights either sunk into the ground, or set in drain pipes placed on the ground and filled with earth or sand.
FIG. 4.2

LONGITUDINAL SECTION

CROSS SECTION

(All dimensions in millimetres)

FIG. 4.3

4.3
LINE LEVEL

Used intelligently, the line level can be surprisingly accurate. It is affected by wind and irregularities in cord lines, and must be set perfectly central on the line for a true reading.

To detect line irregularities the bubble should be read, then the instrument slid 10 mm along the line and re-read. It should then be reversed on the line and read again. Any differences should be averaged.

Accuracy can be considerably increased if a nylon monofilament fishing line is used instead of chalkline. The monofilament line is stronger, lighter and absolutely parallel.

WATER LEVEL

The simplest water level is a length of hose with clear plastic or glass tubes at each end and filled with water. The water level at each end will always be level with the other.

A refinement of this is the use of a constant level reservoir on a tripod or suspended, and connected to one end of the hose. The other end of the hose terminates in a graduated staff. This staff is so designed that levels are directly read as rises or falls, above or below the datum to which the staff is set.

This level is the fastest and one of the most efficient and simple to use of all instruments and has good accuracy. The operator needs no assistant and line-of-sight is unnecessary although distance is limited to the length of the hose which is usually 30 m.

There are, however, two factors which are capable of producing large errors. The first is air in the hose which can be detected by inspection. The second is differential temperature usually caused by sun on portions of the hose. Fairly frequent reference back to datum will show if an error has occurred.

THE COWLEY AUTOMATIC LEVEL

The Cowley automatic level shown in Figure 4.4 requires little setting up and no adjustment, and can be used by any site worker after a brief explanation.

When the instrument is placed on its special tripod pin an internal pendulum is released. It is this pendulum with an attached mirror, that automatically levels the line of collimation (line of sight). While on the tripod the mechanism is prone to damage.

If the instrument is to be carried, it must always be first removed from the tripod in order to lock the pendulum. The lock operates automatically on removal of the instrument from the pin.

In use the tripod is set up so that its pin is approximately plumb and the instrument mounted on it. The operator then sights through the eye piece on the top and directs an assistant to raise or lower the target until it coincides with the line of collimation. The target is seen as two halves, and is at the correct height when the two halves come together. When level, the staff-man reads and, if required, records the staff reading. The significance of this will be explained later. (See Figure 4.5)

As it relies on a level line of collimation, the Cowley level is used similarly to the dummy and tilting levels described later. There are, however, two limitations which are generally unimportant for most work.
. SIGHTING DISTANCE: As there is no magnification the limit for a single sight is about 30 m from the instrument to staff.

. PROBABLE ACCURACY: ± 8 mm in 30 m for a single sight (error up to 8 mm in 30 m). This compares with a water level ± 5 mm, and optical levels ± 2 – 5 mm per sight depending on the quality of the instrument.

In common with the optical levels it should be checked periodically, and especially before any important operations. The method for testing is described later under the heading "Collimation Line", but the pegs need be only 6 – 10 m apart. If the instrument is found to be faulty it must be sent to an instrument maker as there is no provision for adjustment.

THE DUMMY LEVEL

The dumpy level consists essentially of a telescope and a sensitive spirit level fixed together so that they are parallel. The telescope is fitted with cross hairs or metal points so that, when the instrument is levelled, a distant mark can be sighted on the cross hairs or points and the line through the telescope to the distant mark is then level. The instrument is levelled by manipulating three or four screws fixed round a socket joint. Three screws are better than four as the instrument is more readily levelled with three. The level is then used to obtain information as to the relative levels, or shape, of the earth's surface.

As this is a precision instrument it is necessary for it to be in good adjustment. It is advisable to check its accuracy: the time taken is well spent. The main features of the dumpy level are shown in the line diagram in Figure 4.6.

SETTING AND ADJUSTING

Setting the Tripod

The first step will be to set up the instrument. Take the level out of its box and screw it firmly on to the tripod. Spread the legs of the tripod so that the lower parallel plate of the instrument is approximately level. See that the toes or feet of the legs are pushed firmly into the ground so that there is no chance of the legs slipping. If the ground is hard, it is as well to make use of a few bricks to secure the legs.

It is important to see that the level is fixed at a convenient height for sighting. With some of the smaller instruments the legs are telescopic, so that the question of height is easily dealt with. With the usual or normal sized instrument the legs are fairly long and, if the user of the instrument is short, it might be found that the legs have to "spread" rather too much, especially on hard surfaces. It is suggested that the bricks will still be found to be of use.

The adjustments of the dumpy are as follows:
1. adjustment for parallax
2. levelling at the parallel plates
3. making the bubble remain central when the telescope is turned end for end. This is called adjusting the horizontal limb

4.6
4. adjustment of the line of collimation.

Adjustments 1. and 2. are called temporary adjustments and are made every time the instrument is used. Adjustments 3. and 4. are called permanent adjustments and are only carried out when the instrument is faulty. In fact, once an instrument has been properly adjusted there is no reason why it should go out of adjustment unless somebody drops it or tries turning the capstan-headed screws to see what effect it has on the instrument. Although the permanent adjustments are rarely necessary, it is essential to know how to test the instrument to see if it is in good working order.

1. Parallax Adjustment

Having set the legs, the adjustment for parallax may be performed. This simply means that the eyepiece is adjusted so that the cross hairs, cross wires or cross lines of the diaphragm stand out sharp and distinct when viewed from the eyepiece. On modern instruments the eyepiece is screwed in and out. A good way to adjust it is to screw it right in and then turn it back until the lines appear quite distinct; keep on turning until they start to fade a little, then reverse the movement until you have the best possible adjustment. When doing this it is helpful to have the telescope pointing towards a clear sky. Alternatively, a piece of white paper can be held in front of the object glass.

Correct focus, both of cross hairs and of the staff, is vital. It is wise to test this when taking each sight by raising and lowering the eye. If the cross hair appears to move up and down the staff, then the instrument must be refocused.

The diaphragm has been mentioned; its position in the instrument is shown in Figure 4.6. It is usually a glass disc held in a brass circular frame. Very fine lines are etched on the glass and a usual arrangement of the lines is shown in Figure 4.7. The diaphragm may be adjusted vertically by means of capstan-headed screws as shown in Figure 4.6, but we shall have more to say about this later.

2. Levelling the Instrument

Some instruments have three footscrews and some have four. We will deal with the three screw type first. Place the telescope in line with any two of the footscrews, as shown in Figure 4.8, and turn these two screws in opposite directions until the bubble is central. It is useful to know that the bubble will move in the direction in which the left thumb is moving. Simply, if the bubble has to move to the left, then the screw must be turned away from the instrument - that is, outwards; if the bubble is required to move to the right, then the screws must be turned inwards.

Having adjusted the instrument so that the bubble is central, turn the telescope so that it is over the third screw. Now, by turning the third screw, centre the bubble. Return the telescope to its original position and adjust the bubble again if necessary. Now turn the telescope end for end as shown in Figure 4.9. The bubble should be central. If it is not central and it is found impossible to make it so for the telescope in any position, it means that the bubble tube must be adjusted.
It will be seen from Figure 4.6 that the bubble tube is fixed to the telescope by means of a hinged joint at one end and by a screw and capstan-headed nuts at the other end. The method adjusting the horizontal limb is fairly simple. Place the telescope over any two of the footscrews and bring the bubble to the central position. Reverse the telescope; that is, turn it end for end. Note how many divisions the bubble has gone out of the centre. We will assume that it is six divisions out of centre. Now slacken off the nuts holding the spirit level tube and readjust so that the bubble is brought back three of the divisions out of the six it is in error and tighten up the nuts, keeping the bubble in that position. Finally adjust the bubble to centre, using the footscrews.

To adjust the four-screw level, place the telescope over two diagonally opposite screws as shown in Figure 4.10. Using these screws, bring the bubble to the centre of its run. Now turn the telescope over the remaining two screws and bring the bubble to the centre. Return the telescope to its original position and re-adjust the bubble if necessary. Turn the telescope end for end and check if the bubble is central. It should be, if the instrument is in adjustment. If the bubble is eccentric take one-half the error with the footscrews and the remainder with the screws holding the spirit level tube.

3. Central Bubble

The process of levelling the plates should now be repeated and, if the bubble tube has been properly adjusted, the bubble should remain central for the telescope pointing in any direction. If after repeated attempts to make the bubble remain central it is found impossible to do so, it would be necessary to return the instrument to the maker for adjustment.

What we have been trying to do is simply this: if a plumb bob or plumb line were hanging from the centre of the instrument, then when the bubble is central the tangent to the bubble tube is horizontal and therefore at right-angles to the plumb line or vertical axis of the instrument; further than this it does not matter in which direction the telescope is pointing. See Figure 4.11.

---

![Diagram](image)

**FIG. 4.11**

Having fixed the instrument so that the bubble is central for the telescope pointing in any direction, it will be necessary to see that the line of collimation is parallel to the tangent to the bubble tube when the bubble is central.
The line of sight passing through the horizontal crossline and the centre of the object glass and the object being viewed is called the line of collimation. This is shown in Figure 4.12.

4. Collimation Line

The truth of the line of collimation may be tested in several ways. A common method is as follows. Set up the instrument exactly midway at B between two pegs 30 m apart. It would be an advantage if the ground is reasonably level. Set up the instrument very carefully. Take a reading on peg A, making certain that the bubble is central. As the ground is reasonably level, the pegs A and C may be adjusted so that the reading is the same on each. Now, no matter if the instrument is not in perfect adjustment, the two pegs will be at the same level because, as the instrument is central, the line of collimation A and C is as shown in Figure 4.13.

Move the instrument to a point D, 5 m from C and in line with A, B and C. Take a reading on pegs C and A. If the reading is the same on each peg, then the line of collimation is parallel to the tangent to the bubble tube when the bubble is central and, as the pegs are at the same level, the instrument is quite satisfactory.

If the readings are not the same, say the reading on peg A is 1.7 m and that on peg C is 1.5 m, then the line of sight is running up. It is running up 0.2 m in 30 m, therefore the amount of error in 5 m will be:

\[
0.2 \div \frac{30}{5} = 0.33 \text{ m} = 33 \text{ mm}
\]

The diaphragm must be adjusted so that the reading on peg C will be 1.5 m - 0.033 = 1.467. This adjustment may be performed by slackening the screws holding the diaphragm and adjusting it to the correct position and tightening up again. Only a slight movement is necessary, so care should be taken.

The instrument is now ready and fit for use.
USING A FAULTY INSTRUMENT

If an instrument is out of adjustment and cannot be corrected before using, accurate levelling can still be achieved by using only backsights and foresights of identical distance. Provided the distances between the instrument and the staff are exactly the same, then so will the error of reading be exactly the same. The errors then compensate for each other.

THE STAFF

Although there are other systems of graduation the one illustrated here is the easiest to read. It is graduated in metres, tenths of metres, and hundredths of metre divisions (1 m, 100 mm, and 10 mm). Millimetres are read by estimation.

The markings on the staff are carefully designed to aid reading. See Figures 14.14 and 14.15 and note:

1. Even numbered metre divisions are coloured black, while odd numbered metres are red.

2. Metres are numbered with small digits and tenths in large digits.

3. The bottoms of all the numbers are exactly in line with the division to which they refer.

FIG. 4.14
4. A most important difference from other common measuring instruments is that the divisions are not denoted by a line, but by the edge of a painted bar. The bars are exactly 0.01 m (10 mm) thick and so are the spaces between the bars.

5. Every 0.1 m coincides exactly with the bottom edge of the $\square$ or $\square$, odd tenths at $\square$ and even tenths at $\square$.

6. Dimensions .00 - .05 m are always found on the $\square$ or $\square$. Dimensions .051 - .099 are in spaces or isolated bars.

---

**FIG. 4.15**

4.12
THE TILTING LEVEL

This type of level is fast superseding the dumpy level because of the ease with which it is adjusted; this being an important factor in a survey requiring many changes in the position of the level. The instrument is of the three-screw type for the base plates, but as there is a secondary means of adjustment on the level tube itself, very accurate levelling with base screws is not required. This type of level is generally fitted with a small circular spirit level, and it is sufficiently accurate to adjust the base screws so that the bubble of this level lies within a central circular engraving.

There is a variation of this type of level known as the Quick Set Level. It is exactly the same as the tilting type except that the three-screw base is replaced with a spherical or ball and socket joint which is clamped by a threaded ring round the joint.

TILTING LEVELS

FIG. 4.16

Reproduced with the kind permission of Sokkisha Co., Ltd.
The fine adjustment of the level is made "previously to each reading" by a fine adjusting screw underneath the telescope near the eye-piece. The main bubble tube is fixed to the side of the telescope and is fitted with a mirror which is hinged at one end and lifts upwards so that the reflection of the bubble can be seen from the level of the eye-piece. This enables the adjustment of the bubble to be made by the surveyor without movement of his position by viewing the image in the mirror. This also allows the accuracy of the levelling of the instrument to be checked immediately before taking the reading. (See Figs. 4.16 and 4.17).

![Diagram of a theodolite](image)

TILTING LEVELS

FIG. 4.17

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The telescope is of the internal-focussing type and, therefore, there is no movement of the eye-piece, as the two lenses remain in one position throughout, the focussing being carried out by the movement of an internal lens between the above points.

THEODOLITE

Students of building may not be required to use a theodolite but, as they have their place in the setting out of major works, a basic understanding may be useful.

The theodolite is basically the same as a dumpy level. It consists of the same three screw adjustable base with precise telescope and spirit level. Also like many dumpy levels it has
a horizontal circle, divided into 360 degrees to permit setting off horizontal angles.

FIG. 4.18
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There is, however, one major difference. The telescope is pivoted also so that it can revolve in a vertical plane. A vertical circle calibrated in degrees permits horizontal angles to be read. Figures 4.18 and 4.19 show two different types of modern Theodolites.

NEW DEVELOPMENTS - LASER EQUIPMENT

The use of electronic equipment in specialist surveying equipment is not new, but till recently has not been suitable for building construction. A laser instrument developed by the Swedish firm of A.G.A. Geotronics now appears to have tremendous potential for builders.

This instrument is based on an entirely new principle. Supported on a tripod, it projects two diametrically-opposed, horizontal laser beams. These rotate about 10 revolutions per second and so cut or generate a horizontal reference plane over the entire site. The beam can be detected visually whenever required to allow vertical staff measurements to be taken.

Figure 4.20 and 4.21 show two types of modern electronic distance meters.
ELECTRONIC DISTANCE METER

FIG. 4.20
Reproduced with the kind permission of Sokkisha Co., Ltd.

ELECTRONIC DISTANCE METERS

FIG. 4.21
Reproduced with the kind permission of Sokkisha Co., Ltd.
4.2 SQUARING

Most of the modern types of dumpy levels etc, have the facility to obtain square lines from a given period. The following procedure may be followed.

METHOD

A plumb bob is hung down from the centre of the levelling instrument over one corner peg on an established building line. On the instrument itself there is a scale, normally in degrees, with an indicator showing at what degree the instrument set.

A sight is taken to the staff, held plumb, on the second peg on this established building line and the reading on the scale is noted. Now add or subtract 90° from this reading, and set the instrument up facing that direction. Another sighting can now be taken to the staff, held plumb, in line with this sighting, and a mark made on a peg or profile to establish the 90° angle.

VERNIER SCALES

There is always a limit to the minimum spacings to which instruments can be graduated and still be read without confusion. One way of increasing accuracy is to fix microscope lenses to magnify the scales. These can be seen in Fig. 4.22. Another method is the vernier scale which divides the normal scale divisions into any suitable number of smaller divisions.

As surveying instruments are concerned with angles, and it is convenient to graduate the protractor circle in half degrees, the vernier is then based on 30 divisions. This permits accuracy to 1' (1 minute).

The full-circle protractors attached to levels are usually fixed, and are read against a zero mark on a disc attached to and rotating with the telescope. The vernier scale is marked on the movable disc commencing at zero. Figure 4.26 shows a protractor graduated in degrees with the vernier scale marked in 5 minute intervals.

The vernier scale in Figures 4.22 and 4.25 is divided into thirty divisions but is only a length equal to 14 1/2° on the protractor (29 x 30' divisions). Each vernier division is therefore equal to 29/30 of each of the protractor divisions.

TO READ THE SCALE

The position of zero is first noted. In Figure 4.23, zero is given just past 20° so we know the angle will be more than 20° but less than 20 1/2° (20° 30').

The vernier scale is then inspected to determine which of its divisions coincides with one of the protractor divisions. This vernier division is read as the number of minutes to be added to the normal-scale reading. In Figure 4.23 the thirteenth division coincides with a protractor division so the angle is 20 degrees + 13 minutes = 20° 13'.
Optical Square

There are numerous instruments used by surveyors for setting out right angles. A similar instrument especially designed for use on construction sites by construction workers is the site square. It has two telescopes, set exactly at right angles to each other. It is accurate, time-saving and simple to use.
4.3 LEVELLING

Levelling in connection with building may consist of:

(a) Simple levelling, by which is meant finding the difference in level between two points, say A and B, simply by placing the level midway between them and taking a reading at each point. Say reading at A is 2.36 m and the reading at B 1.29 m, then the difference in level will be 2.36 - 1.29 = 1.07 m.

(b) Compound levelling. An example of compound levelling would be as follows. It is necessary to lay a drain from a point A to a point B, a distance of, say, 150 m. By taking a series of levels from A to B it would be possible to draw a cross section of the ground and thereby determine the best run for the drain; that is, depth to give adequate cover, a suitable gradient to avoid excessive excavation. This is, of course, assuming that invert levels are not previously fixed. The amount of excavation necessary could also be calculated from the section.

(c) Spot levels. This means setting out a grid over a building site and obtaining the level of pegs at the intersection of grid lines. From these spot levels the amount of excavation may be calculated.

(d) Setting sight rails for drainage work so as to give accurate falls from point to point. In this connection very accurate work is necessary for situations where only a very slight fall is possible, such as for main sewers in flat country.

For all classes of levelling, it is necessary to start from a bench mark which may be related to the ordnance bench mark, and it is suggested that first of all we consider the definition of some of the terms used.

Levelling may be briefly described as "comparison of height of one spot with another". All heights must be relative; for example, the head of a 2.0 m man is that much higher than the ground at his feet - and may be relative to each other, or both to a third. If we introduce a smaller man to our giant and they stand on the same ground, we can compare the 1.5 m man with the 2.0 m man and know that the difference between their heights is 0.5 m because in each case the heads are compared with the ground at their feet and the difference is 0.5 m.

TRIG POINT

A trig point is, of course, an ordnance survey station used for the triangulation of a country. Such points are intervisible and observations are made between them, usually at night, using lamps to avoid atmospheric distortion. They are shown on ordnance survey maps as a small triangle with a dot in the centre. One type of trig point is illustrated in Figure 4.27.
ORDNANCE BENCH MARK

This is a permanent, established height above sea level. It may be a broad arrow cut into a wall or a brass plate or peg set in concrete. The latter is often set in a footpath and protected by a cover.

The water supply and sewage authorities can usually provide the height-above-sea-level of their sewers, manholes, etc.

---

FIG. 4.27

CROSS-SECTION OF TRIG POINT

FIG. 4.28

BENCH MARK

SITE DATUM

Also called an arbitrary datum or assumed datum, the site datum is an established height to which all levels on the job are related. It must be on something which will not be disturbed during the course of the job. It can be the top of a sewer manhole cover; or it can be a mark on a wall or the top of a peg set in concrete especially for the purpose.

The site datum is usually given an arbitrary value, say 10 m or 100 m to avoid reduced levels below zero. Except on major constructions there is seldom any need to relate the site datum to ordnance datum (sea level).

REDUCED LEVEL

The height of any point with reference to the selected datum. For example, if the datum point A is given a reduced level (RL) of 10 m, and point B is 2 m higher, then the RL of point B is 12 m.

BACKSIGHT

Backsight is the first reading after the level has been positioned or re-positioned. A reading at datum is always a backsight.
FORESIGHT

Foresight is the last reading taken from any given level position, such as on completion or before changing the level position.

INTERMEDIATE SIGHT

Any reading other than backsight or foresight is called an intermediate sight or intersight. Most of the readings on a building site are intersights.

CHANGE POINT

This is the position at which both a backsight and foresight are taken. It becomes necessary because of rising or falling ground, or when levels must be transferred around corners, and the staff cannot be seen in the required position without shifting the level to a new position.

4.4 BOOKING LEVELS

Recording of levels and associated information should be carried out just as carefully and systematically as the levelling itself. The surveyor uses a specially ruled 'field book' in which he records relevant data, sketch plans or maps, etc. The builder does not need such extensive information, especially as he has very detailed plans and usually a limited, clearly delineated site to work on. However, the records should be just as explicit and it is advisable to use properly ruled sheets or books for the purpose.

On the site it is only necessary to record the staff reading in the correct column, with sufficient information to show the position of the staff and of the instrument. Calculations for rise, fall and R.L. may be left until returning to the office.

RISE AND FALL METHOD

This is the most common method of booking levels and is the only one considered here. Figure 4.29 illustrates a simple survey and Table 4.1 shows the method of booking it.

BOOKING OF LEVELS

Set up the instrument in a position where as many as possible of the proposed pegs can be seen. This reduces the number of changes of instrument position. The pegs should be situated at distances no greater than 75 – 80 m apart, and no less than 5 – 6 m.
RISE and FALL METHOD

<table>
<thead>
<tr>
<th>Back-sight</th>
<th>Inter-</th>
<th>Fore-</th>
<th>Rise</th>
<th>Fall</th>
<th>Reduced</th>
<th>Distance</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.000</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>100.000</td>
<td>—</td>
</tr>
<tr>
<td>B</td>
<td>—</td>
<td>3.800</td>
<td>—</td>
<td>2.800</td>
<td>97.200</td>
<td>90 m</td>
<td>—</td>
</tr>
<tr>
<td>C</td>
<td>—</td>
<td>—</td>
<td>1.500</td>
<td>2.300</td>
<td>99.500</td>
<td>90 m</td>
<td>—</td>
</tr>
<tr>
<td>C</td>
<td>3.500</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>90 m</td>
<td>Instrument moved to Y</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>—</td>
<td>0.500</td>
<td>3.000</td>
<td>102.500</td>
<td>120 m</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>2.000</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>120 m</td>
<td>Instrument moved to Z</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>—</td>
<td>1.000</td>
<td>1.000</td>
<td>103.500</td>
<td>135 m</td>
<td>Top of hill</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>—</td>
<td>1.800</td>
<td>—</td>
<td>0.800</td>
<td>102.700</td>
<td>150 m</td>
<td>—</td>
</tr>
<tr>
<td>G</td>
<td>—</td>
<td>3.600</td>
<td>—</td>
<td>1.800</td>
<td>100.900</td>
<td>180 m</td>
<td>—</td>
</tr>
<tr>
<td>6.500</td>
<td>—</td>
<td>6.600</td>
<td>6.300</td>
<td>5.400</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>5.600</td>
<td>—</td>
<td>—</td>
<td>5.400</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>0.900</td>
<td>—</td>
<td>—</td>
<td>0.900</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

N.B. — End each page with a backsight and carry out check.

TABLE 4.1

ANSWER: The ground has recorded a rise in elevation from first to second reading

\[
1.500 - 0.500 = 1.000 \text{ Rise}
\]

ANSWER: A fall has been recorded between the first reading and the second.

\[
1.800 - 2.300 = -0.500 \text{ Fall}
\]

FIG. 4.30

4.23
FIG. 4.31

4.24
Steps

Refer to Figure 4.31 throughout these steps.

1. Read staff at the known datum and enter this first reading in the backsight column. (See Table 4.2)

2. Move the staff to a new location and take a reading and record the reading in the intermediate column. Repeat this procedure for all intermediate readings, between the backsight (the first sighting on that particular instrument position) and the foresight (the last sighting on that particular instrument position).

3. When all sightings have been taken that are possible from the present location, the last reading is recorded as a foresight and the move to a new location is made by leaving the staff at the last station and moving only the instrument to a new location where it will be possible to read the remainder or a large number of the remaining stations. When set up, read the reading from the station which was read last prior to moving (foresight) and record the new reading in the backsight column.
Note: the station is booked twice, once as a foresight and once as a backsight.

4. The remaining stations are booked in the intermediate column.

5. To end the booking, the last reading taken is entered in the foresight column.

6. Fill in the rise and fall columns. These are calculated by subtracting the second reading from the first, and each subsequent reading is subtracted from the reading preceding it. If the answer from the subtractions is positive, the answer is entered as a rise in the rise column; that is, the ground has risen in elevation. If the answer is negative, then the ground has fallen away and the answer is entered in the fall column. (See Fig. 4.30 for clarification).

7. The levels are now checked to see if they "balance" or "close". To do this we add up the backsights, add up the foresights and subtract the smaller of the two from the larger. Next add up the rise column and add up the fall column, and subtract the smaller from the larger. We should get the same result that was obtained when we subtracted the foresights from the backsights. If these two calculations do not balance then an error has been made in our recording system. Possible errors could be readings placed in the incorrect columns, rise and falls in the incorrect column, subtraction errors when calculating rise and falls or any combination of these three possibilities.
<table>
<thead>
<tr>
<th>Station</th>
<th>Back-Sight</th>
<th>Intermediate Sight</th>
<th>Fore-Sight</th>
<th>Rise</th>
<th>Fall</th>
<th>Reduced Level</th>
<th>Distance</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.000</td>
<td></td>
<td>Assumed Datum</td>
</tr>
<tr>
<td>B</td>
<td>2.600</td>
<td>0.400</td>
<td></td>
<td></td>
<td></td>
<td>100.400</td>
<td></td>
<td>Sight 2</td>
</tr>
<tr>
<td>C</td>
<td>2.200</td>
<td>0.400</td>
<td></td>
<td></td>
<td></td>
<td>100.800</td>
<td></td>
<td>Sight 3</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>0.600</td>
<td>1.600</td>
<td></td>
<td></td>
<td>102.400</td>
<td></td>
<td>Sight 4</td>
</tr>
<tr>
<td>D</td>
<td>3.600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Move to new position</td>
</tr>
<tr>
<td>E</td>
<td>0.200</td>
<td>3.400</td>
<td></td>
<td></td>
<td></td>
<td>105.800</td>
<td></td>
<td>Sight 6</td>
</tr>
<tr>
<td>F</td>
<td>1.400</td>
<td>1.200</td>
<td></td>
<td></td>
<td></td>
<td>104.600</td>
<td></td>
<td>Sight 7</td>
</tr>
<tr>
<td>G</td>
<td>2.800</td>
<td></td>
<td>1.400</td>
<td></td>
<td></td>
<td>103.200</td>
<td></td>
<td>Sight 8</td>
</tr>
<tr>
<td>H</td>
<td>2.000</td>
<td>0.800</td>
<td></td>
<td></td>
<td></td>
<td>104.00</td>
<td></td>
<td>Sight 9</td>
</tr>
<tr>
<td>J</td>
<td></td>
<td>1.300</td>
<td>0.700</td>
<td></td>
<td></td>
<td>104.700</td>
<td></td>
<td>Sight 10</td>
</tr>
<tr>
<td>6.600</td>
<td>1.900</td>
<td>7.300</td>
<td>2.600</td>
<td></td>
<td></td>
<td>100.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.900</td>
<td>2.600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.700</td>
<td>4.700</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 4.2**

8. When the sights and rises/falls balance we can calculate the reduced levels. This is done by adding any subsequent rises to the preceding reduced levels and subtracting subsequent falls from preceding reduced levels.

9. When reduced levels have been entered they can be checked by subtracting the first and last reduced levels. The smaller is subtracted from the larger and the difference between the two should equal the differences obtained from the rise and fall columns and the backsight and foresight columns.

Plotting the reduced levels can now be undertaken. Using a grid plan constructed to show the position of the pegs you have used in your spot levellings, enter the reduced levels on the appropriate peg position on the plan. A useful convention is to put whole numbers to the left and diagonally across the junction of the grid lines, and parts of numbers to the right. This ensures that the correct height is established and no error is caused by misplaced decimal points.
Now that all peg positions have a known reduced level, we can estimate the distance from each peg to mark off a whole reduced level.

Example: point D is 102.400 RL and point A is 100.000 RL. Somewhere between these two points are the two RL's 101 and 102. The horizontal distance between A and D is 20 m. The vertical difference in height is 2.4 m so we can assume we have a grade which rises 2.4 m in 20 m. Therefore we have 0.12 m rises every metre of horizontal distance.

To work out how far we have to come along the plan line to find RL 101 we simply calculate how many metres along will raise the RL one metre in height and, if each horizontal metre raises the RL 0.12, then we come along 8.33 m. This is found by finding how many times 0.12 m will divide into 1.0 m.

The same distance can be used for RL 102. But all other RL's must be calculated separately.

When all RL's are located, contour lines can be used to join points of equal height to produce a contour plan. (See Figure 4.32).

THE GROUND PROFILE

When surveying for drainage, a drawn profile of the ground surface will simplify the job of establishing correct falls, while keeping an adequate depth below the surface. Such a drawing can be useful also in 'cut-and-fill' jobs, to show diagrammatically the depth of the excavation or filling required, and also the proposed finished-level of the ground.

To draw a section of the ground, start by drawing a horizontal line and on this line set out the distances to some convenient scale. In Figs. 4.35 and 4.36 our distance is 18 m, so if we use a scale of 1:100 we will have a line 180 mm long. Mark off the distances from A on this line and raise perpendiculars at each point. The horizontal line thus drawn represents the datum line and the verticals the height above the datum line. Choose a convenient scale for the vertical heights - in this case, say, 1:100 - and, taking the heights from the reduced level column, mark each vertical line and then join all the points giving a reproduction of the ground just levelled. (See Fig. 4.33).

It is obvious that if all the levels are at about 150 m above sea level and you wish to plot a vertical scale of 1:100 there will be about 1.5 m of waste paper between the datum line and the ground line. In cases like this where the verticals are inconveniently long, the drawn datum can be assumed at a certain height above the datum of the levels, and this assumed height must be subtracted from each vertical height and the remainder plotted as shown in Fig. 4.34.

Now let it be assumed that the specification for this job stated that "the minimum of excavation and filling must be done". At this stage it is quite a simple matter to take the mean or average between the highest and the lowest reduced levels, or the average of all the reduced levels added together, and, if this line be set out on your selection, it will give you the necessary level.
This is to show how useless it is to use a small vertical scale (1:1000).

**FIG. 4.33**

A = 30m above Datum—All figures above are reduced by 30 metres

This is to show a larger vertical scale (1:100) gives a truer impression of ground surface.

**FIG. 4.34**
"LINE OF COLLIMATION" METHOD OF LEVELLING

This is another method of reducing the levels. Remember that the line of collimation is the line joining the optical centre of the object glass to the axial line of the reticule. When the level is rotated it will sweep out a horizontal plane known as the plane of collimation. See Figure 4.35.

![Diagram of line of collimation](image)

**FIG. 4.35**

Here we see that the plane (line) of collimating cuts a staff held on point A, where the reduced level is 100.500 m. The staff reading is 2.600 m.

Using this method of reduction the height of the plane of collimation above the datum is required for every instrument setting.

In Figure 4.35, the height of the plane of collimation (HPC) above the datum is the reduced level of A (100.500 m) plus the staff reading 2.600 m at that point.

That is, \( \text{HPC} = \text{REDUCED LEVEL A} + \text{STAFF READING} \)

\[ = 100.500 + 2.600 \]

\[ = 103.100 \text{ m} \]

If another reading of 1.700 m is observed at point B, the reduced level of point B can be found easily. The plane of collimation is still at a height of 103.100 m when pointing to point B, and since the ground level at B lies 1.700 m below the HPC, the reduced level of point B is HPC minus the staff reading at point B.

That is, \( \text{REDUCED LEVEL B} = \text{HPC} - \text{STAFF READING} \)

\[ = 103.100 - 1.700 \]

\[ = 101.400 \text{ m} \]
Therefore, the HPC is the reduced level at any starting point plus the staff reading AT THAT POINT, and the reduced level at any OTHER point is the HPC minus the staff reading at the point.

The field book for the line of collimation method is ruled different to the rise and fall method. See Table 4.3. Since the terms are the same as in the rise and fall method, the sighting to A is a backsight, while B is a foresight. The HPC 103.100 is entered only once and is written up opposite the backsight on the first line. This HPC then refers to the whole of that instrument setting. The reduced level of B (101.400) is entered on the second line.

<table>
<thead>
<tr>
<th>BS</th>
<th>IS</th>
<th>FS</th>
<th>HPC</th>
<th>REDUCED LEVEL</th>
<th>DISTANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.600</td>
<td>103.100</td>
<td>100.500</td>
<td>Station A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.700</td>
<td>101.400</td>
<td>101.400</td>
<td>Station B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 4.3**

The following is an example of series levelling reduced by the collimation method. Figure 4.36 shows a series levelling over a rough area on a building site. Then levels are to be reduced and checked by the collimation method.

![Diagram](image-url)

**FIG. 4.36**
The reduced level at A is assumed to be 50.000 - see Figure 4.36 and Table 4.4.

The steps in the reduction of the levels are as follows:

1. Height of plane of collimation of first instrument setting (x) is:
   \[ HPC = RL \text{ OF KNOWN POINT} + \text{STAFF READING} \]
   \[ = 50.000 + 3.800 \]
   \[ = 53.800 \text{ m} \]
   Enter 53.800 in the HPC column, on the first line of Table 4.4.

2. Reduced levels at B, C and D (first instrument setting at x) are:
   \[ RL = HPC - \text{STAFF READING AT THE POINT} \]
   \[ RL \text{"B"} = 53.800 - 2.700 = 51.100 \text{ m} \]
   \[ RL \text{"C"} = 53.800 - 1.800 = 52.000 \text{ m} \]
   \[ RL \text{"D"} = 53.800 - 0.600 = 53.200 \text{ m} \]
   These figures are entered under the RL column on Table 4.4.

3. Height of plane of collimation of second instrument setting (Y)
   \[ HPC = RL \text{ OF KNOW POINT} + \text{STAFF READING} \]
   \[ = RL \text{ OF POINT D} + 1.300 \]
   \[ = 53.200 + 1.300 \]
   \[ = 54.500 \text{ m} \]
   Enter this figure in the HPC column (along side station D in the remarks column) in Table 4.4.

4. Reduced levels of E and F (instrument at Y)
   \[ RL = HPC - \text{STAFF READING AT THE POINT} \]
   \[ RL \text{"E"} = 54.500 - 2.400 = 52.100 \text{ m} \]
   \[ RL \text{"F"} = 54.500 - 1.900 = 52.600 \text{ m} \]
   These figures are entered in the RL column on Table 4.4.
5. Height of plane of collimation of third instrument setting (Z).

\[ HPC = RL \text{ OF KNOWN POINT} + \text{STAFF READING} \]
\[ = RL \text{ OF POINT F} \quad + 0.400 \]
\[ = 52.600 + 0.400 \]
\[ = 53.000 \text{ m.} \]

Enter this figure in the HPC column (on the same line as Station F in the remarks column) in Table 4.4.

6. Reduced level of point G. (instrument at Z)

\[ RL = HPC - \text{STAFF READING AT THE POINT} \]
\[ = 53.000 - 3.200 \]
\[ = 49.800 \text{ m} \]

This figure is entered in the RL column on Table 4.4.

<table>
<thead>
<tr>
<th>BS</th>
<th>IS</th>
<th>FS</th>
<th>HPC</th>
<th>REDUCED LEVEL</th>
<th>DISTANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.800</td>
<td>2.700</td>
<td></td>
<td>53.800</td>
<td>50.000</td>
<td></td>
<td>Station A</td>
</tr>
<tr>
<td></td>
<td>1.800</td>
<td></td>
<td></td>
<td>51.100</td>
<td></td>
<td>Station B</td>
</tr>
<tr>
<td>1.300</td>
<td>0.600</td>
<td>2.400</td>
<td>54.500</td>
<td>52.000</td>
<td></td>
<td>Station C</td>
</tr>
<tr>
<td></td>
<td>1.900</td>
<td></td>
<td>53.000</td>
<td>52.100</td>
<td></td>
<td>Station D</td>
</tr>
<tr>
<td>0.400</td>
<td>3.200</td>
<td></td>
<td></td>
<td>52.600</td>
<td></td>
<td>Station E</td>
</tr>
<tr>
<td>5.500</td>
<td>6.900</td>
<td>5.700</td>
<td>53.000</td>
<td>49.800</td>
<td></td>
<td>Station F</td>
</tr>
<tr>
<td>5.700</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50.000</td>
<td>Station G</td>
</tr>
<tr>
<td>-0.200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.200</td>
<td></td>
</tr>
</tbody>
</table>

\textit{Table 4.4}
The common check is shown in the last 3 lines of Table 4.4 - the difference between the first and last reduced levels should equal the difference between the BS and FS columns - in this case -0.200.

This check, although commonly used, only tells you that the figures in the BS, FS and HPC columns are correct. The reduced levels for ANY or ALL of the intermediate sights could be wrong, and the check would still be successful. The reason for this is that a reduced level does not depend on the value of the preceding level, as it does in the rise and fall method. To illustrate this, suppose that the RL of point B had been found to be 52.200 m instead of 51.100 m. The check would still work!

The complete and accurate check is much more complex and therefore not often used. The complete arithmetical check for the figures in Table 4.4 would be as follows:

COMPLETE CHECK

SUM OF REDUCED LEVELS (EXCEPT FIRST) = The sum of each height of collimation x the number of IS and FS observed from each, minus the sum of the IS and the FS columns.

From Table 4.4

SUM OR RL's EXCEPT FIRST = 310.800

SUM OF HPC x No of IS & FS =

53.800 x 3 = 161.400
54.500 x 2 = 109.000
53.000 x 1 = 53.000

323.400

SUM OF IS COLUMN = 6.900
SUM OF FS COLUMN = 5.700 + = 12.600

323.400 - 12.600 = 310.800
CHAPTER FIVE - FOOTINGS

5.1 FUNCTION

5.2 TYPES OF FOOTINGS
   CONCRETE STRIP
   LIMESTONE STRIP
   BRICK STRIP
   DEEP BEAM
   PIER AND BEAM
   RAFT
   INVERTED TEE
   PAD
   PILE AND BEAM
   BENCHED

5.3 D.P.C.s, MEMBRANES AND SUB-FLOOR VENTILATION

5.4 CONSTRUCTION JOINTS

The Uniform Building By-laws define footings as "the construction by which the weight of the building is transferred to the foundations". There are several ways and means of transferring the weight of the building to the foundations, and in this chapter we will be introducing these footings and studying in detail those most common to local (W.A.) conditions.

5.1 FUNCTION

To be functional and safe there are two main requirements that footings must satisfy.

No amount of pre-treatment and site works can guarantee that there will not be any settlement of the foundations. This settlement will be small and continue throughout the building works but should be finished by the time the building is completed. The first function of the footing, therefore, is to accommodate this settlement by being sufficiently strong to carry over any spots where foundation settlement is greater in one part than another.

The second function is to ensure that the foundation is not over-stressed. This can be done by the designer of the footing ensuring that the footing is wide enough to spread the load of the building without exceeding the safe bearing value of the foundation.

Apart from unequal settlement, there are two other possible causes of footing failure. The foundation material may be eroded away or scoured to reveal the footing, exposing it to the elements.
and further eroding the foundation directly below the footing. This scouring is normally caused by storm water from down pipes but can be caused by wind, particularly in loose running sand such as can be found in coastal regions.

Plastic soils have the capacity to increase and decrease in volume with changes in their moisture content. The topic of plastic soils and their suitability as foundation materials has been fully discussed in Chapter 2. However, it is worth emphasising here that plastic soils can cause the failure of footings with disastrous results, such as large cracks appearing in walls.

5.2 TYPES OF FOOTINGS

- Concrete strip footings
- Limestone strip footing
- Brick strip footing
- Deep beam
- Pier and beam footing
- Raft (or slab-on-ground) footing
- Inverted tee beams
- Pad or blob footings
- Pile and beam footing
- Benched or stepped footing

Strip footings can be constructed of brick, stone or concrete to the dimensions required by the by-laws. Strip footings are mainly used on stable foundations, such as sand or gravel.

CONCRETE STRIP FOOTINGS

Concrete strip footings are relatively wide and shallow and can be used under domestic buildings, light industrial buildings and low rise flats. Depending on the loads and the type of foundations, the concrete can be either reinforced or unreinforced.

The following table of concrete strip footing sizes can also be found in the Uniform Building by-laws.

The concrete strip footing should be sufficiently wide to spread the load of the building over the foundation immediately below the footing without exceeding the safe bearing value of the foundation. The mass of a normal domestic construction has been taken into consideration when the footing sizes for Table 5.1 were calculated.

For work outside the limitations of Table 5.1 - for example, masonry wall greater than 4.2 m - the footing would need to be calculated by an Engineer.

The concrete strip footing also needs to be sufficiently deep to withstand the load from above and the reaction up from the foundation which can cause a shearing effect in the strip footing (see Fig. 5.1).
CROSS-SECTIONAL DIMENSIONS OF CONCRETE STRIP FOOTINGS

<table>
<thead>
<tr>
<th>Construction of Wall</th>
<th>Nominal thickness of wall to be supported (including cavity) not more than - mm</th>
<th>Size of concrete (width x depth) mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single storey masonry wall not exceeding 4.2 m</td>
<td>270</td>
<td>450 x 250</td>
</tr>
<tr>
<td>Single storey masonry veneer wall not exceeding 4.2 m</td>
<td>110</td>
<td>300 x 250</td>
</tr>
<tr>
<td>Single storey building in timber frame construction with masonry foundation wall not exceeding 1500 mm</td>
<td>110</td>
<td>230 x 150</td>
</tr>
</tbody>
</table>

TABLE 5.1

![Diagram showing failure in shear](image)

**FIG. 5.1**

Figures 5.2 (a) and (b) show a concrete strip footing reinforced with 10 mm diameter mild steel rods held apart with 6 mm mild steel ligatures at 600 mm centres, and concrete strip footing reinforced with one layer of F8 trench mesh.

![Diagram showing two different footings](image)

**FIG. 5.2**

5.3
The reinforcement specified, if any, will depend on the nature of the work. It is normal for domestic strip footings to be reinforced with F8 trench mesh while strip footings under heavy loads from flats and light industrial work may require the use of mild steel rods. The size of the footings and number and diameter of rods in this type of strip footing is determined by a structural engineer. Most shires require an engineer's certificate for footings of sizes other than those given in the Uniform Building By-laws - which are the minimum sizes only. Be aware that local authorities have the power to insist on higher standards than those the Uniform Building By-laws lay down. This is particularly so in regions where foundations are of a doubtful bearing value or where sand pads are used.

You will note from the strip footing sketches that the position of the wall on the footing is central. Off-centre or eccentrically-loaded footings are to be avoided wherever possible.

LIMESTONE STRIP FOOTINGS

Limestone strip footings were once very popular and practical. Their use nowadays is rare and they are mainly used in conjunction with timber floors (see Fig. 5.3).

![Limestone Strip Footings Sketch](image)

FIG. 5.3

The limestone footings consist of large boulders; the minimum stone size is 300 mm, laid in random courses similar to a small stone wall. The footing actually rises out of the ground. This is necessary as the floor timbers sit on the footing, and the underside of these floor timbers must be at least 200 mm clear of the ground.

The Uniform Building By-laws set out a series of conditions or requirements necessary in the construction of limestone footings. These requirements are as follows:

"(a) every footing shall consist of first grade limestone laid in lime, cement or composition mortar ..."

5.4
The different types of mortar will be explained in the chapter dealing with brickwork. Most masons prefer to use the weaker, lime mortar mix as this is more compatible with the strength of the stone. If there is a chance that the mortar could be eroded due to weather, then a composition mortar of 1 part cement, 2 parts lime and 9 parts sand is preferred.

"(b) all trenches for the footings shall be thoroughly saturated with water before any limestone is laid, and in every case the footing shall be taken down to solid virgin soil."

Wetting of the trench is necessary to ensure that there is no moisture lost from the mortar because of absorption by the dry soil. It is important that there are no soft spots in the trench as the limestone is unable to span distances unsupported.

"(c) the bottom of the footings shall not be less than 300 mm below the finished ground level and where necessary the footings shall be stepped down to achieve this depth with the steps -
. at least 300 mm in height
. having the top stone overlap the lower stone for a distance of at least 300 mm."

As with other types of footings, they are founded at least 300 mm below ground level to help ensure that firm soil has been obtained and, also, to minimise the risk of exposing the base of the footing to the elements. The step in the footing should work to brick courses if there is to be a brick wall. A straight step would be a weakness. Figure 5.4 shows an interpretation of these step requirements.

![Diagram of footing and limestone]

FIG. 5.4

5.5
"(d) large flat squared through stones 300 mm thick shall be used for bottom and top of footings, and every 1200 mm elsewhere, all laid on a natural bed and no stones used shall be more than 350 mm in height."

Through stones are used to ensure that the wall is "bonded" and laid in separate vertical shins or walls. Restricting the height of the stones minimises the possibility of undetected flaws being contained in them.

"(e) to all external walls extending for a distance of 750 mm in each direction from each corner, the footing shall be increased in width 125 mm beyond adjacent stone- work on both faces."

Because there is a concentration of loads at the corner of the building, the base is widened to spread the load more effectively over the area immediately below the footing.

"(f) sufficient openings shall be left in footings between rooms at doors and openings so as to provide adequate ventilation under floors ..."

The reason for this requirement, is to provide ventilation under the floor and to deter white ants (termite) attack. The ventilation will go a long way towards preventing rotting of floor timbers.

"(g) 230 mm x 110 mm x 75 mm bricks shall be built into the footings to support the ends of every floor bearer."

To ensure that the bearing pressure of the bearer does not shear off part of the stonework, a brick is cut into the stone to act as a support to distribute loads over a greater area. (See Fig. 5.3)

BRICK FOOTINGS

Brick footings are another type of strip footing in that they extend around the perimeter and under internal walls like a strip or ribbon of brickwork. Once used extensively as a footing for all types of construction, this footing has almost disappeared from use. Certainly, it has disappeared from domestic use; it is now used only for small garden walls and unimportant work. The main advantage of brick footings is that they can be built in situ and are a suitable alternative when stone is unavailable; where concrete cartage is not a possibility because of the remoteness of the job or where labour and time are not available for on-site mixing of concrete.

Figure 5.5 (a), (b) and (c) shows brick footings suitable for various wall applications.

DEEP BEAM FOOTINGS

Deep beam footings are best suited for locations where the foundations have good bearing value but some slight movement in the soil can be expected due to seasonal influences. NOTES ON THE SCIENCE OF BUILDING, No. 9, - 'The Design of Footings', deals with the design of footings for small buildings on plastic soils, and states in part that where silted clays have a bearing value of at least 0.107 MPa, the use of deep beams should be considered, as these footings are capable of resisting swelling pressures from the foundation and minimise the possibility of cracking in the walls.

5.6
A table published in the same notes sets out a guide to dimensions and reinforcement used. Figure 5.6 shows a typical deep beam application.

**FIG. 5.5**

**FIG. 5.6**

PIER AND BEAM FOOTINGS

Pier and beam footings support a building above the ground level, where the foundations move considerably due to seasonal influences. Support is provided by piers, usually concrete, which are placed
to a depth in the foundations where seasonal influences are negligible. Figure 5.7 shows the beam kept clear of the ground level by about 75 mm in summer months.

Placing of reinforcement in the beam is of paramount importance. Consideration should be given to placing reinforcement at the top of the beam over the supports and also where openings in the wall above the beam exceed 900 mm.

NOTE: Spacing, size, reinforcement and depth of piers will vary according to conditions and engineer’s design.

FIG. 5.7

Because one of the prime objectives of any footing is to distribute the load equally over the foundation, it is important that the piers all have an equal loading on them. In no case should any pier carry a load less than 75% of the average load for a pier. This factor, of course, makes it necessary for an engineer to design both the isolated beam and the pier. Sizes shown in Figure 5.7 are typical only and should not be regarded as standard for any particular condition.
NOTES ON THE SCIENCE OF BUILDING, No. 9, 'The Design of Footings' and No. 41, 'Pier and Beam Construction', give a detailed account of the use and construction of pier and beam footings.

RAFT (OR SLAB-ON-GROUND) FOOTING

Raft (or slab-on-ground) footing as it is commonly known, is extremely popular and ideally suited to foundations which are reasonably level, well drained and have a bearing value not less than 0.6 MPa.

Slab-on-ground can be suitably adapted to sites with slopes up to 1 in 10, and can also be modified to incorporate piers and beams over sites where there is expected to be severe moisture movement.

The Uniform Building By-laws set out three methods of constructing a slab-on-ground footing. These are repeated in Figures 5.8, 5.9 and 5.10. In the Perth Metropolitan Area and other locations where the foundation is firm sand, the separate edge beam system can be used, as there is no need to form up the sides of the edge beam. Where free running sand or clay is encountered, special forming may be required to cast the slab and edge beam simultaneously as in the monolithic edge beam application.
Where a build-up or footing wall is required, the alternative separate edge beam application can be used. Note that the height of the slab from the edge beam and subsequent backfill may make it necessary to reinforce and fill the cavity with concrete. For this reason, it is advisable to consult a structural engineer.

In general, a concrete slab 100 mm thick will be satisfactory, but for sites requiring special preparation this thickness may have to be increased. At least 25 mm cover should be provided to all reinforcement and any pipes or conduits cast into the slab.

Where ready mixed concrete is supplied, it should have a minimum strength of 15 MPa (Uniform Building By-laws) and a slump of not more than 80 mm.

To absorb shrinkage stresses which occur when concrete dries out, a suitable amount of shrinkage reinforcement is provided in the slab. The steel will absorb the shrinkage stresses and reduce cracking to an imperceptible level. Providing the base has been prepared correctly, this is the only reinforcement required. Depending on the size and shape of the slab, F62 mesh is adequate. However, in some cases, F828 may be required. Once again, an engineer's advice should be sought. Typical reinforcement details are shown in Figures 5.8, 5.9 and 5.10.

INVERTED TEE BEAMS

These are a combination of the normal wide strip footing and the thin deep beam footing, and are suitable for use in poor soils. Their strength is dependent on the depth of their stems, which give stiffness to the footings. While useful, these footings will not totally eliminate movement cracks in walls. See Figure 5.11 for typical details of an inverted tee beam.

![Inverted "T" beam](image)

**FIG. 5.11**

PAD, BLOB OR COLUMN FOOTINGS

Pad, blob or column footings are, as their name suggests, used under columns or any other isolated load. These footings may be square, rectangular or circular on plan and sufficiently thick.
to withstand the loads applied to them. Usually made out of concrete, they must distribute a load to the foundation equal to the stress applied by other parts of the building. (See Figure 5.12 (a)) Pad footings made of brick are also used under brick piers to timber floors. (See Figure 5.12 (b))

**FIG. 5.12 (a)**

![Blob, pad or column footing](image)

**FIG. 5.12 (b)**

![Brick bearer pier](image)

Brick footing for 350 x 350 mm pier

**PILE AND BEAM FOOTINGS**

Pile and beam footings are used where excavation and pouring of in situ concrete is not possible because of non-cohesive soils or the presence of water. To overcome these problems, a timber or concrete pile is driven sufficiently into the foundation to be held
by friction or until solid strata is reached. When the driving of the piles is complete, they are capped and prepared for the pouring of a concrete beam over them similar to that used in a pier and beam construction. (See Figure 5.13 for typical details).

**FIG. 5.13**

**BENCCHED OR STEPPED FOOTINGS**

On sloping sites it is more economical, in most situations, to construct stepped footings. The fall of the ground level will, to a certain degree, dictate the number of steps and their height needed, but the steps should, if possible, be of even size and length. When stepping footings, three points are important.

(a) The steps should be in brick courses, depending on the type of masonry unit used, so that no cutting of bricks or big bed joints are necessary.

(b) The base of the footing should remain at least 300 mm below ground level at any point.

(c) Sufficient lap must be given to the step to strengthen it and prevent shear.

Figure 5.14 illustrates these points.

5.3 DAMP PROOF COURSES, MEMBRANES AND SUB-FLOOR VENTILATION

In order to avoid a damp floor, it is essential that the underside of a concrete slab should not be in physical contact with water. Where construction technique is poor and little attention
has been paid to site selection and drainage, moisture problems can be experienced, even where the slab is above the water table. Two likely reasons for this are the transfer of water by capillary action, and the movement of water vapour from the ground beneath the slab. Proper drainage may take care of both these problems but additional protective measures are usually required. The use of a granular fill deficient in fines and placed under the slab, will break any capillary rise of water, and waterproof membrane will prevent the transfer of water vapour. In cases of a low water table in sandy terrain, where surface water normally percolates downwards, such as in the Perth metropolitan area, the granular sub base is not required.

A suitable vapour barrier is 0.1 mm polythene; however, the thicker 0.2 mm polythene is a greater safeguard against accidental puncturing when working over the surface prior to pouring concrete. The vapour barrier must be continuous over the entire floor area with all joints being lapped a minimum of 200 mm and sealed with pressure sensitive tape. The vapour barrier should be linked with the damp proof course of the outer wall to provide a continuous barrier through to the outside surface. The position of the damp proof course in the actual brickwork is shown in all the footing diagrams in this Chapter.

Where timber floors are specified in buildings with either brick or stone footing walls, adequate provision for sub-floor ventilation must be allowed for.

(a) A clear air space of at least 200 mm between the ground and the underside of any floor timber must be maintained.

(b) Sufficient air vents must be provided in the external walls, at least 2100 mm² in each linear meter of wall.

(c) Internal footing walls should have openings of at least 4000 mm² in each linear meter of wall, and these should be evenly distributed.

Note: Alternate timber, concrete or steel stumps and sole plate footings to timber frame construction are discussed in Chapter 9 of this text.

5.4 CONSTRUCTION JOINTS

A construction joint is a concrete to concrete joint made in such a manner that the faces of the new and old concrete adhere sufficiently to prevent any relative movement across the joint. It is sometimes necessary to stop or interrupt a concrete pour, and the time elapsed before the pour can carry on might be long enough for the old concrete to sifffen to the extent that is necessary to form a construction joint.

These breaks in the concrete pour can be unscheduled or planned. As a construction joint can create some weakness in the concrete structure, care must be taken as to where they are to be placed. If the concreting is stopped for more than an hour, a stop-board must be used to keep the edge vertical and the concrete should be well tamped up to the board.

If the old concrete has not set before the placing of more concrete, any scum should be removed from the old concrete, and then
the new concrete should be tamped thoroughly against that already in position.

If the work has to be left until the older concrete is hard, then the whole of the surface must be thoroughly hacked to form a key for the new concrete. After hacking, a wire brush should be used to remove dust and loose materials, the old surface thoroughly wetted and brushed over with a very thin coating of mortar mixed in the proportions of 1 part of cement to 2 parts of sand, and the fresh concrete then placed. This applies to horizontal as well as vertical surfaces, and to all cases where new concrete is bonded to old. A thick layer of rich mortar or neat cement between old and new concrete must be avoided.

One good method of temporarily stopping off the work, is to form a tongue and groove joint. It costs little to nail a strip onto the stop-board, and the increased strength of the joint makes it well worth while; the strip forming the groove is chamfered so that it can be easily withdrawn.

If there is reinforcement in the concrete, this should not be cut. Instead the stop board should be made in two halves and slotted, so that it can be formed around the reinforcement, without allowing the loss of mortar.

Figures 5.14 and 5.15 (a), (b) and (c) show typical methods of constructing these types of joints, both vertical and horizontal.

\[\text{Overlap } 'X' \text{ to be not less than } 'T' \text{ or } 2 \times 'H' \text{ whichever is the greater, with a minimum of 350 mm.}\]

**Fig. 5.14**

**Benched or stepped footings**
Stop-end or bulkhead

(a)

Reinforcement must not be cut

(b)

Stop-end with keyway

(c)

FIG. 5.15
CHAPTER SIX - CONCRETE

6.1 MATERIALS
   COARSE AGGREGATE
   FINE AGGREGATE
   CEMENT
   WATER
   ADDITIVES
   STORAGE OF MATERIALS

6.2 PROPORTIONING AND MIXING
   PROPORTIONING
   VOLUME BATCHING
   WEIGHT BATCHING
   WATER/CEMENT RATIO
   THE SLUMP TEST
   MIXING CONCRETE

6.3 TRANSPORTING, PLACING AND COMPACTING
   TRANSPORTING
   PLACING AND COMPACTING

6.4 FINISHING AND CURING
   INITIAL AND FINAL FINISHING
   CURING

6.5 PRE-MIXED CONCRETE
   SPECIFYING THE MIX
   ORDERING OR PRICING
   FACTORS AFFECTING SPECIFICATION

The term concrete really covers a vast range of solid masses resembling artificial stones of varying densities and strengths, formed through the mixing and subsequent solidifying of various aggregates, cements and water. A chemical reaction between the cement and the water creates the binding action of this cement paste or matrix which holds the aggregates together in the hardened concrete.

The roof of the Pantheon in Rome was made of one form of concrete nearly 2,000 years ago, and since then many different forms of cement and concrete have been developed. Discussion here will
be confined to those normal dense structural concretes commonly used in the building industry today. These have a bulk density of 2300 - 2400 kg/m³ and a compressive strength of 10 - 50 mega pascals (MPa) at 28 days, depending on the particular specification. The properties of the plastic concrete, such as workability, and of the hardened concrete, such as strength and durability, will depend directly on the following factors which will form the sub-headings of this Chapter:

6.1 MATERIALS
6.2 PROPORTIONING AND MIXING
6.3 TRANSPORTING, PLACING AND COMPACTING
6.4 FINISHING AND CURING
6.5 PRE-MIXED CONCRETE

6.1 MATERIALS

The basic constituent materials of concrete are the graded coarse and fine aggregates, the cement and the water. Chemical additives may be introduced to modify certain properties.

COARSE AGGREGATE

Coarse aggregate consists of clean dense stone (2700 kg/m³) such as granite or diorite which is quarried, crushed, graded into sizes and stockpiled as 7, 10, 14, 20, 30, 40 or 75 mm aggregates, sometimes referred to as blue metal, which is sold ex quarry by the tonne. (1500 - 1700 kg/m³).

FINE AGGREGATE

Fine aggregate consists of clean sharp sand or finely crushed stone which would pass through a 5 mm sieve. Loose, dry sand with a density of approximately 1400 kg/m³ is sold ex pit by the cubic metre.

PORTLAND CEMENT

Cement used for normal concretes is ordinary portland (O.P.) cement which was first developed by Joseph Aspdin in England in 1824. This grey-coloured cement is sold in bulk or in 40 kg bags of approximately 30 litres in volume, and has a loose density of approximately 1350 kg/m³. White portland cement may be used together with white quartz or coloured aggregates to produce a feature concrete for special pavings or claddings.

WATER

Water (1000 kg/m³) should be scheme or clean water, free of excessive dissolved salts or organic impurities.
ADDITIVES

There exists a range of chemical admixtures, each formulated to modify a property of the concrete, should this be required in particular circumstances. Powdered or liquid additives are available which will accelerate or retard the setting time, increase plasticity or workability, or make a concrete more resistant to the penetration of moisture. If specified, these chemicals may be added according to the manufacturers' instructions, to site-mixed or pre-mixed concrete, without impairing the other properties or final performance of the concrete.

STORAGE OF MATERIALS

Consideration must be given to stockpiling materials either at the pre-mix plant or on site, as facilities must be provided - such as separate bins or bankers - to prevent the mixing or contamination of aggregates or the deterioration of the cement through the absorption of moisture. Different aggregates should be tipped onto clean hard surfaces of planks, sheet steel or concrete, with vertical divisions provided as required for separation. Cement must be kept covered and stored in a bin or stacked on a deck clear of the ground. Cement should be used within 3 months of receipt.

6.2 PROPORTIONING AND MIXING

PROPORTIONING

The initial proportioning or parts of each of the materials in a mix will have a direct bearing on the properties of the concrete, in both the plastic and hardened state. The proportioning must therefore be carefully designed and measured or gauged to meet the concrete specification. Quantities of the various materials can be measured out by volume or by weight.

VOLUME BATCHING

Gauging volumes of materials in hoppers, measuring boxes, buckets or shovels is often accurate enough for site-mixing to minor works for concrete of strengths less than 20 MPa. For example, a mix of 1 part cement, 2 parts of sand 3 parts of 20 mm aggregate with 'sufficient' water would produce a workable plastic concrete which could attain a strength of 20 MPa in 28 days. Alternately, this example of volume batching could be shown as: 1 bag cement: 60 litres of sand: 90 L of 20 mm aggregate: 24 L of water.

WEIGHT BATCHING

When batching in all pre-mix plants or on-site for all structural concretes, a specific mass of each material is weighed out for each mix. This is a more accurate method than volume batching, as compensatory adjustments are made to allow for the varying moisture contents of the aggregates used. An example of a weight batched specification would be a mix of 400 kg (10 bags) of cement, 760 kg of sand, 1000 kg of 20 mm aggregate and 170 kg
(170 L) of water, which would produce 1 cubic metre of a plastic concrete with a potential strength of 40 MPa at 28 days.

WATER/CEMENT RATIO

The most vital factor affecting the strength of the concrete is the ratio between the quantities of the water and the cement in the mix design. This water/cement (w/c) ratio may be defined as follows:

\[ \text{w/c ratio} = \frac{\text{mass of water in a mix}}{\text{mass of cement in a mix}} \]

e.g. \( \frac{20 \text{ kg (20 L) water}}{40 \text{ kg (1 bag) cement}} = 0.5 \text{ w/c ratio} \)

As either too little or too much water in a mix will reduce the strength of the concrete, most specified w/c ratios will range between 0.35 and 0.65 as shown in Figure 6.1.

![Graph showing 28 Day compressive strength vs W/C Ratio](image)

**FIG. 6.1**

THE SLUMP TEST

The grading and proportioning of the materials will affect the workability or the consistency of the mixed concrete. The slump test was designed to test, measure and tabulate the consistency and uniformity of mixes, released from a test mould. The mould is the frustum of a cone 300 mm high, 200 mm in diameter at the bottom and 100 mm in diameter at the top, made of 1.5 mm thick sheet metal, complete with foot rests and handles as shown in Figure 6.2. The mould is placed on a flat impervious surface and is filled with concrete, in three layers, with each layer being tamped 25 times with a 600 mm long by 16 mm diameter bullet-pointed steel rod.
The surface of the concrete is struck off and the mould is carefully lifted off, allowing the concrete to subside. The amount of subsidence or slump is then measured against the inverted empty mould. Commonly specified slumps for workable mixes would range from 60 mm to 100 mm with 80 mm being the norm.

![Diagram showing mould filled and removed and inverted concrete](image)

**FIG. 6.2**

**MIXING CONCRETE**

The aim of the mixing, whether by hand by on-site machine or by pre-mix plant, is to form a homogeneous mixture of all materials. Hand mixing to small jobs should be carried out on a flat impervious surface with the dry materials first turned three times with a square-mouthed shovel before water is added, and the wet mix is again turned until thoroughly mixed to the right consistency.

Alternatively, concrete to minor works may be site mixed in 55 or 85 litre capacity tilting or tip-up revolving drum mixers. The revolving mixer is first charged with some water, then coarse aggregates, sand, cement, and finally the balance of the water. These materials are mixed for approximately 1½ minutes before discharge.

Pre-mixed concrete, mixed prior to delivery to site, will be of one of the following 3 categories:

(a) plant mixed entirely;
(b) partially plant and partially truck mixed;
(c) truck mixed entirely. (This is the most likely method).

(a) **Materials** are weight batched and completely mixed in large inclined drum mixers at central mixing plants before being discharged into tip or agitator trucks for transport to site.
(b) Materials are *stage-mixed* partially at the mixing plant before discharge into the revolving drum of the delivery truck, where mixing is completed during transport to site.

(c) *Dry-batched* materials are loaded at the central batching plant into revolving drum mix-agitators. Water is added at the plant, and mixing is carried out in the truck mixer, which then keeps it agitated during delivery.

### 6.3 TRANSPORTING, PLACING AND COMPACTING

Concrete must be transported, placed and compacted in such a manner that will not cause unnecessary *delay, drying out or segregation* and the consequent reduction of the potential strength of the hardened concrete. Final positioning should be completed within 1½ hours of the initial mixing; during transport and placing both the moisture content and the even mix of materials must be retained.

**TRANSPORTING**

Off-site transport in enclosed rotating drum pre-mix trucks will ensure swift delivery of a good quality mix to the site. On-site transport from pre-mix truck or site-mixer to final position must be made without damaging or dislodging any form work or reinforcement, and may utilise any of the following methods:

<table>
<thead>
<tr>
<th>METHOD</th>
<th>CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) chutes</td>
<td>10 - 100 m³/hour</td>
</tr>
<tr>
<td>(b) conventional wheel barrow</td>
<td>0.05 m³ each</td>
</tr>
<tr>
<td>(c) conveyor belt</td>
<td>10 - 100 m³/hour</td>
</tr>
<tr>
<td>(d) two-wheeled hand cart</td>
<td>0.06 - 0.1 m³ each</td>
</tr>
<tr>
<td>(e) powered 3 wheeled barrow</td>
<td>0.1 - 0.16 m³ each</td>
</tr>
<tr>
<td>(f) 'bobcat' type loader</td>
<td>0.1 - 0.25 m³ each</td>
</tr>
<tr>
<td>(g) powered dump buggies</td>
<td>0.5 - 1 m³ each</td>
</tr>
<tr>
<td>(h) front end loaders</td>
<td>0.5 - 1 m³ each</td>
</tr>
<tr>
<td>(i) crane and bucket or kibble</td>
<td>0.5 - 2 m³ each</td>
</tr>
<tr>
<td>(j) pump and pipeline</td>
<td>10 - 100 m³/hour</td>
</tr>
</tbody>
</table>

Sufficient man power must be allowed for to support and complete whichever method of on site transportation is employed.

Concrete to footings and slabs to most housing sites is currently transported to the site in pre-mix trucks and poured through the truck chute directly into trenches or barrowed into position on site. The concrete pump and pipeline method is often used on difficult sloping sites with poor access, or to split level or suspended slabs or swimming pools. Even the smaller types of pump used for domestic construction can convey the concrete up to 200 m or 150 m horizontally over a 10 m rise.
PLACING AND COMPACTING

Segregation of the mix and damage to formwork or reinforcement must be avoided when placing and compacting concrete. Where possible, the concrete should be placed vertically in horizontal layers near to its final position, and hoppers or chutes should be used to avoid any free fall where this would exceed 2 metres. Spreading of the concrete should be with shovels, and never by forcing the mix to flow with excessive use of vibrators.

Concrete should be compacted or consolidated when placing as this ensures that the hardened concrete will have maximum density and strength, good bond with reinforcement and contact with the surfaces of the formwork.

Compaction to minor works may be carried out manually by tamping, rodding or spading, or by tapping and vibrating the formwork - but pours of any consequence should be mechanically vibrated.

There are three forms of mechanical compaction, and the nature of each particular concrete pour would indicate which of the following would be the most appropriate:

(a) Internal or immersion (poker) vibrators, which consist of a poker like vibrating head on the end of a flexible shaft. These range in diameter from 25 to 150 mm and are actually inserted into the wet concrete and vibrate the mix through direct contact. Immersion vibrators are the most effective method of compacting concrete in column, wall, beam, footing and thick slab pours.

(b) External or form vibrators which are of rotary or reciprocating action and are clamped directly to the outside of the formwork or to the tables supporting the forms. These are most suited to complicated or thinly formed sections where congested reinforcement would make the use of the poker vibrator impracticable. Form vibrators or vibrating form tables are used extensively in pre-casting yards where items such as paving slabs are mass produced in strong steel forms.

(c) Surface vibrators such as vibrating screeds or vibratory finishing tools are suitable for compacting thin slabs to a maximum depth of about 150 mm. Concretes of slump less than 80 mm should be specified and care taken not to over vibrate the surface and bring moisture and fines to the top.

6.4 FINISHING AND CURING

INITIAL AND FINAL FINISHING

The initial finishing, which may be all that is required, is carried out with screeds, rules and wooden floats as quickly as possible immediately after placing and compaction. This will produce a reasonably even surface without over-working the wet concrete and bringing up the fines and water.

Final finishing is not commenced until the sheen of free water has left the surface and the concrete will support the

6.7
distributed weight of the finisher. Wood or power floats are first used to work up an even surface. After a short delay, this floated surface can then be brought to a smooth, hard, steel-trowelled, glass finish.

If, after the initial finish, drying is too slow, then a light dusting of 1 part cement to 2 parts fine aggregate may be applied before floating, to enable the finishing process to commence. On no account should neat cement be used to dry up excess water. Coloured oxides can be added to the cement-sand mixture to provide a coloured surface.

Do NOT use a cement-oxide mixture, because surface crazing and scaling may occur.

CURING

Curing may be defined as maintaining an environment of sufficient moisture and warmth to support the continuity of the initial reaction of hydration of the cement in the concrete. All the properties of the hardened concrete, such as strength and durability, are improved dramatically by correct curing. If curing is not carried out, the hydration process is restricted and the concrete may only reach half the designed potential strength.

There are three methods of curing concrete.
(a) Preventing the loss of the initial moisture;
(b) Supplying additional moisture to replace any loss;
(c) Steam curing or autoclaving.

For most in-situ structural pours, methods (a) or (b) should be used and maintained for at least four days - and preferably for a commonly specified period of seven days. Autoclaving - involving high pressure steam, - accelerates the curing process to about seven hours.

(a) Preventing the loss of the initial moisture may be best achieved by covering with, or enclosing the concrete in, an impervious membrane. This is probably the simplest, most practical and recommended method commonly used in domestic construction. One membrane is a polythene sheeting which, when taped over the surface, will prevent the evaporation of moisture from the concrete. Another membrane can be formed by spraying the surface with a wax, chlorinated rubber or resin-based curing compound. The resin-based compounds will not adversely affect the subsequent adhesion of flooring or cladding materials to the concrete. However their curing efficiency may be less than wax or chlorinated rubber.

(b) Methods involving the replacement of lost moisture are often impracticable on many building sites and require constant attention to ensure their effectiveness. These include ponding or covering with water, constantly wet sand or hessian, or the setting up of a sprinkler system.

(c) Steam curing or autoclaving is generally confined to pre-casting yards. Pre-cast beams or cladding units may be covered with tarpaulins into which steam is injected or trucks containing beams, blocks or slabs are loaded into
an autoclaving cylinder and subjected to pressurised steam curing. These methods allow for a rapid production sequence in the manufacture of pre-cast items such as concrete masonry blocks.

6.5 PRE-MIXED CONCRETE

For pours of any consequence, pre-mixed concrete will ensure a convenient supply of an accurately batched, well mixed concrete of consistent quality.

SPECIFYING THE MIX

Pre-mixed concrete is generally specified by stating the properties and performance of the concrete required:

(a) the compressive strength at 28 days;
(b) the nominal A.S. maximum aggregate size;
(c) the slump in mm at time of delivery;
(d) any additives or requirements to special granolithic, shotcrete, slipform or pumped concrete.

For example a typical specification for concrete to a standard domestic slab on ground may be:

20 MPa x 20 mm x 80 mm x mono

the word 'mono', above, indicating that sufficient fine aggregates are to be included to facilitate floating to a monolithic finish.

ORDERING OR PRICING

When placing an order or requesting a price, state:

. name and address of contractor;
. address of job for delivery;
. the mix specification;
. the volume required;
. the date and times of delivery;
. number of and interval between trucks.
. if any testing is required.

FACTORS AFFECTING SPECIFICATION AND PRICE

. Mix strength or compressive strength of concrete in mega pascals (MPa) at 28 days. Standard pre-mixed concrete strengths are in 5 MPa increments: 15, 20, 25, 30, 40 or 50 MPa.

Note: the price of concrete will increase, as the specified MPa increases.

6.9
. *Aggregate size.* Base prices for pre-mixed concrete are for 20 mm aggregate. A surcharge will apply to specified aggregates, graded less than 20 mm and, in some cases, a discount for larger aggregates such as 30 or 40 mm.

. *Volume.* Pre-mixed concrete is ordered in cubic metres (m³) in increments of 0.2 m³. Basic prices quoted are for a minimum 3.4 m³ volume, with a surcharge applying to orders less than 3.4 m³ and a possible discount to large-volume orders.

. *Cartage - Truck capacities.* The base cartage or 'flagfall' charge covers cartage to within a 3 km radius of the plant. Further cartage costs will apply per km, outside the initial 3 km radius. Cartage facilities to pre-mixed concrete range from 0.8 m³ trailers to 'self cart' concrete; mini agitator trucks of 1.2 m³ to standard agitator trucks of 3, 5 or 7 m³ capacity.

. *Waiting Time - Discharge.* A standard time for discharge of concrete at the site, of 20 min. or 6 min. per m³, is included in the cartage, and any additional waiting or discharge time will be surcharged at current ruling rates.

. *Time of delivery - over-time.* A surcharge will apply to concrete deliveries ex-plant before 6.30 a.m. or after 3.00 p.m. Monday to Friday, or during any hour of weekends or holidays.

. *Slump or Workability.* Slump is measured in mm in increments of 20 mm. Standard pre-mixed concrete slumps are: 20, 40, 60, 80, 100 and 120 mm. Pricing is based on a slump of 80 mm and a surcharge will apply to slumps greater than 80.

. *Special Concretes.* Special price and surcharge figures will apply to pre-mixed concretes other than the normal dense concrete; such as those with selected, coloured, rounded or lightweight aggregates; white or early strength cements; cellular, aerated, foamed or pumped concretes.
CHAPTER SEVEN - CONCRETE FORMWORK

7.1 FORMWORK, GENERAL
QUALITY
ECONOMY
SAFETY
PREPARATION
STRIPPING FORMWORK

7.2 PATENTED FORMWORK SYSTEMS
FLOOR AND WALL
PROPS
SUPPORT BEAMS
ACCESSORIES

7.3 TIMBER FORMWORK

7.4 BEAM FORMWORK

7.5 WALL FORMWORK

7.6 SUSPENDED SLAB FORMWORK

Concrete is mixed and placed in a plastic state. It is this plastic state when first mixed, that allows concrete to be cast in moulds to almost any shape. The moulds that hold the concrete until it has set hard and gained strength is known as formwork.

7.1 FORMWORK, GENERAL

As the formwork will be required to carry the loads of the wet concrete, reinforcement, workers and concrete placing equipment, it is essential that formwork be sufficiently strong to carry the imposed loads - as well as prevent any deflection or movement while pouring is being carried out.

Formwork can be a very costly item of construction. This cost can be reduced somewhat over a large job by re-using the formwork several times. The number of re-uses will depend upon the standardization of the components in the structure, as well as the manner in which the formwork is assembled and dismantled or stripped.

The main factors to be considered when using formwork are:
(a) the quality of the formwork;
(b) the economy of using formwork;
(c) the safety of the formwork.

QUALITY

To be of good quality the formwork needs to be accurate; that is, it needs to be built to the size, shape and in the position required. However, the formwork designer must be realistic with tolerances and not specify such a high degree of accuracy which may well make the cost of the formwork prohibitive.

When concrete is placed in formwork, the loads produced often cause movement of the forms. To minimise movement and reduce the possibility of bulging or sagging, formwork must be sufficiently rigid.

Whether formwork is made up from boards, sheets or panels, there will invariably be joints through which the cement and water paste leak out. The loss of this matrix will cause a honeycomb finish and a resultant loss of strength. It is advisable to seal the joints with tape where loss is likely to occur and more importantly, ensure that joints are as tight as can be.

The finished surface of the concrete is a mirror image of the formwork in which it is cast. Where finish is important, the layout of panels and sheets of formply must be considered to produce an acceptable finish. Foreign matter in or on formwork must be removed prior to pouring concrete.

ECONOMY

For formwork to be economical it must be able to be built and stripped quickly, easily, and without damage. That is to say that the designer should keep the design of the formwork simple so that it can be easily handled by men and machines.

A standard design which will permit the formwork to be reused many times (up to ten for timber and 25 or so for metal) will make the use of formwork very economical.

SAFETY

It is essential in phases of construction that safety of men, machinery and materials be foremost in our minds, and particularly when designing, erecting and stripping formwork. As well as the loads of men, machines and concrete on formwork, consideration must also be given to stresses induced by the pressure of the concrete, the vibration and slump of the material, the rate of pouring, and the construction incurred during setting.

To accommodate these forces and render the concrete safe, special attention must be given to all braces, shores and toms, ensuring that they are sound and rigid.

The spacings of soldiers and walers on walls, yokes on columns, and bearers under floors should receive particular attention. They should be closely spaced at the base of the formwork and spaced further apart as the pressure decreases towards the top of the form.

PREPARATION OF FORMWORK PRIOR TO POURING CONCRETE

To ensure that the finish of the concrete is of the standard required and that stripping is simple and safe without damaging the concrete, the formwork must be clean and free from foreign matter (e.g. old concrete left on the formwork from previous pours).
It may be necessary to coat the contacting surface of the formwork with a release agent or solution which will prevent concrete from adhering to the surface of the formwork, thus assisting in the stripping.

There are many patented release agents available and all should be used according to the manufacturer's recommendations. Release agents may be brushed on for small jobs, but for large work a spray-on application is recommended. It is important not to coat the reinforcement with release agent, as this will reduce the ability of the concrete to attach itself firmly to the steel. Where there is to be reinforcement used then spraying must be done prior to positioning the reinforcement.

STRIPPING FORMWORK

To avoid damage to the concrete which has gained some strength but is still considered green, and to minimise risk of injury to workers, care must be taken when dismantling formwork.

The sequence of stripping formwork is a consideration that must be given much thought at the design stage. The basic principle of stripping is that 'what goes up last comes down first'. However, care must be taken to ensure that formwork is not damaged and that concrete is not chipped or disturbed in any way by the stripping process.

7.2 PATENTED FORMWORK SYSTEMS

There are several organisations which supply not only the component parts for formwork systems but also provide a competent design and technical advisory service as well.

It is useful to be familiar with proprietary formwork systems, as generally they have many advantages over timber systems.

The following diagrams show the major components and the manner in which they are used.

FLOOR AND WALL PANELS (Figure 7.1)

Lightweight panels are framed from a special rolled structural steel section and sheeted with resin bonded plywood for the working face. Because of such features as holes (for wedges and ties) located in the steel frame, assembly and alignment is quick and accurate.

PROPS (Figure 7.2)

Tubular steel, height-adjustable props are used to support floor beams - which in turn support floor panels.

SUPPORT BEAMS (Figure 7.3)

Manufactured from structural steel; are available in varying lengths; and where odd lengths are required an adjustable floor centre can be utilised. Floor beams have locating pins which fit into the locating holes on the top plate of the prop.
FIG. 7.1
(Courtesy Acrow Australia Limited)

STANDARD PROP

The patented, self-cleaning nut that saves time and money. It automatically cleans dirt and concrete from the thread as it is rotated.

FIG. 7.2
(Courtesy Acrow Australia Limited)
FIG. 7.3
(Courtesy Acrow Australia Limited)

ACCESSORIES

Accessories which assist in quick and accurate assembly include such items as:

(i) clips or clamps (see Fig. 7.4) which locate walers on the back of panels;

(ii) walers (see Fig. 7.5) to stiffen panels;

(iii) keys and wedges (see Fig. 7.6) to fix panels together;

(iv) column clamps (see Fig. 7.7) to form square columns;

(v) corner panels (see Figs. 7.8 (a) and (b)) - used to construct right angled corners;

(vi) panel infills (Fig. 7.9) to make up lengths of walls other than standard sizes;

(vii) wall ties (Fig. 7.10). Standard-width ties are available to keep wall thickness uniform and parallel;

(viii) shee-bolts (see Fig. 7.11): heavy duty bolts for use in crane hoisted formwork and walls other than standard width.

7.5
Proprietary formwork companies will supply formwork details for any job as part of their service to the client. They will also supply the client with a large range of pamphlets, giving all the details of the type of formwork and associated material available.

A CLAMP
To secure and align adjacent panels

B CLAMP
to secure and align panel forms and one scaffold tube

C CLAMP
to secure and align panel forms and two scaffold tubes or 4" x 1¾" R.S.J.

FIG. 7.4
(Courtesy Rapid Metal Developments (Australia) Pty. Ltd.)

scaffold tube

102 x 45 mm RSJ WALERS

FIG. 7.5

7.6
FIG. 7.6
(Courtesy Acrow Australia Limited)

FIG. 7.7
(Courtesy Rapid Metal Developments (Australia) Pty. Ltd.)
Corners and make-up pieces

Figure 7.8 (a) and (b)

For wall dimensions of irregular lengths.

Multi-form filler utilizes 19 mm site plywood. 19 mm ply both eliminates the need for stiffening and makes use of site offcuts.

Figure 7.9
(Courtesy GKN Mills Building Services Company)
This system is ideally suited for large areas of crane handled forms, timber or steel, as the whole assembly of she bolt, tie rod and she bolt can be passed through both faces of the form from one side.

7.3 TIMBER FORMWORK

Where there is only a small amount of formwork involved or the work is a "one-off" situation, then the use of timber has some advantages.

Timber boards have been widely replaced with purpose-made wide formwork sheeting such as resin bonded plywood or chipboard; however, care must be taken to ensure that only resin-bonded sheet material is used.

Props and toms are usually 100 x 75 or 100 x 100, and reliable softwoods such as oregon are used in preference to heavier hardwoods for this purpose.
Keeping in mind all the principles and basic requirements that have been covered previously, it is possible to construct timber formwork equal in performance to that of steel proprietary systems. The following figures show typical formwork to beams, slabs and columns using timber and proprietary steel applications.

7.4 BEAM FORMWORK (see Figure 7.12)

In domestic, light industrial and small commercial work, beam formwork is usually in the form of lintels spanning openings and beams supporting concrete floors.

With the availability of wide sheeting in long lengths it is sufficient these days to cut the sides and soffit from such sheets and stiffen the sides of the beam if a deep beam is planned. To ensure rigidity and strength, adequate bracing is essential. Timber tombs with folding wedges at their base enable fine adjustments to be made to the elevation of the beam. Longitudinal bracing to the tombs is often required to ensure stability.

One of the advantages of both timber and steel formwork is that they are completely compatible with one another, and composite formwork like that shown in Figures 7.13 (a) and (b) are possible.

7.5 WALL FORMWORK

Figure 7.14 shows one method of forming a small wall up to about 1.5 metres high. Such a wall might be used as a retaining wall or a footing wall. In Figure 7.14, bracing has been omitted for the sake of clarity, and - depending on the head of concrete - a runner at the base of the wall may be necessary.

Also, depending on the height, the walers will be closer together towards the base than towards the top of the wall.

Ideally, the soldiers should be spaced about 600 mm apart, but this would depend upon the thickness of the sheeting and the height of the wall. Walers need to be spaced about 375 mm apart at the base, increasing to 600 mm apart at the top of a 3 metre wall. Once again, this would depend on the wall dimensions, sheeting thickness and the spacings of the soldiers.

Tie bolts are used to prevent the wall from spreading apart. The tie bolts can be 10 - 15 mm rod cut to length and threaded for the particular job, or they may be purpose-made shee-bolts, which are available from formwork system suppliers.
spread

17.5–19mm resin bonded structural ply or aquatite particle board to sides and soffit

75 x 38 strut
75 x 25 cleat or stiffener
75 x 38 block

100 x 75 bearer
75 x 25 cleat
75 x 50 brace

100 x 75 tom

folding wedges ex 100 x 75
225 x 32 soleplate continuous under toms

Alternative for deep or large sectioned beam

75 x 38 stiffening to sides

TIMBER

FIG. 7.12
COMPOSITE BEAM FORMWORK

(a)

COMPOSITE COLUMN FORMWORK

(b)

FIG. 7.13
7.6 SUSPENDED SLAB FORMWORK

Most suspended concrete floors will require temporary support while the concrete sets, cures and attains sufficient strength to be self-supporting. The concrete load on formwork is greatest when the concrete is wet, and the load on the formwork diminishes as the concrete becomes self-supporting. Therefore, formwork for slabs - or indeed any formwork - must be sufficiently strong and rigid to support the initial load plus placement loads.
The general principle of slab formwork is to provide a smooth even base on which the concrete will be poured. The level of the formwork is the invert level of the floor or the soffit of the floor.

To achieve the height necessary, the floor soffit or face of the formwork is kept clear of ground level, by props or toms. These can be either timber or steel. The props support beams which in turn support joists. Over the joists, resin-bonded sheeting is laid close-jointed ready to receive the concrete. One can easily imagine slab formwork as being very similar to timber floor framing.

To limit the number of supports required under the slab, there are available telescopic beams known as floor centres, which are capable of spanning 6.63 m. See Figure 7.15.

For timber formwork to slabs, there are many things to be considered when designing formwork, but it is not the function of this text to design formwork for all general situations. As a guide, the decking would need to be about 19 mm thick – at least. With this thickness, floor centres could be spaced up to 800 mm apart where the grain of the decking material is parallel to the span, or 600 mm apart where the grain is at right angles to the span.

Where steel formwork systems are to be used, each supplier has his own system, but basically every system consists of tubular steel props, supporting beams or floor centres over which wall/floor panels or sheeting are placed, respectively.
Note: Dimensions are in imperial measurements

FIG. 7.15

(Courtesy Rapid Metal Developments (Australia) Pty. Ltd.)
CHAPTER EIGHT - BRICKS AND BRICKWORK

8.1 BRICK TYPES AND CLASSIFICATIONS
   MANUFACTURE
   BRICK BONDS

8.2 BRICKWORK MORTARS
   WHY USE MORTAR?
   INGREDIENTS
   MORTAR MIXES
   JOINTS

8.3 CAVITY WALLS
   VENTILATION
   OFFSETS, CORBELS AND PIERS

8.4 BRICKWORK REINFORCEMENT
   STEEL ROD
   LINTELS
   ARCHES

8.5 BUILDING IN FRAMES AND JOINERY

8.6 DAMP-PROOF COURSES AND FLASHINGS
   DAMP-PROOF COURSES
   FLASHINGS

8.7 THE FIRE PLACE
   FACTORS TO CONSIDER
   FLASHING THE CHIMNEY STACK

8.8 CLEANING OF CAVITIES

8.9 CLEANING BRICKWORK
   COMMON DISFIGUREMENTS
   TREATMENTS
   SAFETY

CC BY
8.1 BRICK TYPES AND CLASSIFICATIONS

The following brick types are used in Western Australia:

1. Clay bricks - Standard metric size 230 x 110 x 76
   - Modulars 290 x 90 x 90
   - Modulated 290 x 90 x 76
   (See Table 8.1)

2. Calcium-Silicate - Standard Size 230 x 110 x 76
   (See Table 8.1)

3. Concrete Masonry - Common Sizes 390 x 90 x 90
   390 x 190 x 90
   390 x 190 x 190

Concrete blocks are made in a variety of other sizes, such as ¾ sizes and half blocks, etc., but the above are the most common ones used.

CLAY BRICKS

<table>
<thead>
<tr>
<th>TYPE OF BRICK</th>
<th>DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LENGTH X THICK. X HT.</td>
</tr>
<tr>
<td>STANDARD - CORED</td>
<td>230 x 110 x 76</td>
</tr>
<tr>
<td>STANDARD - ON EDGE</td>
<td>230 x 76 x 110</td>
</tr>
<tr>
<td>MODULAR</td>
<td>290 x 90 x 90</td>
</tr>
<tr>
<td>MODULATED - STD.</td>
<td>290 x 90 x 76</td>
</tr>
<tr>
<td>INT. BLOCK UNIT</td>
<td>295 x 90 x 162</td>
</tr>
</tbody>
</table>

CALCIUM SILICATE BRICKS

<table>
<thead>
<tr>
<th>TYPE OF BRICK</th>
<th>DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LENGTH X THICK. X HT.</td>
</tr>
<tr>
<td>STANDARD - HOLED</td>
<td>230 x 110 x 76</td>
</tr>
<tr>
<td>STD. SOLID 90</td>
<td>230 x 90 x 76</td>
</tr>
<tr>
<td>STD. SOLID 130</td>
<td>230 x 130 x 76</td>
</tr>
<tr>
<td>STD. SOLID 145</td>
<td>230 x 145 x 76</td>
</tr>
<tr>
<td>STD. SOLID 165</td>
<td>230 x 165 x 76</td>
</tr>
<tr>
<td>STD. HOLED 119</td>
<td>230 x 110 x 119</td>
</tr>
<tr>
<td>MODULAR HOLED</td>
<td>290 x 90 x 90</td>
</tr>
<tr>
<td>MOD. HOLED 76</td>
<td>290 x 90 x 76</td>
</tr>
<tr>
<td>MOD. HOLED 119</td>
<td>290 x 90 x 119</td>
</tr>
<tr>
<td>MOD. HOLED 162</td>
<td>290 x 90 x 162</td>
</tr>
<tr>
<td>MOD. HOLED 190</td>
<td>290 x 90 x 190</td>
</tr>
</tbody>
</table>

TABLE 8.1

8.2
Bricks are graded according to their average crushing strength, which is the average strength of a random sample of twelve bricks, tested in accordance with the ASA 21 and ASA 91, Australian Standards.

The compressive strength of various types of bricks or masonry units tested in Australia, under these conditions, is as follows:

(a) For clay bricks from 10 MPa to 110 MPa.
(b) For sand-lime or calcium-silicate bricks from 20 MPa to 40 MPa.
(c) For concrete blocks from 10 MPa to 30 MPa.
(One MPa is 145.038 lbs per square inch).

MANUFACTURE

Clay bricks are manufactured as either pressed or extruded bricks. The manufacturing process is the same in both cases, except for the stage of the actual pressing or extruded.

There are eight stages in the manufacturing of bricks and these are listed below.

MINING THE CLAY

Up to 20 varieties of clays are mined and taken to the plant and held under cover in big holding sheds.

MIXING THE CLAY

Up to six different types of clay may be mixed to obtain the desired colour of the finished product. At this stage, other ingredients can also be mixed with the clay to produce different textures and colours in the bricks. Cinders and coal are commonly used.

CRUSHING THE CLAY

This is done in two stages. The primary crusher reduces the clay to lumps no bigger than 100 mm in diameter. The second crusher reduces the clay to a consistency of coarse flour.

The clay is then passed over a vibrating screen to eliminate any lumps, before passing into the holding bins.

MOULDING THE CLAY

Here the clay comes from the holding bins and goes to either the pressing machine or the extruding machine. Water is added to the clay to get it to the right consistency for either pressing or extruding. Once the brick is moulded it is then ready for burning. The tunnel kiln is now the most common kiln used.

DRYING THE BRICKS

This is the first stage in the kiln. The bricks are dried, using the hot air extracted from the cooling chamber of the kiln.
BEJSER VIBROPAC MASONRY SCHEMATIC PRODUCTION DIAGRAM

FIG. 8.2

FINISHED PRODUCT IN APPROXIMATE 8 1/2 HOURS WITH EQUIVALENT 28 DAY STRENGTH

AUToclave:
1. STEAM INTRODUCED AT 150°F AND PRESSURE RAISED TO 150 PSI
   OVER A 1/2 HOUR PERIOD - HELD LIKE THIS FOR 2 1/2 HOURS.
   STEAM THEN EXHAUSTED OVER 20 MINUTES.
   CREATING VACUUM - RESULT - DRY BLOCKS.

RAW MATERIALS:
AGGREGATE
SAND
CEMENT
POZZALIN
WATER
OXIDE (IF REQUIRED)

STOCKPILES

BEJSER MACHINE

GREEN (UNCURED BLOCKS)

AUTOMATIC STACKING ON RACKS

PRE SETTING PERIOD OF TWO HOURS
PRE-HEATING THE BRICKS

This is the second stage in the kiln, where the bricks are pre-heated to temperatures of 800 to 1000°C.

BURNING THE BRICKS

Depending on the type of brick required, the temperatures range from 1100 to 1250°C.

COOLING THE BRICKS

The last stage of the kiln; this part is split into two sections. The first is the quick cool area, where the hot air given off by the bricks is extracted from the kiln and transferred through pipes to the drying area of the kiln. The bricks are cooled to about 600 to 700°C.

The second section is where the bricks cool down by themselves until they come out of the kiln.

See Figure 8.1 for a diagram of the Midland Brick Company tunnel kiln.

Figure 8.2 shows the manufacturing process of a concrete block. This same process applies to calcium silicate bricks.

BRICK BONDS

The definition of bond, in relation to brickwork is: the overlapping of bricks, to a definite pattern, so as to maintain the greatest possible strength.

Figure 8.3 shows that if bricks are laid straight on top of one another, each section (A, B and C) is entirely independent of the others and receives no support from the other sections.

In Figure 8.4, we show a wall using the same amount of materials, yet the bricks are bonded. In this case, any mass imposed on the wall would be evenly distributed.
There are several types of bonds, the main ones being: half bond (using stretchers with half laps), third bond (using modular bricks) and quarter bond (English, Dutch and Flemish bonds). The first two of these are mainly used in single leaf brickwork. Quarter bond is used in walls of 230 mm thickness or thicker walls. Figure 8.5 (a) and (b), shows the different types of bonds as they would appear in the wall.

![Half bond and Third bond](image)

(a)

![English bond and Flemish bond](image)

(b)

**FIG. 8.5**

**ENGLISH BOND**

This is one of the strongest bonds used. It consists of a course of headers, followed by a course of stretchers. To obtain the quarter bond, next to the first header brick on the corner, a closer is placed (50 mm on the face) and this then creates the quarter lap.

Some of the main principles of English bond are:

- The corner brick determines the rest of the course. For example, a header is followed by a header course, a stretcher on the corner is followed by a stretcher course.

- Next to the header on the corner is a closer, which goes through the full width of the wall.

- Face bricks are always backed by headers wherever possible; these must maintain sectional bond the full width of the wall.

- If you start with a course of headers, this becomes a course of stretchers around the corner. This works all around the building, provided the corners are 90°.
Always tie in with a header course.
When walls are of even brick thickness, they have the same bond internally and externally. The opposite applies to walls of uneven thickness.

**FLEMISH BOND**

This consists of a header and then a stretcher alternating in the same course. Again, next to the header on the corner, a closer is placed to create the quarter bond. Flemish bond is not as strong as English bond.

**BRICK-ON-EDGE BOND**

This is not really a bond, but here the bricks are laid on edge with a 76 mm wide bearing surface. Brick on edge creates about a third bond. It saves space, as the walls are only 76 mm wide, but it is not as strong as conventional brick-on-flat walls. With the use of modular bricks these days, brick-on-edge construction is now very seldom used.

### 8.2 BRICKWORK MORTARS

Mortar forms an important part of any masonry construction. Different types of masonry require different types of mortars, and the position in which mortar is used will determine the proportions of its ingredients. It is, therefore, important to understand the reasons for which mortar is used and the part each ingredient plays in mortar.

**WHY USE MORTAR?**

There are five main reasons for using mortar in brickwork. Each is important:

. to provide strength
. to provide stability
. to absorb irregularities in the bricks
. to provide protection from weather
. for appearance.

**STRENGTH**

Brickwork laid without mortar joints would be unable to support any loading such as beams or roof structures. Mortar binds the individual units of masonry into one solid mass, giving strength.

**STABILITY**

Brick walls are also given lateral strength by the binding action of mortar. Without this, walls would easily fall if any heavy object applied lateral pressure to them. Wind loading for instance, applies enormous pressures at times, which would easily topple a wall laid without mortar.

8.8
ABSORBING IRREGULARITIES

Mortar forms a cushion which absorbs any difference in size or shape of bricks, caused during the manufacturing process. It enables the bricklayer to keep the brick courses level, the perpendicular joints plumb above one another, and his walls plumb and level generally. This "cushion" effect is also important in compensating for minimal movement caused by expansion and contraction of masonry units.

WEATHER PROOFING

Good mortar joints retard the passage of moisture through walls. Tests have shown that about 90% of the water which passes through walls, comes through between the bricks, not through the bricks themselves. Where there is no mortar joint, there is no resistance to the passage of moisture and dampness results. However, mortar which is properly compacted by jointing, provides an effective seal against rain and wind.

APPEARANCE

Very pleasing effects can be obtained by using a suitable colour of mortar with a particular brick. There is no doubt that the mortar which bonds the individual bricks into one solid mass can also greatly enhance the total appearance.

INGREDIENTS

THE MATRIX IN MORTAR

The most common matrix (binding agents) used in mortar are lime and/or cement.

LIME

It is not known when man first discovered the use of lime as a building material, but it has been used for several centuries. Ancient civilisations such as the Egyptians, Persians, Greeks and Romans used lime for mortar, some of which is still in excellent condition today. Until cement was discovered in 1824, lime was the only matrix used for mortar and it is still an important ingredient today. Lime in mortar provides:

- plasticity
- water retention
- bond strength
- autogeneous healing
- flexibility.

Plasticity - It is important for mortar to flow easily to ensure that it can be easily trowelled and that the joints are well filled. If a cement mortar without lime or additive is used,
it will be difficult to use and joints will tend to be honeycombed.

Water Retention - Masonry units absorb moisture from the mortar. If this occurs quickly, there will be a poor bond between the masonry units and the mortar. Lime-based mortar resists 'bleeding' of the mortar by the masonry units. A second important aspect of water retention is that during construction the presence of lime in the mortar reduces the need for re-mixing.

Bond Strength - A plastic, workable mortar that retains water and fills the joints well, will also give a better bond. The lime finds its way into the minute pores of bricks, giving a strong keying action. Poorer bonds are achieved if air-entraining agents or plasticizers are used in place of lime.

Autogeneous healing - Should minute cracks develop in mortar containing lime, a chemical reaction known as autogeneous healing (self-healing) starts as moisture from the atmosphere or rain reacts with the lime. This is similar to the action of water forming stalagnites, although autogeneous healing is much faster. This is a very important process in the prevention of leaks in walls, as the small cracks automatically heal up.

Flexibility - Lime gives mortar the ability to flex without cracking. Any movement caused by wind or thermal shock will cause strong cement mortars to crack, but mortars with a reasonable lime content have the ability to move without cracking.
An outstanding illustration of this is in the construction of tall chimney stacks. A 114.3 m stack has been found to sway up to 600 mm each side of a centre line in winds up to 135 km per hour, without causing damage to the construction.

MANUFACTURE OF LIME

Lime is made from either limestone or chalk. When limestone or chalk is burned at high temperatures, it becomes quick lime or rock lime. This lime is in lump form and is very dry. As soon as water is added to this rock lime, it begins a process known as slaking.

During the process, heat is given off and the rock lime breaks down into a paste-like substance, which, when dried out and ground into a fine powder form is hydrated lime. When this hydrated lime is mixed with water and then begins to dry out, it hardens slowly, changing back to its original form, limestone.

PORTLAND CEMENT

This is an artificial cement manufactured by calcining chalk and clay or rivermud, containing certain chemical constituents in definite proportions. These materials are then mixed and ground
into a slurry which, after being strained through very fine sieves, is pumped into an orifice in the top of an inclined revolving cylinder. A blast of intense flame is directed through this cylinder, which is lined with fire bricks.

As the slurry drops through the flame, it is turned into small clinkers which are afterwards ground exceedingly fine in specially constructed mills and then passed through sieves, having as many as 21 meshes to the square mm. The powder is sometimes aerated by being spread on a wooden floor to ensure the thorough slaking and cooling of all particles.

It is then placed in paper bags, each of 40 kg.

The process of aeration has now nearly been superseded by the addition of a small quantity of gypsum (Plaster of Paris) which retards the otherwise rapid setting tendency of a freshly ground cement.

SAND

When used for mortar, it should be angular in grain, free from clay or dirt and moderately coarse. If too fine, the proportion of lime or cement will have to be considerably increased.

Sand should be washed, if necessary, as the presence of foreign matter will weaken the mortar by affecting its setting qualities.

Clean sharp pit sand forms the best aggregate.

The qualities and characteristics of sand vary considerably. Pit sand, for instance, is sharper than river sand. River sand, on the other hand, is much finer and is consequently very desirable for use in plastering. Sea sand is rounded in grain and is impregnated with salt. The salt attracts moisture and dissolves, and, on evaporation in dry weather, a salty white deposit known as "efflorescence" appears on the brickwork, and is very difficult to clean off. If sea sand is used, it must be thoroughly washed in running water, to remove all traces of salt.

Old bricks, stones, and clinkers, crushed to the size of sand particles may be substituted for sand.

MORTAR MIXES

There are various types of mortar mixes used in Western Australia. The following are the most common and proven ones:

CEMENT MORTAR

Mix: 3 parts of sand to 1 part of cement.

To make this mortar more workable, \( \frac{3}{10} \) part of lime may be added.

Cement mortar is mainly used in footings, below D.P.C. level and also over openings or arch bars and in reinforced brickwork or brick lintels.

LIME MORTAR

Mix: 3 parts of sand to 1 part of lime.

Lime mortar can only be used in brickwork that is non-load-bearing and is covered with rendering or cladding.

Lime mortar will not stand up to the elements and, with exposure to the weather, could fret away.

[CC BY]
COMPOSITE MORTAR

Mix: 6 parts of sand to 1 part of cement and 1 part of lime (6:1:1).

Composite mortar is used for most general building construction brickwork. The mix can vary slightly, according to the specifications of the building contract.

With the use of masonry cement, now manufactured, it is necessary to follow the recommended mix proportions as specified by the manufacturers.

These mix proportions are:

(i) below ground mortars (severe conditions) - one part of masonry cement to three parts of sand;
(ii) normal facing mortars - one part of masonry cement to four parts of sand;
(iii) internal brickwork - one part of masonry cement to six parts of sand.

Except for unusually heavy loads or in reinforced brickwork, moderate-to-low strength mortars are adequate. Mixes of 6:1:1 or 9:2:1 (sand, lime, cement) have ample strength for buildings of up to three storeys. Stronger mortars become rigid and brittle and are less able to absorb stress and movement caused by settlement, temperature change, wind and moisture.

MORTAR WITH ADMIXTURES

Any material, other than the normal aggregate - cement, lime and water - that is added to the mortar, may be considered as an admixture or agent. Those mainly used in mortar are air-entraining agents.

These agents, sometimes referred to as plasticizers, cause the formation of minute air bubbles in the mix. The addition of these agents to mortar does improve workability, and allows a considerable reduction in the quantity of water. Another advantage claimed is that the resulting mix resists the penetration of water more than a mix without these agents.

Any decrease in the quantity of water added to cement does mean an increase in strength and, if this can be achieved with a marked improvement in the workability of the mix, the admixture must then receive favourable consideration.

A lot of research has been carried out in the development of air-entraining agents and tests indicate that their use in bricklayers' mortar is justified, providing that the manufacturer's instructions are strictly adhered to.

Some architects and local authorities are not completely in agreement with admixtures and, for this reason, specify against their use. The builder must at all times comply with the specifications of the contract.

COLOURING OXIDES

These may be added to the mortar to provide a coloured mortar to match, contrast, the blocks used in the construction. Trial
batches of mortar might have to be mixed to obtain the desired colour.

JOINTS

Joints in brickwork are finished in a variety of ways for two main reasons:

. to prevent the entry of water into the brickwork
. to give a neat and attractive finish to the face of the brickwork.

Jointing is normally done as the brickwork is being constructed and before the mortar has reached its initial set.

Important points to note when jointing:

. Keep the joints full for bond strength.
. Keep the face of the brickwork clean.
. Brush the face of the work after jointing has been completed, to keep the work clean.

TYPES OF JOINTS:

Flush Joint

The mortar joints are trowelled to a smooth surface, flush with the face of the brickwork, using the trowel.

Struck Joint

This may be either struck or weather struck.

This joint is not a common joint these days, but is still used in restoration and additions.

It is made by using the trowel, and the joint is slightly indented either at the bottom or top.

The indent should not be more than 1.5 mm. This prevents water gathering at the joints so causing damp walls. The weather struck joints are used in areas of high rainfall or frosty conditions. It slopes inwards towards the top of the joint and has the disadvantage that it will show up any irregularity in the joint size, due to the fact that bricks are not always even and true.

Recessed Joint - Raked joint

Here the joint is raked out to a depth of 8 to 10 mm. In face brickwork, after raking the joint out, the surface of the joint should still be smoothed to a hard surface to prevent the penetration of water. This is generally not done.

Raked joints are also used on rendered walls, to give an extra key for the plaster.

Concave Joint

Here the joint is finished with a piece of mild steel rod with a diameter of 12 mm or 10 mm.

In all cases, the joints in face brickwork should have a smooth hard finish to prevent the penetration of water and deterioration of the joint itself. Figure 8.6 shows the types of joints.
**TYPES OF JOINTS**

<table>
<thead>
<tr>
<th>FLUSH</th>
<th>VEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRUCK</td>
<td>RAKED</td>
</tr>
<tr>
<td>WEATHER STRUCK</td>
<td>RAKED FOR PLASTER</td>
</tr>
<tr>
<td>CONCAVE OR ROLLED</td>
<td>FLUSH POINTED</td>
</tr>
</tbody>
</table>

*NOTE: Weather struck joints are used only where climate demands it*

**FIG. 8.6**

Note: Do not confuse the terms **jointing** and **pointing**.

**Jointing** is the finishing of the joint during the actual construction of the brickwork.

**Pointing** is the filling and shaping of a mortar joint after construction is finished, such as filling in joints left out during the construction or in old houses where the original joints have fretted away.

Pointing should be done with the same strength mortar as used in the original construction, otherwise differences in shrinkage can occur between the mortars, resulting in the pointing becoming loose and falling out of the joint.

### 8.3 CAVITY WALLS

Walls may be built as solid walls - that is, having one thickness only - or as cavity walls, being comprised of two walls (not necessarily of equal thickness), with a space (cavity) in between. These walls are called leaves which are generally referred to as the outer and inner leaf. The space between the walls has two main advantages:

- when the outer leaf becomes wet, the cavity prevents water passing from the outer leaf to the inner leaf and thus the interior of the building remains dry;
- the cavity will not allow heat to be transferred from one wall to the other. This arises from the fact that air is
a bad conductor of heat and so the cavity acts as a barrier. The cavity, therefore, is a good heat insulator and helps keep the building cool in summer and warm in winter.

VENTILATION OF CAVITY WALLS

Cavities may be ventilated or unventilated. The insulating factor of the cavity is lost to a great degree if it is ventilated. It is for this reason that most council by-laws allow cavities to be unventilated. If the inside of the building has to be ventilated, the ventilators should be boxed through the cavity, to allow air flow into the building, without the air flow getting into the cavity. Weep holes must be left at ground level or just above, to allow for any accumulated moisture in the cavity to escape.

The cavity should be large enough to provide suitable insulation, but not so large as to make it difficult to tie the two leaves together. Wall ties of a minimum thickness of 3.5 mm are used, spaced at not more than 900 mm apart horizontally and not more than 450 mm vertically, in a diamond pattern.

Most wire ties are now manufactured with a "drip" in the centre, to prevent the water from travelling along the tie from the outer leaf to the inner leaf.

The cavity must be kept clear of any obstructions likely to allow the passage of water through to the inside leaf, during and after construction.

Most cases of dampness showing up on the inside leaf can be traced back to obstructions in the cavity, caused by either bad workmanship or not keeping the cavities clear.

OFFSETS, CORBELS AND PIERS

OFFSET

Horizontal breaks in walls to diminish the thickness.

They are used to reduce the thicknesses of walls and they can be found at the base of walls, where the brickwork is spread out over the width of the concrete step footing, and then steps back until the required wall thickness is obtained. This reduction in thickness is done by the use of 60 mm offsets. (See Fig. 8.7). Offsets can also be found at parapet walls where a 270 mm cavity wall is reduced to a 230 solid parapet wall with a 40 mm offset. See Uniform Building By-Laws, Regulation 36.1 (4) (c) (iii).

CORBELS

These are used to hide gutters at eaves level of houses with brick gables or, at the end of parapet walls to hide the rain-water heads and gutters.

They can also be used as a feature at the start of a brick gable. (See Fig. 8.8).
PIERS

These are used to give extra support to walls over a certain length. The size of the pier and the intervals at which they have to be spaced depend on the length, height and thickness of the wall, as well as the load supported by the wall.

Free-standing piers are used to support parts of the roof structure, arches or beams, or they can be constructed for aesthetic purposes only - for example, in the case of fences with chains running between the piers.

8.4 BRICKWORK REINFORCING

Brickwork without reinforcement is strong in compression, but weak in tension and shear. This makes it strong under a vertical load but comparatively weak against oblique or side thrust. By reinforcing the brickwork with mild steel rods or patent forms of steel or wire reinforcement, considerable strength in tension and shear is gained. (See Fig. 8.9 (a)).

LONGITUDINAL WALL REINFORCEMENT

FIG. 8.9 (a)

(Reproduced from 'Basic Trades Manual - Bricklaying Operations', with the permission of the Australian Government Publishing Service)
STEEL ROD REINFORCEMENT

Mild steel rods 6 mm in diameter can be used to reinforce a brick wall. The rods can be built in the horizontal bed joints or vertically either through holes in specially made bricks or where piers are attached to walls. (See Fig. 8.9 (b)).

STEEL ROD REINFORCEMENT

FIG. 8.9 (b)

(Reproduced from 'Basic Trades Manual - Bricklaying Operations', with the permission of the Australian Government Publishing Service)

Other forms of reinforcements are:
(a) 25 x 1 mm galvanized hoop iron;
(b) stamped or expanded metal;
(c) wire mesh, usually supplied in rolls.

These types of reinforcements are usually placed in a continuous length, one per each 110 mm in wall thickness, and they should be adequately hooked or lapped at all junctions or corners.

It is good practice to provide one continuous row of reinforcement one or two courses below a window opening, and the same over the lintels over door and window frames. Mild steel rods and stirrups or patent reinforcement can also be used to form reinforced brick lintels. (See Fig. 8.9 (c) and (d)).

FREE-STANDING CARPORT ROOFS

Again, the size of the pier depends on the load it has to support and the height of the pier.
Brick or concrete block free-standing piers shall have brick, concrete block or concrete footings not less than 150 mm thick and projecting not less than 50 mm beyond each face of the pier.

8.18
REINFORCED BRICKWORK LINTELS

FIG. 8.9 (c)
(Reproduced from 'Basic Trades Manual - Bricklaying Operations', with the permission of the Australian Government Publishing Service)

Mild steel rods built into horizontal mortar joints

Mild steel rods threaded through purpose made bricks

PATENT REINFORCEMENT

FIG. 8.9 (d)
(Reproduced from 'Basic Trades Manual - Bricklaying Operations', with the permission of the Australian Government Publishing Service)

LINTELS

Steel lintels or angle bars are the most common form of spanning over openings, as they have the advantage of being light and are easy to handle. They also lend themselves readily to concealment in the construction, but precautions must be taken against corrosion if they are used in locations with a highly corrosive atmosphere, as in close proximity to the sea.

For spans that are too large to bridge with normal angle bars, it may be necessary to use rolled steel beams or reinforced concrete lintels. (See Fig. 8.10)
TYPES OF LINTELS

FIG. 8.10

(Reproduced from 'Basic Trades Manual - Bricklaying Operations', with the permission of the Australian Government Publishing Service)

Plastercut lintels can also be used internally. These are available on request from the manufacturers of plasterboards, etc. Size and load bearing capacity have to be stated when ordering.

DESIGN FACTORS

Important factors governing the design of lintels of any type are:

. the width of the opening, or the span of the lintel;
. the thickness of the wall to be carried by the lintel, and the type of wall: for example, face brickwork or rendered;
. the strength of mortar used immediately above the lintel;
. the load assessed as being supported by the lintel;
. the deflection that will occur in the lintel under load.

Before the loads to be supported can be calculated, it is necessary to know:

. the height of the wall above the opening,
. the length of the wall extending laterally on each side of the opening, and
. the type of masonry to be used and the size of the units.

8.20
The following is an extract from the Notes on the Science of Building (N.S.B.) 27.

END BEARING

Arch bars and angle lintels must be provided with adequate end bearing. This should be provided by extending the steel along the supporting brickwork at each end for a distance of not less than 50 mm plus 4 mm for every 100 mm of span, and bedding it carefully in cement mortar or strong composition mortar, e.g. a 2400-mm span will need about 150-mm length of bearing at each end.

However in view of the above statement from N.S.B., it is considered that a minimum of 230 mm at each end be considered good building practice.

TABLE 36.9
LINTELS
Straight Openings

<table>
<thead>
<tr>
<th>Openings in mm</th>
<th>Steel angle in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1500 mm</td>
<td>76 x 76 x 8</td>
</tr>
<tr>
<td>Over 1500 but not over 2700</td>
<td>102 x 102 x 8</td>
</tr>
<tr>
<td>Over 2700 but not over 3150</td>
<td>127 x 76 x 10</td>
</tr>
<tr>
<td>Over 3150</td>
<td>To be designed by a practising Structural Engineer</td>
</tr>
</tbody>
</table>

Corner Openings

<table>
<thead>
<tr>
<th>Openings in mm</th>
<th>Steel angle in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2700</td>
<td>102 x 102 x 8</td>
</tr>
<tr>
<td>Over 2700 but not over 3150</td>
<td>127 x 76 x 10</td>
</tr>
<tr>
<td>Over 3150</td>
<td>To be designed by a practising Structural Engineer</td>
</tr>
</tbody>
</table>

BRICK REINFORCED LINTELS

Brick lintels have been in use for a considerable time but, it is probably true to say in many cases, without knowledge of their true value in relation to the construction of brick walls. The reinforcement of brickwork skilfully applied over any sized opening, not only enhances the general appearance of the finished work but, because of the extra strength being impregnated into the wall must, of necessity, improve the general structure.

The skill of the craftsman is sufficient guarantee of the quality of reinforced brickwork. The generally accepted standards of brick lintels comprise:

- solid well burnt bricks, true in all details, well wetted before laying;
- cement mortar mixed true to gauge of three parts of clean sand to one part of fresh cement, and used fresh;
- straight and true 6.4 mm mild steel rods, and well made 2.5 mm gauge wire stirrups;
- neat, straight soffit piece with sufficient toms on folding wedges, to support the load during construction. (See Figs. 8.9 (c) and 8.11.)
ARCHES

Brick arches of various kinds and elevational designs are mostly structural in character - that is, they have to support loads - but often they are used for aesthetic purposes as well, and sometimes solely for this purpose. Most arches in modern housing construction are for aesthetic purposes only.

An arch derives its strength primarily from the wedge-shaped bricks (voussoirs) forming it. Again, in modern housing construction, arch bricks are seldom cut to shape for economical reasons.

Structurally, the loads imposed on an arch tend to compress the bricks and mortar together, and transmit the pressure to the abutments or supports; therefore, care must be exercised to ensure sufficient strength is obtained. Figure 8.12 shows the various parts and terms used in relation to arches.

Following are the geometrical methods of setting out three different types of arches.

1. Semi-circular arch - Figure 8.13.
   (a) Draw a line A - B, and mark off the span of the arch (C - D).
   (b) Find the centre of the span - E.
   (c) Mark off the size of the face of the arch, from C to F.
   (d) Using point E as centre, scribe the two arcs F - G and C - D, giving the shape of the arch.
1. **Span**  
2. **Rise**  
3. **Springing Line**  
4. **Springing Points**  
5. **Springer Voussoir**  
6. **Striking Point**  
7. **Intrados or Soffit**  
8. **Extrados or Back**  
9. **Face or Depth**  
10. **Key Brick**  
11. **Crown**  
12. **Haunch**  
13. **Collar Joint**  
14. **Abutment**  
15. **Spandril**  
16. **Arch Bed Joint**  
17. **Skewback**  
18. **Voussoirs - cut or shaped bricks in an arch.** (Both 5 and 10 above.)

**SEMI-CIRCULAR ARCH**

**FIG. 8.12**

**SEMI-CIRCULAR ARCH**

**FIG. 8.13**

8.23
2. **Segmental arch - Figure 8.14.**

(a) Draw a line A - B, and mark off the span of the arch on this line, C - D.

(b) Bisect C - D with a line E - F, crossing C - D at G.

(c) Mark off the rise on this line, from G to H.

(d) Draw a line from H to C, and bisect this line, crossing line E - F at I. This is the striking point for the arch and, using point I as centre, the two arcs C - D and K - J can be drawn.

Note: The triangular areas ACK and BDJ are the skewbacks.

![Segmental Arch Diagram](image)

**SEGMENTAL ARCH**

**FIG. 8.14**

3. **Tudor arch - Figure 8.15.**

(a) Draw the springing line A - B.

(b) Mark off the span on this line, points C and D.

(c) Bisect the span, line E - F, crossing line C - D at point G.

(d) Mark off the rise on line E - F, from G to H.

(e) Mark off two-thirds of the actual rise, from point C, along the springing line to point I.

(f) Using point C as centre, scribe an arc from point I to J. Using point I as centre, scribe an arc from point C to J.

(g) Draw a line from point J to point H.

(h) Bisect line J - H, carrying it well down to point L (line K - L).

(i) Draw a line through points J and I, crossing line K - L at point M.
(j) Draw a line, parallel to the springing line, from point M, crossing line E - F at N. Carry this line past the centre line, about equal distance to M - N.

(k) Using point N as centre, scribe an arc from point M to cross line M - N at point 0.

(l) Mark off an equal distance to C - 1, on the springing line, from point 0 to P.

(m) Draw a line from point 0, through point P.

(n) Use centres 1 and P to scribe the intrados and extrados for the hunches.

(o) Use centres M and 0 to scribe the crown of the arch.

8.5 BUILDING IN FRAMES AND JOINERY

All frames must have some adequate means of being fixed to and built into the surrounding walls.

For timber frames galvanised hoop iron straps are used. These are nailed to the frame and bedded into the brickwork.
On door frames, straps should be spaced 600 mm apart on each side, or one strap about every seventh course of metric standard brickwork. The first strap should be only one course from the bottom of the frame. (See Fig. 8.16).

Timber frames built into a cavity wall should have the straps built into the internal leaf only. Cavity cleats can be nailed to the frame to help hold it firmly into position. (See Fig. 8.17). Note the position of the flashing on the frame.

![Diagram of door frame](image)

**FIG. 8.16**

**FIG. 8.17**

Metal door frames are now commonly used and the method of building these in is shown in Figure 8.18.

It must be remembered, that when building in these metal frames, the hollow spaces, left around where the brick fits into the frame, must be filled in with mortar to make the whole frame solid.

8.26
Aluminium frames are built into brickwork with straps that are provided by the manufacturers. These straps fit onto the protruding flashing of the frame. (See Fig. 8.19).

8.6 DAMP-PROOF COURSES AND FLASHING

The selection of suitable materials for D.P.C. and flashings from the many types available, and the proper installation of such materials, are both of great importance.

If failure occurs, replacement is usually a matter of great difficulty and considerable expense.

The following notes explain the characteristics and application of the D.P.C.s and flashings commonly used in domestic buildings.

DAMP PROOF COURSES

In general, D.P.C.s are intended either to prevent the rise of moisture in a building from the ground, caused by capillary action, or to prevent water from penetrating the structure downwards and, occasionally, sideways. Therefore, it is necessary that materials for D.P.C.s should be resistant to the passage of moisture, either by capillary or gravitational action, depending on their situation in the building.

PRINCIPAL MATERIALS

The principal materials used may be conveniently classified as flexible, semi-rigid or rigid types. The flexible types may be used in any position in the building, but the semi-rigid or rigid types are generally used to resist the capillary penetration of moisture only.

FLEXIBLE TYPES

Examples of flexible types are listed below:

Metallic - Copper, lead
Bituminous - Compound coated fabrics
Compound - Aluminium, copper, lead and zinc coated with bitumen.
Polyethylene.

SEMI-RIGID TYPES

Asphalt
Bituminous materials
Tar

usually coated with sand

RIGID TYPES

Cement mortar containing integral waterproofing compounds.
No fines concrete.

FLASHINGS

The requirements for a good flashing material are similar in many respects to those of D.P.C.s, but usually another quality - flexibility or working ability - is also essential and the effect of corrosion of the material by mortar is of less consequence in the case of flashing, than in the case of D.P.C.s.

Some materials which are unsatisfactory for D.P.C.s may, nevertheless, be used in flashings.

The principal materials used for flashings are:

Bituminous - bitumen coated fabrics
Metallic - Aluminium, copper, lead and zinc - usually coated with bitumen.
Polyethylene

For positions of D.P.C.s and flashings see Figure 8.20. (a), (b) and (c), and Figures 8.21 and 8.22.

FIG. 8.20 (a)

8.28
8.7 THE FIREPLACE

The open fire was the earliest method of warming rooms, and many people still consider it by far the best. In early times, it was usual to form the fire upon a solid hearth; this is still carried out in some cases. Examples of this are seen in wood-burning cooking stoves.

FACTORS TO CONSIDER

One or two essential points should be borne in mind in considering the subject of open fires. An open fire does not warm the air of the room by direct radiation to any appreciable extent, but the rays of radiant heat strike the solid objects such as the walls and pieces of furniture, and these heat the air by conduction. A fire, of course, requires oxygen to keep it burning, and the action of combustion in a fire is as follows.

As air is heated it expands and, consequently becomes lighter, volume for volume. A fire, therefore, causes a column of heated air to rise, and its place is taken by colder air which descends. The air, a mixture of nitrogen and oxygen, is drawn into the lower part of the fire; the nitrogen is merely heated and passes away unchanged, but the oxygen unites with the carbon of the incandescent
material and forms carbon dioxide gas (CO₂). This gas rises through the heated mass, and is changed to carbonic oxide gas (CO). It then combines with another atom of oxygen and should pass away as carbon dioxide (CO₂) if there is perfect combustion. The action of an open fire in a room is that there is a constant current of heated air rising up the chimney and, to take its place, air is drawn from other places - such as the cracks around the doors and windows. If these were to be sealed off, the fire would gradually die out. There is always a current of cold air passing along the floor toward the fireplace. Part of this air passes directly up the chimney and part is heated by contact with the fireplace.

The feet of persons in the room are invariably subjected to a current of cold air; this can be overcome to some extent by raising the fire-bed higher above floor level.

The advantages of an open fire are its home-like and cheerful appearance and the assistance it gives to ventilation.

A good open fireplace must conform to certain well-known principles: the flue should be 1/3 to 1/2 of the area of the fireplace opening, and it has been proved that the absence of any unnecessary air space is most important, the semi-octagonal internal shaped firebox being vastly superior to the rectangular shaped firebed, although the latter is more popular.

To successfully construct an open fireplace a great deal of skill and thought is required of the craftsman. Basically the problem is to devise and construct a fireplace and chimney which will cause air from the room served to move freely to the burning fuel to promote adequate combustion, and to make sure that smoke will be contained within the fireplace as it rises from the fuel bed to the chimney and is not restricted in any manner during its passage to the outside atmosphere.

The position of the fireplace plays an important part in obtaining maximum efficiency. If possible, cross draughts should be avoided as these may cause smoke to puff into the room.

There are many opinions regarding the dimensions of openings and depths, but it has been proved and practised over many years that an opening of approximately 970 x 600 and depth of 480 is satisfactory.

The design of an open fireplace has to be both pleasing to the owner and efficient in its function.

The fireplace opening needs only to be large enough to receive the wood that is going to be used but the design must conform with the room. The shape internally is most important. Experiments carried out have proved that angled sides or cheeks of the fireplace which dispense with cold air pockets are more efficient.

The depth of 480 approx. is necessary to allow a sweeping over of the back and maybe the sides, which will assist the flow of heat into the room.

The height of the opening should not exceed 600 if possible as, if made higher too much cold air could pass into the opening and correct combustion might not occur.

The back of the fireplace should be sloped or curved forward to assist in the projection of the heat into the room, the completion of the slope finishing over the centre of the fire or slightly forward of it.

At the completion of the slope the throat of the fireplace is formed. This is indeed a critical section of the construction.
It must be designed in such a manner as to allow the free passage of any cold air which would pass under the supporting bar to carry the smoke directly up the flue and, in turn, to transfer as much heat as possible into the room. See Figure 8.23 (a) and (b), for a front view and a section of a typical fireplace.

**FIG. 8.23 (a)**
FIG. 8.23 (b)
FLASHING THE CHIMNEY STACK

There is a method of flashing the chimney stack to make it waterproof. Figure 8.24 (a) shows a section through a chimney stack, indicating the position of the chimney tray and apron, the back gutter and the counter flashing.

Note: the chimney breast is inside the room.

FIG. 8.24 (a)

Figure 8.24 (b) shows the position of the back gutter, side flashing or gutter and the chimney tray.

Note: the position of the weepholes to allow any moisture accumulating on the chimney tray inside the flue to escape.

8.34
FIG. 8.24 (b)

Figure 8.24 (c) shows the position of the stepped side flashing.
8.8 CLEANING OF CAVITIES

The cavity in the external wall of a building has to be kept clean from mortar droppings or any other debris that could bridge the gap between the external leaf and the internal leaf. There are two methods used to keep the cavity clear from mortar droppings.

(a) In the bottom course of brickwork on the external leaf, a brick is left out at predetermined intervals. At the end of each day, the cavity is hosed out with water to clear any mortar that has accumulated. When the brickwork is complete, these bricks can then be replaced.
(b) The use of cavity battens. This batten is placed on the wall ties, when the internal leaf has been built, and the external leaf is started. There are flexible wires or cords attached to the ends of each batten, allowing the batten to be lifted out of the cavity and the mortar droppings to be removed. The battens should be from 3 to 6 mm less in width than the cavity. When the external leaf has been built up to the next row of wall ties, the batten is removed, cleaned, and placed back on top of this row of wall ties. (See Fig. 8.25).

METHOD OF PREVENTING MORTAR DROPPINGS

FIG. 8.25

8.9 CLEANING BRICKWORK

COMMON DISFIGUREMENTS

The more common disfigurements occurring on brickwork are:

MORTAR DROPPINGS

New brickwork generally requires cleaning down to remove mortar droppings or other dirt that accumulates during building operations.
WHITE POWDERS - EFFLORESCENCE

Efflorescence on brickwork appears as a white powder and is always soluble in water. It is caused by one or more of the following:

- Transportation of soluble salts from the ground if the brickwork is inadequately protected by damp-proof courses.
- Presence or formation of soluble salts in the bricks.
- Presence of soluble salts in the mortar.

If the efflorescence is of a lime nature and is allowed to remain for some time, it may be converted to an insoluble white powder.

GREEN, YELLOW AND PINK STAINS

Stains caused by Vanadium salts often form on lighter coloured bricks. These are usually light green but are occasionally yellow or pink. Brickwork which experiences a cool moist atmosphere may exhibit the formation of moss or fungus growths which are generally dark green.

BROWN STAINS

Brown stains may occur when brickwork is in direct contact with steelwork or borewater. These are caused by the formation of iron oxide (rust) on the surfaces of the bricks. Other causes of brown stains are chemicals from untreated timber, oil tars, paints and manganese dioxide.

RECOMMENDED TREATMENTS

MORTAR DROPPINGS

- Remove large lumps by rubbing down the brickwork with a stiff brush (not wire) aided by a piece of wood, bricks or carborundum.
- Thoroughly drench the face of the brickwork with clean water to wash off loose dirt and reduce suction of the bricks.
- With a brush (not wire) apply a solution of one part Hydrochloric acid (also known as muriatic acid or spirits of salts) added to at least 10 and up to 20 parts of water to about 1 to 2 square metres of the thoroughly wet wall. The solution should be made as weak as is possible for the particular situation in which it is being used.
- Hose the treated section immediately after cleaning, working down from the top of the wall.
- Mop off the excess water with a rag or sponge.
SAFETY

Care is necessary in the use of hydrochloric acid, oxalic acid, copper sulphate and all other chemicals. Do not work in a confined space and always ensure good ventilation. Protect hands and eyes.

SEEK MEDICAL ATTENTION IF TAKEN INTERNALLY
CHAPTER NINE - TIMBER

9.1 GENERAL COMMENTS
   BUILDING TIMBERS

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9.7 PLYWOOD
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9.1 GENERAL COMMENTS

A tree grows upwards by the addition of cells to the tip, and outwards by the addition of cells around its girth. The first part of the tree to form is the pith. This, in the young tree, is soft tissues carrying food. As cells are added around it forming sapwood, the pith dies. In time, the inner cells of the sapwood die and become true wood (heartwood) which stores food and gives strength to the tree. The outer cells of the sapwood form the cambium layer. The addition of cells to the cambium layer constitutes the growth of the tree. In the growing tree, the inside cells of the cambium layer become the sapwood and the outer cells the bark. As the tree grows outward, it leaves a deposit of dead wood behind. The living part is around the outside only, just inside the cambium layer. Food (water with some mineral salts) entering from the soil through the roots is carried to the leaves through channels in the sapwood. Green leaves acting in sunlight convert carbon dioxide from the air and water from the sap into starches, sugar, etc. These substances serve to nourish the tree, passing down the cambium layer at the inner ring of bark cells, forming new wood and new bark. Ring-barking breaks the supply of food, and the tree dies.

ANNUAL RINGS

Every year the tree increases its girth by adding another layer of cells, and each layer is called an annual ring. In early spring growth is rapid, and large open cells carry the food. As the food supply slackens in the late summer, smaller and denser cells do the work and in winter, growth almost stops. (See Fig. 9.1) In Australian trees, annual rings are hard to recognize and it is said that our trees show seasonal changes rather than annual rings and we should refer to growth rings not annual rings.

There are two kinds of wood:

1. **Hardwood.** The food vessels in this timber are cells joined end-to-end with the dividing wall broken down forming a continuous duct. In hardwoods these vessels are clustered around with fibres. They extend the length of the tree and provide it with strength. It is these fibres which are of importance when considering the size of joists, etc.

2. **Softwood.** There are no separate vessels and fibres, the two being combined in a single cell which does the work of both.

These descriptions, established by usage, do not exactly concern the actual hardness or softness of the wood but concern the specific species. Thus, softwoods are a group which is confined to conifers, which are evergreen trees with needle-like leaves, and which bear cones. Hardwoods are a class of broad-leaved trees some of which cast their leaves in Autumn.
Softwoods are characterized by:
1. distinct annual rings
2. indistinct medullary rays
3. comparatively light colour
4. the heartwood and sapwood are not readily distinguishable.

Hardwoods are characterized by:
1. less distinct annual rings, which are closer together
2. distinct medullary rays
3. richer colour
4. darker coloured heartwood which is readily distinguished from sapwood.

**PART OF SECTION ACROSS A 10 YEAR OLD TREE**

**FIG. 9.1**
CHARACTERISTICS OF GOOD TIMBER

It should be straight in fibre, uniform in substance, free from blemishes (knots, shakes, flaws, etc.) and should smell sweet when cut. The surface should be firm and bright when planed; growth rings should be regular and close together (indicating slowness of growth which adds to the strength) and colour should be uniform. It should "ring" when struck, should be well seasoned and should have sapwood either removed or treated.

TIMBER IDENTIFICATION

Certain features such as colour, weight and hardness, are useful in timber identification. The structure of wood can also assist greatly because of variations in size and arrangement of the various types of cells. Examination of an end surface cleanly cut with a very sharp knife, often reveals the identity of a timber, particularly if a hand lens is used to magnify the structure. Some timbers are very difficult to identify and here the microscope in the hands of an expert is necessary.

BUILDING TIMBERS

LOCAL TYPES

The following West Australian timbers are in common use in the building trade:

JARRAH (Eucalyptus marginata)

Jarrah is the principal timber of Western Australia. Though it is found scattered throughout the south-west of the State over many millions of hectares within the 250 to 400 mm rainfall belt, the prime jarrah forest extends over only 1 million hectares, along the Darling Range from the latitude of Perth right down to the extreme south of the State in the neighbourhood of Albany. As the tree grows to a height of 40 to 50 metres, with a clean bole of 15 to 20 m and a girth of 6 m, large sizes of timber free from blemish are obtainable.

Jarrah has a world-wide reputation on account of its durability. Timbering in the houses built when the State was first established is still sound today and some of the post and rail fences of the early settlers are still standing. Its strength and durability make it very suitable for all classes of structural work, while in the form of sleepers, bridge and wharf timbers, and power and telegraph transmission poles, it finds wide application. A further advantage of jarrah is its high quality of resistance to fire.

The timber of jarrah is beautiful in grain and colour, can be readily worked, and finishes and polished well.

It is essentially a furniture and cabinet wood, but its wonderful durability, combined with the plentiful supplies available, led to its extensive use in the early days for the purposes mentioned above, and the suitability of jarrah for higher grade uses was overlooked. In furniture, interior trim, carving, cabinet work, cooperage, etc., it gives excellent service, and for this purpose
the consumption is steadily increasing. Commercial drying kilns of modern design are operating in the State and produce an excellent seasoned product ensuring that timber for high grade furniture and joinery work is available when kiln seasoned.

**KARRI (Eucalyptus diversicolor)**

This tree is the largest and second most important in the forest. It occurs in a limited area - some 100,000 ha being estimated as the extent of the prime karri forest - in the South-West of the State.

Karri is a magnificent tree, both from the standpoint of the timberman and of the tourist for it attains a height of over 60 metres while the long bole has a length of 30 to 40 metres and a girth of 9 metres. The tallest karri measured has a height of 86 metres and is still standing.

Karri timber greatly resembles jarrah in appearance, and those without considerable experience in the handling of the two timbers are unable to distinguish between them. Karri is somewhat stronger than jarrah and consequently superior for superstructural work. It is not so durable in the ground, however, and so it is important that the timbers should not be confused.

While these timbers can be readily distinguished by persons working with them every day, almost the only practical test for other users is the burning of a splinter of each timber in a sheltered position. The jarrah splinter will char, leaving a blackened mass of charcoal, the Karri splinter will burn away leaving a fine white ash.

Karri was once used for wooden pipes, wagon scantling, and transmission line poles and cross-arms. Karri, on account of its high beam strength and its long clean lengths, is now used extensively in superstructural work, and for this purpose it is steadily coming more and more into favour. It makes excellent flooring on account of its strength and wearing properties and is also used for furniture, furnishings and interior trim. For these higher grade purposes it can be kiln-dried, and suitable drying schedules for all sizes have been developed.

**TUART (Eucalyptus gomphocephala)**

The small strip of coastal plain between Lake Pinjar on the north and Busselton on the south holds all the Tuart forest. Tuart has a height of up to 50 m with a girth up to 9 m in exceptional trees.

The timber is pale yellow in colour and has a dense, interleaved grain. It resembles wandoo in mechanical properties and holds the same high place for railway wagon undercarriages, etc.

**WANDOO (Eucalyptus redunca, var elata)**

This tree is to be found in the south-west portion of the State on the edges of the jarrah belt. The tree attains a height of 30 m with a bole of 9 to 12 m and a girth of 3.5 m.

The wood is very hard, strong, and durable. It is greatly prized for railway wagon underframes and, for this purpose, was used on the State railways in preference to steel. In large sizes its "work" with changing weather conditions is infinitesimal and it has
the further advantage of being quite free from corrosive action on iron. Bolt holes, after 20 years' wear, still show the auger marks distinctly. Wandoo is used for bridge and wharf construction, and shipbuilding generally.

**SHEOAK** *(Casuarina Fraseriana)*

A tree attaining a height of 12 to 16 m, with a bole 3 to 4.5 m, and a girth of 2.5 m.
A sound wood with broad medullary rays which show up and make the timber particularly beautiful when cut on the quarter.
The most important use for this timber was for barrel staves.
It takes a good polish and stands up well and, therefore, makes an excellent cabinet wood. It splits well and was used almost exclusively in the early days of the State for roofing shingles.

**AUSTRALIAN TIMBERS**

Some Australian timbers which are in common use in the Eastern States are given in the following list.

**HARDWOOD**

The name *hardwood* is applied in general to cover several varieties of Australian eucalyptus, such as red ash, woolly butt, stringy bark, mountain ash, and messmate. There is so close a resemblance amongst these varieties after milling, that only those who have studied timber very closely are able to express a decided opinion as the the name of one selected sample board.

**Description**

Colour, when newly cut, varies from light oak through shades of yellow, light pink, and light brown. Exposed to the weather, it quickly becomes a common grey. Grain is straight, even, and tough, which makes hardwood timber of great use in constructional work.

**Sizes**

Hardwood is available in building scantlings up to 6 m. Fencing palings are sawn or split while unseasoned. At the saw mill the most suitable timber is cut into planks and boards for seasoning and for conversion into weather-boards, tongue and groove flooring, and lining.

**PINUS RADIATA**

**Description**

Colour is light yellow with darker yellow and light brown lines of grain. Coarse in figure, it frequently has dark brown knots. It is light-to-medium in weight, and seasons readily, but is very liable to twist. It is soft and brittle, and is used for internal fittings and concrete forms.
Sizes

Pinus radiata is available in narrow widths, weatherboards, flooring and lining. It comes mainly from pine plantations in the State forests and so may be classed as a local timber in each State.

HOOP PINE

Description

Colour is yellow to light brown. It is generally straight, even grained, and easy to work. Medium in weight, heavier boards are easily split along the grain. Seasoned material is quickly affected by changes in climate.

Sizes

Hoop pine is mainly available in manufactured plywoods, but sometimes in mouldings, planks and wide boards when it is used for draining boards, shelving, cupboards and joinery. It is imported to W.A. from Queensland, but is not readily available.

KAURI

Description

Colour is pale yellow to light brown. Grain is straight and even. It is soft, medium in weight and seasons slowly. In changes of humidity, its length varies considerably. It shows very little figure in grain, is easy to work along the grain, and is cheesy to cut across the grain.

Sizes

Kauri is available in manufactured plywood, planks and wide boards. It was formerly used in W.A. for shelving, cupboards and joinery, but now mainly imported for boat building.

OTHER SPECIES

Many beautiful and valuable timbers are found in Queensland and were once used in building construction there. However, the demand for high grade plywood is so great that most of the better class wood finds its way to the market in this way. Plywoods faced with Australian walnut, silky oak, tulip oak, red cedar, etc., are exported as well as being used in furniture.

Some Queensland maple and other timbers are imported for furniture making and occasionally used in joinery.

IMPORTED TIMBERS

The following are some of the timbers which are imported into Australia from other countries:
OREGON (Douglas Fir) (U.S.A.)

Description

Colour is yellow to reddish brown, with prominent growth rings in the grain. Light in weight and reasonably strong, it is easy to work and very useful. Imported in flitches, work squares, and in the form of plywood, this timber is used in structural work, concrete forms, and joinery, when it is available.

BALTIC DEALS (Norway and Sweden)

Description

White deal is pale yellow with light brown knots. Red deal is yellow with red and brown knots. Deal is medium in weight, and seasons readily. White deal is more liable to twist than red deal.

Sizes

Baltic deals are mainly available in milled weatherboards, flooring and lining.

PACIFIC SOFTWOODS

From the Phillipines, Malaya and islands in the East Indies fairly steady supplies of softwood are imported for use in furniture and joinery. These timbers include meranti, Pacific maple, capur and nyahthah. They are not particularly long-lived, especially when exposed to the weather and, if used for window sashes, must be kept well painted. The colour varies from yellow to pink and light brown and some species are extremely soft.

9.2 SEASONING

The principal object in seasoning timber is to bring it to a condition best suited to its ultimate use. Since it is subject to shrinkage and sometimes to distortion, during the process of drying out, timber can rarely be used satisfactorily in an entirely green, or unseasoned, condition. In addition, the tendency of some timbers, when unseasoned, to develop decay, fungi, stain, or insect attack, makes some degree of seasoning necessary. In the case of scantlings for building purposes, the relatively small loss of dimension caused by shrinkage is not, as a rule, of any significance. Green timber, however, may subsequently warp during the early stages of its drying and for this reason a short period of seasoning, sufficient to produce a skin-dry condition, is advisable whenever timber is to be used for structural purposes. For uses such as joinery, furniture, flooring, etc., it is essential that timber be seasoned to the point where least possible movement can occur.

Results achieved by the efficient seasoning of timber may be listed as follows:

(a) a reduction to the minimum of shrinkage, checking and warping;
(b) prevention of blue stain and similar forms of mould and incipient decay;
(c) reduction in susceptibility to some forms of insect attack;
(d) increase in strength;
(e) reduction in weight;
(f) improvement of conditions suitable for painting, etc.

KILN SEASONING

Kiln seasoning has advantages over air seasoning in the following respects.

(a) Controlled conditions can minimise the cause of seasoning defects.
(b) Moisture content may be reduced to any desired percentage and usually to a value lower than that practicable by air-seasoning.
(c) Complete destruction of insects or fungi present in the wood.
(d) Considerable reduction in the time required for seasoning.
(e) Saving of considerable yard space compared with that required for the air seasoning of large quantities of timber.

EFFECTS OF SEASONING

SAP

Green timber - that is, timber in the growing tree or immediately after it has been felled - contains a large quantity of liquid, usually termed sap. Sap is mainly water, but it also contains in solution small quantities of organic and mineral matter. While these other ingredients are important in the growing tree, and to some extent in the converted timber, they do not appreciably affect the seasoning properties of the wood.

FREE MOISTURE AND COMBINED MOISTURE

Sap exists in wood in two forms - as free moisture, contained within cells which make up the wood, and as combined moisture, which is absorbed within the cell walls.

FIBRE SATURATION POINT

During the process of seasoning a wood cell first gives up its free moisture, the combined moisture in the cell walls remaining until the cell cavity has become empty. This latter condition, when it is reached (usually when the moisture content has been reduced from 35% to 25%), is termed fibre saturation point. During the next stage in seasoning the cell walls begin to give up their combined moisture and it is from this point that the wood commences to shrink.
MOISTURE GRADIENT

In seasoning, the exterior portion of the timber is the first to yield moisture and will reach or fall below, fibre saturation point, before the inner portion, or core, has reached this condition. Until the timber has dried throughout to a state of equilibrium moisture content the distribution of moisture, from centre to surface, will not be even, the outer sections being of lower moisture content than the inner. Actually, this condition is necessary for the progressive drying of the piece from the surface towards the centre. The extent and degree of moisture content occurring between core and case (i.e. from centre to surface) is termed the moisture distribution of the piece, and the relation between the moisture content at its highest value at the centre and its lowest value at the surface is referred to as moisture gradient. If the moisture content decreases rapidly from centre to surface, the moisture gradient is said to be steep. Steep gradients are associated with severe drying conditions and/or impervious timbers. If there is no gradient—that is, if the moisture content is constant throughout—then no drying of the interior will take place.

MOISTURE CONTENT

The quantity (weight) of moisture contained in a piece of wood, expressed as a percentage of the oven-dry weight of the piece, is termed moisture content. It is determined by comparing the weight of a sample piece of the wood with the weight of the same sample when all moisture has been removed; that is it is oven dry. The calculated weight of the moisture thus removed is expressed in terms of the percentage of the oven-dry weight.

EQUILIBRIUM MOISTURE CONTENT

Timber is hygroscopic; that is, it possesses the property of yielding or absorbing moisture to or from the surrounding air, its moisture tending always to effect balance with that in the atmosphere. When this balance condition is reached, and the timber does not tend either to absorb or to lose moisture, its moisture content is said to be in equilibrium. Variation in the relative humidity of the surrounding air, however, will create a tendency in the timber to absorb or lose moisture according to whether the air becomes more moist or drier.

Table 9.1 gives an indication of the approximate equilibrium moisture content of timber at various relative humidities and at temperatures of 20° C and 80° C the latter being of the order commonly used in drying kilns. It will be noted that E.M.C. varies with both relative humidity and temperature.
<table>
<thead>
<tr>
<th>RELATIVE HUMIDITY %</th>
<th>EQUILIBRIUM MOISTURE CONTENT %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 20° C</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td>60</td>
<td>11</td>
</tr>
<tr>
<td>70</td>
<td>14</td>
</tr>
<tr>
<td>80</td>
<td>17</td>
</tr>
<tr>
<td>90</td>
<td>22</td>
</tr>
<tr>
<td>100</td>
<td>31</td>
</tr>
</tbody>
</table>

**TABLE 9.1**

Actually, different timbers may vary a few per cent in their equilibrium figures when exposed to the same humidity. In normal practice, timber is not exposed to conditions of constant humidity, but to atmospheric conditions in which the humidity is varying almost continuously. In these circumstances the denser timbers usually have a greater lag and hence absorb or lose less moisture than less dense timbers.

From the above it will be seen that the average, or mean, relative humidity of the locality in which it is to be used is an important factor in determining the moisture content to which timber should be seasoned.

**SHRINKAGE**

In considering loss of dimension resulting from shrinkage in seasoning, the amount of shrinkage is usually referred to as a percentage of the original green dimension. This percentage varies according to whether the timber is quartersawn or backsawn. In most cases the amount of shrinkage in quartersawn timber is about half that of backsawn timber. The degree of seasoning will, of course, also affect the amount of shrinkage. Given these common characteristics, the percentage of shrinkage varies considerably in Australian timbers.

**EFFECT OF GRAIN DIRECTION ON SHRINKAGE OF TIMBER**

If a moisture content change occurs in a piece of timber, so that normal shrinkage or swelling results, the proportional movement in a backsawn direction will be about twice as much as that in a quartersawn direction. This means that if, for any reason, it is important that minimum changes occur in the width of a piece of
wood, it should be quartersawn, (Fig. 9.2A); whereas, if it is
important that little change in thickness occurs, the wood should be
backsawn, (Fig. 9.2B).

Two methods of sawing a board
from a log

TWO METHODS OF SAWING A BOARD FROM A LOG

Fig. 9.2

Fig. 9.3 shows the distortion caused by differences between
quartersawn and backsawn shrinkage. The difference between A and C
is accentuated by collapse. Green sections, of original size and
shape, are shown as a background.

Fig. 9.3A shows an oval section obtained by drying a round
section turned while green.

Fig. 9.3B shows a diamond-shaped section obtained by drying
a section cut square when green, with growth rings running diagonally
across the section.

Fig. 9.4D shows a "cupped" backsawn board, showing "cupping"
away from the heart.

How grain direction affects shrinkage

HOW GRAIN DIRECTION AFFECTS SHRINKAGE

Fig. 9.3
THE RELATION OF EQUILIBRIUM MOISTURE CONTENT AND SHRINKAGE

To reduce these changes in size and shape, the timber used should be as near as possible to the equilibrium moisture content for the conditions of use. The cramping of floors illustrates the need for an understanding of the equilibrium moisture content. If the moisture content of the wood is a little too high, the floor can be cramped tightly and, with subsequent drying out, cracks will not be quite as obvious as they would otherwise be. Flooring boards which are much too high in moisture content should be avoided no matter how tightly they are cramped; a poor floor with very open joints will result. However, if the wood is too dry, say 5% below equilibrium moisture content, or when the floor is laid over a poorly ventilated or damp site, the floor should be loosely cramped, otherwise lifting of the boards or badly ridged floor joints will occur.

Table 9.2 will prove a useful guide to the moisture content suitable under various conditions of use.
### APPROXIMATE MOISTURE CONTENT RANGE ATTAINED BY WOODEN ARTICLES OR FITTINGS IN SERVICE

<table>
<thead>
<tr>
<th>Article</th>
<th>Moisture Content Range (Percentage of Oven Dry Weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxes and Crates</td>
<td>10 - 17%</td>
</tr>
<tr>
<td>Flooring</td>
<td>8 - 16%</td>
</tr>
<tr>
<td>Framing (House)</td>
<td>8 - 20%</td>
</tr>
<tr>
<td>Furniture</td>
<td>8 - 16%</td>
</tr>
<tr>
<td>Gates and Fencing</td>
<td>8 - 20%</td>
</tr>
<tr>
<td>Stock for bending</td>
<td>15 - 25%</td>
</tr>
</tbody>
</table>

**TABLE 9.2**

The moisture content of timber for dry areas should lie towards the bottom of the range shown for the particular case, whereas materials for moist areas should lie towards the top of the range. For most of the capital cities of Australia, a suitable moisture content for any particular article lies at about the mid-point range.

### VARIATION BETWEEN SPECIES OF TIMBER

The variation of shrinkage or swelling between different timbers is, in some cases, even greater than that between different grain directions. Where a small shrinkage is desirable, a suitable timber should be chosen.

### COLLAPSE

Collapse is a peculiar form of shrinkage. It is distinguished from ordinary shrinkage in that the latter occurs in all woods, whereas collapse occurs to an appreciable extent in only a few timbers and can generally be removed.

Collapse in timber usually appears as irregular shrinkage ridging across the surface or cupping of the faces, as illustrated in Fig. 9.5.

Collapse can generally be removed by a "reconditioning" treatment given towards the end of seasoning.

To recondition timber showing collapse, it is placed in a closed chamber to which steam is admitted. Several hours are usually sufficient to cause the collapsed timber to recover its shape, after which it is re-dried.

### MAIN CAUSES OF DISTORTION

Seasoned timber may change shape after machining due to either of the following causes:
1. Uneven moisture distribution in the wood; e.g., the centre may be wetter than the surface so that when the interior of wood is exposed it dries and shrinks.

2. Stresses in the wood. These are forces developed in the wood if the surface layers are dried at a somewhat faster rate than the centre. Until the wood is machined the stresses are balanced and it holds its shape. Machining or resawing may unbalance these stresses, causing a change in shape, as shown in Fig. 9.6.

Uneven moisture distribution and the presence of stresses are indications of poor drying. They can be removed by a treatment at a high humidity.

![Diagram of wood before and after collapse and sawing]

EXAMPLE OF "COLLAPSE" OF TIMBER
FIG. 9.5

CHANGE OF SHAPE DUE TO POOR DRYING
FIG. 9.6

AIR SEASONING

Efficient air seasoning demands certain essential condition. A good circulation of air throughout the seasoning yard is necessary; a wide open area is the most suitable. Good drainage is essential since the more moisture the atmosphere has to evaporate from the ground, the less it can dry up from the timber. Stacks should not be built close up to a wall and a space of at least 450 mm should be allowed between them. They should not be more than 1.5 m wide. If the area will allow, stacks should be confined to about 1.8 m in height since stripping becomes slower and more costly beyond this.

Foundations must be perfectly level since any irregularity will cause distortion in the stacked timber. They must be high enough to ensure a free circulation of air underneath the stack, and at all times be kept clear of rubbish and weeds. It is an advantage to slope the stack longitudinally, as this will drain off any rain water.
It is usual to use strips 19 or 25 mm thick and from 25 mm to 38 mm wide. The thicker the strips used, the freer will be the flow of air between boards and the more rapid will be the rate of drying. But at the same time, fewer boards can be built into a stack of a given height. If drying conditions are too severe for a particular timber, thinner strips will correct these conditions. If high stacks are built, wider strips should be used since the weight on the lower layers may cause narrow strips to bruise the timber.

Strips must be sawn to uniform thickness, and from timber which is not susceptible to attack by borers. These are essential points to remember. The use of seasoned timber for strips is advisable; the use of green strips can cause blue stain and decay, and result in uneven drying at the places where the strips are laid.

In building the stack the strips must be placed exactly one above the other across each successive layer. Any strips not in this vertical alignment will cause distortion in the boards. A space of 25 to 50 mm between the edges of the boards in each layer should be arranged in order to allow the vertical passage of air. In high stacks, a "funnel" down the centre is advisable, especially in the lower portion. Strips should be placed at from 750 to 900 mm intervals, immediately above the cross-bearers of the foundation which must be arranged accordingly. Too wide a spacing of strips will allow the boards to bend and warp.

Stacks should be protected from the effects of sun and rain. Simple covers made of thin waste timber, and in short sections for easy handling, can be easily made and fitted for this purpose. They should have a good slope to the weather, overhang each side of the stack by at least 225, and be firmly fastened down to the stack by wiring.

KILN SEASONING

Kiln seasoning, or the accelerated drying of wood, is being increasingly recognised as a development of major importance in timber usage. Its advantages, compared with air seasoning have been mentioned earlier. The disadvantages may be summed up in the capital outlay required, cost of operation and maintenance, and the additional skill and study necessary for efficient operation. However, in more and more cases it is found that the advantages outweigh the disadvantages.

There are two main types of kilns used in the seasoning of timbers:

1. the compartment kiln of the internal cross-shaft fan type (see Fig. 9.7)
2. the progressive type of these two types, the compartment kiln is, by far, the one more in general use.

PRINCIPLES OF KILN SEASONING

(a) Compartment Kilns

The accepted seasoning of timber by the use of Kilns is achieved by the provision of three fundamental conditions:
1. rapid circulation of air
2. reasonably high temperatures
3. reasonably controlled humidities.

In cross-shaft type compartment kilns, the air circulation is crosswise from one side of the stack of the other and is induced by internal fans mounted on cross shafts. These fans are placed along the length of the kiln at intervals of 1.8 m or so and, in the overhead type, drive the air over the heating pipes down the side and through the stack from where it is returned to the fan over a second set of heating coils. By reversing the fans, the direction of the air flow can be reversed. A steam spray line, and exhaust and inlet air vents located in the ceiling, control humidity. Where possible it is advisable to build compartment kilns in pairs, in which case a central driving shaft may be used to drive each fan installation, right-handed fans being used in one and left-handed fans in the other kiln. Compartment kilns are ideally suited for use with a lifting truck system, which lends itself to an economical arrangement for combined air and kiln seasoning.

In the early stages of seasoning the drying rate is comparatively rapid. With relatively impervious, slow drying species, or those subject to collapse, it is a distinct advantage to be able to air-season timber for some time until it reaches a moisture content of, say 30%. The whole stack may then be lifted by means of a lifting truck and moved into the kiln where it is subsequently dried to equilibrium moisture content.

![Diagram of Compartment-Type Kiln](image-url)
(b) Progressive Kilns

In progressive kilns, the arrangement is usually for a number of truckloads of timber to be ranged one behind the other and moved progressively along the kiln as drying proceeds. Where longitudinal air flow is provided, the flow is usually from the hotter and drier end of the kiln to the cooler and moister end. As the air passes through the timber it absorbs moisture from it and cools in the process, so that the green or entry end of the kiln is usually subject to greater humidity and lower temperature than the dry, or discharge end. Where cross circulation is provided, the fans are arranged as in a cross shaft compartment kiln. The advantage of this type is that the distance of air flow is short and drying is more uniform. Periodically, as the truckload of timber at the discharge end becomes sufficiently dry, it is taken out of the kiln, the remaining truckloads are moved up, and a fresh load placed into the kiln at the green end. It is from this progressive movement that this type of kiln drives its name.

Control of temperature and humidity along its length, in order to conform to a specific drying schedule, is difficult in a progressive kiln with a longitudinal air flow: it is usual to attempt control at one end only. Satisfactory operation, moreover, can only be assured by the continuous supply of timber of the same kind and of the same thickness. This lack of flexibility is a serious drawback to the progressive kiln, and it can only be regarded as suitable for mills producing the same class and size of timber, and where exacting conditions in seasoning are not required. The degree of skill required, and the cost of operating progressive kilns is, however, probably much less than is the case in operating compartment kilns. With cross-circulation progressive kilns, however, many of the above disadvantages disappear. This type of kiln combines some of the advantages of the compartment kiln with that of progressive movement.

PRE-DRYING

As indicated previously it is a measure of economy to give timber some preliminary air drying before completing this process in the kiln. In some localities, however, air drying is extremely slow. When the timber has been dried to a moisture content of 25% to 30% it is moved to normal kilns by means of lifting trucks. Thus the pre-drier is working in conjunction with the kilns in a manner similar to, and as a substitute for, air drying.

RE-DRYING

In many cases, even though timber has been dried properly, it absorbs a considerable amount of moisture during manufacturing processes, such as gluing. Under these circumstances special re-drying rooms, provided with heating units and some system of air circulation, are advisable. As a re-drying room is only required to remove from 3% to 6% of moisture from the timber, the conditions in the room may be fixed and do not, therefore, require constant attention.
KILN CONTROL

The three main factors affecting the drying of timber in kilns are circulation, temperatures, and humidity. Air circulation is usually constant, but temperature and humidity must be varied in accordance with schedules applicable to various kinds and thicknesses of timber. Heat in the kiln is provided in most cases by banks of steam heated coils, whilst humidity is provided by the introduction of steam through perforated steam pipes. Control of these agents is effected either by the use of automatic controlling instruments or by manual control. The former will automatically maintain required conditions of temperature and humidity, but manual control involves periodic attention to the valves controlling steam supply to this heating coil and humidity pipe.

RE-CONDITIONING

Re-conditioning is a treatment applied to collapsed timber with the object of removing this condition. It is effected by subjecting the timber, stripped as for kiln seasoning, to steam treatment. This is usually carried out in a more-or-less sealed compartment specially constructed for the purpose, generally of concrete. Treatment usually takes from four to eight hours, and at a temperature of from 80°C to 100°C. Steaming should not be continued longer than is necessary to restore the timber to normal condition.

The moisture content of the timber before reconditioning should be well below fibre saturation point, but not lower than 12%, preferably at about 17%.

After treatment the timber must be re-dried, either by mild heat treatment in the kiln, or by a few days air seasoning under cover.

Reconditioning, in addition to removing collapse, will relieve stress in case-hardened timber and tend to restore warped, cupped and twisted boards to normal condition. Existing checks, however, tend to increase under this treatment and further surface checking may occur.

HIGH HUMIDITY TREATMENT

This consists of subjecting the timber to conditions of high humidity at a temperature of about 70°C to 80°C. The object is to relieve case hardening and to reduce - and, if possible, eliminate - any moisture gradient present in the timber.

DRYING STRESSES

During the process of seasoning the core and case of a piece of wood will shrink unevenly. If the conclusion of the process the timber will usually be in a state of stress with the surface layers in compression and the core in tension. This condition, if serious, may be relieved by re-conditioning and humidifying treatments as indicated in the previous paragraph. It is, however, necessary - as part of kiln drying routine - to test the condition of changes for moisture distribution and stress as seasoning progresses and, if necessary, to vary drying schedules with the object of reducing stresses to a minimum.
VAPOUR DRYING

Vapour drying is a method of drying wood by exposing it to a vapour of an organic chemical maintained at high temperature within a tightly closed cylinder or compartment. Any one of a number of drying agents, the liquids of which have boiling points within a range of 100° C to 200° C (e.g. coal tar fractions) may be used to provide a vapour which introduced into the drying chamber. The vapour circulated in the drying chamber provides the necessary heat for drying by condensation and liberating latent heat. The vapours and the moisture evaporated from the timber within the drying chamber, are then passed through a condenser and a separating tank, by means of which the water is separated from the drying liquid.

The water is returned to a storage tank for re-circulation within the system. Condensed vapour is removed by means of a vacuum system.

CHEMICAL SEASONING

Chemical seasoning consists of holding green timber in an aqueous solution of a hygroscopic chemical for periods and at temperatures dependent on the species and size of timber being treated.

Chemicals used in this process can be either sodium chloride, urea, invert sugar, mono-ammonium phosphate, or sodium sulphate. After remaining in the solution from two days to two weeks the timbers are removed and either air or kiln dried in the usual way.

Chemical seasoning reduces stress development within the wood and prevents differential shrinkage between outer shell and inner core.

9.3 WHY TIMBER IS GRADED

Timber is subject to defects which may be defined as any irregularity occurring on or in the timber which may lower its strength, durability, or utility value. The individual pieces of timber, obtained when a tree is sawn, vary considerably in quality. Some will be free or practically free from defects, but the majority will contain knots, gum veins, gum pockets, splits and checks, or other defects, some of which are natural to the tree, while others may have occurred during felling, transport, sawing, or drying. The presence of defects does not necessarily prevent timber from being used for many purposes.

To ensure the best utilization, segregation of timber into grades with a relatively narrow range in quality is necessary. Grading thus permits charging for timber according to quality, and enables a user to buy the lowest grade material which fulfils his requirements.

The grade of a piece of timber is determined by the size, frequency and location of defects. Descriptions of the defects permissible in the various grades are given in grading rules published by the Standards Association of Australia.
DEFINITIONS

The more common terms used in grading Australian and imported timbers are defined on the following pages. A full list of terms and definitions is available in Australian Standard No. 0.1 - 1964 "Terms Used in Timber Standards".

**Intergrown Knot.** One in which the growth rings are completely intergrown with those of the surrounding wood.

**Sound Knot.** One which is solid across its face, as hard as the surrounding wood, and free from decay.

**Tight Knot.** One which is so fixed by growth or position that it will not fall out.

**Gum Pocket.** A cavity which has contained or contains gum (kino).

**Pitch Pocket.** A cavity which has contained or contains pitch. (Bark may also be present in the pocket.)

**Blemish.** Anything which mars the appearance of the timber and which is not classed as a defect.

**Check.** A crack running along the grain and formed during drying.

**Split.** Cracks extending from one surface to another and located at the ends of a piece.

**Wane.** The absence of wood on the edge or corner of a piece of timber showing the bark or the surface of the sapwood.

**Want.** The absence of wood, other than wane, from the face or edge of a piece of timber.

**Warp.** Any variation from a true or flat surface. (It includes bow, cup, spring, twist, or any combination thereof.)

**Decay.** Rot, or partial disintegration of the wood substance, due to the action of wood destroying fungi.

**Heart.** That portion of the centre of the tree having little strength and probably affected by decay. The term brittle heart is sometimes used to describe this condition.

**Grain.** A term used to indicate the general direction or arrangement of the fibres and other wood elements.

**Interlocked Grain.** The fibres of adjacent layers are spirally inclined in opposite direction.

**Sloping Grain.** The fibres do not run parallel with the length of the piece of timber.

**Straight Grain.** An arrangement of fibres in which they run parallel to the length of the piece when converted.

**Wavy Grain.** A wavy arrangement of the fibres. (This may be known as wavy, curly, or fiddle-back, depending upon the fineness of the wave).

**Growth Rings.** Rings on the cross section of a piece of wood, which mark successive stages of growth.
Pith. A small soft core running along the structural centre of the log.

Sapwood. Timber from the outer layers of the log which, in the growing tree, contained living cells. The sapwood is generally lighter in colour than the true wood.

Gum Vein. A ribbon of gum between growth rings which may be bridged radially at short intervals by wood tissue.

Loose Gum Vein. One in which the wood bridges are widely spaced.

Tight Gum Vein. One in which the wood bridges are closely spaced.

Knot. A branch or limb embedded in the tree and cut through in the process of manufacture. (Knots are classified according to form, quality, and occurrence.)

Encased Knot. One in which the growth rings are not completely intergrown with the surrounding wood.

9.4 THE PRESERVATION OF TIMBER

CAUSES OF DETERIORATION OF TIMBER

The main causes of timber deterioration are decay (rot), termites (white ants) and attack by other insects. Decay and insect attack may occur in timber under widely varying conditions. Decay is chiefly confined to timbers such as posts, poles and sleepers, which are in contact with the ground, or in which moisture may collect; for example, house footing timbers, wharf decking, or the junction of two or more timbers exposed to the weather, the points of contact allowing moisture collection and absorption into the wood. Termites, likewise, do considerable damage to timber in contact with the ground but, because of their habit of constructing runways, the attack may extend from the ground line even to the timbers in the roof of high buildings. Under certain conditions, furniture may also be attacked. Borers are of different kinds, some attacking green timber and other seasoned timber. Those attacking the seasoned timber may commonly be found in the various parts of a house, such as the flooring, lining, joists, or rafters, or in furniture. Sometimes careful examination, especially in the constructional timbers, is necessary before their presence is noticed.

Decay

Decay is a general term covering the breakdown of wood by the action of wood-destroying fungi. Various terms are used for describing it, some of these terms being indicative of the final nature of the disintegrated wood or of the location of the decay in the wood. Thus, there are such terms as dry rot, wet rot, heart rot, and punk. All of these merely describe the type of damage which may be done by the fungi.

Wood-destroying fungi live in the timber, and consist mostly of fine threads which penetrate the wood in all directions, and
actually absorb certain portions of it. As these substances are absorbed, the normal structure of the wood is broken down until it becomes soft and friable - that is, typically rotten.

Decay of timber from fungus attack can be prevented or minimized by the use of preservatives (as described later) or by such good building practices as listed below.

(a) Maintaining a clear air space of at least 100 mm between the ground and the underside of any floor timber.

(b) Providing sufficient air vents under floors (6000 sq. mm per linear metre of wall is recommended).

(c) Providing proper damp proof course in walls.

(d) Preventing accumulation of water beneath floors due to faulty sewers or pipes or poor drainage.

(e) Removing all debris from under floors.

(f) Discarding any timber showing sign of previous fungal attack.

(g) Using treated timber for stumps, bearers, plates etc.

(h) Using well-seasoned timber throughout. (Where timber is built in to brick or concrete structures it should be treated and adequate ventilation provided).

Termites

Termites, popularly known as "white ants", are very prevalent in Australia; about 160 different species have been identified.

To control wood-eating termites, it is necessary to distinguish between the various types. At present the most satisfactory way of identifying varieties is on the basis of their nesting habits. In this way the termites can be classified into three main groups:

1. subterranean
2. dry wood, and
3. tree-dwelling species.

The subterranean species live in the soil and often construct mounds in the ground. The dry wood species never live in the soil or in mounds, and are generally found in seasoned timber, particularly in buildings. The tree-dwellers live almost entirely in galleries tunnelled in growing or dead trees. By far the greatest damage to timber structures is caused by the subterranean species; the dry wood species cause considerable damage, chiefly in a few coastal localities in Queensland and Northern Australia, and are much less important in other parts of the continent. The tree-dwelling species rarely attack construction timber (See Fig. 9.8).
Subterranean termites need to have access to the soil. When timber above the ground is attacked, they provide access by building communication or shelter tubes (see Fig. 9.9). Because of this, it is often possible to trace the entry of the subterranean species to timber which is above the ground. They may traverse cracks in cement floors or brickwork or travel through heart pipes or cracks in wooden foundation stumps. On the other hand, they may build their covered runways over any convenient surface. Termites conceal themselves in wood, in mounds or in their communication tubes. If the means of access to the soil is broken, those termites isolated above the ground will die.

Damage by subterranean species above ground level may be prevented by ensuring that all means of access are eliminated. Special stump caps can be used in construction to prevent their passage from the foundations to other parts of the structure.

Termites can cause serious damage to timber and prevention of this is some times difficult in the case of materials such as sleepers, poles posts, etc. The only practical method is by the use of termite-resistant woods, or preservative treatment by means of which less resistant timbers are rendered immune from attack.

earthen tubes built by termites

**FIG. 9.9**
Borers

Numerous species of insects at some stage of their life cycle live in and on timber. Their presence is seen in a piece of timber when they leave holes or channels sometimes filled with powdery substances. Their importance varies with the species, the locality and the type of timber, and it is usual to apply a suitable preservative wherever there is any danger of attack. A piece of timber showing attack by borers is best discarded as, even if there are no live insects visible, there is no guarantee that active infestation does not exist inside the surface. Borers can seriously damage a piece of timber without any sign of their presence on the surface.

The Powder Post Borer attacks Australian hardwoods only as far as the sapwood and hence is of little importance, but it can play havoc with softwoods. The Furniture Borer also does most of its damage in imported softwoods. In both cases the damage to the timber is done by the time the signs of infestation are visible.

Pinhole borers attack many of our eucalypt timbers in the green state in the forest. The insects cannot live in seasoned timber and, provided the pinholes are not so numerous as to weaken the timber, their presence does not mean the piece cannot be used.

DURABILITY OF AUSTRALIAN TIMBERS

The durability of timber from different species of trees varies widely. Some species, such as ironbark or jarrah, will be very durable, whereas others, such as mountain ash, will be less durable. The results of chemical and laboratory tests on durable and non-durable timbers have shown that the durable timbers contain substances which are poisonous to fungi and termites, whereas the less durable ones have a much smaller quantity of such substances or none at all. In some cases, the poisonous material is an oil; in others, it is probably a solid material.

SAPWOOD AND TRUEWOOD

The sapwood or outer part of a tree, which is usually of a lighter colour than the truewood, is chemically different from the truewood in that it does not contain substances which are poisonous to fungi or termites. As a result, sapwood does not resist decay or insect attack. A common practice in Australia is to remove the sapwood from poles and posts at, and near, the ground line.

In milling timber, sapwood is usually cut away, but occasionally a scantling will show a small part of it. Such timbers should not be used in a situation where decay or insect attack is likely.

PRINCIPLES OF WOOD PRESERVATION

Certain woods are durable because of the presence of poisonous substances. If, therefore, materials which are poisonous to decay and insects are introduced into less durable woods, such will become durable. Wood preservation treatments are designed to introduce materials which will render the wood poisonous, and thus prevent the growth of fungi or insects. It is not necessary to penetrate the wood completely with preservatives, but only to
provide a continuous outer layer of impregnated wood. In some cases, this layer should cover all surfaces of the treated timber; in others, as in the cases of poles or posts, it may be only necessary to treat that portion to be placed in the ground and just above the ground line.

PRESERVATIVES

The requirements for the ideal wood preservative have often been set down as follows: highly poisonous to fungi and insects; chemically stable for long periods of external exposure; cheap and easily available; easy to apply and non-harmful to human beings; non-deleterious effect to the timber; non-corrosive to iron and steel; odourless; colourless; fire resistant or at least not increasing the inflammability of the wood; permanently fixed in the wood; not subject to severe leaching or evaporation; and free from effect on the subsequent painting or finishing. It is sufficient to say that the perfect preservative has not yet been found, but, in a large number of cases of timber usage, all the above factors are not essential.

In general, wood preservatives can be divided into two main classes, namely, oil preservatives and water-soluble preservatives, the latter being, as their name indicates, used in water solution.

(a) Oil Preservatives

Coal Tar Creosote, or, as it is usually known in Australia, "creosote" or creosote oil" is the most used and commonly accepted standard preservative both in Europe and the United States of America. It is produced by the distillation of coal tar.

Provided that creosote oil is deeply and evenly introduced into wood in sufficient quantity, there is an assurance of good protection from both termites and decay. The oil is easy to apply, its depth of penetration is clearly visible, it does not easily leach out or evaporate from the wood, and it is easily available and relatively cheap. A common objection to its use is its fire hazard. Experience has shown that this is not as serious as was first considered.

Creosote also has a distinctive smell which to some people is objectionable. However, working with creosote has no deleterious effect on the health.

Tar is often used for the treatment of poles either alone or in combination with oil or bitumen, etc. It is not as good as preservative as the creosote which may be prepared from it. It is definitely less poisonous to fungi and insects, and is much more difficult to apply to the wood. In addition, penetration may be almost completely prevented owing to the type of tar and the presence of free carbon. Brush treatments with tar have given very unsatisfactory results in Australia and abroad, and this treatment, using tar of any quality, is not advisable.
(b) **Water Soluble Preservatives**

Has type consists of chemicals dissolved in water. This preservatives are usually odourless, do not stain, and the treated wood, when dry, may be painted. They also have the advantage of being supplied in powder form. Some, however, are corrosive to metals; and some have a tendency to leach out of the wood when in contact with water. Timber treated with water soluble preservatives should be re-dried before use.

**Zinc Chloride** is probably the most widely used of the water soluble preservatives. It is highly toxic to all fungi, is odourless, easy to handle, has little or no corrosive effect and, when dry, has no effect on paint.

**Sodium fluoride** is not very soluble, a maximum concentration of 4% being obtainable. Sodium fluoride is one of the constituents of "Wolman Salt". This mixture becomes strongly "fixed" in the wood and is, therefore, suitable for interior or exterior use. It is highly toxic to all fungi insects and termites.

**Benzene Hexachloride** is a chlorinated hydrocarbon insecticide available in dispersible powder, miscible oil and in dust and smoke generator forms, which has been found to control termites and boring beetles.

**Aldrin and Dieldrin.** Dieldrin is generally more effective than Aldrin, not so much because of higher initial toxicity, but because of its longer residual action. The potential use of these materials, in approximate order of importance, are: the control of soil insects, grasshoppers, flies and mosquitoes, ants and termites, and forest insects.

**Copper Sulphate** has been used successfully for many years in the treatment of poles, but it has the disadvantage of attacking iron and steel and is subject to the leaching action of water. When combined with chromates, these defects disappear.

**Arsenic** is used with other preservatives principally as a combative against borers and termites.

**METHODS OF APPLICATION**

(a) **Brushing or spraying** - is the simplest but least effective since only a light surface penetration can be obtained and subsequent abrasion may expose untreated wood.

(b) **Dipping** - this method ensures that all cracks and openings in the timber will be treated and a better penetration obtained.

(c) **Steeping** - is used where time is not critical as it may take up to several weeks for the timber to soak up the preservative.

(d) **Hot and cold bathprocess** - this method consists of immersing the seasoned timber for a few hours in hot preservative and allowing it to cool. The hot liquid
heats the wood and causes the air in the wood to expand and a certain amount is expelled. On cooling, the air contracts and forms a partial vacuum and the preservative is sucked in.

(e) *Pressure process* – this involves the use of special high pressure plants.

A preliminary vacuum is applied to the inside of the pressure cylinder and it is then pressure-filled with the preservative which is forced into the timber under pressure.

9.5 STRUCTURAL METHODS FOR PREVENTION OF TERMITE ATTACK

STRUCTURAL METHODS

1. *Termite shields* made of sheets or strips of 0.5 mm galvanized steel or copper may be used as follows:

   (a) Sheets, called *caps*, are placed on top of the stumps under the bearers, as shown in Figure 9.10. They may be fastened by nailing but care must be taken not to split the cap. Before nailing the cap, the top of the stump should be swabbed with creosote oil.

   To avoid nailing through the cap, a special type of cap may be used with a hoop iron strap soldered to each face. These straps are nailed to the bearer and stump respectively. In northern Australia, bearers are usually fastened to the stump by a bent belt passing around the cap. Termites for some unknown reason, do not readily climb the belt.

   ![Diagram of termite attack prevention by caps](image)

   **PREVENTION OF TERMITE ATTACK BY CAPS**

   **FIG. 9.10**
(b) Strips are placed on the inside of foundation walls, as shown in Fig. 9.11. They must be continuous, and should be grouted into the walls. They should also be applied to the outside of the walls where this is not easily inspected.

Caps and sheets must project at least 50 mm beyond the edge of the stump or wall with the projecting lip inclined downwards at an angle of 45°.

Termite shields may be rendered useless by heaps of rubbish touching the bearers, or by unprotected trellises, outhouses, drainpipes, steps, etc., which provide the termites with a path between the ground and the portion of the building above the caps. All such structures must be protected with suitable shields or else separated from the main building. There must be a clearance of at least 150 mm between the bearers and the ground and, where termites are particularly aggressive, 300 mm clearance should be maintained.

2. Solid Concrete Floors. Wooden structures placed on solid concrete floors receive excellent protection from termites, provided that the concrete floor is raised some mm above ground level and that it projects at least 50 mm all around the building. All construction joints are poisoned with creosote or filled with bitumen containing 1.0% white arsenic. Regular inspections are essential with this type of floor to detect termite tubes over the concrete.
PREVENTION OF TERMITE ATTACK BY USE OF CHEMICAL SUBSTANCES

Timber placed in contact with the soil, or on foundations without termite shields, can be made resistant to termites by painting thoroughly with creosote oil and, in the case of stumps or foundations, puddling the soil around them to a depth of 300 mm with the same material, to form a layer 150 mm thick of treated soil. The protection is temporary and may cease in a year or two under severe exposure. Under a floor it may last longer.

ERADICATION OF TERMITES

When termites are discovered in a wooden structure it is important to destroy the whole colony if possible. Locate the termite tubes or the galleries in the wood, gently open them, and blow in 3 grams of finely powdered white arsenic, and seal immediately.

If the treatment is successful, the termites will continue to move in the tubes and galleries, pick up the arsenic on their legs and bodies and pass it on to one another until finally the entire colony is killed. If this method of termite eradication proves unsuccessful, or undesirable, the following procedure may be adopted.

(a) Trace the termites back to the soil and break any communication tubes.

(b) Puddle the soil and paint the foundations, as described above, with creosote oil, at the point of emergence from the soil.

(c) Remove any harmful structures giving the termites access to the building if these are present.

(d) If structures cannot be removed, apply creosote at point or points of contact with the building.

When these measures have been taken effectively, any termites left in the building will die.

9.6 TIMBER MILLING

ROUGH SAWN TIMBER

In cutting timber from a log, far more consideration is given to the amount of timber that can be cut from the log than to the direction in which the grain of the timber will run. This latter point, however, is important in seasoning, and also in timbers needed for fine work.

The size of a piece of timber does not indicate the purpose for which it is most suitable. The illustrations on the diagram (Fig. 9.12) indicate how logs should be cut to produce timber for special purposes.
CONVERSION OF TIMBER

FIG. 9.12

CONVERSION OF TIMBER

1. **Live or slab sawing.** The inner pieces are quartersawn and the outer slabs cut more or less tangentially. There is less waste by this method and it is therefore the cheapest. Thin boards used as flooring should be quartersawn to give the best results but to reduce cost is backsawn and should be laid heart-side down as that portion (the heart) is liable to be kicked out. See Figure 9.12 (A).

2. **Quarter Sawing.** This is an expensive form of conversion does show the Medullary Rays to an advantage in timber such as Oak, as well as showing ribbon grain figure is Queensland Maple and Walnut. Quartersawn timber seasons slowly but retains its shape. See Figure 9.12 (B).

3. **Back or Tangential sawing.** This method of timber conversion is adopted when the timbers have ill-defined medullary rays and distinct annual rings as in pitch pine, as the boards (having their faces tangential to the annual rings) show up to advantage when cut in this manner. Figure 9.12 (C).

The following terms apply to the various pieces of converted log of timber.

*Flitches* from the mill become heavy beams in the building. They are fixed on edge to carry heavy loads.

9.31
Big Planks of hardwood or oregon are suitable for floor joists for the first floor, or for hanging beams that hold up the weight of the ceilings.

Dressed boards are used to form plinths at the base of walls. They are made in good durable timber, especially when they come in contact with the soil.

Squares have width and thickness of equal size. They are used as stumps or storey posts to stand upright and support heavy loads. They are made square so that they will not collapse towards one side more easily than towards another.

Scantling is the name used to cover timber in a variety of sizes, that is cut as stock to be used in structural building work. It is sometimes referred to as quartering. It may be cut in the bush mill straight from the log, or may be recut from flitches or big squares.

Small scantlings are used in the wall framing of timber buildings and in the roofs and floor construction of ground floors in residences. The most common width is 100 mm. This is one of the standard dimensions in walls, floors and ceilings. The second dimension of the timber section is made thicker or thinner, as the position requires.

Boards of approximately 25 mm thickness have a great number of uses. Large quantities are used in making forms and decking for concrete. Their light weight allows them to be easily handled and fixed. Temporary woodwork of this kind is commonly re-used several times, in order to economise on its initial cost.

Battens of good size section are necessarily used for holding the heavy gauge nails required when fixing corrugated "roofing", whether iron or cement. A common size is 75 x 38 mm. The widest spacing of both the battens and the rafters under them is 900 mm. When the rafters are given wider spacing the section size of the batten must be increased and it is then referred to as a purlin, not as a batten.

Small battens are strong enough to make braces in timber-framed walls of residences as these do not have great heights and widely spaced studs. The braces are usually placed on the outer sides of the walls where they can be easily nailed into the studs and plates when the wall is plumbed in its upright position.

Cover strips may be either square or moulded by machine at the mill. They cover the joints in vertical sheeting or other abutting materials. The term is applied only to small sizes of materials.

Three ply is made up of thin layers of thin veneer of heavier timber. The grain of the centre layers runs across the grain of the other two, and the three are well glued together. It is used for wide panels in doors, walls, backs of cupboards, and similar purposes.

9.32
Milled timber. Timber that is specially prepared to shape for a single purpose by machining at the source of supply is commonly referred to as milled. Practically all the timber that is visible when a building is finished has been milled.

Flooding is generally dressed on both sides and the edges are made with tongues and grooves so that when a number are put together they will maintain an even surface, not only immediately over the joists where they are nailed, but also along their lengths between the joists. Joints in well milled flooring will not crack when weight is applied to single boards in the unsupported part between joists.

Tongued and grooved lining boards are used for interior wall covering and are more durable than plaster sheets, especially where they will be subjected to hard knocks from furniture. In order to obscure the joints, some are run with a chamfered edge in addition to the tongue and groove. This makes a vee joint between boards.

Weatherboards are used on walls that are exposed to weather. An overlapping edge gives them room to swell and shrink in width without damage, as atmospheric conditions change. Weatherboards are run with square edges or round edges.

Soles and struts are cross cut at the mill on the circular saw so that fencing work can be carried out quickly. A set of three pieces, comprising one sole piece and two struts, is necessary for every post.

Angle rails for fences do not provide a lodging place for rain and usually prove longer lasting than those with flat top edges. They are cut diagonally from square timber at the mill.

Palings may be either split or sawn to size. Split palings always have tapered sections; sawn palings may be either tapered or parallel in thickness.

Mouldings are milled to standard shapes and sizes from planks and boards that have been sawn to the regular sizes of 25, 32, 38, 50 mm, etc. They come from the moulding machines in smaller actual dimensions than the original sawn material but many of them retain the nominal size of the sawn material. With the exception of beads, they commonly finish 4 mm less than the nominal size in small mouldings and 8 mm less in large ones. The mouldings form finishing pieces in angles, around openings in walls and make dividing pieces between one fitting and another.

Quarter round is used in many angles where a very close joint is difficult to make or maintain. It is the moulding most commonly used.

Scotia is the common name applied to a shape which is strictly speaking "Cavetto". This latter name is rarely used.
Ovolo moulding has, in part, a resemblance to the quarter round but has the additional squares at the top and the bottom which make quirk lines to relieve the bold look that a plain round mould gives.

Architraves are moulded in a variety of shapes. The main object is using moulds instead of plain square material around a wall opening is to improve the appearance and to remove much of the thickness which is a disadvantage when hinged doors are opened to more than 50°.

Skirting is fixed on the walls close to the floor to give protection to the more fragile plaster sheeting or rendering which would be damaged by continuous knocks from brooms, heels and toes of chair legs, and personal footwear.

Window nosing is made with a tongue on its inside edge that will fit into a groove in the window sill. The width of the nosing is made to suit the position of the window frame in the thickness of the wall. It forms a cover to the top edge of the wall sheeting and a stop for the bottom end of the architrave.

Bead is the name applied to almost any thin strip with a rounded edge. Part ovolo beads are used to hold glass in place in doors or windows. Their shape is made to match the solid moulded edge on the other side of the rebate. Parting beads keep the top and bottom sashes apart in box frames and, with the stop beads, they help to form running grooves for the sashes. The fly wire beads are used to cover the edges of the wire on both door and window screens.

9.7 PLYWOOD - IT USE AND GRADING

1. INTRODUCTION

Like every other material, it has its limitations but, by an intelligent selection of the requisite grade for the purpose in view, its range of usefulness appears to be very extensive.

The bulk of the plywood manufactured in Australia today is made from hoop pine, bunya pine, and kauri. So, it is only logical that the first set of grading rules drawn up by the Standards Association of Australia for this class of material should embrace plywood fabricated from these timbers. Some plywood is made in W.A. from karri, and facing with both Australian and imported fancy woods is also done.

The art of veneering and the manufacture of plywood has been known for many years. Production continued on a restricted scale, however, until the period 1870 to 1880 when, with the development of the prototype of the modern veneer lathe, an enormous impetus was given to the industry.

The importance of rotary peeling of veneer may be gauged from the fact that, at the present time, over 90 per cent of the world's production of veneer is cut in this manner.
Plywood manufacture in Australia dates from the early days of the Great War when the first factory was established in Queensland. Hoop pine (Araucaria cunninghamii) formed the raw material and is still the most important species used.

Recent indications are that timbers from New Britain, the Solomon Islands and New Guinea will play an important part in the future.

2. ADVANTAGES OF PLYWOOD CONSTRUCTION

Plywood, by virtue of its method of construction, exhibits well-defined characteristics and possesses certain advantages which may be summarized as follows:

(a) **High uniform strength** - Wood is 25 to 45 times stronger along the grain than across the grain. Crossing of the grain at right angles in the adjacent veneers thus tends to equalize the strength in both directions.

(b) **Freedom from shrinking, swelling and warping** - Solid wood exhibits considerable movement across the grain but generally negligible longitudinal shrinkage. The balanced construction of plywood panels tend to equalize stresses in the panel, thus reducing shrinkage and swelling to a minimum and eliminating warping.

(c) **Non-splitting** - Plywood can be satisfactorily nailed and fastened near the edges without damage from splitting.

(d) **Economical and effective utilization of figured wood** - Twenty or more sheets of figured veneer can be sliced from 25 mm of solid wood. This veneer can subsequently be glued to a core of cheaper material to form a high grade panel: for example, for flush panel doors.

(e) **Fabrication of curved surfaces** - The trend of some architectural design is to feature curved surfaces. The desired shapes are readily built up of plywood construction utilizing male and female form or a single form in a vacuum press.

3. USES OF PLYWOOD

(a) **Building purposes** - A large volume of plywood is used in house construction for the panelling of interior wall surface. Flush doors built up of plywood sheets on an internal frame, or of cross-bands and face veneers on a thick core, have almost replaced the panel-type door. Such doors possess all the advantages to be derived from plywood construction and are obtainable with face veneers which harmonize with adjacent panelling or furniture.

Built-in kitchen cabinets in modern homes are largely constructed of plywood.
The development of the pre-fabricated house in the United States of America employing the stressed covering principle, where plywood is glued to studs and joists to carry its share of the load, indicates a large-scale future use for this material.

Plywood in the United States of America is replacing solid timber for sub-flooring and wall sheathing, where its unusual stiffness, freedom from cracking, and large panel sizes make it eminently suitable for this purpose. Use of synthetic glues for binding the plies enables waterproof plywood (bondwood) to be made, and this can be used for exterior work.

(b) Furniture construction — Ordinary plywood is extensively used for the panels and backing of wardrobes, sideboards and mirrors, and for medicine cabinets, drawer bottoms, chair backs and seats. Appropriately stained or polished it may be used for almost any piece of furniture.

Curved and bent panels with fancy face veneers play an important part in modern furniture construction.

(c) Coachwork — A considerable quantity of plywood panels is used in the interior decoration of railway carriages and buses. The use of this light-weight material reduces labour costs and gives a smooth finish together with superior strength and stiffness.

In the motor body building field, a certain amount of plywood is used for the bases of seats, for flooring, and in the construction of commercial trucks and vans.

(d) Caravan construction — Caravan construction is now providing an important outlet for considerable quantities of plywood. It is used for walls, roofs, floorings, built-in cabinets, partitions, shelving, and as a base for the exterior covering, or, in some instances, as the exterior covering itself when bondwood is substituted.

(e) Shipbuilding — Modern ship architecture requires large volumes of fancy plywood for the furnishings and fittings of luxury passenger liners and smaller craft. The smooth clean surfaces, the variety of figure and design, and ease of fabrication of curved surfaces contribute largely to its usefulness in this sphere.

Ever increasing use is being made of special grades of waterproof plywood in the construction of yachts, skiffs and racing boats.

(f) Concrete formwork — Overseas, special grade bondwood panels are now recognized as the outstanding form material where economy, smooth appearance and architectural detail are of paramount importance. Economies are made possible by a reduction in finishing costs due to the even and smooth texture imparted to the concrete by the plywood and by repeated use of the same panels.
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**IMPORTED TIMBERS**

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<tr>
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<td>UNIDENTIFIED SOFTWOODS</td>
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Visual grades defined in Australian Standards are as indicated below:

<table>
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<tr>
<th>Build.</th>
<th>Building Grade</th>
<th>Std Eng.</th>
<th>Standard Engineering Grade</th>
</tr>
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<tr>
<td>Sel.</td>
<td>Select Grade</td>
<td>Str. 1</td>
<td>Structural Grade 1</td>
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<tr>
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<td>Str. 2</td>
<td>Structural Grade 2</td>
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<td>Light Scant.</td>
<td>Light Scantling Grade</td>
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<tr>
<td>Eng.</td>
<td>Engineering Grade</td>
<td>Std Build.</td>
<td>Standard Building Grade</td>
</tr>
</tbody>
</table>

†In seasoned condition as required by AS O78.
‡Excluding pith-in material.

**NOTE:** A number of the standards referred to in the table are presently being revised in metric terms. Each revised standard will be issued under a different number to the one shown in the table.
CHAPTER TEN - TIMBER AND METAL FRAMING

10.1 TIMBER FRAME CONSTRUCTION
    CODES, STANDARD AND BY-LAWS

10.2 FRAMING TERMS
    PLATES
    STUMPS
    ANT CAPS
    BEARERS
    JOISTS

10.3 WALL FRAMING
    BOTTOM PLATES
    STUDS
    NOGGING
    BRACING
    TRIMMERS
    LINTELS
    TOP PLATES

10.4 FLOORING

10.5 WALL CLADDING
    INTERNAL
    EXTERNAL

10.6 STEEL FRAME CONSTRUCTION
10.1 TIMBER FRAME CONSTRUCTION

The use of timber-framed floors, walls and roofs in housing constructions has been long-established in Western Australia and, indeed, in all States and Territories of Australia. Changes in design, construction methods, style of living and the availability of suitable timber has seen a decline in the number of completely timber-framed houses in recent years although timber-framed roofs have maintained their prominence in housing construction.

Basically, the method of constructing a timber-framed house involves supporting a floor framework of timber members clear of the ground. On top of the floor framework are timber-framed walls which, in turn, will support a timber-framed roof. After framework has been assembled the roof and walls are clad, windows glazed, external doors fitted and the timber flooring boards are fixed in position. Fixing and finishing trades then complete the house.

CODES, STANDARDS AND BY-LAWS

Because timber is a natural material it is also variable in its quality. To compensate for any possible strength variations caused by defects in the timber, there are carefully formulated standards and codes governing the strength or stress grading of timber and detailed codes by-laws concerning the use of timber and positioning of members in timber-framed construction. One such code is the Timber Framing Code - SA1684-1979. This code of many parts specifies the sizes of timber members to be used in any of the spacings or spans of the timbers and the stress grade or strength of the timbers.

One of the objectives of the code is to set out the strength or stress grade of common, identified timbers in general use in building construction.

In Western Australia the common timbers used in building construction generally, and the timber-framed construction in particular are Jarrah and Karri, and to a lesser degree, Wandoo, Marri (Red Gum) and Blackbutt.

The current trend is to make greater use of more readily available and less expensive soft woods, particularly in roof framing. Radiata Pine, used seasoned (dry) and gauged to accurate sizes, is currently being used for ceiling joists to obtain a stable (distortion-free) flat ceiling, as well as being used in prefabricated roof trusses.

To gain an appreciation of the strength of various timber, it must be remembered that there are two classes of timber, hardwoods and softwoods and that there are two conditions in which these timbers are available: green or unseasoned, and dry or seasoned timber.

Hardwoods are generally denser than softwoods and also have a higher stress grading. Similarly, seasoned timbers have a higher stress grading than unseasoned timbers.

The term stress grade means a value assigned to a piece of timber to indicate the basic stresses appropriate to that piece. Stress grade is designated in the form of a number preceded by the letter "F". The greater the strength of timber, the greater will be the designated number.

Table 10.1 sets out the two hardwood timbers in common use; their common, referred to or known grades; the applicable Australian Standard; and the Visual Stress Grade.
<table>
<thead>
<tr>
<th>Timber</th>
<th>As Known</th>
<th>Australian Standard</th>
<th>Visual Stress Grade</th>
<th>Dress Grading</th>
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<td>Appearance 2 &amp; Better</td>
<td>F27</td>
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</tbody>
</table>

**TABLE 10.1**

10.2 FRAMING

Timber is a durable material, but only when certain precautions have been taken and preventive measures employed. It is essential that the timbers be kept dry and, in the case of floor members, that they be kept well ventilated. Where it is impossible for the timbers to be kept dry, they must be protected with a preservative that will protect them against rot and decay.

It is important that this fact be borne in mind when constructing the timber-framed sub-floor.

Study Figure 10.1, as reference will be made to certain timber members and it will be necessary to refer to this figure frequently.
TERMS APPLYING TO FRAMING GENERALLY

FIG. 10.1
SOLE PLATE

Sole plates are used to distribute the load of the building over as large an area as possible. The timber used should be a hard wood, preferably one that is durable and will resist insect attack. Jarrah is ideal. The area of each sole plate should not be less than 460 cm². To achieve this, a plate 310 mm x 150 mm is needed. The plate should be 50 mm thick.

STUMPS

Stumps rest on the sole plate and support the building clear of the ground. The minimum distance between ground level and the underside of the lowest timber member (which will be the bearer) is 200 mm. This clear space will ensure that there is adequate ventilation between floor and ground level. The minimum nominal cross-section used for timber stumps is 100 mm x 100 mm. Where timber which is not classified as durable is in contact with the ground, it should be impregnated with an approved preservative to comply with the requirements of Australian Standard 1604.

FIG. 10.2
ANT CAPS

It is necessary to install physical barriers to prevent the movement of termites into the structure. These physical barriers are known as Ant Caps, and are placed on top of the timber stumps which have already been discussed.

Ant caps are usually made from 0.50 mm thick galvanized steel and have the four sides turned down at an angle of 45°. The turned edge of the ant cap should not be any closer than 38 mm to the vertical face of the stump or pier. No bolts or other fixings should pass through the ant cap which would affect the performance of the shield. Where it is necessary to secure bearers to stumps or piers, it is suggested that a cranked bolt be used as shown in Figure 10.2 (a).

Fixing straps can also be welded to the ant cap for fixing to timber stumps and bearers as shown in Figure 10.2 (b).

For fixing to concrete piers, a bolt is cast into the precast pier and the ant cap is passed over the bolt. It must be pointed out that the aperture where the bolt passes through the ant cap, must be thoroughly sealed to prevent penetration of white ants through the aperture into the timber bearer. (See Figure 10.2(C))

BEARERS

Bearers are the prime supporting members for timber-framed floors. The common size of a bearer used is 100 x 75 fixed on edge. This size may be varied according to Tables 1S(A) and 1S(B) in the 'Light Timber Framing Code'.

Bearers rest on isolated or attached piers. The maximum distance between these supports for standard 100 x 75 bearers is limited to 1200 mm. This spacing may vary with timber size according to Table 2S of the Code (See Figure 10.3 (a)).
FLOOR JOISTS

Floor joists are the supporting framework for the floor surface which can be either floor boards or sheet flooring. The space between the joists is related to the flooring material. As most can span only about 450 mm without deflection when laden, the spacing of floor joists is 450 mm centre to centre.

The same principle applies to the span of the joist. As the most suitable size for the joist is 100 x 50, the most efficient span is 1500 mm between support. For this spacing to be achieved, the bearers must not be spaced more than 1500 mm apart. (See Figure 10.3 (a)).

By referring back to Figure 10.1 it can be seen that under the timber-framed wall there are two floor joists close together and with sufficient space to allow at least 25 mm width of joist available for bearing for the floor boards.

Figure 10.3 (b) shows the double joisting under walls of 75 mm stud-framing and 100 mm stud-framing.

\[ \text{STUD FRAMING} \]

\[ \text{FIG. 10.3 (b)} \]
10.3 WALL FRAMING

The wall framing in timber construction should be assembled with regard to the "Light Timber Framing Code". The following members can be identified in Figure 10.1 as being parts of the wall framing:

- bottom wall plate
- sill trimmers
- jamb stud
- studs
- nogging
- brace
- ledger or window head trimmer
- lintel
- top wall plate

There are two standard sizes of wall framing timbers: 100 x 50 and 75 x 50 sawn (green or unseasoned) hardwood. Another type of framing timber in use is seasoned hardwood off-cuts that have been "finger jointed" with high strength glues to form a stable, strong piece of timber. This type of timber is machined to uniform width and thickness and is slightly smaller in section than conventional timber framing timbers.

Steel framing for wall framing is increasing in use. The standard width of the steel framing is 75 mm and is manufactured from light gauge galvanised iron bent to form channels which are then assembled with similar spacings as for timber framing.

BOTTOM WALL PLATE

Bottom wall plates are made from walling material of 100 x 50 or 75 x 50. It is preferred that wall plates be in as long a length as is possible. Where jointing is necessary, a butt joint will suffice only when both ends can be fully supported. Where full support is not possible jointing by halving and lapping, fish-plating or metal strapping can be used.

The trenching or housing in the place for the studs is optional but, if used, the depth should be at least 10 mm and measured up from the bottom of the plate to accommodate any inequalities in plate thickness.

SILL TRIMMERS

As can be seen from Figure 10.1, sill plates are placed over trimmed studs where windows or other openings are formed. As the studs under the trimmer are spaced at the normal acceptable spacings, there is no structural advantage in increasing the sill trimmer in sectional size.

To obtain support at the ends of the trimmer it is common practice to house the trimmer 10 mm into the jamb stud.
JAMB STUDS

Jamb studs are those studs which are positioned to the sides of openings. Because door or window frames are to be fixed to these studs, they are carefully selected for straightness and he free from defects.

STUDS

Stud sizes can be either 100 x 50 or 75 x 50. Although By-Laws do not restrict timber-framed walls to single storey construction, they do restrict their maximum wall height to 2 500 for 75 x 50 framing and 3 000 for 100 x 50 framing.

The maximum spacing for all studs is 600 mm. This spacing not only ensures structural soundness but also is most compatible for standard sized lining and sheeting boards.

To achieve a uniform thickness wall, it is advisable to have all framing timber gauged to width. Gauging is achieved by placing all the timbers through a wood machine which reduces the timber to a pre-selected width. This gauging is done at the mill and would need to be specified when ordering the timber.

It is important that the wall is braced, to maintain it in a true and square grid. The carpenter will frame up using the floor framework as an even base from which to work. After setting out his wall plates for doors and windows, he will mark and house the position for studs. Studs are cut to a uniform length and nailed into the housings in the wall plate. Noggings are placed to suit sheet sizes but should not exceed 1350 centres. The framed wall is now squared using the diagonal method that was used in Chapter 3 for setting out a building. When squared, the positions of the braces are marked, then housed and finally fixed in position.

Special consideration is given to the junction of walls. Provision must be made for the fixing of internal and external claddings. Figure 10.4 (a - i) shows some methods which are acceptable practices.

Figure 10.4 (a - d), employs three studs the same size as common wall studs. Note that each example provides for internal and external fixing in both directions. With each of these examples, it is desirable to use blocking pieces in between the corner studs to maintain width and eliminate twisting.

Figure 10.4 (e) shows two studs of common studs dimensions, arranged to provide internal fixing only. This example is used in brick veneer construction. Note that a blocking piece is used to eliminate twisting.

One method of framing up an intersection is shown in Figure 10.4 (g). This method is only suitable where internal metal clip fixing is allowable for internal linings.

Where a metal clip fixing system is not permissible, Figure 10.4 (h) could be adopted.

A more common method at intersecting walls is shown in Figure 10.4 (i). Although this method is not shown in the Light Timber Framing code, it is a widely used and accepted practice. Figure 10.4 (f) allows for fixing of external cladding only.
FIG. 10.4

STUDS AT WALL JUNCTIONS
NOGGINGS

Noggings are pieces of timber of the same sectional size as the wall frame. The noggings are cut to fit between the studs to provide stiffening to the wall and to provide fixing for the wall sheeting materials. (See Figure 10.1 for location of noggings).

BRACING

Bracing is required to all frames to maintain rigidity and squareness.

The size of bracing material is 50 x 25 sawn timber. However, for walls exceeding 2.7 m high, 75 x 25 brace should be used.

Braces should be approximately 45° degrees to the horizontal and, where possible, there should be two braces to each wall. This may not always be possible because of the position of doors and windows, particularly in short walls.

It is possible to use corrosion-protected formed metal sections such as 25 x 25 mm x 1 m galvanized iron for bracing. The metal brace is let in flush to the wall by making a saw cut in the studs. Figure 10.5 shows the positioning of the galvanized iron brace.

Flat galvanized steel strap may be used as a double cross bracing. When this is used the strap is tensioned across the face of the wall and nailed to each stud it crosses.

FORMED GALVANISED IRON ANGLE BRACE

FIG. 10.5
The bracing of short walls and walls with openings should not be overlooked. Figure 10.6 shows how bracing to restricted wall spaces is effected.

**BRACING TO RESTRICTED WALL SPACES**

**FIG. 10.6**

**LEDGER OR WINDOW HEAD TRIMMERS**

Ledger or window head trimmers are used at the back of lintels to make up the width of the lintel to that of the wall. The ledger is also a suitable means for fixing the window to as well as providing support for jack studs.

**LINTELS (Head Trimmers)**

Lintels give support to the wall plate above an opening. Figure 10.7 shows methods of support for lintels to openings. It is suggested, when the lintel is housed into the jamb stud, that the depth of the housing does not exceed one quarter of the width of the jamb stud.

Where an on-edge lintel is used, and particularly where the lintel exceeds 125 mm deep, then a ledger should be used to provide fixing for internal sheeting.

**TOP WALL PLATES**

Top wall plates should be marked out with the bottom wall plate. This will ensure parallel studs and openings. The depth of housing should not exceed 10 mm and should be marked down from the top of the top plate.
ISOMETRIC

Lintel housed into jamb studs for spans not exceeding 1.2m

-isogring close to vacinity of joint is good practice

ISOMETRIC

Lintel notched into jamb stud and next adjacent stud

SECTION

where lintel exceeds 125mm in depth fix 50mm \( \frac{D}{2} \) ledger to support jack studs

ELEVATION

Jack stud

Lintel

Jack stud

Lintel notched for stud housing

not to be housed for stud

housing \( \frac{1}{4} \) max width

FIG. 10.7
10.4 FLOORING

Both timber-framed and brick veneer structures lend themselves successfully to the use of timber floors. Figure 10.1 shows how the sub-floor timbers are arranged for timber floors.

In Western Australia, hardwoods such as jarrah, karri, Wandoo and blackbutt are used for timber floor with jarrah being the most popular. Sizd range from 75 x 25 to 150 x 25 nominal with the narrow boards having less shrinkage and warping.

There are various grades of flooring. They are select and standard in one length or select and standard in finger-jointed pieces.

Flooring is jointed along its length by tongue and groove milling and the ends are butt-jointed over a joint.

Endmatched flooring in lengths of 1.8 metres is available. Endmatching is where the ends of the boards have a tongue on one end and a groove on the other. As all the boards are 1.8 metres long and joists are spaced at centres of 450 mm, jointing can be staggered and occur on joists.

Flooring is secured to joists by two 50 or 65 mm nails where the boards cross a joist. These nails are punched below the surface of the floor. For a better finish, secret nailing is used.

Secret nailing boards have a slightly different profile and are usually thicker than standard boards. Figure 10.8 shows examples of standard flooring profiles.

---

**T & G FLOORING**

126 x 19 (120)

100 x 19 (96)

100 x 25 (96)

84 x 19 (78)

84 x 25 (78)

**SECRET NAILED FLOORING**

64 x 19 (58)

85 x 25 (73)

85 x 19 (76)

64 x 19 (55)

**STANDARD FLOORING PROFILES**

NOTE: Finished sizes shown. Figure in brackets denotes cover.

**STANDARD FLOORING PROFILES**

FIG. 10.8

10.14
10.5 WALL CLADDINGS

Wall claddings can be subdivided into two areas:

(a) Internal linings.
(b) External claddings.

(a) INTERNAL LININGS

Internal linings consist of sheeting materials or timber mouldings which can be fixed to the timber or metal framework of either brick veneer or framed construction.

Common types of internal linings include:

- plasterglass
- gyprock
- asbestos cement
- plywood panels
- vertical timber lining boards
- hardboards.

PLASTERGLASS

Plasterglass is a reinforced plaster sheet. It is manufactured by casting a flat sheet approximately 8 mm thick. A slurry of casting plaster is mixed which is poured onto a flat, smooth table and fibreglass is worked into the slurry. Plasterglass is suitable for walls and ceilings.

GYPROCK SHEETING

Gyprock sheeting is a paper sandwiched board which is also known as plasterboard.

This lining board consists of a gypsum plaster fill inside two thick paper veneers. Plasterboard should not be used in wet or moist areas. Plasterboard is suitable for ceilings and walls.

FIBRE CEMENT

Fibre cement products have wide applications both internally and externally. The wide range includes flat sheeting profiled sheets, textured sheets, and decorative sheets. Further information on the range of products is available from hardware and building materials outlets.

PLYWOOD PANELS

Plywood panels are a suitable decorative finish to internal walls. There are local varieties and imported sheets available.
Care must be taken when using decorative plywood sheets to ensure that a sufficiently strong backing is provided for the plywood sheets which are usually adhered to the backing.

**VERTICAL TIMBER LINING BOARDS**

Vertical timber lining boards give a pleasant effect to internal walls. There is a wide range of profiles available which can be nailed, secret-nailed or adhered to the framework.

**HARDBOARDS**

The use of hardboards is now limited to wet areas where a hardboard with a baked enamel surface is used. The surface of these hardboards is usually figured to present wall tiles or similar wall finishes. Hardboards were once known as masonite or Burnie board and produced from the constituted pulp of hardwood timbers.

(b) **EXTERNAL LININGS**

- fibre cement products
- timber weather boards
- metal sheet material

**FIBRE CEMENT PRODUCTS**

Fibre cement products include those mentioned earlier plus a panel of pre-formed weatherboard.

**TIMBER WEATHERBOARDS**

Timber weatherboards of at least three different profiles are nailed horizontally onto studs or screwed to metal framework. The overlapping effect of weatherboards ensures that they maintain a weatherproof seal.

**SHEETMETAL PROFILED MATERIAL**

Sheetmetal profiled material is usually installed vertically. There are several manufacturers and many suppliers, each of whom have full details of the range of sheets available and the technical information relating to performance and fixings.

Figures 10.9, 10.10 and 10.11 show examples of fibre, metal and timber wall claddings and linings respectively.

Figure 10.11 (a), (d) and (e) are batwing mouldings used vertically for internal wall linings. Figure 10.11 (d) is a rusticated weatherboard; figure 10.11 (e) is a shiplap vertical wall board. Figure 10.11 (f) is also a rusticated weatherboard.
BUILDING PLANKS:

A single faced cellulose fibre building plank for exterior use.

A tough, durable material for external wall lining, gable end lining, screens and fences.

'ASBESTOS' AND CELLULOSE FIBRE WALL AND ROOF CLADDINGS
FIG. 10.9
SOME EXAMPLES OF SHEET METAL WALL AND ROOF CLADDING MATERIALS

FIG. 10.10

TIMBER MOULDINGS USED VERTICALLY OR HORIZONTALLY FOR WALL LININGS AND CLADDINGS

FIG. 10.11
10.6 STEEL FRAME CONSTRUCTION

Galvanized Steel wall and roof frame systems are often used as an alternative method of frame construction to timber frames. Several manufacturers of framing sections give the builder a wide range of choice, while a number of fabricators are available to cut and assemble walls and roof trusses ready for quick onsite erection.

Steel framed systems have several advantages. Strong galvanized steel frames are durable and will resist white ant attack and corrosion. The high strength of steel enable the use of spans not possible by sawn timbers with similar dimensions.

The strength of the steel ensures that the handling of off-site prefabricated wall and roof components will not suffer injury with appropriate care. Prefabricated components are electrically welded in the workshop and are easily transported.

Small size teams of 2 or 3 men can easily erect an average size cottage framework in less than a day.

Provided that compatible items are used it is a relatively simple operation to secure wall linings to the framework with self-drilling fasteners and even adhesives.

Basic components used in steel framed construction carry the same name as in timber framed construction e.g. studs, noggings, plates etc. See Figure 10.12.

There are two systems of "framing up". One manufacturer produces studs of a slightly smaller width to fit into top and bottom plates. Another manufacturer makes all the studs, plates and noggings the same size and then compresses the end of the studs to a width that will fit into the plate sections.

There are two styles of top plates; the standard channel consisting of 78 mm x 31 mm section which is used as a bottom plate and a top plate when it is possible to locate the rafter directly over the studs, the stiffened top plate is a larger plate 75 x 79 overall and is used where it is not possible to locate the rafter over or adjacent to the wall studs, See Figure 10.13 (a) and (b).

Because the steel framing is often prepared off site it is possible to ensure that the wall sections are firmly, braced by welding in position diagonal braces or "K" braces (Figure 10.12).

Where an opening is to be formed in a wall, the framework above the opening is trussed to transmit the loads down studs adjacent to the opening.

Steel framing to walls can be installed on concrete slab floors, on timber floor framing or on steel floor framing. The steel floor framing members consist of a network of joists anchored to stumps. Load-bearing studs must terminate over the joist or the area below the stud should be blocked up.

Where services are located in the wall it will be necessary to cut holes in the framework for the services to pass through. (See Figure 10.12).
TYPICAL WALL FRAME ASSEMBLY

FIG. 10.12
STANDARD TOP AND BOTTOM PLATE

12 mm long fillet weld at 4 places on each side

STIFFENED TOP PLATE

butt joint located over stud
sections to be pushed hard together with min. gap and welded each side as shown

WALL PLATE JOINTS
FIG. 10.13
CHAPTER ELEVEN - BRICK VENEER CONSTRUCTION

11.1 DESCRIPTION

EAVES
FOOTINGS

11.2 DOOR AND WINDOW FRAMES

11.1 DESCRIPTION

Brick Veneer construction consists of a timber or metal-framed skeleton with a skin of brickwork as the external face.

The construction is framed up as for timber or metal framing, then the window and door frames are installed complete with flashings. The brickwork is then placed around the outside of the framework and taken up to eaves height.

To minimise brickwork and steel lintels, the window and door heads are taken to eaves height and the boxed eave is used. Purpose-made wall ties are fixed to the internal framework and bedded into the bed joints of the brickwork at regular intervals of 450 mm vertical height and 900 mm horizontal distance (see Fig. 11.1). To maintain a damp-free internal wall face, the external skin of brickwork is positioned to form at least a 38 mm cavity between the outside face of the internal frame and the inside face of the external skin. This cavity should be kept clean and clear of mortar droppings. Any breach of the cavity will provide an avenue for penetration of moisture from the outside to the inside of the wall.

WALL TIES FOR BRICK VENEER WALLS

FIG. 11.1
Figure 11.2 (a) shows the section through a brick veneer wall on a concrete raft footing.

Figure 11.2 (b) shows a section through the external doorway in a brick veneer.

In both sketches a boxed eave has been used, but any of a range of eave treatments can be used with brick veneer, as they can with cavity brick wall construction.

Where timber floors are to be used, the base or dwarf walls are taken up to the underside of the bearers. At this stage a P.G.1 ant cap is placed over the entire wall including the attached bearer pieces. (See Fig. 11.3 (a) and (b)).
The timber framing is now completed before the brick skin or veneer is put around the frame. The roof can be pitched either before or after brickwork is completed. There are no constructional restraints but it is more convenient for the brick-layers if they are not restricted by these overhanging rafters and eaves of the roof framework.

As mentioned above, a wide range of eave treatments can be used. Figure 11.4 shows two types of open eaves. Figure 11.4 (a) shows the eave with lining fixed to the soffit of the eave. Because it is necessary to maintain 10 - 15 mm clearance between brickwork and eave, a quad or scotia is required to conceal this gap. The quad or scotia is best fixed to a trimmer cut in between the rafters.

Figure 11.4 (b) shows the open eave with the feet of the rafters exposed. Top lining asbestos is used to conceal the tiles and tile battens. To keep dust and birds, etc., out of the ceiling, a board is cut in between the rafters and fixed in position flush with the outside skin of brickwork. This is generally known as a bird board.

To improve the appearance and to assist in painting, it is advisable to dress the exposed feet of the rafters prior to fixing them in position.

The footing details shown in figure 11.2 are for concrete floors only. Figure 11.3 shows the details to a timber floor. 11.3 (a) shows the details on concrete strip and 11.3 (b) shows the details on limestone footings.
11.2 DOOR AND WINDOW FRAMES

In brick veneer construction, window and door frames are installed in the framed structure prior to the brickwork being installed. Because of this, it is necessary that the joinery is securely fixed to the framework. This is done by means of carefully placed nails and, in the case of metal framework, countersunk metal screws. Figure 11.5 shows a vertical and horizontal detail of a timber window frame fixed to timber frame. Nail holes in the timber window are best pre-drilled to ensure accurate and neat fixing. The broken lines in Figure 11.5 indicate suggested positions for fixings.

When metal, i.e. aluminium, window frames are installed in timber or metal framework the fixings are made through the cavity lugs on the extruded frame. Fixing for the head and the stiles is similar.

Figure 11.6 shows an aluminium window fixed to a timber frame. There are several methods of finishing the opening and two of them are shown in Figure 11.6.

(a) Open eaves - bottom lined        (b) Open eaves-top lined

ALTERNATIVE EAVE STYLES TO BRICK VENEER

FIG. 11.4
vertical section

window sill
nosing
scotia
sill trimmer
sill brick
flashing
stud wall

flashing
window stud
nosing
architrave
reveal lining
window stile
window sill
sill brick

timber window frame in brick veneer construction

fig. 11.5
METAL (ALUMINIUM) WINDOW FRAME FIXED IN POSITION IN
BRICK VENNER CONSTRUCTION

FIG. 11.6
CHAPTER TWELVE - ROOF CONSTRUCTION

12.1 CLASSIFICATION

12.2 MEMBERS AND PARTS OF A CONVENTIONAL ROOF
   WALL PLATES
   CEILING JOISTS
   HANGING BEAMS
   RAFTERS
   RIDGE BOARDS
   VALLEY BOARDS UNDER PURLINS
   ROOF STRUTTING
   COLLAR TIES
   STRUTTING BEAMS
   SCISSORS RAFTERS

12.3 EAVES AND GABLE OR VERGE DETAIL
   EAVES CONSTRUCTION
   GABLE CONSTRUCTION

12.4 ROOF TRUSSES
   GANG-NAILS
   APPLICATIONS
   SIZES
   SUPPORT OF
   SET-OUT FOR

12.5 PATENTED METHODS TO SUPPORT SPANS

One of the most uniform trades throughout the domestic building industry is that of roof carpentry. This has evolved because of several important factors, not the least being the publication of the Uniform Building By-laws and the "Light Timber Framing Code: AS 1684-1975". Other factors include the standardisation of timber sizes, relatively little variation in types of roof covering materials and widely accepted trade practices.
12.1 CLASSIFICATION

Domestic type roofs can be one of two classifications.

(a) Those incorporating one system of timbering where no internal support is required. Some examples of this type are flat roofs, lean-to and coupled roofs. See Figure 12.1(a).

(b) Those incorporating two systems of timbering such as purlins and struts supporting the rafters. Most general residential roof constructions are of this classification. Figure 12.1(b) shows the basic roof shapes such as gable and hips and valley. These roof shapes are adaptive to variations, and composites of each example can be designed.

![Diagram of roof types: lean-to roof, couple roof, collar roof, close-couple roof, flat roof, and purlin roof (traditional).]

**FIG. 12.1(a)**
12.2 MEMBERS AND PARTS OF A CONVENTIONAL ROOF

The traditional conventional roof structure shown in Figure 12.2 is the underlying support to all the basic roof shapes. Simplified roof construction is possible (particularly in single systems such as lean-to, couple, collar and close couple), but those are seldom used for domestic construction - with the possible exception of the lean-to which can be incorporated in roof designs to give high-raked ceiling to feature areas of the building (exposed beams or rafters).

Two main sources of reference and regulations regarding roofing are the Western Australian "Uniform Building By-laws" and the "SAA Light Timber Framing Code". Figure 12.2 identifies the parts in a conventional roof frame. The view is sectional, looking into the roof space above the ceiling.
Following is a list of the structural members of a conventional roof frame, indicating their function, size and spacing.

WALL PLATES

Where timber-framed walls are used, the width of the wall plate must be the same as the wall framing and should have a minimum thickness of 50 mm. Special conditions apply in framed walls where the points of support for rafters, trusses, etc., are not within 1 to 5 times the thickness of the place from the wall stud. Your attention is brought to this point as it will be necessary to use a plate of dimensions specified in Table 75 of the "Light Timber Training Code, AS 1684-1975".

Where it is thought that high winds may cause "uplift", top plates to masonry walls can be secured by the use of 25 x 1.6 mm galvanized steel shapes embedded into the brickwork 1.2 m below the plate and the upper end wrapped over the plate and firmly nailed to it. This anchoraged can be provided at 1.8 m centres for tiled roofs and at 1.2 m centres for metal roof coverings.

CEILING JOISTS

Ceiling joists are the members which span horizontally across the room at ceiling height to which the ceiling lining material is fixed. Building practice in domestic construction gives two sizes for ceiling joists.

(a) 75 x 50 mm timber at 450 mm spacings for a single span of 1.8 m and a double span of 2.0 m;

(b) 100 x 38 mm timber at 600 mm spacings for a single span of 2.0 m and a double span of 2.4 m. The minimum truss grade for ceiling joist timber is given in Table 10.5 of the "Light Timber Framing Code".

HANGING BEAMS

Hanging beams or hangers provide immediate support to ceiling joists. Building practice gives a size of 200 x 32 mm, with a maximum span of 3000 mm for hanging beams. The connection between the hanger and ceiling joist should be effected by purpose-made galvanized hoop-iron hanging straps or by the use of 32 x 32 mm hardwood soldiers fixed on alternative sides of the hanger.

Hangers should be blocked up from the plate to place the bottom of the beam on top of the ceiling joists. Where the pitch of the roof necessitates the reduction of the hanger by more than two-thirds of its depth, provision must be made to provide adequate support. Figure 12.3 shows an example of end support.
COMMON RAFTERS

There several factors to be considered when determining the span and size of rafters. Considerations include overall span of rafters, spacings of rafters, eaves projection, system of roof cladding, and the stress grade of the timber to be used.

Building practise gives two sizes:

(a) 100 x 50 mm at 600 mm spacings for a maximum single span of 2.0 m and maximum double span of 2.4 m each;

(b) 125 x 38 mm at 600 mm spacings for a maximum span of 2.2 m and maximum double span of 2.7 m each. Where sizes are required to vary from those given, they should conform to height Timber Framing Code, Tables 13 S (A) and 13 S (B).

RIDGE BOARDS

Ridge boards are used to provide fixing for the upper ends of rafters, and to maintain equal spacings and keep them parallel. Ideally, ridge boards should be at least 25 mm thick and the vertical depth should exceed the plumb cut of the rafters by at least 50 mm. This would give most ridge boards a size of 175 x 25 mm.

When splicing or jointing of ridge boards is unavoidable, a suitable scarf joint should be used, or the ridge board may be abutted - provided a 25 mm thick timber fish plate is fastened to each side of the ridge board for its total depth.
HIP RAFTERS

According to the Light Timber Framing Code, hip rafters may be 50 mm deeper and 13 mm thinner than the size of the common rafter used. Building practise considers 175 x 25 mm is more than adequate.

VALLEY RAFTERS

Because of the different loading on a valley rafter to that of the hip rafter, the thickness of a valley rafter is recommended in the "Code" as 38 mm, while, once again, the depth is recommended as 50 mm more than the depth of the common rafter. This specification is greater than the Building practice minimum size of 175 x 32 mm.

JACK RAFTER

The jack rafter runs from the end of the ridge to the wall plate. It is one half the thickness of the common rafter shorter than the common rafter itself.

CREEPER RAFTER

The creeper rafter runs from the hip rafter to the wall plate.

CRIPPLED RAFTER

The crippled rafter runs from the ridge brand to a valley rafter.

CRIPPLE CREEPER RAFTER

This runs from the hip rafter to a valley rafter.

VALLEY BOARD

Valley boards of not less than 19 mm in thickness should be laid over the ends of crippled rafters where they join into the valley rafter, in order to support the valley gutter.

UNDERPURLINS

Underpurlins are used to provide immediate support to rafters. Underpurlins are usually 100 x 75 mm, fixed on edge at such spacings so that they do not exceed the rafter spans given earlier under "Common Rafters". Generally, underpurlins should be in as long a length as possible and, when jointing is necessary, the joint should be of the half-lapped type and the parts nailed together. Underpurlins need to be supported by struts, and the specified strut centres and underpurlins spans should not be exceeded.
UNDERPURLIN STRUTS

FIG. 12.4

ROOF STRUTTING

The concept of roof strutting is that all roof loads and wind loads imposed on the roof structure are taken by the most direct route to the building footings and thus the foundations.

Purlin struts are generally 75 x 75 mm or 100 x 75 mm for tiled roofs, and should be fixed either plumb or perpendicular to the roof slope. Struts should be either birds-mouthed or halved to accommodate the purlin. They should only come to rest on load-bearing walls or adequate strutting beams. Figure 12.4 shows roof strutting and purlin fixing details.
TERMS APPLYING TO ROOF FRAMING

FIG. 12.5

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COLLAR TIES

Collar ties should be fitted to each alternate pair of rafters where the span is great enough to warrant support by underpurlins. The collar ties should be fitted immediately above the underpurlins and be bolted to the rafters with 10 mm diameter galvanized bolts. The size for collar ties as stated in the U.B.B.L. is 75 x 50 mm. However, this is a minimum size only and should be increased up to 100 x 38 where the length of the tie is greater than 4.2 m.

STRUTTING BEAMS

Strutting beams are used to provide a solid means from which roof struts can be founded. This is necessary when there is no load-bearing wall within practical strutting distance.

There are a few rules to be observed when considering the use of strutting beams.

(a) Strutting beam ends must rest on load-bearing walls.

(b) Strutting beams must be blocked up so that the bottom of the beam is 25 mm clear of ceiling joists to allow for deflection.

(c) When strutting beams are also used to support intersecting hangers, then the size of the beam must be increased accordingly.

(d) Where it is not practical to land strutting beams other than over openings, then the beam must rest on a lintel above that opening. The lintel above the opening must be designed as a strutting beam. See Figure 12.6 for one method of fixing a strutting beam.

A METHOD OF FIXING STRUTTING BEAMS TO ACHIEVE FULL END SUPPORT UNDER LOW-PITCHED ROOFS AND CLEARANCE ABOVE CEILINGS

FIG. 12.6

(Reproduced by Courtesy of the Standards Association of Australia)
SCISSORS RAFTERS SUPPORTING UNDERPURLINS

FIG. 12.7

(Reproduced by Courtesy of the Standards Association of Australia)

SCISSOR RAFTERS

Scissor rafters can be used to provide support to underpurlins where conventional strutting is not practical.

12.3 EAVES AND GABLE OR VERGE DETAILS

EAVES CONSTRUCTION

Eaves construction consists of open eaves or boxed eaves, although there are a variety of ways to construct each of them. In Chapter 11 there are diagrams showing types of eaves for brick-veneer construction. Figure 12.8 shows different methods of constructing both open and boxed eaves.
GABLE OR VERGE CONSTRUCTION

Where a roof construction is projected beyond an external wall to form a gable end or verge overhang, the unsupported length of any cantilever should not exceed one quarter of the maximum span for that size timber used elsewhere in the roof construction. That is to say, if a 100 x 50 mm trimmer is used, it should only cantilever quarter of the 2.0 m allowable span for single span rafters. At least one half of any such projecting member must be retained within the building. (See Figure 12.5)

12.4 ROOF TRUSSES

A timber roof truss is a self-contained frame, usually (but not necessarily) triangular in shape, which is designed so that the truss members will transfer all of the loads acting on the frame onto the outside support walls.

GANG-NAIL ROOF TRUSSES

The gang-nail roof truss system has rapidly gained acceptance as an effective alternative to on-side roof construction. This truss derives its name "gang-nail" from the patent gang-nail connector plate which is used to connect the various truss members. The connectors are high-tensile steel plates from which a number of nail-like spikes have been punched out at right angles to the plate itself. They are made in a variety of sizes to suit the size of the timber used in the truss. When correctly placed, and firmly pressed into the timber, the gang-nail connector provides a simple and effective joint between the truss members. While there are other types of connector plates available, the gang-nail truss system is the one most commonly used today.

APPLICATIONS OF GANG-NAIL TRUSS SYSTEMS.

Gang-nail truss systems are designed by the fabricator’s own engineers to suit the roof slope and the roof profile specified in the builder’s plan. A licensed truss fabricator can produce trusses to suit a wide range of roof designs, from simple gable and saw-tooth roofs to hip and valley roofs. Gang-nail truss systems can also provide an economical roof for certain types of industrial buildings where the manufacturers claim that they can compete favourably in price with steel truss systems.

TIMBER AND TIMBER SIZES OF TRUSS MEMBERS

The dimensions for the timbers chosen will depend upon the design of the truss and on the type of timber used. At the factory the wood is graded visually and timber possessing any of the following defects is rejected: sloping grain, knots, filling faults, sapwood, splits, excessive spring, and brittle heartwood.

Unseasoned hardwood is commonly used in the manufacture of roof trusses; the common thickness of all truss members for domestic roofs is generally 38 mm. Top and bottom chords and web
members are 125 mm and 100 mm wide. However, variations to these sizes will occur according to the type of timber used, the imposed roof loads, and the type of truss design.

SUPPORT FOR TRUSSES

The standard gang-nail roof truss is designed to span from one outside wall plate to the other and to bear ONLY AT THESE TWO POINTS. It is most important that the truss bottom chords, and, if used, ceiling joists, do not bear on internal walls unless specially designed to do so. These should be a minimum gap of 12 mm between the bottom chord and the top of internal walls.

Loads over openings in the outside bearing walls must be contained and transferred to each side of these openings and so onto the footings. For a large opening, extra reinforcing is required in the top part of the footings to compensate for bending action that takes place under the opening, due to the extra load imposed on each side of the opening.

SET-OUT FOR ROOF TRUSSES

It is usual for the truss manufacturer or fabricator to supply a plan of the roof showing the lay-out of the various trusses. The measurements to which each truss is to be located on the top wall plate is also provided. Each of the different types of trusses is coded with an identifying symbol or member which is marked on the plan and on the truss. It is important that the on-site carpenter sets out the wall plates strictly in accordance with these directions. Figure 12.9 shows a typical gang-nail truss.

12.5 PATENTED METHODS TO SUPPORT SPANS

There are several patented designs of straps or bolts on the market designed to support spans in roof members where struts or strutting beams are uneconomical, or where there is no other means of support for these members. Figure 12.10 shows four types of straps or bolts and where they are commonly used.

Some straps are tensioned by extending a screw jack in the centre, whereas the bolt type are usually tensioned by the use of nuts at each end of the bolt.

There are other types than those shown available, but the principle in most cases is the same.
TWISTED HIP & RAFTER STRAP

UNDERPURLIN STRAP

RAFTER BOLT

HIP, VALLEY or RIDGE BOLT

FIG. 12.10
CHAPTER THIRTEEN - JOINERY

13.1 GLUES

13.2 DOOR FRAMES AND DOORS
   DOOR FRAMES
   DOOR FRAME CONSTRUCTION
   DOOR JAMBS
   METAL DOOR FRAMES
   DOORS

13.3 WINDOWS
   TYPES
   CORNER WINDOWS

13.4 FIXINGS

13.5 JOINTS USED IN JOINERY
   WINDOW AND DOOR FRAMES
   WINDOW SASHES AND FRAMED DOORS
   INTERNAL DOOR FRAMES
   DRAWER AND CUPBOARD CONSTRUCTION
   ARCHITRAVES AND SKIRTINGS

13.6 GENERAL HARDWARE
JOINERY

The work of the joiner, although closely allied to that of the carpenter, is distinguished from it by the fact that the former deals with the fittings and finishings and not with the structural members of the buildings. Such items as doors, door frames, window frames and sashes, linings, panelling, stairs, etc. are included in the term finishing.

A wide variety of timbers suitable for joinery is available. The factors affecting the choice of the type of timber to be used are:

- appearance
- cost
- working qualities
- moisture movement
- availability in sizes required.

Timbers for joinery can be selected from the following list, considering the factors already mentioned:

- Jarrah
- Western Australian Blackbutt
- Pacific maple (red) and (white)
- Radiata Pine
- Oregon.

13.1 GLUES

There are many glues suitable for use in joinery. As with timbers, the choice will depend upon the performance required. P.V.A. (polyvinyl acetate) is the most common woodworking glue. It is cheap, easy to use, and has a long pot life - but is not waterproof.

A wide range of synthetic resins and glues is available to suit a wide range of situations and materials. Even the humble P.V.A. is manufactured to several different specifications to suit different materials and ambient temperatures.

Some glues used in building and joinery work are:

(a) Casein - used cold, cheap, moisture resistant.
(b) Urea Formaldehyde - used in manufacturing, resistant to moisture.
(c) Phenol Formaldehyde.
(d) Melamine Formaldehyde
(e) Resorcinal Formaldehyde (produced in a variety of formats and is waterproof).
(f) Epoxy glues (have superior adhesion and gap filling qualities).

13.2
(g) Contact cements (used for site fixing laminates, etc., which would otherwise require pressing).

Where the exact characteristics of the material to be glued is unknown, advice should be sought from the manufacturer to ascertain the limitation of the various glues being considered.

The following list of variables will give some indication of the number of factors which may effect the suitability of a particular glue:

(a) cost
(b) adhesion to non-porous surfaces
(c) colour/stain (Does the colour matter, or does the glue stain the timber?)
(d) resistance to water, chemicals mould, high ambient temperature
(e) gap filling properties (Is close contact necessary?)
(f) compatibility (with the material to be glued)
(g) creep resistance (Will it yield under constant stress?)
(h) conditions of use such as:
   . pot life
   . setting time
   . ease of application - skill, special equipment
   . suitability for site use.

13.2 DOOR FRAMES AND DOORS

The doors and windows of buildings are of exceptional importance in utility and design and, while many of the old principles and details of construction are not very frequently followed nowadays, it is still difficult to better them. As an example, internal doors were once almost all of the panelled type; in modern times the flush door is most favoured because of cost and architectural styles. Another example is the replacement of timber door frames with metal door frames, because of costs and durability.

DOOR FRAMES

In brick constructions wooden frames for doors are built into the wall as the brickwork proceeds, being secured at intervals by means of hoop iron fixing straps. These straps are nailed onto the back of the frame at brick course heights and built into the bed joints of the brick work.

Frames built into a cavity wall can be secured by cavity cleats made to the exact width of the cavity and nailed to the back of the frame. There are usually three or four cleats, each about 300 mm long, equally spaced on each of the jambs.

Figure 13.1 shows a solid rebated door frame with sill, commonly used for buildings of brick construction.
DOOR FRAME CONSTRUCTION

In good work all the main frame joints are mortise and tenon. The jambs and heads for rebated frames are made out of 125 x 75 mm timber, and the sill at least 225 x 75.

Internal door frames for brick construction are made out of 125 x 50 material, and a stop is attached later during fixing out.

The width of the jamb will be governed by the width of the brickwork plus allowances for wall plastering. The plaster should finish flush with the door frame, and an architrave will cover the joint between plaster and frame.

Figure 13.2 (a) and (b) shows the recommended door-set sizes and clearances for a frame fixed into a wall.
Figure 13.2 should be read in conjunction with table 13.1: "Recommended Dimensions of Door-Set and Components".

NOTE: For explanation of $T_L$, $W_S$, and $W_L$ see Table 19.1.

**PLAN OF ALL DOOR-SETS**

13.2(a)

**SECTION OF ALL DOOR-SETS**

13.2(b)

(Reproduced by Courtesy of the Standards Association of Australia)
### RECOMMENDED DIMENSIONS OF DOORSETS AND COMPONENTS

<table>
<thead>
<tr>
<th>Dimension (Refer to Figs 1.1 and 1.2)</th>
<th>Description</th>
<th>Sizes</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>( H_b )</td>
<td>Height of doorset* (Coordinating dimension)</td>
<td>2100, 2400</td>
<td></td>
</tr>
<tr>
<td>( W_b )</td>
<td>Width of doorset† (Coordinating dimension)</td>
<td>600, 700, 800, 900, 1200, 1500, 1800, 1108†, 1208†, 1408†, 1708†</td>
<td></td>
</tr>
<tr>
<td>( T_L )</td>
<td>Thickness of door leaf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joinery ledged and braced doors</td>
<td>30, 35</td>
<td>+1, -2</td>
<td></td>
</tr>
<tr>
<td>General internal doors</td>
<td>40</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td>General external doors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( H_L )</td>
<td>Height of door leaf</td>
<td>2040, 2340</td>
<td>±2</td>
</tr>
<tr>
<td>( W_L )</td>
<td>Width of door leaf</td>
<td>520, 620, 720, 820, 1120, 1420, 1720, 1028†, 1228†, 1428†, 1628†</td>
<td>+2, 0</td>
</tr>
</tbody>
</table>

* The tabulated values for height include an allowance of 60 mm to cover the tolerances of the leaf and door frame or door jamb lining, and a carpet clearance.
† The tabulated values for width include an allowance of 80 mm to cover the tolerances of the leaf, the door frame or door jamb lining, and the coordinating planes.
‡ These widths are not dimensionally coordinated but are listed in the table for convenience.
§ The tabulated widths for double-leaf doors include an allowance for a rebate of 12 mm and are the total widths of rebated doors ready for hanging.

**TABLE 13.1**

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**DOOR JAMBS AND DOOR FRAMES**

The terms door frame and door jamb are used to differentiate between items of joinery which may have a sill, be rebated and used on an external wall such as a door frame, and those with no sill, used internally and with a planted stop - such as door jambs or jamb linings.

There is a marked difference between the two, as Figure 13.3 shows, however, the common usage of terms seem to be either "internal door frame" and "external door frame".

Because door jambs or internal door frames are built into brick walls which contain no cavities, fixing straps are used as the sole means of fixing the frame to the wall. Figure 13.4 illustrates the frame fixed in a partially built wall. The brick layer usually braces the frame up plumb with a plank or similar to maintain a true position while building in.
Door Frames and Door Jambs

Fig. 13.3

Internal Door Frame Being Built Into Position

Fig. 13.4
METAL DOOR FRAMES

Pressed metal door frames are now widely used throughout the building industry. There are significant advantages in the use of metal door frames:

- they are less expensive than timber door frames
- no mouldings have to be supplied and fixed, which is a labour cost and time factor
- they are less susceptible to damage during works
- they are resistant to termites and fire
- they do not warp.

VARIABLES METAL DOOR FRAMES

FIG. 13.5

13.8
Figure 13.5 shows a metal door frame being built in position. Note that the "Tee"-shaped metal fixing strap is placed behind the architrave return and laid in the bed joint of the brickwork.

Figure 13.5 also shows various metal door frame sections to suit particular brick sizes and cavity construction. Note again the position of the fixing strap; note, also, that the brickwork is built as far as possible into the back of the frame. Mortar should be placed in the remaining recess to give solid fixing and to eliminate the hollow drum sound when the door closes against the jamb.

DOORS

Doors in domestic construction are used to give privacy, security, and to divide areas.

Doors for security are usually entrance doors and should be either solid-core flush doors or panelled doors.

Internal doors are primarily used for privacy to rooms. The most economical and practical door for this use is the flush door, which consists of a light frame with a reinforced cardboard infill or horizontal rails. The framework is covered completely with hardboard, ply or veneered ply, depending on the quality of finish required. The door may or may not be finished with edge or margin strips to conceal the end grain of the hardboard or ply sheeting.

Figure 13.6 shows typical doors. Doors 1 to 7 inclusive are mainly used externally to buildings where appearance is secondary to security.

Doors 8 to 14, with the exception of 9, 10 and 11, offer very little security and it is advisable only to use them as internal doors.

Figure 13.7 gives sectioned views through the styles of doors 8 to 14.

Doors are usually fixed in position with butt hinges rebated into the jamb and also into the edge of the door. Where it is required to allow an external door to open flat against the wall—that is, to open 180°—a parliament hinge is often required, to place the turning point of the hinge outside the internal face of the wall.

For doors of less importance, such as doors which are unframed, a "Tee" hinge may be used, with the hinge fixed onto the waling or ledger.
DOORS

FIG. 13.6

SECTIONS THROUGH DOOR STYLES

FIG. 13.7

(From: A Glossary of Building and Planning Terms (2nd edition), Courtesy of the National Committee on Rationalised Building)
Figure 13.8 shows typical hinges in use.

TYPICAL HINGES

Fig. 13.8

(From: A Glossary of Building and Planning Terms (2nd edition), Courtesy of the National Committee on Rationalised Building).
When adjustment of the door is to be made it is often convenient to use loose-pin hinges. This enables the door to be removed from the jamb by simply removing the pin in the hinges instead of unscrewing all the screws.

Confusion is sometimes met when describing the opening of a door. The rule for designation of the "hand" of the door is:

- face the door to see the knuckles of the hinges
- when the knuckles of the hinges are on the left hand it is a left-hand hung door
- when the knuckles are on the right hand, it is a right-hand hung door.

Figure 13.9 (a) illustrates this for single leaf doors, and Figure 13.9 (b) illustrates the first opening for double doors.

**DESIGNATION OF CLOSING AND FACES FOR SINGLE-LEAF DOORSETS**

**FIG. 13.9(a)**

(Reproduced by Courtesy of the Standards Association of Australia)
The locking of doors is an over increasing concern for households. To obtain advice on the most modern security latches it will be necessary to discuss particular needs with the manufacturer's agent or an informed builder's hardware merchant.

Basically there are two classes of security devices - latches and locks.

The working mechanisms of latches cannot be locked, and merely serves to retain the door in a closed position. Latches are usually concealed inside the style by placing the case into a prepared mortice with the face of the case flush with the style. This unit of hardware is often called a mortice latch. (See Figure 13.10).

Locks obviously can be locked, as the name implies; however, the degree of security varies greatly between types of locks.

There are mortice locks available. As Figure 13.10 shows, there is provision for key locking of the apparatus. The key can usually be inserted from either side of the door.

A more sophisticated type of lock recently introduced is the dead lock, and double lock. (See Figure 13.11).

The dead lock is equipped with a multipinned cylinder. The lock incorporates an exclusive security device which can be triggered from outside with a key to prevent the turn knob separating, so that the door cannot be opened from inside.
FIG. 13.10

(From: A Glossary of Building and Planning Terms (2nd edition), Courtesy of the National Committee on Rationalised Building).
DEADLOCKS

FIG. 13.11

(Reproduced by Courtesy of Whitco Pty. Ltd.)
The automatic double deadlock is equipped with an inside as well as outside cylinder lock which, in the locked position, will prevent the turn knob from operating so that the door can only be opened from the inside or outside by using the key.

13.3 WINDOWS

All habitable rooms are required to meet minimum standards for the admission of natural light. This is usually done by using windows, which also serve as a means of providing natural ventilation to the rooms.

TYPES

Windows are described according to their opening mechanism, and the number and types of sashes which are incorporated in the overall frame. Like door frames, window frames are available in either metal or timber. The most common metal used is aluminium, extruded to shapes designed to lock together and hold glass in position.

Steel window frames are not in common use with domestic construction; however, they are often used in public building such as schools.
Figure 13.12(a) shows an extruded aluminium jambs, head and sill. Figure 13.12(b) shows the section through the jamb. The extruded sections are typical. It is important that the frame be securely fixed in position; this is done by anchor straps fixed to the head and bent over the inside lintel, and bricked in by the inside leaf of brick work. Further fixing is given by the use of anchor straps which lock onto the back of the jambs and are bedded into the brickwork, as well as sill anchors, which may be used when the sill is plastered. Where timbers sills are used internally, the sill anchors may be left out.

Horizontal Section
METAL WINDOW FRAME IN CAVITY CONSTRUCTION
FIG. 13.12(b)

It is important to note that windows are manufactured in sizes according to brick opening dimensions or brick-and-a-half opening sizes.

Timber window frames have been used for a long time and will continue to remain so where quality work is required.

There are many varieties of sash and frame varieties. The following figures show the opening sashed, as well as the general sash and frame profiles.

Figure 13.13(a), shows the awning sash window. The advantage of this type of opening is that it provides shelter from rain because of the sash projecting outwards, enabling ventilation to take place during humid, and wet days. The sash is held in place with a friction stay fitted to the side of each sash. This articulated fitting is suitable for timber or metal joinery. Sashes are secured with a sash fastener or chain winder. Figure 13.14(a) and 13.14(b) show examples of these.
AWNING SASH WINDOW ASSEMBLY

FIG. 13.13(a)
(Reproduced by Courtesy of the Standards Association of Australia)
CASEMENT SASH WINDOW ASSEMBLY

FIG. 13.13(b)

(Reproduced by Courtesy of the Standards Association of Australia)
DOUBLE-HUNG SASH WINDOW ASSEMBLY

FIG. 13.13(a)

(Reproduced by Courtesy of the Standards Association of Australia)
HOPPER SASH WINDOW ASSEMBLY

FIG. 13.13(d)

(Reproduced by Courtesy of the Standards Association of Australia)
PIVOT SASH WINDOW ASSEMBLY

FIG. 13.13(e)

[Reproduced by Courtesy of the Standards Association of Australia]
All brass combination pull and fastener for single or double casements or hoppers. Smooth surface prevents curtain tearing.

Designed for aluminium or timber awning type (hopper) windows with or without fixed fly screens. Allows window to be operated without removing the screen. Incorporates detachable arm chain.

(a) SASH FASTENER

(b) FULLY ENCLOSED WINDOW CHAIN WINDER

HARDWARE FOR AWNING WINDOW

FIG. 13.14

(Reproduced by Courtesy of Whitco Pty. Ltd.)

The most common type of timber windows would be the casement sash. (See Fig. 13.13(b)). Fixed about a vertical axis, the casement can be hung on friction stays fitted to top and bottom rail or hinged on butt hinges. Where butt hinges are used, a casement stay will need to be fixed to the bottom rail and sill to keep the window open. To lock the window sash fasteners are often used. Figure 13.15 shows a casement stay.

The hopper window shown in Figure 13.13(d) has the advantage that there is some protection from the weather, particularly if the spandrel between the sash and frame can be covered in. Because of the mechanics of sashes opening and closing a common horizontal point, the light hoppers must use either friction stays or side-arm stays to control the degree of opening. Securing the sashes is achieved by utilizing casement fasteners. Figure 13.16 shows a side-arm stay.

Pivoted sashes are a useful window in protected locations and are often used as high-lights over doors or internally over partitions. The pivoted sash embraces features of the hopper and awning sashes. However, there is difficulty in maintaining the sash in an opening position, as the pivot is slightly off centre, making the bottom portion of the sash the larger so that the sash will close under its own mass.
HARDWARE FOR CASEMENT WINDOWS

FIG. 13.15
(Reproduced by Courtesy of Whitco Pty. Ltd.)

FIG. 13.16
(Reproduced by Courtesy of Whitco Pty. Ltd.)

Where the sash is fixed over doors or in inaccessible positions, a cord-operated casement stay can be used for operating it from a lower level. Because of the threaded bar and secured cord, no further fitting as required to secure the sash. Sash pivots are fitted to each style and jamb.

(See figures 13.17(a) and (b) for fittings).
Double hung windows were once very bulky, because the styles were built up boxes to house cast iron counter-weights. These weights were connected to the sashes by cords which ran over a pulley on the style and suspended the weight out of sight inside the boxed section. Maintenance was often necessary - to replace damaged cords and to retrieve dropped weights.
DOUBLE-HINGE BOX FRAME

FIG. 13.18

(From: A Glossary of Building and Planning Terms (2nd edition), Courtesy of the National Committee on Rationalised Building).
DOUBLE-HUNG SASHES WITH SPIRAL BALANCE
FIG. 13.19

SASH FASTENER
(NOT TO SCALE)
FIG. 13.20

1 Stud
2 Head (A), Stile (B)
3 Outside sash lining
4 Top sash
5 Parting bead
6 Gears
6a Alternate gear position (B)
7 Meeting rails
8 Glass
9 Bottom sash (B)
10 Sill
11 Drip groove

(From: A Glossary of Building and Planning Terms (2nd edition), Courtesy of the National Committee on Rationalised Building).
Figure 13.18 shows the many parts of a boxed frame window designed to take double-hung sashes.

In recent times the weights and the boxed frame have been replaced by the sash balance, and, still more recently, by the spiral spring balance. Both of these fittings allow for the replacement of the bulky box frame with a smaller sectioned style. Figure 13.13(c) shows a part-sectioned view of a double-hung sash.

The advantage of such a window is that both sashes can be partly opened (that is, there will be openings at the top and bottom of the window), which will encourage a ventilating thermal cycle in the room.

Figure 13.19 shows a section and part plan of a double-hung sash with a spiral spring balance. The balance is recessed into the styles or, alternatively, it can be housed into the sash. Note how, in the sectioned view, the spiral is extended when the sash is down and compressed when the sash is up. Spiral balances come in a wide range of "sizes" which are determined by the weight of the sash. The object is for the spiral to maintain the sash in equilibrium so that the operator needs only a slight effort to raise or lower the sash.

Securing the sashes is by means of a "sash fastener" fixed on top of the meeting rails. (See Figure 13.20).

CORNER WINDOWS

Where it is a requirement to install a corner window, support of brickwork and roof over the opening must be provided. In a straight opening, support by on angle lintel would be provided and would be sufficient. However, on corner situations there must be two lintels from different directions meeting at the corner, and this corner needs to be supported.

Support to the corner is usually given by a steel pipe with base plate and top plate fixed.

Figure 13.21 shows a sectional plan, elevation and part isometric view of the pipe in position. The same arrangements can be made for metal joinery.
Components
1 Arch bars
2 Steel pipe
3 Base plate
4 Top plate
5 Sill, mitred at corner
6 Boxed-in pipe
7 Sill bricks
8 Window stile
9 Cement rendered reveal

SUPPORT FOR CORNER WINDOWS
FIG. 13.21

(From: A Glossary of Building and Planning Terms (2nd edition),
Courtesy of the National Committee on Rationalised Building).
13.4 FIXINGS

Fixing is the term applied to the fitting and securing into place of the internal finishings of a building, such as architraves, skirtings, picture rails, chair nails, window designs and wall panelling.

In brick construction, plugs need to be provided in the brick wall to receive the nails securing the moulding in place. Plugs were once positioned in the "perp" joint and this was necessary where large fluted skirtings were used. However, with the advent of small-section skirtings, it is now only necessary for one small plug to be positioned exactly where the nail is to be fixed.

The method of fixing skirting is to drill a fine hole in the skirting while it is held in position, so that the drill bit marks the wall. The nails to be used should be about the 3 mm to 3.75 mm size in diameter, so the bit needs to be about 2 mm to 2.5 mm to ensure a tight fit. The brickwork is drilled to receive a 10 mm dowel and plugged, then the skirting is fixed home.

The "fixer" uses a method of working around the room in sequence so that he minimises the number of scribes he has to do. Internal joints are scribed over and external joints are mitred.

The objective of the skirting is to finish the joint between wall and floor, and to provide protection to the plaster from furniture and cleaning equipment.

To conceal the joint between the wall and timber door and window frames, a moulding - also known as an architrave - is used. This piece is fixed to timber door frames by fine nails, and the intersection of horizontal and vertical pieces is formed by a neatly cut mitre joint.

Where windows are set into reveals, timber nosings are often used to form an internal ledge and thereby conceal the brickwork. Nosings are fixed onto the brickwork by plugging with a timber dowel and nailing securely in position.

Below the nosing a scotia mould is used to cover the joint between nosing and wall. Figure 13.18 shows the nosing (window board) and scotia in position.

Figure 13.22 shows a few common sizes and profiles of mouldings used in joinery.
<table>
<thead>
<tr>
<th>PROFILE SECTION</th>
<th>NOMINAL SIZES</th>
<th>FINISHED SIZES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200 × 38</td>
<td>181 × 30</td>
</tr>
<tr>
<td></td>
<td>175 × 38</td>
<td>155 × 30</td>
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<td>100 × 38</td>
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<tr>
<td></td>
<td>38 × 38</td>
<td>29 × 29</td>
</tr>
<tr>
<td></td>
<td>25 × 25</td>
<td>19 × 19</td>
</tr>
<tr>
<td>QUARTER ROUND</td>
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<td>40 × 40</td>
</tr>
<tr>
<td></td>
<td>38 × 38</td>
<td>29 × 29</td>
</tr>
<tr>
<td></td>
<td>25 × 25</td>
<td>19 × 19</td>
</tr>
<tr>
<td>SCOTIA</td>
<td>100 × 25</td>
<td>80 × 19</td>
</tr>
<tr>
<td></td>
<td>75 × 25</td>
<td>60 × 19</td>
</tr>
<tr>
<td></td>
<td>50 × 25</td>
<td>40 × 19</td>
</tr>
<tr>
<td>ARCHITRAVE</td>
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</tr>
<tr>
<td></td>
<td>75 × 25</td>
<td>60 × 19</td>
</tr>
<tr>
<td></td>
<td>50 × 25</td>
<td>40 × 19</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
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<td></td>
<td>38 × 19</td>
<td>30 × 12</td>
</tr>
<tr>
<td>DOOR STOP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TIMBER MOULDINGS**

**FIG. 13.22**

13.31
13.5 JOINTS USED IN JOINERY

Throughout the construction of domestic dwellings, and particularly in the fixing of fittings such as skirtings of architraves, the construction of window and door frames, and the installation of cupboards, various techniques in joining pieces of timber together are used.

The following notes describe some of the joints used in joinery and cabinet making.

WINDOW AND DOOR FRAMES

When the door is used in conjunction with a sill the construction is similar to that of a window frame in that the stiles are tennonned into the heads and sills. The figure below shows a mortice and tenon joint to the head and sill.

![Diagram of mortice and tenon joint]

**FIG. 13.23**
WINDOW SASHES AND FRAMED DOORS

The framework for a sash consists of a top and bottom rail and the vertical stiles. The stiles are morticed out to receive tennons from the rails. The joint is secured by using wedges to lock the tenon in place.

Framed doors also consist of rails and stiles, however a middle or lock rail may sometimes be used and often a centrally-placed vertical member known as a muntin is utilized.

The rails and stiles are morticed and tenoned together but the muntin mortice would not go all the way through the stiles but should be a stub tenon.

Window sashes use a single mortice and tenon joint, while the larger lock and bottom rails on doors use a double mortice and tenon joint.

FIG. 13.24

INTERNAL DOOR FRAMES

When timber door frames are used without a sill and are built into the wall, the only joint is between the stile and the head, and this is by means of a through housing joint. Fixing of the joint is done by two nails sloped together.
DRAWER AND CUPBOARD CONSTRUCTION

Drawer construction may utilize an interlocking joint known as a dovetail joint to hold the sides together. There are two types of dovetail joints used here; a common dovetail is used between the sides and back of the drawer, and a lap dovetail may be used between the sides and the front of the drawer.

The base of the drawer is held in position by placing the base into a groove moulded around the inside of the drawer carcase.

For cupboard constructions where a frame or skeleton is built up, the most common joints between rails and stiles are a butt joint with a corrugated fastener across the joint, a dowelled joint with two dowels sunk into each piece of timber and crossing the joint, or a checked joint when one piece of timber is housed into another.
When sheet material is used in lieu of a framework the sheets are housed and fixed together.

ARCHITRAVES AND SKIRTINGS

When a change of direction has to be made and the material is to keep the same format, a mitred joint is employed. For external corners on skirtings a mitre joint is used, and for internal corners the joint is scribed.

Architraves are mitred to form around door opening. With architraves the mitre is on the face, while with skirtings the mitre is on the edge.
13.6 GENERAL HARDWARE

From time to time during the construction of a domestic dwelling the builder will be required to fix items of hardware other than those mentioned previously in this chapter. Such items include latches for gates, door closes, sliding barrel bolts, roller catches, etc.

The following illustrations are typical items and an indication of where they may be required.

(a) Barrel Bolts - used on the inside of doors and cupboards.

(b) Flush bolts - designed for use on timber doors; they are recessed into the back of the door to set flush with the surface.

FIG. 13.29  FIG. 13.30
(c) **Cabin Hook** - used on the inside of doors and also on gates to keep them closed.

![FIG. 13.31](image1)

(d) **Hat and Coat Hook** - fixed to walls or on the back of doors to suspend coats and hats on.

![FIG. 13.32](image2)

(e) **Cleat Hooks** - used to secure restraining cords from fanlights, overhead pivot hung windows, etc.

![FIG. 13.33](image3)

(f) **Screen door Catch** - designed to suit metal or timber doors, opening in or out.

![FIG. 13.34](image4)
(g) Handles – suitable for drawers or doors.

(h) Door Knocker and plate – designed to receive night-latch cylinder.
(i) Surface mounted bolt and indicator with slotted button - designed for use with toilet partitions/doors.

**FIG. 13.37**
CHAPTER FOURTEEN - ROOF PLUMBING

14.1 ROOF COVERING MATERIALS
14.2 PROFILED SHEET METAL
14.3 ROOF TILES
   FIXING TILES
14.4 CORRUGATED ASBESTOS CEMENT
14.5 PROFILED ALUMINIUM SHEETING
   ROOFING PROFILES
   ROOFING SHEET ACCESSORIES
   FIXINGS
   COMPATIBILITY
14.6 CUTTERS AND DOWNSPUES
   GUTTERS
   DOWNSPUES
   SEAM POSITIONS
   FASTENING OF
   PROTECTION OF
   RAINWATER HEADS
14.7 FLASHINGS
   TYPES
   CHIMNEY FLASHING
14.1 ROOF COVERING MATERIALS

The materials in common use are tiles (cement and clay), corrugated asbestos cement, corrugated and profiled sheet metal, and profiled sheet aluminium.

Associated materials which can be used as flashings and water-proof barriers include copper, lead, zinc, specially manufactured bituminous felts, and asphalt.

The selection of anyone particular roof covering material could be influenced by one or more of the following factors:

- pitch of roof
- durability
- maintenance cost
- fire hazard
- weight
- design and appearance
- initial cost.

14.2 PROFILED SHEET METAL

Corrugated profiled sheetmetal has been accepted as a roof covering material in Australia for many years. Technological advances have made it possible to produce corrugated sheetmetal and, indeed, most profiled sheetmetal products in long lengths to suit the customer's exact requirements.

Galvanized steel is seldom used for profiled products these days. An aluminium/zinc alloy coating known as zinclusm is now used. It is important to note that where zincalume products are used it is not practicable to solder; instead, sealants and fasteners should be used. Also, lead flashing or lead accessories should not be utilised; use only zinc, zincalume or galvanized flashings.

The minimum pitch to which corrugated sheets should be used is 5° or a slope of 1 in 12.

Other types of profiled sheeting are available from various fabricators. The sheeting falls into two basic categories:

(a) rib-fixed sheets
(b) clipped-on tray-type sheets.

Rib-fixed sheets must only be fixed through their ribs or crests. A range of fasteners (complete with neoprene seals) is available to suit the various products. The pitch of rib-fixed profiles is usually limited to 5°:

Clipped-on tray-type sheets are attached by means of fixing clips which are fastened to the roof framework by means of screws, etc., and the tray-type sheeting is positioned over the clip and pushed down onto it thus locking it in position (as the clip and tray sheet have a rib designed specifically to lock tight after being pushed together). The pitch of such types of roof sheeting materials is usually only 1° - sufficient to allow for water run-off.
14.3 ROOF TILES

Tiles for covering can be readily divided into two types - clay tiles and cement tiles.

Clay tiles are made from specially selected and blended clays to give the required colour and finish, and are cast in moulds before being taken to a kiln for firing. (See Figure 14.2)

Cement tiles are manufactured from sand, cement and selected fines. After shaping and colouring, they are steam-cured under controlled conditions to give the strength required. (See Figure 14.1).

FIXING TILES

Clay tiles are nailed to battens, the size of which varies according to the spacing of rafters. For the normal rafter spacing of 600 mm, the battens used are 50 x 25; for 900 spacings, 50 x 38 battens; for 1 200 spacings of rafters, 50 x 50 batten. Battens are spaced at from 335 to 350 mm centres according to the pattern of the tile used.

Marseilles-pattern clay tiles have a minimum of 18° pitch without sarking and 15° pitch where sarking is used.

Swiss-pattern clay tiles have a minimum of 15° pitch without sarking and 12° with sarking.

When nailing clay tiles onto the battens, 50 x 2.65 mm galvanised nails should be used.

Concrete tiles are normally nailed to 50 x 25 battens for the usual rafter spacings of 600 mm. For spacings up to 750 a 38 x 38 mm batten is used, and for spacings up to 900 mm a 50 x 38 batten is used.

The minimum pitch for cement tiles is 15° unsarked; 12½° with sarking. Every cement tiles in the second course is usually nailed, there after, every tile in every third course. 57 x 2.65 galvanised cleats are used.

TYPICAL CONCRETE TILE

FIG. 14.1
14.4 CORRUGATED FIBRE CEMENT

Corrugated fibre cement is made from fibre (or substitute), portland cement and water. Though many products are called "asbestos" (e.g. "asbestos fencing"; "asbestos sheeting", etc.) the actual asbestos content of such products is being reduced or completely removed, due to the health hazard of this material.

Corrugated cement can be fixed to roofs pitched as low as 5° or 3° with side and end lap sealed. However, consultation with the manufacturer is advisable when fixing below 5° pitch.

The roof sheets are fixed to roof purlins which should not exceed 1.2 m. Battens or purlins should be no less than 75 x 38 where the rafter spacing does not exceed 750 mm.

Under the Constructions Safety Regulation, it is required that safety mesh be fixed immediately under the sheeting and over the rafters. Safety mesh is not required where the purlins or battens are spaced closer than 610 mm or where the roof is to a single storey dwelling house or one of its out-buildings.

The fixing of fibre sheeting requires no highly specialised skills. Observance of the manufacturer's instruction regarding
size and type of screws, direction of fixing, precautions, preparation and laying should ensure a neat, waterproof and aesthetically pleasing roof covering.

Manufacturers of corrugated fibre cement sheets have at their disposal competent and helpful representatives, as well as design and estimating teams which are available to perspective users. It is sensible to make use of these facilities when building with any fibre product.

14.5 PROFILED ALUMINIUM SHEETING

Profiled aluminium sheet is suitable for long span, lightweight roofs. Examples of the types of structures on which aluminium sheeting has been used include industrial buildings (such as factories, warehouses, storage sheds, etc.), covers on reservoirs, agricultural uses (such as shearing sheds, stock sheds, poultry sheds, equipment and storage sheds, etc.), educational buildings, sporting stadiums, hospitals and health centres, domestic uses (such as houses, carports, porches, garden sheds), and construction uses (such as site storage, site workshop, temporary site housing, etc.).

Aluminium is one of the lightest practicable roofing materials available. Typical weight comparison are:

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight Range</th>
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</thead>
<tbody>
<tr>
<td>aluminium</td>
<td>1.37 kg/m² - 3.27 kg/m²</td>
</tr>
<tr>
<td>galvanized steel</td>
<td>8.54 kg/m² - 10.99 kg/m²</td>
</tr>
<tr>
<td>fibre cement</td>
<td>17.09 kg/m²</td>
</tr>
<tr>
<td>terracotta tile</td>
<td>58.6 kg/m²</td>
</tr>
<tr>
<td>concrete</td>
<td>87.88 kg/m²</td>
</tr>
</tbody>
</table>

Aluminium sheet is extremely resistant to atmospheric corrosion. In marine and industrial environments the service life of aluminium is much longer than other metal roofing sheets of comparable price; in certain environments, it is superior even to expensive cladding metals.

ROOFING PROFILES

Aluminium roofing sheet is produced in a wide range of profiles, the various configurations being designed to combine maximum flexural strength, weather sealing, and optimum rain shedding characteristics consistent with economic use of the metal.

Aluminium roofing sheets fall broadly into three categories:

1. laterally over-lapping sheets
2. side locking sheets
3. end locking sheets.
LATERALLY OVERLAPPING SHEETS

Laterally overlapping sheets are of three types:

(a) Deep rib sheets with 30 - 50 mm deep ribs usually in a rib-pan configuration. (See Figure 14.3(a)).

(b) Shallow rib sheets with ribs less than 30 mm deep. The profiles may be angle rib or double rib type. (See Figure 14.3(b)).

(c) Corrugated sheets with symmetrical rib-trough configuration with a rib depth of approximately 20 mm. (See Figure 14.3(c)).

SIDE LOCKING SHEETS

Side locking sheets have a snap-locking action at the overlapping rib providing weather sealing characteristics without the necessity for intermediate side fixing. They are normally fixed to the purlins with patented fastenings which avoid the need to pierce the roofing sheet.

Side locking sheets are usually of the single or double-rib type, with rib depths of 40 to 60 mm. (See Figure 14.3(d)).

---

**SHEET ALUMINIUM PROFILES**

**FIG. 14.3**

14.6
**END LOCKING SHEETS**

End locking sheets are supplied in coils up to 40 m long and approximately 700 mm wide, with the profiles across the width of the sheet. This type of sheet is unrolled and fixed parallel to the eaves. Successive strips are overlapped and snap-locked along their entire length and attached to continuous cleat strips fixed to the purlins. No further fixing is necessary. (See Figure 14.3(e)).

**ROOFING SHEET ACCESSORIES**

The availability of accessories varies from manufacturer to manufacturer. Generally the following accessories are available ex stock.

- Ridger Capping
- Eaves Flashing
- Gutter Flashing
- Fascia Flashing
- Flashing Closure
- Valley Gutter
- Moulded Closure Strip
- Barge Flashing

**FIXINGS**

- aluminium wood screws
- aluminium self tapping screws
- aluminium hookbolts, bolts and nuts
- aluminium ring and domed washers
- aluminium shaped washers
- neoprene washers
- stainless steel nails
- stainless steel self tapping screws
- patented clip fixings.

**COMPATIBILITY**

Physical contact between aluminium roofing sheet and other materials commonly employed in construction may give rise to conditions conducive to corrosion, so steps should be taken to interpose barriers between them. These barriers are usually in the form of coatings with a very low moisture transmission factor or, in severe environments, plastic sheet or tapes.

Under no circumstances should copper or copper alloys be allowed to come into physical contact with aluminium roofing sheet, and care must be taken to avoid water run-off from copper coming into contact with the sheet.
14.6 GUTTERS AND DOWNPIPES

GUTTERS

There are two main types of gutters used: those which pass around the outside of a building and known as eaves gutter, and those which are used with the roof itself (of which the most common is a boxed gutter). Gutters are named by virtue of their shape or application (box, roof, hidden, etc.).

1- ogee  2- quad  3- streamline  4- sheerline fascia gutter

5- hidden gutter  6- box gutter

7- parapet box gutter

COMMON TYPES OF GUTTERS

FIG. 14.4
8. half round

9. chimney tray

10. valley gutter

11. secret gutter

COMMON TYPES OF GUTTERS (cont.)

FIG. 14.5
Eaves and box gutters are joined by rivetting and sweating, or rivetting and sealing if zincalum is used. The most commonly used gutters are: (See Figure 14.4 and 14.5)

<table>
<thead>
<tr>
<th>ogee</th>
<th>box</th>
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<tbody>
<tr>
<td>quad</td>
<td>parapet box</td>
</tr>
<tr>
<td>streamline or longline</td>
<td>chimney tray</td>
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<tr>
<td>a sheerline fascia gutter</td>
<td>valley gutter</td>
</tr>
<tr>
<td>hidden</td>
<td>secret gutter</td>
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</tbody>
</table>

Provision must be made for expansion in a line of gutter when it is over 15 m long. In a box gutter, this is done by soldering a stop end in each section of gutter and allowing at least 25 mm space between each section. The gap is then covered with a loose cover piece to prevent leaking. In eaves gutter where expansion must be allowed in the middle of a long run, a stop end is provided 50 mm to 75 mm from one end of one section and a normal stop end in the other section. The second piece is allowed to fit inside the first piece so that one overlaps the other and no break is visible from the ground. A cover piece is then used over the stop ends similar to that used for box gutters.

DOWN PIPES

To convey rainwater to the ground from gutters, downpipes of round, square or rectangular sections are used. The size of the downpipe required is related to the area of the roof being drained, and for every one square metre of actual roof area drained, 100 square millimetres (end section area) of downpipe is required. This is based on a maximum rainfall of 140 mm per hour.

It is advisable to drain to different points using smaller downpipes, rather than one large outlet. Maximum spacing advisable for downpipes to eaves gutters is 12 metres and, for box gutters, 18 metres.

POSITION OF SEAMS ON DOWNPIPES

On graded downpipes seams should be kept at the top so that, if the seam should become defective, it will not leak so rapidly as it would if placed on the bottom.

On vertical downpipes, the seam is usually hidden at the back or facing the wall. If a vertical downpipe is fixed abutting a wall and a seam becomes defective, serious damage to the building may result. Where the position of the downpipe is not conspicuous, the seam should be kept to the front.

METHODS OF SECURING DOWNPIPES

Downpipes are secured to walls by means of pipe hooks, straps or bolted clips. These should be of the same metal as the downpipe to avoid possible deterioration of the metal by electrolytic action.
PROTECTION OF DOWNPIPES

The lower ends of downpipes, which are liable to be damaged, may be protected by one of the following methods:

(a) by placing the downpipe in a recess formed in the brick or concrete wall (see Figure 14.6(a));

(b) by building a stout timber box around the pipe (see Figure 14.6(b));

(c) by changing the lower end of a sheet iron downpipe to cast iron downpipe (see Figure 14.6(c));

(d) by fitting a sleeve of wrought iron pipe around a sheet iron pipe, (see Figure 14.6(d)).

(e) by fitting a length of square or rectangular cast iron drain pipe in a prepared recess in the wall, (see Figure 14.6(e)).

METHODS OF PROTECTING DOWNPIPES

FIG. 14.6

RAINWATER HEADS

The discharge of water from a roof gutter or an eaves gutter is often made into a rainwater head, which is fixed externally and to which a downpipe is connected.

Water overflowing from the back and sides of a rainwater head will cause dampness on the walls behind it. To overcome this, an overflow from it should be provided in case stoppage occurs in the
downpipe. Covers are fixed over the top of rainwater heads to prevent foreign matter entering the head or downpipe and thereby causing a stoppage. (See Figure 14.7).

RAINWATER HEAD

FIG. 14.7

Where a parapet wall intervenes between the head and the end of a boxgutter, the roof water is passed through a shute or rectangular opening in the wall. This opening should be the same width and twice the depth of the gutter, to permit an unrestricted outlet for the water.
TYPES OF FLASHINGS

FIG. 14.8
14.7 FLASHINGS

Flashing is necessary to make water-tight connections between a roof and another part of a building, such as:

- gutters against a parapet wall
- walls against which roof may abut
- pipes passing through roofs.

Flashings are of the following general types:

(a) apron flashing

(b) straight hanging flashing

(c) stepped hanging flashing

(d) side flashing

(e) collar flashing

(See Figure 14.8)

(a) **Apron Flashing** is used where the top edge of a roof abuts a wall. The top edge of the apron flashing is turned into a brick course horizontal joint and should be carried up the wall above the roof surface by at least one course of bricks. They are only suitable for short sections of roof unless some allowance can be made for expansion and contraction.

(b) **Straight Hanging.** Flashing is secured by brick walls by inserting the turned-over portion of the flashing into a convenient horizontal joint in the brickwork.

The flashing is held in the joint of the brickwork with wedges made from lead or sheet iron, and with clips on them which will support lead flashing and prevent stretching.

The joint where the flashing is turned into the wall is pointed up with cement mortar.

(c) **Stepped hanging flashing** is fixed to brick or weatherboard walls. The side of soaker flashing is turned up the wall, and the hanging flashing placed over the outside of the turned up edge of the soaker flashing to form a watertight seal.

(d) **Side flashing** (or soaker flashing) is used with stepped flashings where a pitched roof abuts a wall, or where a chimney passes through a roof. Side flashing made of lead is laid on the top and is dressed into the shape of the tiles, and secured near the top of the upstand by nails driven into framework where it will be covered with stepped flashings.
(e) **Collar flashing** is used to provide a watertight seal where pipes pass through roof surfaces. Where the roof surface is tile, the lead flashing is dressed into the shape of the tiles at the sides, and the top edge lapped under the tiles above.

The joint between the collar upstand and pipe can be made water tight by:

i. soldering the colar upstand to the pipe;

ii. soldering a splay cone to the pipe to lap over the collar;

iii. fitting the top length of pipe over the collar.

**CHIMNEY FLASHINGS**

When a chimney intersects a roof, the junction between the roof and the chimney must be made watertight. The method used depends upon the type of roofing material used. On a tile roof the following flashings are required:

- chimney tray
- chimney gutter
- apron flashing
- side flashing
- stepped hanging flashing.

The position of the chimney tray is such that approximately half the length of the tray projects above the finished roof surface. The back edge of the tray is turned up as are the edges around the flue. Part of the sides are turned up and, where the tray breaks out over the roof surface, the sides at this point are turned down. The front of the tray is turned down over the top edge of the apron flashing.

On a tiled roof the first part of the flashing to be fixed is the chimney gutter. It should be given a good lap under the tiles at the back, and extended 150 mm past the sides of the chimney and lie on the surface of the tiles.

The apron flashing is let into the first suitable mortar joint under the turned-down edge of the chimney tray, and extends downwards on the surface of the tiles.

The side flashing with a 150 mm wide base and with a 50 mm upstand, is fixed at each side of the chimney, and should extend under the chimney gutter and lap over the side of the apron mould. The sheet lead is then dressed into the shape of the tiles. The stepped flashing is placed on the sides of the chimney and laps of the upturned edge of the side flashing.

**NOTE:** See Figures 8.23(a), 8.23(b) and 8.23(c) in Chapter 8 for the positioning of chimney flashings.
CHAPTER FIFTEEN - SANITARY PLUMBING

15.1 WATER SUPPLY
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15.6 SANITARY PLUMBING

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   DEFINITIONS
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15.8 SYSTEMS OF DISPOSAL
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15.9 WASTE WATER PIPES
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15.10 TESTING THE DRAIN
   VISUAL TESTING
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Continued ...
15.11 PROTECTION OF PIPES
SUPPORT

15.12 SEPTIC TANKS
REGULATIONS
SOAK WELLS
LEACH DRAINS
EVAPORATION DRAINS

15.1 WATER SUPPLY

All water supplies in Perth are under the jurisdiction and regulations of the Western Australian Water Authority. These regulations are officially called the "Metropolitan Water Supply, Sewerage and Drainage Act CTS and CAWS by-law 1990 and control all matters referring to water supply in the metropolitan area.

WATER SUPPLY SYSTEMS

Perth has an average rainfall of approximately 875 mm per annum. This quantity of rainfall would seem adequate to satisfy the needs of a population of about 1 million people. However, not all rainfall reaches catchment areas and dams.

Rain which falls on the ground may become contaminated with oils from vehicles, faeces from animals, and bacteria from the ground - just to mention a few causes. To help reduce the degree of contamination, water for domestic supply is only collected from specific locations known as to catchment areas, and from underground supplies known to be relatively pure.

Catchment areas are the first stage of the water supply system, and consist of rigidly controlled areas of virgin bush where only casual activities (such as bush walking) are permitted. Animals, hunting, camping and fishing are all prohibited in forest catchment areas to reduce the chance of pollution.

Despite all the above restrictions, pollution does occur, and needs to be removed by filtration and sterilisation using filters and chemicals - which often tend to make the water harder and less palatable than in its natural state.

Figure 15.1 shows a diagrammatic layout of water supply system.

From catchment areas the water flows to main reservoirs (3). (See Figure 15.1). As the water is stored (1), it goes through a natural purification process of sedimentation where the denser impurities gravitate towards the bottom of the reservoir. Finer particles remain suspended in solution, usually near the surface. To overcome this problem, the water is drawn off from the level of its greatest purity, which is usually 1 to 6 metres below the surface. The drawing off is done through the valve towers (2), which have inlets at various levels (4) in both the main and pipehead dams.

15.2
Pipehead dams (5) store water to provide a continuous supply should there be any problems at the main reservoir.

Water at the pipehead dam is allowed to stand for further purification by sedimentation before being chemically treated with chlorine and fluoride, and then passed into the trunk mains (6).

From the pipehead dams water is carried through trunk mains to service reservoirs (7) and service tanks (8). Service reservoirs and tanks allow for 3 - 4 days of emergency supply should there be a breakdown at the pipehead dam or in the trunk mains. A further breakdown in pressure is provided at the service reservoirs and tanks, the initial breakdown being at the pipehead dam.

For high areas tanks are preferred to reservoirs, to improve the water pressure in the supply to surrounding areas.

Service mains from the service reservoirs (9) and tanks (10) are usually built as interconnected networks which serve to allow for the constant flow of water (preventing any of it from becoming stagnant) and to allow for alternative water supply should there be any breakdown due to a burst water main.

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**Diagrammatic Layout of a Water Supply System**

*Fig. 15.1*

1. stored water from catchment area
2. valve tower
3. reservoir
4. inlet
5. pipe head dam
6. trunk main
7. service reservoir
8. service tank
9. service mains
10. service mains

[Diagram of water supply system]
15.2 WATER SUPPLY AND SEWERAGE PLUMBING

Plumbing services are of concern to everyone. It is a service which we have come to rely on for provision of hot and cold water, disposal of human waste matter, and provision of ventilation and air-conditioning.

AUTHORITIES

In everyday work the plumber, in most cases, operates under one or more of the many controlling bodies. These bodies or authorities govern such things as the standard of work, types of materials, and methods of installation. All plumbers should be familiar with these authorities and the areas which come under their control. The following list is for your guidance.

WESTERN AUSTRALIAN WATER AUTHORITY

The W.A.W.A. controls all the plumbing work in connection with the sewerage and water supply systems in Western Australia. This Board also provides and controls the storm water drainage system in the Metropolitan area. By-laws published by W.A.W.A. give the standards and requirements of plumbing work coming under their jurisdiction. As a result of new autonomy given to Government instrumentalities, W.A.W.A. has directed that licensed plumbers be responsible for their own testing of works being carried out. Thus, responsibility no longer rests with W.A.W.A. inspection staff, but with the installer - as was previously the case. As a result of this and other changes, W.A.W.A. issued a note to all licensed plumbers, to be effective from 18 September 1991. This note has been produced in its entirety at the end of the chapter.

LOCAL AUTHORITIES

Shire, Town and City Councils throughout W.A. have control over a certain amount of plumbing work through the application of the Health Act. Health inspectors are employed by these local authorities with part of their duties directed to the inspection of plumbing work covered by the Health Act. This control covers such things as the bactoriolytic treatment of sewerage (i.e., septic tanks) and the disposal of effluent and liquid wastes by soak wells, leach drains or French drains.

STANDARDS ASSOCIATION OF AUSTRALIA

This body sets the standards for the manufacture of most of the materials used by plumbers, whether they be in sheet, pipe or any other form. The W.A.W.A. uses these standards in the specification of materials to be used and these are listed in the appropriate By-laws. A.S.3500 Pts 1,2, & 4.

FIRE BRIGADES BOARD

Any equipment or fittings used in connection with a fire service to a building must meet the standards and specifications set out by this authority.
Approval must be obtained from this authority before any plumbing work on ships is carried out.

REGISTRATION AND LICENSING

When an apprenticeship is commenced the apprentice must be registered with the Western Australian Industrial Commission and the W.A.W.A. Proof of this registration is in the form of a certificate issued by W.A.W.A. This registration allows an apprentice to carry out work in connection with sewerage installations, provided the employment is under the direction and supervision of a licensed sanitary plumber.

At the satisfactory completion of an apprenticeship by an apprentice, a final certificate is issued by the Western Australian Industrial Commission, and the person is then registered with the W.A.W.A. as a tradesperson. To become a 'licensed' plumber, it is necessary to pass further examinations, set by the W.A.W.A. and satisfy the examiners of a sound knowledge in both the theory of the trade and in practical ability. The licensed water supply and sanitary plumber is then able to carry out any work in connection with the water supply, sewerage plumbing or drainage work within the area controlled by the W.A.W.A. In addition this license allows a person to employ registered plumbers to carry out work on their behalf.

15.3 WATER SUPPLIES - PIPES AND JOINTS

There is a large range of piping approved as being suitable for water supply work and the conditions under which they can be used are laid down in W.A.W.A. By-laws. The selection of piping used for each particular job will depend on the size of pipe required, the use for which it is intended, the initial cost and lifetime of material, together with the cost of installation. Considering each material in turn, they are:

1. CAST IRON PIPE

These are manufactured by pouring a measured quantity of molten cast iron, equal to the weight of the pipe, into a metal mould coated with a substance called plumbago which prevents the cast iron adhering to the mould. The mould is then rotated rapidly, utilising centrifugal force, to throw the molten metal against the sides to give an even wall thickness. When cool, the pipes are removed from the mould hydraulically. The pipes are then tested for flaws and leaks and coated with bitumen ready for use. When used for water supply work, cast iron pipes are usually coated internally with a cement lining to prevent corrosion and give a longer life. Cast iron pipes are usually of large diameter (100 mm and over) and are used for water mains (an soil stacks).
Jointing

These may be joined by the use of mechanical bolted gland joints or by circular rubber ring joints depending on the manufacture. In the case of repairs, "Gibault" mechanical joints can be used.

CAST IRON JOINTS (OLD TYPE)

FIG. 15.2

STRAIGHT CAST IRON PIPE FOR RUBBER SEALED JOINT

FIG. 15.3

(From: Water Supply 1, Basic Trade Manual 11-1, , Courtesy of the Australian Government Publishing Service)
THE GIBAULT JOINT

FIG. 15.4

(From: Water Supply 1, Basic Trade Manual 11-1, Courtesy of the Australian Government Publishing Service)

Changes of Direction

These are usually made with cast iron fittings joined in a similar manner as for pipes; however, where rubber ring joints are used, a certain amount of flexibility is achieved and curves of very large radius can be made.

2. FIBRE CEMENT PIPE

These are manufactured from three basic raw materials: cellulose fibre, cement and finely ground silica (sand).

The cellulose fibres are treated and blended and added to the finely ground cement and silica. A slurry is formed with the addition of water and the mixture is fed to the pipe machine. Here it is transferred from a rotating sieve onto an endless wool and nylon felt which transfers a thin layer onto the pipe-forming mandrel. As the pipe wall is built up to the required thickness, the layers are compressed
by high pressure rollers to form a homogeneous or uniform structure.

The pipe is freed from the mandrel by electrolysis and the mandrel is extracted hydraulically leaving a smooth polished bore. The pipes then pass through a hardening chamber to allow initial setting of the cement before the pipes are autoclaved in an atmosphere of high pressure saturated steam for final curing or setting. The pipe ends are then machined to take the required coupling.

Fibre cement pipes have a wide application in plumbing and are particularly suitable for high pressure water supply including industrial water supply, fire service mains and irrigation schemes. They are available in sizes ranging from 50 mm to 600 mm diameter.

**Jointing**

As a general rule, fibre cement pipes are joined by rubber ring joints but, where fittings are used or a break occurs in a pipe, "Gibault" type mechanical joints are used.

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**FC PIPE SPIGOTS AND COUPLING**

**FIG. 15.5**

(From: *Water Supply 1, Basic Trade Manual 11-1, Courtesy of the Australian Government Publishing Service.*)
Changes of Direction

These are usually by means of cast iron bends mechanically joined to the pipe. Because of the movement in the rubber rings joints when the pipe is filled with water, the pressure is likely to force the pipes apart, so large concrete blocks may be required behind the bend to prevent movement.

3. GALVANIZED WROUGHT IRON

These must conform with A.S. B105 of the Australian Standards Association to comply with the requirements of the by-laws.

G.W.I. pipes are made from flat steel strips or bars of the required wall thickness which are heated and drawn through formers and dies on a tube-making machine. The edges are automatically prepared for either a butt or lap weld in a continuous seam welding process. The pipes are then cut to length before being hot-dip galvanized, and the ends threaded. To increase the life span of G.W.I. pipes, they are sometimes lined with cement.

Jointing

Galvanized wrought iron pipes are joined by means of screwed threads. The external or male thread is usually tapered so that it will tighten up as it is screwed into the parallel female threads on the fittings.

GALVANIZED PIPE JOINT

FIG. 15.6

BSP THREAD ON GS PIPES

FIG. 15.7

(From: Water Supply 1, Basic Trade Manual 11-1, Courtesy of the Australian Government Publishing Service)
Changes of Direction

All malleable fittings for use with Galvanized pipe must conform to B.S. 1740. Changes of direction in G.W.I. pipes for water services may be made with the use of bends when used in an underground situation or elbows when used above ground. Bends are preferred for use underground because they give less restriction to the flow of water through them.

4. COPPER TUBE

These must conform to Australian Standards and be used in accordance with the W.A.W.A. By-laws.

Copper tubes are manufactured by a cold-drawing process where a cylindrical billet of solid copper is first heated to red heat then pierced on a mandrel to form a tube shell of much larger diameter and wall thickness than the finished size. When this is cooled, one end is reduced in size so that it can enter a cold drawing machine where it is drawn through a die. The drawing process stretches the tube, reducing both the diameter and wall thickness.

The process is repeated using successively smaller dies until the pipe is the required diameter and wall thickness or gauge. During the process of drawing, the pipe becomes work hardened which increases its tensile strength but reduces its ductility; therefore, it may be necessary to reheat the copper during the drawing process so that the final drawing imparts the required malleability to the finished pipe.

Copper pipes are usually supplied in hard-drawn lengths up to 6 m long, or coils of annealed or softened tube up to 30 m long.

Jointing

The most common method of jointing copper tubes is to heat one end, which is then expanded slightly to allow it to slip over the pipe and the capillary joint so formed is made watertight by the use of a silver brazing alloy (min. 1.8% silver on scheme water). All copper tubes used in a concealed position must be silver brazed and tested to withstand a pressure of 2 000 kPa.

Alternative methods of jointing to the above include the use of compression couplings and copper or brass capillary fittings using either soft solder joints or silver brazed joints.

Heavy gauge copper tubes are also manufactured which are suitable for threading in the same manner as G.W.I piping but using Brass fittings.
**CAPILLARY JOINTS—COPPER PIPES**

*FIG. 15.9*

**EXPANDED COMPRESSION JOINTS—COPPER PIPES**

*FIG. 15.10*

(From: Water Supply 1, Basic Trade Manual 11-1, Courtesy of the Australian Government Publishing Service)
Changes of Direction

These can be made with the use of suitable fittings and these must be used when light-walled tube is used, but for heavier walled tubes, bends may be formed in the tube itself. Bends may be made by cold forming using machines or the pipe may be softened, cooled and bent by using either internal or external springs, or the tube may be packed with clean dry sand and a suitable section of pipe heated and the bend made while hot.

5. PLASTIC PIPING

Although plastic piping has been available for some time for use on low-pressure water services (such as sprinkler systems), it is now available for use on high-pressure water services connected to the government mains. The conditions under which the pipe may be used are contained in Schedule D of the W.A.W.A., by-laws.

There are two types of plastic which have been approved for water supply work and these are un-plasticised polyvinyl chloride (which must conform to AS-K138-169 class P.F. up to and including 25 mm pipe) and high density polythene pipe (conforming to AS-K119-1969 type 50 class D up to and including 25 mm diam. pipe.

Because of the effects of ultra violet light on plastic, there are restrictions placed on its use in external locations where it is exposed to sunlight.

Both P.V.C. and polythene are known as thermoplastic materials and are manufactured by an extrusion process rather like squeezing toothpaste from a tube. The plastic granules are poured into a hopper, heated to the correct temperature at which they will bond and then forced out between a mandrel which gives the correct internal diameter and a die which gives the correct wall thickness and outside diameter. The plastic hardens on cooling to make it rigid.

Jointing

When used for water services, P.V.C. plastic tubing is joined by a solvent welding or gluing process where a chemical solvent painted on the internal surface of a fitting and the external surface of the pipe chemically bonds the two together.

High density polythene pipe cannot be joined by solvent welding or gluing and can be joined only by using approved screwed or compression joints.

Changes of Direction

Although these pipes may be gently heated to make bends of large radius, the most common method of changing direction is by the use of moulded fittings.
6. REINFORCED CONCRETE PIPES

These pipes are manufactured in sizes ranging from 100 mm diameter upwards and are used mainly for water supply mains. The pipes are manufactured to standard specifications set by the W.A.W.A. They are made in 2 m lengths but are extremely heavy to handle.

Jointing

Rubber rings are used to make a water tight joint similar to that used for cast iron or asbestos; however, mechanical type "Gibault" joints are available in case of pipe fracture and maintenance.

Changes of Direction

These are the same as for asbestos cement pipes.

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**Rubber Ring Joints in Reinforced Concrete Pipes**

FIG. 15.11

(From: Water Supply 1, Basic Trade Manual, 11-1, Courtesy of the Australian Government Publishing Service)
15.4 WATER SERVICE (GENERALLY) TO DOMESTIC RESIDENCES

Tapping into the main is the responsibility of the W.A.W.A. which brings the service to the boundary of the site. This service is not performed by the Authority until application is made to it for supply of water.

With the application on the prescribed form, an applicant must also provide two copies of the building plans, and pay the assessed building fee.

Before the Authority will connect to the main and give supply, the builder must engage a licensed plumber to provide and install an adequately supported stand pipe, complete with hose tap, situated not less than two metres horizontally from the proposed stop-cock position, together with the connecting pipe.

When the domestic service is complete and the temporary service is no longer required, the plumber can connect the consumer's pipes to the Authority's system direct. All pipe-work placed below ground level must be securely fixed to the structure by approved compatible straps fixed at centres applicable to the dimension of the pipes.

Where hot water supply pipes are concealed in chases, in brick or masonry wall, they need to be lagged with a suitable material of at least 6 mm thickness to accommodate thermal expansion of the pipe and to prevent cracking of the plaster over the pipe-work.

15.5 HOT WATER SERVICE

A hot water system can be described as a means of supplying water to any point or fixture at a desired temperature with little or no inconvenience to the user. The term HOT can be used when cold water has to be added to attain the desired temperature.

(a) NON-STORAGE

The non-storage of instantaneous or continuous flow type of heater, is a self contained unit without hot water storage, in which the cold water is heated as it flows through the heater. These heaters range from the low pressure single point types to multipoint mains pressure units; the former is manually controlled and the latter automatic in operation.

The low pressure single point units are usually situated over the fixture to be supplied with water and are connected direct to the mains supply by means of a stop-cock (for manual control) and a copper connection. The outlet to the fixture is an open pipe or shower rose as the case may be. Caution should be exercised so that no restriction whatsoever to outlets should occur, as any build up of pressure within the units can cause severe damage. Indeed, the result can be fatal!
To operate, first the stop-cock and then the heating system is turned on. The electric types are provided with an element which heats the water as it flows through the unit. The power supply is controlled by an on-off switch.

INSTANTANEOUS GAS UNIT (NATURAL OR L.P.G.)

FIG. 15.12

The gas types contain a small jacket of water and the heat transfer is speeded up by fins attached to this jacket. To ensure efficient conduction through the metal, the fins and jacket are tinned as one. This is exposed to the radiant heat emitted from the gas flame. Control of temperature is usually maintained by the combined adjustment, at the unit, of water flow and gas flame intensity.

This adjustment is so designed that the water flow through the unit cannot be directly turned off unless the gas is also turned off.

Reference should be made to the "Installation Code for Gas Burning Appliances and Equipment" by the Australian Gas Association 1969 (or a subsequent publication superseding this code) before any gas installation is attempted. Many tragedies have occurred due to improper practice and lack of knowledge by the installer.
The multipoint units are usually situated as near as practicable to the fixture which is most often used (e.g., K.S.), as long "dead" lines waste hot water, adding to the running costs. These units are automatic in operation. Immediately a tap on the hot water line is opened, a control is operated by the sudden drop of water pressure in the unit, causing the heating element or flame to come into action. Electric systems are controlled by a mercury switch and are similar in design to the single-point unit. The gas multi-point has a pilot light constantly burning which ignites the main gas burner when the diaphragm-controlled valve opens. The design inside the heater is slightly different from the single-point unit inasmuch as the water is carried through the heater in a coil which is wrapped around a metal lining exposing a large heating surface to the radiant heat from the gas flame. The unit's efficiency is increased by passing the coil back and forth through several fins or vanes above the flame. As with the single-point unit, the whole of this heat transfer plate, fins and coil are tinned as one to increase heat conduction to the water.
(b) STORAGE

The storage-type hot water system employs more or less continuous heating with consequent storage of hot water within the unit itself or in a cylinder separate from the heating unit. These may be low-pressure or mains supply. However, at this point only the low-pressure units as used in average cottage systems will be considered.

These are all multi-point systems.

The combined heating and storage system (direct fired storage) is probably the most common storage system being installed, for example, Braemar and Uniheat type. It consists of a storage cylinder through which the flue passes, and a base forming the 'fire-box'.

![SOLID FUEL SYSTEM](FIG. 15.14)
The means of heating may be either by automatic gas or oil operated by a thermostat control, or by solid fuel.

Where the unit is heated by electricity, the system consists only of a cylinder with a thermostatically controlled element inserted.

The separate heater and storage cylinder (circulating storage) installation consists of a heating source (boiler, coil in stove, or solar absorber), a storage cylinder (varying in capacity from 90-227 litres), and a 'primary circuit' to connect the two. In this system, convection is relied upon to carry the heated water from the 'boiler' to the storage cylinder. When water is heated above 4° C it expands and becomes less dense than cooler water. When this happens the heavier or more dense, cooler water displaces the lighter water, forcing it to rise. This is facilitated between the 'boiler' and cylinder by means of the 'primary circuit'.

The installation must be such that the storage cylinder is above the boiler. Hot water is forced up through the Primary Flow, to be stored, by cold water descending the Primary Return to the boiler.

This process is continuous, causing the water to circulate through the system (thermo-cycle).

Reducing the pressure into the heatex units can be carried out by either one of two methods. First method is the use of a pressure reduction valve. This fitting is so designed that when the pressure on the outlet side is equal to the pre-determined pressure setting of the valve, the water is shut off, preventing any more water entering the system unless a tap is opened to let it out. These valves are installed close to the unit and preferably above the storage cylinder and are preceded by a stop-cock on the mains supply. (See Figure 15.15).

Secondly, there is the supply tank method. This should be preferred when there is a need for an uninterrupted supply of hot water, for depending on the nature of the installation the capacity of the tank can vary from 9 litres to thousands. The height of the water level in the supply tank must not exceed the maximum 7.6 m above the low pressure unit.

The tank is supplied through a ball valve which automatically opens when the water level drops. A stop-cock must be provided on the supply to the tank.

Supply tanks must be fitted with tight fitting lids and an overflow, and where there is a danger of damage overflowing or leakage, the tanks must sit on a tray provided with a 38 mm minimum diameter overflow drain pipe, discharging to a conspicuous but safe place.

The tank must be adequately supported, so consideration must be given to the position where it is to be fixed. For instance, the ceiling over the dividing walls. This offers a firm support and should be utilized. (See Figure 15.16)
SOLAR UNIT WITH BOOSTER

FIG. 15.15
LOW PRESSURE UNIT (FROM OVERHEAD TANK)

FIG. 15.16
In both cases, the cold water from the reduction mains should enter the hot water storage near its bottom, and when a tank is used, the pipe to the unit should leave the tank not closer than 25 mm above the bottom and at the opposite end to the incoming water.

The hot water to the various points is taken from the top of the cylinder (this is the hottest part), and usually this is in conjunction with the pressure relief point or exhaust which releases any build up of pressure within the unit.

The pressure relief valve is so designed that when the pressure within the system exceeds the pre-determined setting of the valve, a diaphragm in the valve opens, allowing the release of the increased pressure factor. Open exhaust pipes should not be smaller than 20 mm diameter and should be carried up to a height of not less than 0.6 m above the cistern water level (or static head equal to the reaction valve setting plus 0.6 m), but should never exceed 7.6 m above the hot water unit.

SOLAR HOT WATER HEATERS

Australia is in a very favourable position to use solar energy as a means of heating water for domestic use. Studies have shown that the needs of an average family can be provided for by a solar hot water system.

A solar hot water system consists of solar collectors connected to a storage tank for the heated water, and it works mainly on the natural-circulation or thermosiphon principle.

Water in the collectors is heated by solar radiation and it then flows to the upper part of the storage tank, and it is replaced by cooler water from the bottom of the tank.

To maintain thermosiphon flow and to prevent reverse circulation, which would result in heat loss, the top of the collectors must be lower than the bottom of the storage tank.

The collector or absorber, as it is sometimes called, is most commonly a flat blackened plate to which a number of copper tubes are thermally bonded to ensure good heat conduction between the plate and the tubes. The plate is backed by insulation, such as mineral wool, and the plate, tubes and insulation are enclosed in a case of sheetmetal or stainless steel, with a clear glass cover. See Figure 15.16(b). The coating on the plate should preferably be specially selective, that is, it absorbs a maximum of sunlight in the visible and near infra-red region and re-radiates a minimum of heat.

The housing of the absorber plate is designed to obtain the maximum absorption of heat, while minimising heat losses. The insulation at the back of the plate reduces heat losses from the back and the case and glass cover panel prevent the loss of heat by convection, as well as protecting the collection plate.

The clear glass acts as a heat trap by permitting high-temperature solar radiation to enter through to the plate, but preventing the loss of lower-temperature heat radiation from the collector.
The collector plates are commonly made from copper with the following advantages:

- high thermal conductivity, which means a thin plate can be used
- durability
- no electrolytic corrosion is the thermal bond between the copper pipes and the plate.

Flat plate collectors or absorbers are available in a range of sizes and can be used on either low or high pressure systems, and one of their advantages is that they still operate, at a reduced level, even when the sun is obscured by clouds.

The collectors can be installed on the roof, as an awning or on the ground. This depends largely on the house design and the appearance of the installation. The collectors should be installed where there is no shade for the major part of the day, and they should be facing due north to obtain maximum benefit from the winter sun.

For maximum year-round performance the collectors should be inclined to the horizontal at an angle equal to 0.9 times the latitude of the locality. Perth in Western Australia is nearly on a latitude of 32°, therefore the inclined angle should be 0.9 x 32 = 28.8°.

As the most common pitch for a tiled roof is from 17 to 18°, some efficiency is lost if the collectors are placed straight on the roof. To obtain the ideal angle of 28.8°, a support frame would have to be used, and in any case, to ensure thermosiphon flow a minimum slope of 10° is required.

STORAGE TANK

The storage tank stores the hot water collected for later use. A typical storage tank can hold between one to two days supply of hot water, and common sizes available are 180 L, 300 L, 440 L and 600 L.

The tanks come in a variety of shapes and sizes, including horizontal and upright types both suitable for low or high-pressure operation. Most tanks have a boosting system incorporated into the tank to heat the water after a period of prolonged rain or cloudy days, where there has not been enough sun light to heat the water through radiation. Some solar systems can be connected to hot water coils is slow combustion stoves or even pot-belly stoves.

Care must be taken to follow the manufacturer's specifications, as some solar systems can not be connected to such boosters. See Figure 15.26(a) and (b) for typical installations.
CLOSE-COUPLED THERMOSIPHON HOT-WATER SYSTEM
FIG. 15.16(a)

THERMOSIPHON SYSTEM WITH SEPARATE STORAGE AND COLLECTORS
FIG. 15.16(b)
15.6 SANITARY PLUMBING

Sanitary plumbing is a branch of plumbing dealing specifically with the installation, repair and replacement of the following types of fixtures:

(a) ablutionary fixtures, such as baths, hand basins and shower recesses;

(b) waste water fixtures, such as wash trough, washing machine, drinking fountain;

(c) greasy water fixtures, such as kitchen sinks and dish washers;

(d) soil fixtures, such as water closets, urinals and hospital waste disposal units.

Before any plumbing work is carried out, the relevant authorities should first be contacted for permission to undertake the projects and for the necessary forms that must be submitted. Authorities may include the Western Australian Water Authority, Public Works Department, Public Health Department, etc.

Observance of regulations administered by these authorities helps protect the community from the danger of disease.

The Western Australian Water Authority By-laws state that it is necessary to apply for permission to undertake work in connection with water supply, sewerage, or drainage.

There are two types of permits.

(a) A minor permit is required for minor repairs and alterations such as repairing burst water pipes, replacing pedestal pans or cisterns, and extensions to existing plumbing (except in the case of drains where a major permit may be required for extensions).

(b) Major permits are required for all other work. The procedure is to submit two copies of a block plan showing the building at 1:200 scale, and also one copy of an application for examination of the plan. There is a fee payable.

One copy is given back to the applicant showing main, manhole, and location and depth of junction.

The major permit is issued to the applicant. The plumber must sight the permit if the plumber is not the applicant. Before commencing work, the plumber must give 48 hours' notice to the Authority of his intention to commence work.
15.7 DEFINITIONS AND ABBREVIATIONS

DEFINITIONS

Before continuing with further discussion of the Metropolitan Water Authority requirements, it is necessary to define the terms used and abbreviations likely to be found on drawings and in regulations.

'Anti-Syphonage vent' (or 'back vent') means any vent pipe from an individual trap to the open air or to a main or branch vent pipe having for its purpose the prevention of loss of water seal in the trap.

'Bore', 'Diameter', or 'Size', in reference to -

(a) any pipe of copper or brass, means the external diameter of the pipe; and

(b) any pipe of any other material, means the internal diameter of the pipe.

'Boundary Trap' (or 'Interceptor Trap') means a composite fitting incorporating a trap for preventing the passage of gases from the sewer to the drain.

'Branch Drain' means any branch off a main property-connecting drain.

'Branch Pipe' means a common discharge pipe to which two or more fixture traps at any one floor level are connected.

'Check Valve' - (Non-return valve or reflux valve), is a valve which prevents reversal of flow in the pipes of a water supply system by means of the check mechanism, the valve being open by the flow of fluid and closed by the action of the check mechanism when the flow ceases, or by back pressure.

'Cistern-Fed Water Heater' means a water heater which is supplied with cold water from a feed tank in which the level of the water is automatically maintained. The cold water feed tank may form an integral part of the water heater or it may be detached and mounted separately in such a manner that the maximum working head is not exceeded.

'Combined Waste Pipe' means any pipe which receives the discharge from both soil and waste fixtures and conveys those discharges to the drain; combined waste pipes are connected directly to the drain and are used only in connection with the combined pipe system.

'Domestic Sewage' means all faecal matter, urine, household slops and household liquid refuse.

'Disconnector Gully' means a trap used in the separate pipe system for isolating or disconnecting waste pipes from the drain and soil pipes and for providing inlet ventilation to the waste pipe or pipes discharging into it.
'Discharge Pipe' means any pipe for the conveyance of sewage or waste.

'Displacement Water Heater' means a water heater in which cold water is fed into the container at or near the bottom, and displacing but not mixing with the hot water as it is drawn off at, or near, the top.

'Drain' every part of any conduit laid through, under, or upon any street, way, or land, whether public or private, by or at the expense of the owner or occupier of any premises for the carriage therefrom of any sewage to any sewer.

'Eductor Vent' means an opening or pipe for the exit of air from a soil pipe, waste pipe, combined waste pipe or drain.

'Expansion Joint' means a joint which permits relative axial movement of the jointed parts.

'Falling Level Water Heater' means a water heater with a free water surface, from which hot water is drawn off at or near the bottom, the level of the water falling as the hot water is drawn off.

'Fittings' means all pipes, meters, or other apparatus used for or in connection with the supply of water; and all pipes, cisterns, traps, syphons, manholes, ventilators, and all other apparatus connected with and requisite to secure the safe and proper working of any sewer or drain.

'Fixtures' means all apparatus that may be attached to the plumbing or drainage system of a property for the collection or retention of any wastes or waste waters for ultimate discharge into the sewerage system and includes closet pans, urinals, baths, sinks, basins and troughs connected with the sewerage system.

'Fixtures Discharge Pipes' means the discharge pipe to which the single fixture trap is connected.

'Fixture Unit' means a unit of measure based on the rate of discharge, time of operation and frequency of use of a fixture that expresses the hydraulic load imposed by that fixture on the sanitary plumbing installation.

'Fixture Unit Rating' means the system loading value in fixture units assigned to a fixture.

'Float Valve' means a valve operated by a float and designed to maintain a constant level of water in a feed tank; sometimes called a ball valve or ball cock.

'Flood Level Rim' is the lowest part of the top edge of any fixture from which water will overflow.

'Floor Waste' means the grated inlet within a graded floor intended to drain the floor.
'Free-Outlet Water Heater' means a water heater with a permanently open outlet from which hot water is discharged by displacement, the flow of water being controlled by means of a valve or tap in the inlet water feed pipe.

'Fully Vented System' means a system of plumbing with provision for the separate ventilation of every fixture trap connected other than to a floor waste-gully and of the trap of every floor waste-gully.

'Fully Vented System - Modified' means a system of plumbing differing from a fully vented system in that the traps of any group of two or more fixtures, or floor-waste gullies, discharging to the same branch pipe are vented in common by one or more group vents connected to such pipe.

'Gate Valve' - a valve which provides a straight through passage for the flow of fluid. The body ends are in line, and a shaped gate is moved between the body seats by a stem whose axis is at right angles to the line between the body ends.

'Heat Exchange Water Heater' means a water heater in which cold water is fed into a heat exchanger (e.g. a coiled tube or similar device) which is immersed in a container of static heated water or other suitable medium.

'Horizontal Branch' means that part of a soil and/or waste pipe extending laterally from a soil and/or waste stack with or without vertical section or branches which receives the discharge from one or more waste and/or soil pipes and conducts it to the soil and/or waste stack.

'Hot Water Service' means all parts of the installation and all equipment and materials necessary to provide an efficient supply of hot water at the specified outlets.

'Indirectly Connected' means interrupted by a water seal or air gap as applicable to the situation.

'Induct Vent' means an opening or pipe for the admission of air to a soil pipe, waste pipe, combined waster pipe or drain.

'Industrial Waste' means the liquid, solid or gaseous refuse from any business, industry, warehouse or manufacturing premises other than domestic sewage, stormwater, or unpolluted water.

'Inspection Opening' means an access opening in a pipe or fitting sealed with a removable plug or cover, used as access for purposes of inspection and maintenance, and testing where provided in drains.

'Instantaneous Water Heater' means a water heater in which the heat energy is applied only while water flows to the outlet(s).

'Interceptor Trap' or 'Boudry Trap' means a trap situated on the drain at some point between the sewer and the lowest inlet to the drain, for the purpose of preventing the passage of air or gases from the sewer to the drain.

'Invert' means the lowest point of the internal surface of a pipe or channel at any cross-section.
'Mains Pressure Water Heater' means a water heater, hydrostatically tested to a minimum of 2 000 kPa, which is connected directly to the cold water mains in such a manner that hot water is delivered at the cold water mains pressure.

'Pipe' - a main, reticulation, or service pipe used for or in connection with the supply of water.

'Pipework' is the assembly of pipes and fittings.

'Plug Tap' means a device used to regulate or stop the flow of a fluid by the rotation, in its seating, of a drilled or slotted plug.

'Pressure-Reducing Valve' means a valve which automatically reduces inlet water pressure to a specified value at its outlet.

'Pressure-Relief Valve' means a pressure-actuated valve which automatically discharges fluid at a specified set pressure.

'Pressure Water Heater' means a water heater having a maximum working pressure greater than 21 kPa (maximum working head greater than 2 m) but less than that of mains pressure. This includes both vented and unvented water heaters.

'Primary Circuit Flow and Return Pipes' means pipes which respectively convey water from the source of heat to the container, and from the container back to the source of heat.

'Relief-Vent' means a vent branching from a stack below the point of connection thereto of the lowest fixture.

'Residential Building' means a building in which sleeping accommodation is provided for persons other than caretakers and their families and includes dwellings, tenements, flats, hotels, lodging houses, dormitories, hospitals and motels.

'Sanitary Plumbing Installation' means an assembly of pipes, fittings, fixtures, and appliances connected thereto, which is used for or intended to be used to convey sewage to the sewer system.

'Secondary Circuit Flow and Return Pipes' means pipes which respectively convey hot water from and return it to the container, and from which hot water may be drawn off.

'Sewage' includes faecal matter, urine and liquid wastes whether domestic or otherwise.

'Sewer' - every part of any conduit through, under, or upon, any street or land, whether public or private, for the carriage of any sewage, not being a drain within the meaning of the Act.

'Side-Fed Water Heater' means a displacement type of water heater with a free water surface in which the cold water is supplied from an integral feed tank attached to the side of the heater. The hot water is drawn off at an outlet located below the free water surface.
'Single-Stack System' means a system of plumbing in which the stack and discharge pipes serve also as vent pipes.

'Single-Stack System-Modified' means a system of plumbing differing from a single stack system in that a relief vent is provided appurtenant to the discharge stack and is interconnected therewith at alternative floors, or at every floor by a cross-vent.

'Soil Fixture' means a water-closet pan, urinal, slop hopper, autopsy table, bed pan washer or sanitary napkin disposal unit.

'Soil Pipe' means a pipe which conveys the discharge from a soil fixture.

'Stack' means any vertical pipe extending more than one storey in height.

'Stack Vent' means the extension of a discharge stack above the highest connected discharge pipe.

'Stop Tap' means a screw-down pattern tap with or without a loose jumper valve arrangement, with the inlet both having suitable means for connection into a pipeline.

'Storage Water Heater' means a water heater incorporating a thermally-insulated container in which the water is heated and stored for subsequent use.

'Temperature-Relief Valve' means a temperature-actuated valve which automatically discharges fluid at a specified temperature.

'Trade Waste' means liquid waste other than domestic sewage and as defined by the Board. See "Industrial Waste".

'Trap' means any fitting designed to retain a water-seal.

'Trap Vent' means a vent pipe venting an individual trap to the open air or to a main or branch vent pipe for the prevention of loss of water-seal in the trap.

'Unvented Water Heater' means a water heater without provision for a vent permanently open to the atmosphere.

'Vent or Exhaust Pipe' means an open-ended pipe connected at any high point in a hot water system, or from any vessel containing hot water and so arranged that the open end discharges into the air space of the cold water storage tank or to the outer atmosphere.

'Vent' means a pipe provided to limit the pressure fluctuations within the discharge pipe system.

'Vent Pipe' means any pipe used or intended to be used for ventilating soil pipes, waste pipes, drains, traps, connections or sewers.

'Vent Stack' means a vertical vent pipe installed primarily for the purpose of providing circulation of air to and from any part of the drainage system.
'Water Heater' means an appliance, usually self-contained, for heating water which is either stored in it or passing through it.

'Water Seal' or 'Trap Seal' means the vertical distance between the dip and the crown weir of a trap as shown in sketch.

'Water Supply System' means the pipes and fittings used or intended to be used for the supply of water from a meter assembly to the points of usage within any property, and includes any water storage tank or pipes therefrom.

'Waste Fixture' means any fixture, other than a soil fixture.

'Waste Pipe' means a pipe which conveys the discharge from waste fixtures only.

'Yard Gully' means a disconnector trap which is used externally and fitted with a basin top and grating.

ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>B</td>
<td>Basin</td>
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<tr>
<td>B.T.</td>
<td>Boundary Trap</td>
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<tr>
<td>C.I.P.</td>
<td>Cast Iron Pipe</td>
</tr>
<tr>
<td>C.C.</td>
<td>Chemical Closet</td>
</tr>
<tr>
<td>C.E.</td>
<td>Cleaning Eye</td>
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<tr>
<td>C.D.</td>
<td>Clothes Drier</td>
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<tr>
<td>C.W.</td>
<td>Clothes Washer</td>
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<tr>
<td>C.W.T.</td>
<td>Cold Water Tank</td>
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<tr>
<td>C</td>
<td>Cooker</td>
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<tr>
<td>Cu</td>
<td>Copper</td>
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<tr>
<td>Corr</td>
<td>Corrugated</td>
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<tr>
<td>C.O.V.</td>
<td>Cut-off Valve</td>
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<td>D.G.</td>
<td>Disconnector Gully</td>
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<td>D.W.</td>
<td>Dishwasher</td>
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<td>D.F.</td>
<td>Drinking Fountain</td>
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<td>E.W.</td>
<td>Earthenware</td>
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<tr>
<td>E.V.</td>
<td>Educt Vent</td>
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<td>Eff</td>
<td>Effluent</td>
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<td>F.W.S.</td>
<td>Fire Water Service</td>
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<tr>
<td>F.A.</td>
<td>Fire Alarm</td>
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<tr>
<td>F.D.</td>
<td>Fire Detector</td>
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<tr>
<td>F.H.</td>
<td>Fire Hyrant</td>
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<tr>
<td>F.W.</td>
<td>Floor Waste</td>
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<tr>
<td>G.E.W.</td>
<td>Glazed Earthenware</td>
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</table>
G.V.C.          Glazed Vitrified Clay
G.I.T.          Grease Interceptor Trap
H.W.            Hot Water Unit
I.V.            Induct Vent
I.C.            Inspection Chamber
I.O.            Inspection Opening
I.T.            Interceptor Trap
M.              Meter
O.I.T.          Oil Interceptor Trap
PED             Pedestal
R.W.H.          Rain Water Head
R.W.P.          Rain Water Pipe
S.V.            Safety Valve
S.D.            Sewer Drain
S.V.P.          Sewer Vent Pipe
SHR             Shower
S.P.            Stand pipe
S.C.            Stopcock
S.T.            Stop Tap
S.V.            Stop Valve
S.W.D.          Storm Water Drain
UR              Urinal
V.P.            Vent Pipe
VENT            Ventilator
V.C.P.          Vitrified Clay Pipe
W.P.            Waste Pipe
W.M.            Washing Machine
W.T.            Wash Trough
W.MR            Water Meter
Y.G.            Yard Gully.

15.8 SYSTEM OF DISPOSAL

Before discussing the various methods available for the disposal of wastes, a definition of sewage is essential. Sewage has been defined as the spent water supply of the community together with those human and household wastes which are removed by water carriage.

Generally, there are two systems for the disposal of human waste products: the conservancy system, and the water carriage system.
CONSERVANCY SYSTEM

This is the system practised in country districts where there are isolated dwellings, the costs of providing a water carriage system are prohibitive and where a shortage of water makes any alternative impossible. The method adopted in this case is to collect the wastes in receptacles which are removed regularly for disposal in a safe place where contamination of water supplies is not likely.

WATER CARRIAGE SYSTEM

These systems rely on the availability of an adequate supply of water to remove the waste products effectively to a place where they can be treated before disposal in such a manner as not to contaminate water supplies. The plants for sewage treatment vary in size from the single unit septic tank to the larger package treatment plant suitable for up to 1000 people, or to the sewerage system suitable for large towns and cities.

The septic tank system is a miniature treatment plant suitable for single unit disposal. Treatment is by means of bacteriolytic decomposition of sewage into its natural elements, with the effluent being disposed of through soak wells or leach drains.

In the sewerage system, the individual units are connected through a network of pipes (sewers), pumping stations and main sewers to the treatment works.

15.9 WASTE

Waste pipes are fitted to convey the waste from fixtures - such as bath, hand basin, shower recess, wash trough, washing machine, drinking fountain, kitchen sink and dish washer - to the drain. The pipes are connected together with a wide variety of fittings, and fixed to the building with clips appropriate for the material and building structure. The connection to fixture outlets must always be a screwed connection allowing removal of the unit from the disposal piping to allow replacement or repairs of the unit.

Waste pipes are made from the following materials:

- lead
- cast iron
- galvanized steel pipe
- copper
- copper alloy
- unplasticised polyvinyl

While lead, cast iron and galvanized steel waste pipes will be found in older buildings, copper and U.P.V.C. are used in most new constructions.
COPPER, COPPER ALLOY PIPES AND FITTINGS

Copper pipes, in the form of hard-drawn tubing, are frequently used for waste pipes. Copper is expensive and, in view of the large diameters specified for waste pipes by the M.W.A. the pipes are cut to size and joined by brazing, rather than by costly fittings. Where fittings are necessary, for example in the form of traps or inspection openings, these are moulded from brass and brazed to the waste pipes. Copper tubes and fittings may not be used for the discharges from urinals.

Two types of tubing are generally used:

(a) type A - must be used in straight lengths and never offset by bending. Type A must not be embedded in concrete or used below ground level;

(b) type B - maybe bent in the field to an offset angle of 10° only.

For the fabrication of bends in the field between 10° and 45°, type A tubing must be used for sizes of up to 50 mm bore. Larger bores: the wall thickness must be at least 0.4 mm greater than the same type B tubing size.

COPPER ALLOY

The material specified is usually type 259 A as per AS1567 for tubing and AS 1589 for the fittings.

Tubings of this material used for waste pipes and fittings must be at least equivalent in wall thickness to that specified for type A copper. Copper alloy tubing may not be bent, and the fittings to be used with it must be of either cast or hot pressed copper alloy - to prevent corrosion between tubing and fitting material.

U.P.V.C. PIPES AND FITTINGS

The physical properties of U.P.V.C. pipes make them very suitable for use as waste pipes. Of particular importance is the smooth interior surface which is not subject to corrosion. This property renders the pipe substantially free from silting and consequent blockage.

U.P.V.C. pipes are available in a variety of standard lengths and diameters. Each pipe is provided at one end with a socket to match the spigot of another pipe. U.P.V.C. tubing used in sanitary plumbing must comply with the requirements of AS 1415 for soil waste and vent applications, and AS 1260 class S.H. For drains less than 90 mm, U.P.V.C. pipes and fittings must be in accordance with AS 1415.

The use of plastic piping and fittings in buildings may be subject to restrictions by the building authority.

A range of fittings is produced to suit the requirements of various installations, and some of these are shown in Figure 15.17.
The fitting are available with or without inspection openings, as required.

The pipes and fittings are joined with special solvent cement. It is important that the cement specified by the manufacturer of a particular pipe be used in accordance with the instructions given. Screwed fittings in a wide range also exist; for example, as used for the connection of traps to fixture outlets, and of traps to waste pipes.

A special range of fittings is also available for connecting U.P.V.C. pipes with pipes made of other materials. These are necessary when existing waste drain systems are being modified or extended.
VITRIFIED CLAY PIPES

The pipe materials specified previously for water pipes are also applicable for waste pipes.

Waste pipes carry the collected material from water closets, urinals and hospital waste disposal units.

As well as the previously mentioned pipes, vitrified clay pipe may be used - but for drains only, and should be in accordance with AS 1741, and as approved by the M.W.A.

The joints between V.C. pipes must be by means of rubber rings.

Where V.C. pipes are used as risers, only one pipe may rise above ground level, and this not more than 1.0 metres. The joint for the riser pipe must be below ground level.

Where a V.C. pipe penetrates a wall or footing, there must be 25 mm annular clearance around the pipe. The pipe penetrating the footing should be kept as short as possible and generally should not exceed 600 mm.

To ensure that large, coarse particles do not get into the annular clearance, the clearance could be kept filled with sand.

JOINING SOIL AND WASTE PIPES

Vitrified clay pipes are moulded with a socket at one end of the barrel and a spigot at the other. Standard sizes of pipes are 75, 100, 150 and 225 mm.

The distinctive constructional details of the pipe are:

(a) an internal recessed lip at the top of the socket to locate a rubber sealing ring in the assembly process of the joint;

(b) a single ring groove at the end of the spigot to locate the rubber seal properly in the sealing joint;

(c) a single, shallow groove marking on the barrel a short distance from the spigot seal groove to serve as an indicator. The joint is correctly assembled when this indicator lines up with the inside edge of the socket end. (See Figure 15.18).

Such a joint is flexible and is able to adjust to the movements of the soil without breaking, as was the case with the old type of rigid mortar-sealed joint in vitrified clay pipes. Mortar jointing is still used in special applications and as approved by the M.W.A.

Cast iron pipes are stronger and more durable than vitrified clay pipes, and are frequently used where drainage systems are subject to stresses caused by roadways and driveways over the pipes; long stacks in multi-storey building; and vent shafts or rises in locations where the pipes are likely to be damaged.

Cast iron pipes can be joined by:

(a) a mechanical joint socket;
(b) caulked lead or epoxy resin joint;
(c) the use of gland ring joints incorporating rubber rings and bolts to make an air and water tight seal. (See Figure 15.19.)
JOINING VIT. CLAY PIPES

FIG. 15.18

MECHANICAL

FIG. 15.19

(From: Sanitary Plumbing 1, Basic Trade Manual 10-1, Courtesy of the Australian Government Publishing Service)
U.P.V.C. pipes and fittings may be joined in the following ways:

(a) with solvent cement;

(b) with a rubber sealing ring fitted in a groove in the spigot end. (this joint is usually used on large diameter pipes and pipes under pressure);

(c) by means of threaded joints.

ASSEMBLING P.V.C. PIPING

FIG. 15.20

(From: Sanitary Plumbing 1, Basic Trade Manual 10-1, Courtesy of the Australian Government Publishing Service)
Copper pipes and copper alloy fittings can be jointed by screwed joints if heavy gauge screwing copper is used or, otherwise, by:

(a) silver brazing, or

(b) bronze welding.

COPPER WASTE PIPES AND BRASS FITTINGS ARE USUALLY JOINED BY BRAZING

FIG. 15.21

(From Sanitary Plumbing 2, Basic Trade Manual 10-2, Courtesy of the Australian Government Publishing Service)

15.10 TESTING THE DRAIN

When the pipes have been laid in the trench, aligned and properly joined, the drain must be tested before the trench is closed.

The test will either be performed by an officer of the Western Australian Water Authority (W.A.W.A.) or, in the presence of an officer, by the plumber.

The test is carried out in two parts:

(a) visual inspection

(b) pressure testing

(a) VISUAL INSPECTION

Visual inspection will include checking of the drain alignment and the quality of the pipe joints. The interior of the drain may be subjected to a glassing test (sometimes called mirror test). If carefully set up, it will provide an accurate check of the alignment of the pipes and also reveal any internal obstructions in the drain caused by poor jointing.
To perform this test, a mirror is set at an angle below an inspection opening at each end of the drain. The light entering the I.O. is reflected along the drain interior to the other mirror. By looking down at one of the mirrors through the inspection opening, a view of the interior of the drain is obtained.

If the joints between the pipes appear clean and as a series of concentric circles, the drain has been laid correctly.

TESTING THE DRAIN BY GLASSING

FIG. 15.22(a)

PIPES LAID CORRECTLY

PIPES OUT OF ALIGNMENT AND INTERIOR OBSTRUCTED

VIEW THROUGH THE DRAIN

FIG. 15.22(b)

(From: Sanitary Plumbing 2, Basic Trade Manual 10-2, Courtesy of the Australian Government Publishing Service)
(b) PRESSURE TESTING

Before the drain is closed, regulations demand that the drain system is tested for leaks.

A test plug is inserted at the lower end of the drain. By this time, any inspection openings will have been closed off with their plugs or discs as the case may be.

The actual testing of the drain can be done in two ways:

. with a water pressure test, or
. with a smoke-under-pressure test.

i. To carry out the water pressure test, the drain is filled with water. This is done slowly to allow any air to escape the drain, as entrapped air may render the test useless.

The pressure head of water required is laid down in the M.W.A. regulations and is 1.5 m of head above the highest point in the drain.

The drain is considered satisfactory if the loss of capacity of the drain is no greater than two and a half percent per hour. For cast iron and U.P.V.C. drains, the testing time is five minutes, and the test is successful if there is no water loss.

ii. The smoke test is performed by forcing smoke into the drain under a 25 mm head of water applied through a smoke test apparatus. As smoke appears at each opening, that opening is closed and, when all openings are sealed, the pressure is maintained for five minutes.

The test is successful if so smoke appears at joints and there is no loss of head.

15.11 PROTECTION OF PIPES

Where no protective cover (such as concrete) is used over pipes, a minimum amount of cover from the top of the socket to the ground surface must be 450 mm to accommodate light vehicular traffic; 750 mm in public thoroughfares and places subjected to heavy vehicular traffic; and 300 mm elsewhere.

SUPPORT OF PIPES

Where stable support cannot be assured for house drains connecting to sewer lines, support to the connection must be given by way of timber piling and keel. The keel is nailed or keyed to the piles which are driven to the inspector's satisfaction at centres not more than 1 m apart, and then cut off to the line and grade of the drain. The keel is then nailed to the piles and the drains are laid on the keel and wedged into position using wooden or concrete wedges, and held by hoop straps passed over the drain.
15.12 SEPTIC TANKS

REGULATIONS

In areas where there is no deep sewerage system but an adequate water supply, a method of sewage disposal known as the BACTERIOLYTIC TREATMENT OF SEWAGE (Septic Tanks) is used. This system should only be regarded as second best and purely a temporary expedient until such times as the premises can be connected to a deep sewer system.

A septic tank is a series of water-tight compartments designed to slow down the flow rate of raw sewage and wastes passing through it so that the solids can separate out and settle and the suspended solids rise and form a scum or blanket. The contents are then broken down by bacterial action and liquifaction. The bacterial action in a septic tank is of the anaerobic variety, that is i.e., bacteria which lives only in the absence of oxygen; their action turns the matter in the tank septic (from the word sepsis which means to putrify). A septic tank does not render sewage harmless, eliminate odours, or destroy all solid matter; it is merely a retention chamber that enables effluent to be conditioned so that it can be safely disposed of to a sub-surface leaching system (whether soak well, leach drain or French drain) without prematurely blocking the system. While it is true to say that bacterial action does take place in a septic tank, we must NOT assume that the effluent is harmless - it is probably more dangerous than the influent.

In Western Australia, this important aspect of health is controlled by the Public Health Department under the BACTERIOLYTIC
TREATMENT OF SEWAGE AND DISPOSAL OF EFFLUENT AND LIQUID WASTE REGULATIONS. These regulations cover the whole of the state, under the Public Health Act, and are administered through the Local Health Inspector for that particular area whose job it is to make sure that the systems are correctly installed in accordance with the regulations.

The following regulations are extracted (by permission) from the Health Department Regulations, and apply to the application for, and the installation of, septic tanks.

DIVISION 2 - APPLICATION AND INSTALLATION

4. (1) The owner, or person authorised to act on behalf of the owner, of any premises whereon it is intended to construct an apparatus shall apply to the Commissioner on the prescribed form for permission to construct the apparatus, and shall pay the prescribed fee.

(2) Where the proposed apparatus is to be constructed in conjunction with the erection of a new building, then the application shall be lodged with the local authority with the building plan.

5. (1) An application pursuant to regulation 4 shall be in the form of Schedule "A" to these regulations and shall be accompanied by:

   (a) a copy of plan and specifications of the proposed apparatus showing plan and longitudinal section to a scale of not less than 6.5 mm to 300 mm.

   (b) two copies of a block plan of the premises accurately drawn to a scale not less than 3 mm to each 300 mm, showing:

      i. the position of all buildings erected or proposed and the position of the proposed apparatus;

      ii. the position and dimensions of the closet, the position of the door and pedestal, and details of ventilation;

      iii. the position of all drains, pipes, inspection openings, vents, traps and junctions in relation to buildings and boundaries;

      iv. the sizes of pipes and fittings and the fall of the drains;

      v. details of the effluent disposal system; and

      vi. the source of water supply to be used in connection with the apparatus; and

   (c) if so requested by the Commissioner, a detailed architectural drawing of the proposed apparatus.
(2) No alteration or deviation from the approved plans shall be made until an amended plan has been lodged with the local authority.

(3) Any person who gives any false or misleading information in, or in relation to, an application under this Division commits an offence.

6. A person who applies for permission to construct a combined system shall, in addition to complying with the requirements of regulation 5 of these regulations, show on the block plan the position, type and proposed use of all fixtures intended to discharge into the apparatus, and shall also show particulars of all drains, pipes, inspection openings, vents, traps and junctions to be used in connection with the apparatus.

7. (1) All materials, fixtures and fittings to be used in the construction of an apparatus shall be first approved by the Commissioner but for the purpose of this regulation, a material, fixture or fitting which has been branded in accordance with the By-laws made under the Western Australian Water Authority shall be deemed to have Act and By-laws approved by the Commissioner if the material fixture or fittings bear a mark indicating that they have been inspected by a person authorised under one of the Acts or Regulations, and passed as fit for use.

(2) All materials, pipes, junctions, traps, vents and apparatus shall be sound and free from defects and shall be installed in accordance with the By-laws and practices of the Western Australian Water Authority, as the case requires and these regulations.

8. (1) All educt vents in connection with septic tanks and receptacles for drainage, whether on combined systems, separate systems or liquid wastes only, shall be fitted, by the owner, with an approved mosquito-proof cowl and be so maintained by him.

(2) Where a back vent is required but cannot to the educt vent by means of a saddle piece, the back vent shall also be fitted with an approved mosquito-proof cowl to be so maintained.

Inspection and Approval to Use an Apparatus

9. A person who constructs an apparatus, pursuant to a permit issued by the Commissioner, whether as owner or contractor to the owner or otherwise, shall forthwith, after the construction of the apparatus is completed, notify the local authority of the fact.
10. (1) A local authority which has received a notification in accordance with regulation 9 shall as soon as reasonably practicable thereafter arrange for the apparatus to be inspected with regard to its compliance with the plans and specifications relating to the permit under which the construction was undertaken, and the standard of materials and workmanship.

(2) If the apparatus complies with the requirements of these regulations, the local authority shall grant approval for the use of the apparatus, and issue a certificate in the form of Schedule "B" to these regulations.

11. A person who gives notice to the local authority in accordance with regulations shall prepare the apparatus for inspection at the time set by the local authority or its officer, and in particular shall -

(a) fill the treatment tank to overflow level with clean water 24 hours prior to inspection; and

(b) ensure that all lines of drain, fixtures and fittings are exposed to view, and all inspection openings are unsealed.

Tests

12. The apparatus shall be submitted to hydrostatic and mirror tests, and such other tests as an Inspector may order.

13. The equipment, material, power and labour necessary for the inspection and tests shall be furnished by the person installing the apparatus.

14. Any materials, pipes, bends, junctions, fittings, fixtures and apparatus found to be defective shall be removed and replaced and all defective joints made tight and every part of the work shall be made to conform to these regulations and shall be again subject to the approval of the Commissioner or Inspector.

Prohibiting Entry of Certain Matters into Tank

15. The occupier of any premises whereon there is an apparatus, shall not cause or permit any wastes from any business or industry to discharge into the apparatus except with the approval of the Commissioner.

16. The Commissioner may forbid the discharge into a septic tank of any matter which may interfere with the efficient bacterial operation of the septic tank.

17. No person shall turn into, or cause or suffer to enter, any apparatus or receptacle for drainage used for the reception of effluent or liquid wastes:
(a) any surface or subsoil drainage, rain water from any pavement or roof, or overflow water from rainwater tanks or flushing systems, or other relatively clean water;

(b) any inflammable or explosive materials that are not readily soluble in water, or any materials which when mixed with sewage or water are liable to form explosive compounds or to interfere with the treatment process;

(c) any insoluble matter or articles, dead animals, or rubbish whatsoever; or

(d) any liquids or solids that are bactericidal in effect in such quantity as to militate against the proper functioning of the septic tank.

Interfering with Tanks

18. No person shall, without first obtaining permission in writing from the local authority, dismantle or remove wholly or in any part any apparatus, or alter or change the mode of operating the apparatus.

Damaged and Defective Tanks Not to be Used

19. (1) A person shall not use a septic tank that becomes damaged or defective.

(2) The owner of any premises shall not permit or suffer any person to use on such premises any septic tank which is damaged or defective.

Prohibition

20. A permit shall not be issued for the installation of a septic tank for any property which can be connected to an existing sewerage system, unless the Commissioner is satisfied that in all the circumstances it would be unreasonable to refuse the issue of the permit.

21. (1) No septic tank shall be constructed closer than 1.2 m to the foundations of any house or other building, or the boundary of any lot, unless otherwise approved by the local authority.

(2) No foundations of any house or other building or additions thereto shall be permitted closer than 1.2 m to any existing septic tank, unless otherwise approved by the local authority.

(3) A person shall not cause any structure to be erected above any septic tank, receptacle for drainage line if that structure:
(a) obstructs free access to the septic tank, receptacle for drainage or drainage line; or

(b) has walls on more than one side or end.

22. A gully trap shall not be used in an installation for the bacteriolytic treatment of sewage.

Fees

23. (1) The fee to be paid to the Commissioner by an applicant for a permit to construct an apparatus is six dollars (1982).

(2) Where the local authority carries out the inspection of the installation of the apparatus, the Commissioner shall pay to the local authority one half of the fee received under this regulation.

(3) Where a local authority undertakes a general scheme for the installation of septic tanks in accordance with Part IV of the Act, the local authority shall pay to the Commissioner one half of the fees prescribed in this regulation and in such a case the provisions of sub-regulation (2) of this regulation do not apply, but if the number of installations in the scheme is 100 or more, the fees to be paid by the local authority to the Commissioner shall be one-quarter of the fees prescribed by sub-regulation (1) of this regulation and, in such a case, the provisions of sub-regulation (2) of this regulation do not apply.

After crude sewage has been conditioned in the septic tank it is essential that we have an efficient and safe method of disposing of the effluent from such tanks. It must be remembered that this material is potentially dangerous to health and must be disposed of with great care.

The design criteria must be based on a measure of soil permeability; that is, the ability of the soil to absorb water. Perth is rather fortunate in being built largely on sandy soil through which clean water passes easily. Other areas including some in and around Perth are not so fortunate, having either high water tables or heavy clay and loam through which water will only pass slowly, if at all.

Before commencing the job, it is wise to contact the local Health Inspector who will advise you as to the number of square metres of leaching system you will require for that particular area. When constructing such a system it must be constructed at least 30.5 m away from any bore or well that is used or intended to be used for human consumption.

There are four methods of disposing of effluent allowed by the Regulations: soak, wells, leach drains, standard French drains and evaporative drains.
SOAK WELLS

FIG. 15.25

SOAK WELL SPECIFICATION

To be constructed as shown on plan, having the three top courses or all courses above the overt to be set in 2 in 1 cement mortar, the remainder in open jointed brickwork, laid dry, in stretcher courses, or constructed in approved cement segments or bricks which comply with the standard for blocks, Class A. AS A87-1963. Size - Bricks or segments shall have a minimum bearing face of 100 mm and shall be laid over the full bearing face in each course.

Sufficient openings shall be provided in any soak well to allow for the efficient disposal of the effluent, and shall be not less than 10% of the surface area.

Inspection opening and square junction to be provided as shown. When completed it shall show a circular, smooth and regular internal surface.

All soak wells shall be 1.2 m in Dia. and with a 1.5 m effective depth unless otherwise specified or approved by the Local Authority. The top of the soak well shall not be more than 300 mm or less than 150 mm below ground level, unless otherwise approved by the Local Authority.

Soak wells in series shall have a long square on the outlet as shown.

Cover - shall be of concrete in section with rebated or 45° splayed joint as shown reinforced with No. 606 steel mesh fabric; joints of mesh shall be securely tied with a full two mesh overlap, unless otherwise specified.

The covers shall withstand a flexural test of 2068 Pa and a load bearing of 1034 Pa.

Traffic covers shall be constructed to specific Departmental Specifications.

No soak well shall be situated closer than 1.8 m to any building, boundary fence or septic tank, unless otherwise approved by the Local Authority.
LEACH DRAINS

LEACH DRAINS CAN BE OF THREE TYPES

GROUND LINE

TOP THREE COURSES TO BE LAID IN CEMENT MORTAR

600 X 400 X 50mm CONCRETE SLAB

300 50 900

LONGITUDINAL SECTION
DEEP TYPE DRAIN

BRICKWORK SPACED 25mm APART

600 X 600 X 50mm REBATED CONCRETE SLABS REINFORCED WITH F.41 FABRIC SLABS TO HAVE WEAK CEMENT MORTAR TO ALL JOINTS.

LONGITUDINAL SECTION
INTERMEDIATE TYPE DRAIN

GROUND LINE

600 X 600 X 50mm REBATED CONCRETE SLABS REINFORCED WITH F.41 FABRIC

TOP THREE COURSES TO BE LAID IN CEMENT MORTAR

300 50 900

SECTION A-A DEEP DRAIN

SECTION A-A INTERMEDIATE DRAIN

PLAN

600 X 400 X 50mm CONCRETE SLAB

100

100

9000 COMB SYSTEM

100 600

100

A

110 1 bk

110 1 bk

170 1 bk

400

STD TYPE LEACH DRAIN

FIG. 15.26

15.49
SECTION A-A SURFACE DRAIN.

SEMI INVERTED TYPE LEACH DRAIN

FIG. 15.27(a)

FULLY INVERTED TYPE LEACH DRAIN

FIG. 15.27(b)
Details of leach drain:

No leach drain shall be situated closer than 3.6 m from any dwelling, nor closer than 6 m from any window or any door of any building.

Minimum length:

Separate systems to have leach drains 6 m long.

Combined systems to have leach drains 9 m long.

Reinforced concrete paving slab positioned beneath inlet, and brick spreader walls provided at not more than 1.2 m centres.

Segments - where segments are used, all the courses above the inlet will be laid in 3 & 1 cement mortar.

FRENCH DRAIN

French Drains may be of two types: Inverted and Standard.

STANDARD FRENCH DRAIN

FIG. 15.28(a)

INVERTED FRENCH DRAIN

FIG. 15.28(b)
STANDARD FRENCH DRAIN - SPECIFICATIONS

Trench to be not less than 9.1 m long, constructed as shown. Filling to consist of 50 mm or 75 mm gauge broken blue metal; filling on top may be of smaller gauge metal, with sand over approved sheeting. Distributing pipe to be 75 mm or 100 mm diameter unglazed agricultural pipes laid with open butt joints, or approved piping.

Grade shall be laid at not more than 1 in 200.

A French drain shall not be situated closer than 3.6 m from any dwelling, nor closer than 6 m from any window or door of any dwelling, nor closer than 1.8 m from any boundary.

Impervious sump

Where the septic tanks are located at a level below the leach drain, an air-tight sump can be provided at the septic tank outlet to receive the effluent.

A float-switch operated electric pump is fitted to the sump. The effluent on filling the sump, operates the float switch triggering the pump. The effluent is pumped to the leach drain on higher ground.

This type of disposal system must be designed after consulting the local health inspector. The sump, pump and switches, pipe sizes, and the general layout, will be determined by him.

The impervious sump must comply with the following conditions:

i. the contents of the receptacle shall be removed at such times and with such frequency and in such a manner as are directed by an inspector;

ii. The occupier shall not permit the receptacle to overflow or become offensive;

iii. the receptacle shall be situated where directed by an inspector;

iv. where the contents of the receptacle are to be disposed of by pumping to some other outlet, the capacity of the receptacle shall be not less than twice the estimated daily flow into the receptacle, shall be provided with an approved automatically operated electrically driven pump, permanently installed and equipped with an approved warning device;

v. where the contents of the receptacle are to be disposed of by tanker, then the capacity of the receptacle shall be as directed by the local authority;

vi. impervious receptacles shall be suitably anchored in the ground to prevent them from floating or otherwise moving when subjected to external hydrostatic pressure; and

vii. the material used in the construction of an impervious receptacle shall be to the same specification as that for a septic tank of equivalent size.
a. minimum distance 1.8 m
b. min. 1.8 m for leach drain
c. min. 1.0 m, max. 1.8 m
d & e. min. 1.22 m, taken from footings or boundary

Leach drain 9.0 m long
for combined system,
6.0 m long for separate system

combined septic system

Laundry
bathroom
kitchen

SET BACK DISTANCES
FIG. 15.29
EVAPORATION DRAINS

Plastic or fibre glass corrugated shells can be installed below ground level in a horizontal position to receive effluent. As Figure 15.30 shows, the inside of the drain is an open space which will assist in evaporating effluent entering the drain. Some effluent will permeate into the ground below the drain and some will leach out through the 50 mm aggregate at the sides, however in our climate (W.A.) most effluent will evaporate inside the drain.

FIG. 15.30
TO ALL LICENSED PLUMBERS

Dear Sir or Madam,

The attached notice constitutes a notice "in writing given, as far as is practicable to every licensed plumber" as required by the MWSS&D, CTS and CAWS by-law amendments of 1990.

It will have the effect of placing a legal responsibility on all licensed plumbers to test their work or to have it tested (by persons under their direction and control) in accordance with the instructions in the notice.

The test procedures are the same as detailed in Parts 1, 2 and 4 of AS 3500 (National Plumbing and Drainage Code).

Yours faithfully

[Signature]

W.J. COX
MANAGING DIRECTOR

September 18, 1991

(A:MH6-01)
IMPORTANT NOTICE TO LICENSED PLUMBERS

This notice is issued in accordance with:

* the Metropolitan Water Supply Sewerage and Drainage Amendment By-laws 1990,
* the Country Areas Water Supply Amendment By-laws (No. 2) 1990, and
* the Country Towns Sewerage Amendment By-laws 1990.

From October 1, 1991 it will be a legal requirement that work carried out by, or under the direction and supervision of a licensed plumber be tested by the licensed plumber responsible for the work, or by a person under the direction and supervision of that licensed plumber. This will apply to all work carried out regardless of whether or not it is inspected by the Authority.

It is a by-law requirement that:-

* the equipment, material, power and labour necessary for these tests be furnished by the licensed plumber and,
* that plumbing systems not be used until the work has passed the required tests.

Existing arrangements for booking of both property sewer and final inspections will be retained. It is necessary that inspections be booked with the appropriate inspector’s office as follows:-

* Perth North Region  tel:  (09) 345 8126  (Balcatta)
  * Perth South Region  tel:  (09) 455 0244  (Canning Vale)
  * South West Region  tel:  (09) 535 6333 (Mandurah)
                         (097) 910 425  (Bunbury)
                         (097) 523 844  (Busselton)
  * Great Southern Region  tel:  (098) 420 229  (Albany)
                          (098) 811 088  (Narrogin)
  * Central Region  tel:  (096) 224 888  (Northam)
  * Goldfields Region  tel:  (090) 801 000  (Kalgoorlie)
                         (090) 711 388  (Esperance)
  * Mid West Region  tel:  (099) 210 864  (Geraldton)
  * North West Region  tel:  (091) 868 222  (Karratha)
                         (091) 921 237  (Broome)

In some cases the Authority may opt to not carry out any inspection of work. Unless otherwise advised by the Authority, licensed plumbers should allow 30 minutes after the prearranged booking time before assuming that the inspection will not occur.

For property sewer inspections it is required that the property sewer be exposed and your testing witnessed by the inspector. Where work is not ready at the prearranged time, subsequent inspections will attract a reinspection fee.
The current by-law requirement for licensed plumbers to lodge a notice of intention to commence work and to certify compliance of completed work with the by-laws will still apply. In certifying the work a licensed plumber is testifying that the work complies with the by-laws and that all of the required tests have been carried out and proved satisfactory.

LICENSED PLUMBERS HAVE A CLEAR RESPONSIBILITY TO ENSURE THAT THEIR WORK ACTUALLY DOES COMPLY WITH THE BY-LAWS.

All plumbers should be well aware of the risks attached to non-conforming plumbing systems. Examples are:-

* water heaters exploding through inadequate provisions for expansion,
* sewage flooding homes through the incorrect installation of overflow relief gullies, and
* pollution of water supplies through the use of non-authorised products or through the backflow of chemicals and other substances.

The false certification of work is not only risky but will be treated as an offence. There are substantial penalties for non-compliance with the notification and certification by-laws.

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TEST REQUIREMENTS

Test requirements are consistent with those in the National Plumbing and Drainage Code AS3500 and are detailed as follows:

SANITARY PLUMBING

Sanitary plumbing installations shall comply with the following when tested:-

(a) The respective sections of any soil pipe, waste pipe, vent pipe or above-ground drain shall be free of leaks when subjected to:

* hydrostatic (water pressure) test to flood (overflow) level; or
* air test to 30 kPa for a minimum period of 3 minutes.

(b) The discharge pipe, through which sewage is pumped to the sewer, shall be free of leaks, when subjected to a hydrostatic pressure equal to twice the shut-off head (head at which flow becomes zero) of the pump or, if a relief valve is fitted, twice the pressure at which such valve operates.

(c) Sanitary fixtures of all kinds shall be tested by subjecting them to normal use. After each relevant test, the residual water seal in the trap of the fixture concerned, and in the trap of any other fixture connected to the same system of discharge pipes, shall retain a water seal depth of not less than 25mm or, for traps that are installed in a pressurized chamber, not less than 70mm when maximum pressure is applied within the chamber.
SANITARY DRAINAGE

Every new below-ground property sewer, or section of an existing below-ground property sewer, that has been replaced, shall be tested by either a water test or an air test. Water tests are not permitted in areas where water restrictions are in force.

(a) Water Test

The head of water on any section of the property sewer shall not exceed 3 metres. The test shall be applied by:-

* sealing all openings except the top of the section of the below-ground property sewer to be tested, then
* filling the below-ground property sewer with water to the highest level in that section; and
* maintaining the water at this level for a period of :

* 10 minutes for vitrified clay property sewers, by the addition of measured quantities of make-up water as set out below; or
* 5 minutes for property sewers of other materials.

* The installation is considered to have passed the test if during the test period the quantity of make-up water:

* does not exceed 1 litre per 30 metre length of DN 100 vitrified clay property sewer,
* does not exceed 1.5 litre per 30 metre length of DN 150 vitrified clay property sewer; or
* is zero for property sewers of other material.

(b) Air Test

The air test may be applied to completed work, either in its entirety or in sections according to the following:

* The air pressure test shall consist of applying a pressure of 30 kPa to the drain and holding this pressure for 3 minutes to allow the air temperature to stabilize.

* The air supply shall then be shut off and the time taken for the pressure in the pipe to drop from 25 kPa to 20 kPa shall be measured.

* The property sewer is considered to have passed the test if the time taken is greater than 90 seconds for pipes of size DN 225 or smaller, or 180 seconds for pipes of sizes DN 300 and DN 375.
COLD WATER SERVICES

(a) For the following materials the service shall not show any leakage when subjected to a hydrostatic (water) test pressure of 1500 kPa applied for a period of not less than 5 minutes:

* copper pipe
* uPVC pipe (solvent cement joints)
* polybutylene
* polyethylene

(b) Flexible jointed installations (i.e. rubber ring joints) however shall not show any leakage when subjected, for a period of not less than 15 minutes, to whichever is the greater of the following hydrostatic test pressures:

* mains pressure with all joints exposed, or
* not less that 700 kPa (100 psi)

When pressure test is carried out, it may be necessary to disconnect and cap the water service to isolate it from fixtures and appliances which may be damaged by the test pressure applied. The water service shall be isolated from the Authority’s water main when testing is carried out.

HOT WATER SERVICES

Hot water systems shall be tested prior to commissioning as follows:

(a) The completed hot water reticulation, excluding the storage container or water heater, shall not leak when tested with water at ambient temperature at a pressure of 1500 kPa for a period of not less than 30 minutes.

Prior to testing, the heating medium shall be isolated. It may be necessary to disconnect fixtures, appliances and valves in order to prevent damage during testing.

(b) Testing shall be carried out on all pipework prior to its being concealed in ducts, chases or trenches.

(c) The complete system (including valves, pumps and other equipment) shall be tested under normal working conditions for a period of not less than 48 hours. The system shall be checked visually for leaks.

(d) All drain pipes from expansion control valves, and temperature/pressure relief valves, shall be tested with water to ensure that they are unobstructed and are open to the atmosphere.

(e) All vent pipes shall be tested with water to ensure that they are unobstructed and open to the atmosphere.
TESTABLE BACKFLOW PREVENTION VALVES

Backflow prevention valves that are fitted with test cocks are required to be tested immediately prior to commissioning, immediately after servicing and at intervals not exceeding twelve months.

Note:

The introduction of testable backflow prevention valves represents a significant change in technology. The correct selection and testing of valves, and certification of their compliance with the by-laws is essential.

Testing is an integral part of the required installation, servicing and maintenance procedure for backflow prevention valves.

It is therefore necessary that plumbers who install, maintain or service these valves will have previously received specialised additional training. A pass grading in the W.A. TAFE Backflow Prevention Course is accepted as meeting this requirement.

This requirement applies to both the licensed plumber responsible for certifying compliance of the work with Authority by-laws and the person installing, maintaining or servicing the valve under the licensed plumber’s direction and control.

Otherwise reduced-pressure-zone devices, double-check valve assemblies, and pressure -type vacuum breakers shall not be used.

This notice does not cover normal commissioning requirements of licensed plumbers. The notice may be amended by any subsequent Authority notice issued in writing as far as is practicable to every licensed plumber.
CHAPTER SIXTEEN - PLASTERING

16.1 INTRODUCTION

16.2 MATERIALS FOR PLASTERING
   SAND
   LIME
   CEMENT

16.3 MORTARS
   TYPES
   MIX RATIOS

16.4 PREPARATION OF WALLS
   BRICKWORK
   CONCRETE

16.5 TYPES OF FINISHES
   PLASTER SETTING
   SAND FINISH
   FLOATING WITH SAND AND PLASTER

16.6 LATHINGS

16.7 ASSESSMENT OF PLASTERING

16.8 GENERAL INFORMATION ON PLASTERING
   MORTARS
   SETTING TO CONCRETE CEILINGS

16.9 WALL AND CEILING LININGS
   PLASTERGLASS
   GYPROCK
   GYPROCK LINING FAULTS
   FIBROUS PLASTER FAULTS
16.1 INTRODUCTION

The term *plastering* is usually applied to internal wall and ceiling finishes, which give jointless, hygienic, easily decorated and usually smooth surfaces to often uneven backgrounds.

External plastering is usually called *external rendering*.

There can be some confusion in usage of the term "plaster". It can be taken to mean any plastic material or mortar used to surface a wall, and it is also an abbreviation for "gypsum plaster".

Gypsum is a hydrous sulphate of lime which is found as a rock or granular crystals precipitated out on the bottom of salt lakes. This raw material must first be washed to remove impurities such as salt, clay, etc.

The gypsum is crushed, then calcined to drive off water taken up during crystallization. At temperatures in the region of 150°C, most of the combined water is liberated and the result is *hemihydrated gypsum plaster* or *Plaster of Paris*. This is the most common plaster used in the trade, either as it is, or after modification by the addition of a retarding agent to slow the setting time.

If the calcining temperature is raised, all the water-of-crystallization is removed, leaving *anhydrous gypsum plaster*, sometimes referred to as *hard-burnt plaster*. This produce does not combine readily with water and is usually mixed with an accelerator.

16.2 MATERIALS FOR PLASTERING

Like most finishing trades in the building industry, the quality of work depends on the degree of supervision, skill of the operative and, perhaps most importantly, the quality of materials used.

SAND

The importance of selecting good plastering sand is critical in the production of good plastering.

Some factors should be considered prior to defining what is required.

Plasterers usually consider several points when deciding which sand they will use. The yardstick may not be technically correct but few will have the knowledge to know better! These points include:

- cost
- easy to work
- saving on material - less handling

Cost

What is known as good plastering sand usually costs more than what is sold as bricklayers' sand. Plasterers consider savings of $6 – $8 reasonable when plastering 100 - 120 cottages per year: the savings are substantial.

Easy to work

Many plasterers feel sand with a high clay content is easier to spread and so continue to use this material, feeling that the more spread per day represents money in the pocket.
Saving on material - less handling

Because cheaper sand saves money on the initial cost and contains a high clay content, plasterers are also attracted to this type of sand because they can use little lime or, in many cases, no lime. Cost savings on not using lime are considerable for floating - $30 - $40 per cottage.

The fact that no lime is used means most plasterers do not need to handle extra material and so save time loading and unloading, and using heavier vehicles.

These aspects may seem minor in the overall question of which sand to use, but are the major reasons why most plasterers purchase cheaper grades of sand.

Whether it is by design or lack of technical knowledge that this occurs is debatable, but one thing is apparent and that is that there is no replacement for good sand. Cost savings do not replace good workmanship or quality work.

Poor sand produces the following problems:

. shrinkage
. staining
. weaker mortar
. less adhesion
. uneven suction
. discolouration.

In comparison, good plastering sand - used in accordance with correct mortar ratios - offers the following advantages:

. strong mortar
. good adhesion or bond
. no staining
. good suction
. even colour on the finish

The comparison shows the benefits of using good plastering sand. Why, then, use a second-grade material when for many years it has been a fact that plasterers' sand contains so many advantages?

DEFINITION OF GOOD PLASTERING SAND

Plasterers' sand should be sharp with various sized grains, light yellow or white, clean and free from impurities, have little or no clay content, include no vegetable matter, and be washed or sieved.

It must be stated that correct plastering sand is not always easy to use, but ease of use is not a major criteria in the selection of sand. It is the incorrect use of sand which is often the basis for faulty plastering. Incorrect sand often leads to the undesirable factors mentioned, and entices the operatives to add substitutes to the sand in an attempt to compensate. (This matter will be dealt with later).
It is unfortunate that plasterers have adopted the attitude of "if it's easier, it's better", rather than "what is best for the trade and the client".

**ADVANTAGES OF GOOD SAND (SHARP GRAINS)**

The grains of sand in good plastering sand are larger than those in bricklaying sand, therefore providing a larger aggregate for final strength. If compared with concrete where a good comparison can be made between concrete containing 19 mm metal and concrete of 6 mm metal, in final strength there is no comparison between the two. A 6-1-1 mix of both materials usually shows plastering sand material with greater strength. To obtain the same strength with bricklaying sand a greater amount of cement will be needed, therefore creating greater shrinkage. The various grain sizes also provide the same benefits in mortar as do various-sized stones in concrete - to form with the matrix (cement + lime) to form a mass with no voids.

**COLOUR OF SAND (LIGHT YELLOW OR WHITE)**

The colour indicates the amount of clay content in the sand. Clay in sand provides some assistance to workability, but lime is used to produce the same thing. Hungry sand often needs more lime and is therefore more costly. The colour varies between sand pits and between areas. Some sand may come from depths of 30 - 40 metres and in other areas from topsoil, creating different colours. It is possible for sand with no clay content to give the greatest strength.

**CLEAN AND FREE FROM IMPURITIES (ESPECIALLY VEGETABLE MATTER)**

This is a most important factor in the selection of sand. Small root matter can cause the following:

- **Staining.** Various types of roots or leaves can produce stains on the finished coat of plastering. These can be blue (blue boys), green, yellow or brown. In the past it has often been required to cut these areas out, necessitating patching the finished walls.

- **Swelling.** Larger roots can swell up in the wall and "pop" off the surface. Usually this occurs before setting, but moisture gain on application of the second coat can cause the root matter to swell, thereby causing popping.

- **Impurities.** This term refers to such things as: coffee rock lumps, stones, etc. To achieve a good surface finish (either floating or a finished rendered wall), impurities such as those mentioned above tend to cause scratches when ruling off, and show through on finished walls. Brown lumps and scores on the surface of the wall in floating do not assist in producing a good wall finish. Often coffee rock lumps wash out of the wall, leaving holes which when filled in with hardwall setting often shrink, creating cracks on the wall surface. The same applies to scores in the floated surface. (The shrinkage occurs because of the extra thickness). Blemishes can also occur on the finished surface because of the extra thickness of finishing material.
The advantages in using good sand are, again:

. **Strong mortar** - (already explained).

. **Good adhesion** - with the addition of lime (to be explained later). Lime can be added to sand to suit the plasterer but sand, which already contains clay (which provides plasticity) precludes the plasterer from removing excessive clay.

. **No staining** - (already explained).

. **Good suction** - this coincides with the addition of lime and the lack of clay content in the sand. Lime provides suction - but clay seals, when brought to the surface, forming a waterproof area where water cannot be absorbed. Patchy suction then occurs.

. **Even colour on the finish** - when an even float is obtained, a more even finish is likely to occur. In some cases where high clay content sand is used, a brownish stain can appear through the surface of a set wall, especially when the float is a little bit wet.

Good sand not only allows for a harder float coat, but affects the final finish to be achieved on the wall.

The importance of good sand in plastering cannot be over-emphasized. In float and set, cement dado (G.F.C.) and sand finish, the sand will control the ultimate finish. Generally, less shrinkage cracks will occur with good sand and better quality work will be produced.

**LIME**

Lime is used in the plastering trade for several purposes. Lime is added to mortar and also used in the finishing of walls with hardwall plaster.

Many of the reasons lime is used in the plastering trade seem now to be forgotten and substitutes have been introduced. Basically there is no substitute for lime - that is, good quality lime.

The two basic forms available are:

1. **Hydrated lime**. This is a dry powder, packed in paper bags, ready to use.

2. **Lime putty**. Also a hydrated lime but in moist form.

**REASONS FOR ADDITION OF LIME TO MORTAR**

Lime performs various functions when added to sand and cement.

**Plasticity - Workability.** These two may be combined. Lime enhances the "flow" of material, giving it a plastic effect and so enabling the work to be shaped and smoothed easily. The more lime added, the more "fatty" the material.

**Bond - Strength.** The bond onto the surface provides what is called "strength of bond". Lime adheres to brickwork as well as cement, giving good adhesion.
Water retention. Lime retains moisture, which enables composition mortar to obtain greater strength. The same water retentiveness eventually assists in providing suction in the mortar for the final coat of plaster.

Flexibility. Lime allows some movement to take place without causing excessive damage or cracking. In cement mortar (which is more rigid) any movement is likely to cause severe cracking.

MANUFACTURE

Hydrated lime

Factory-produced lime in powder form is marketed under the name of 'Marvelime'. This material is most suited for addition to mortar rather than for use as a putty.

The hydration or slaking is similar to that for lime putty but excess moisture is withdrawn and the stone is crushed to a fine powder. Screening is then carried out to extract impurities.

Lime putty (rock lime)

Rock lime is produced by the burning of limestone (capstone) in kilns which removes the carbon dioxide. Lime (calcium carbonate) is only produced from good limestone.

To produce lime putty, the rock lime or hot lime is added to water. The limestone hydrates or expands with the addition of water. This process is called 'slaking'. The material creates heat during this process and eventually forms a thick paste. The material is then sieved into a draining tank and allowed to stand for 14 days before use.

Care must be taken to remove substances such as cone (hard burnt pieces of lime) and root matter from lime. Root matter can discolour the lime.

Core or partly unslaked lime can cause popping, blowing or pitting on wall surfaces. These particles, if present in the lime, can hydrate or slake when moisture is added or absorbed from the atmosphere and, in so doing, expand and blow holes in the plaster.

Lime is at present being dredged and manufactured from sand silica. This material is used in the manufacture of hydrated lime.

The arguments over which type of lime is best to use depend upon the operative and the type of work to be performed, but good lime putty provides the best workability of both types.

It is the improper use of lime which creates the problems associated with its use, not the material.

With the expanding use of high clay content sand, first, hydrated lime was used because it was not as "fatty" as lime putty; since then, lime substitutes have replaced hydrated lime.

High clay content sand requires far less lime than coarse, sharp plastering sand. When lime is added to clay sand far more shrinkage takes place.

Clay sand without lime has less suction, whereas plastering sand with lime offers good suction for the final coat, producing a better finish.
BOND TO WALLS

As stated, lime provides bond to clay or lime bricks, but some doubt exists in applying lime directly to concrete or concrete masonry.

When lime is not present (as in the case of mortar plasticiser) less adhesion to the base occurs.

CEMENT

Cement is added to mortar to provide the set in the material. For cement to provide its maximum effect it must be allowed to set and not dry.

The basic types of cement available are:
- grey portland cement
- white cement
- masonry cement
- brighton-lite (white cement)
- fondue cement.

Little needs to be said on the manufacture of cement, but a few basic rules in its use should be noted.

- Cement should always be used fresh and should not contain lumps. Floating lumpy cement can cause popping.
- Cement should be used within a short time of mixing and not be remixed several hours after the initial set has occurred.
- Cement should be allowed to cure to obtain its maximum strength. By maintaining moisture within the floating, etc, the strength will be maintained.
- All mixes containing cement should be of the same ratio.
- Excessive amounts of cement should not be used if it is not necessary. Too much cement causes shrinkage.

Uses for various types of cement:

Portland cement - cement floating, rendering concrete, etc.

White cement - Finishes where an alternative colour is required: for example white cement sand finish, white cement dado, fancy finishes, grouting for tiles.

Masonry cement - This is designed more for bricklaying. Problems have occurred in its use for plastering (contains plasticiser). Contains furnace slag, limestone, etc.

Brighton-lite - manufactured in South Australia from marble. It is a greenish coloured material but dries out fairly white when mixed with white sand. It is a high early strength cement which attains great final strength. It is used for finishing swimming pools mixed with snowstone quartz.

Fondue cement - quick setting cement; will set underwater. It can be used in fire work and areas of extreme cold.
Cement is a product which is rarely used wisely. Too much cement causes shrinkage and often produces the opposite effect to what is intended.

A major problem is interference by other trades, for example, plumbers and electricians who patch up pipes using much stronger mortar than is required. This often cracks away from existing mortar, or becomes brittle and is affected by the pipes expanding and contracting, causing cracks to appear on the surface of the wall.

16.3 MORTARS

Several types of mortar are available to the plastering trade. Each has a specific use relating to various types of finish.

The selection of which mortar to use and where, often produces conjecture within the trade, and few plasterers appear to agree. Several factors, however, need to be considered before selecting a mortar mix for any particular job or finish.

TYPES

To begin with, the type of background or base to which the mortar is to be applied must be considered. These backgrounds can be divided into soft, medium and hard categories.

SOFT BACKGROUND

Limestone

A general rule is that no strong coat should be applied over a weak base; strengths of mortar should be commensurate to the base. Limestone is regarded as a weak or soft base; therefore, the mortar to be applied should be in the proportion of 9 sand 2 lime 1 cement. A high lime content is necessary because of the weak nature of the stone. Also, lime becomes the common factor or common material to both base and mortar.

Lime mortar

Consisting of lime and sand, mixed 2 sand 1 lime - can be applied to limestone where moisture will not be excessive.

MEDIUM BACKGROUND

Wire cut bricks (clay)

Possibly the best base for plastering. The most suitable ratio of mortar for these bricks would be 6 sand 1 lime 1 cement. However, these bricks have been known to withstand cement mortar up to 3 sand 1 cement. For external rendering, 4 1/2 - 1 - 1 can be used.

Tunnel bricks - modular - extruded (clay)

These should not cause a great deal of worry. Internally 6 - 1 - 1 mix should be acceptable. Externally 4 1/2 - 1 - 1 cement mortar or 3 or 4 - 1 can be used, provided good preparation takes place.
Pressed bricks - extruded solids and commons (clay)

Most of these bricks can have almost any mix of mortar applied, from 3 - 1 cement mortar onwards.

Lime silicas

Usually where composition mortar is used it is recommended that a higher proportion of lime should be used; therefore, instead of 6 - 1 - 1, a mix ranging from 6 sand 1½ lime 1 cement to 9 sand 1½ lime 1 cement can be used. Care should be taken in applying cement mortar to lime silica bricks. The use of good sand assists in obtaining maximum bond.

HARD BASES

Besser masonry

Cement mortar 3 - 1 onwards can be applied to these bricks. Where composition mortar is to be used, less lime should be added; i.e., 6 - 1 - 1 should be 6 sand ½ part lime 1 cement. With cement bases the cement content can be increased.

Dense concrete

It is not recommended that composition mortar should be applied directly to concrete, but cement mortar 3 - 1 can be applied directly to concrete. If composition mortar is required, a scratch coat of cement mortar should be applied first, followed by the composition mortar.

MIX RATIOS

There are four (4) main mortar types:
- cement mortar - cement and sand
- composition mortar - cement, sand and lime
- lime mortar - lime and sand
- plaster mortar - plaster and sand

The second factor in selection of mortar is the finish which is to be applied as a second coat.

For example: A hardwall plaster finish with a ratio of
- 75% plaster 25% lime would require a stronger base than a 50% plaster 50% lime ratio.
- 75% plaster 25% lime - mortar ratio 5 - 1 - 1
- 50% plaster 50% lime - mortar ratio 7 - 1 - 1

When the ratios are established, a check on the base is necessary to consider if it will provide the contrasting strength.

CEMENT DADO OR GLASS FACE CEMENT

The base coat - 3 or 4 sand 1 cement (rendering)
Second coat - 1 sand 1 lime 1 cement
The rendering needs to be strong to facilitate the strong second coat. Therefore, the base on which the rendering is to be applied should be one which will be able to receive the strong mortar.

**RECOMMENDED MORTAR MIXES AND FINISHES**

1 coat sand finish - Internal - 6 sand 1 cement 1 lime
1 coat sand finish - External - 4\(\frac{1}{2}\) sand 1 cement 1 lime
2 coat sand finish - Internal - 1st coat: 5 - 1 - 1
   2nd coat: 6 - 1\(\frac{1}{2}\) - 1,
   2-3 mm thick
2 coat sand finish - External - 1st coat: 4\(\frac{1}{2}\) - 1 - 1
   2nd coat: 4\(\frac{1}{2}\) - 1\(\frac{1}{2}\) - 1,
   2-3 mm thick

Hardwall plaster - 1st coat floating: 6 - 1 - 1
   2nd coat setting: 60% plaster 40% lime
   putty (internal only)

Cement dado - glass face cement:
   1st coat rendering: 3 or 4 - 1 cement mortar
   2nd coat: 1 sand 1 lime 1 cement,
   3-4 mm thick

Hardwall plaster dado - 1st coat: 4 - 1 - \(\frac{1}{2}\) lime
   2nd coat: 90% plaster 10% lime

Ultra hard or titan plaster will act as hardwall dado.

**16.4 PREPARATION OF WALLS**

One of the main objectives of plastering is to obtain a plaster finish which is pleasing to the eye and can be decorative. This type of work, to continue to fulfil this objective, should remain on the wall!

Where plaster material leaves the base, the cause is often lack of preparation. Whether on new work or old, the preparation often accounts for lesser or greater strength of the bond.

In latter years the trade has engaged the use of bonding agents, which have been of some advantage. However, for this material to succeed, it must be used properly; in many cases, its use is not to the best advantage.

For many years there have been accepted methods of achieving bonds between different bases, which have had enormous success but are not universally known or understood in the trade at present. The trade of plastering is not endowed with scientific background or knowledge, but methods evolved from trial and error with different materials available.

Listed below are some accepted methods for obtaining bond to various walls or bases.

**BRICKWORK**

It is important that these be damp and free from surface dust. Wetting down, therefore, done correctly, does both. Where dust is apparent and the walls are already damp, either a broom or an air pressure hose can remove most of it.
It has always been accepted that water assists in the adhesion of mortar to brick walls. It is believed that the suction of the bricks encourages the mortar to bond and the more suction the better the bond. Harder burnt or pressed bricks offer less suction, therefore care must be taken with these types of bricks. Depending on the requirements of the finish, extra lime may be needed to increase the bond.

A cement slurry was often used on hard-type bricks to provide a key. This was a fairly weak solution of cement and water brushed onto the surface. The harder the base, the more cement was added. This was covered while still wet.

The same method was often used on secondhand bricks which sometimes had old surface mortar attached. Many old bricks required 'hacking' or 'chopping' first to break the surface, which often had a weathered surface.

It was possible on some walls to fix expanded metal over the whole area to be done, to make sure that the mortar remained in position.

To assist in obtaining better bond, a list of bricks and the appropriate preparation is listed.

Wire-Cut bricks

Wet down well from top to bottom, wetting to remove dust.

Modular - extruded

Wet down as previously suggested if walls are not wet. If wet, remove dust by method suggested.

Pressed clay

Wet down as required; apply previous methods.

Lime silica

For floating with compo mortar, wet down or dampen before applying mortar if required. For applications of stronger mortar or cement, splash or wash is acceptable.

Concrete masonry

Dampen if required; a cement slurry or splash can be used. An alternative can be a splash with a mix of 3 metal dust 1 cement, or 2 metal dust 1 sand 1 cement. This will give a better bond. It is not advisable to use straight cement and sand for a splash coat. Splash coats should not be allowed to dry out too quickly, as they tend to 'dust' - which can cause drummy work.

CONCRETE

An application of bonding agent followed by either a splash coat of metal dust and cement, or a scratch coat of 2 - 1 cement mortar. (Note: concrete must be free from dust as for brickwork; a wash down or wire brush can be used).

It is not always necessary to apply a bonding agent to concrete. Often a good wire brush, wash down and splash coat is all that is required.
Concrete floors

When topping is to be applied to an existing floor, dust must be removed first. An application of cement slurry or bonding agent can be applied but must be covered before drying out.

Patching to concrete

Clean dust and loose material from area. Paint with either bonding agent or cement slurry. Some bonding agent may be added to the patching material. Keep the area damp to slow down shrinkage at the edges.

Patching to cement floating

Cut away loose material. Dampen area to remove dust. Paint with weak solution of bonding agent. Apply mortar to the same strength as existing.

It should be noted that in all cases of preparation the dust factor is most important. No material will bond to a base which has dust present.

Epoxy resin bonding material (Epi-crete) can be applied to concrete surfaces to provide a bond between new and old material.

16.5 TYPES OF FINISHES

PLASTER SETTING

This is an internal finish only using hardwall plaster and lime putty.

This type of wall finish is used extensively in cottages and office areas. It is not recommended to use in those places where a hard wearing surface is required, or where the walls will come into contact with excessive moisture.

The final strength of this type of finish will rely upon the following factors:

The ratio of plaster to lime - The high proportion of plaster the more strength on the finished wall.

The strength of the floating coat - If the floating coat is weak the final coat will not stand extensive hard wear.

The drying of the wall - If hardwall plaster is not allowed to set within a reasonable time, it loses some strength on the final coat.

Insufficient trowelling - Plaster setting which does not receive sufficient trowelling will not attain a hard finish.

Re-mixed plaster - Plaster which has been re-mixed will not attain maximum strength if applied after re-mixing.

Plaster is a material which requires careful handling and working. Abuses in using this product can cause problems in obtaining a good finish.

The set of plaster can be changed by any of the following:
The weather - For example, cold weather can cause a slowing up of the set by up to 1 hour. Hot weather increases the set by up to 15 minutes.

The age of the plaster - Plaster which has been around for any length of time will usually set slower.

The lime putty - Hot lime putty can cause a quicker set if used fresh compared to putty which has been standing for some time.

The temperature of the water - This will affect the setting time, depending on whether it is hot or cold (summer or winter).

The following factors are also important:

Soaking of the plaster - If the plaster is not allowed to soak sufficiently, or if the plaster is added in large amounts too quickly, this can cause quicker setting and increases the possibility of lumps and streaks.

Too much mixing - The longer plaster is worked, the quicker it sets.

Dirty water - If dirty water is used, the plaster will set quicker and this often produces a weaker mix.

Not enough water on the floating - Insufficient wetting of the float coat can cause:
. crazing on the surface
. uneven wall finish
. uneven texture.

Plaster setting should provide the following:
. A neat smooth finish.
. It is usually easy to patch.
. Easy to paint - does not use a lot of material.
. Easy to wallpaper.

DISADVANTAGES OF PLASTER SETTING:
. usually a fairly high degree of maintenance
. does not stand up to hard wear and tear
. is not recommended for use in excessive wet areas
. is an internal finish only.

Plaster setting, done correctly, is a most acceptable wall finish. To be a good finish it should not have the following faults:

Blemishes - These are dull areas on the wall.

Water or trowel marks - The wall should be of even texture; these marks should not be apparent.

Galls - These are holes in the wall which have not been filled in when trowelling.

Crazing and firecracking - These are shrinkage cracks which appear for any of the following reasons:
insufficient trowelling
  too much lime
  allowed to dry too quickly
  too much suction in the floating
  sometimes the base on which the floating has been applied:
    e.g. concrete, cement, bricks
  high clay content sand in the floating.

As plaster setting is only a finishing coat, to obtain straight
skirting or ceiling lines it is important for the floating to be
accurate. Internal angles, bullnoses, etc., must also be straight
in the floating if the setting is to enable accuracy on the finish.

Some factors which should be considered in obtaining the best
finish for plaster setting are listed below:

*Good floating* - Floating which provides an even suction will
assist in producing a good finish. Walls which have several
different types of bricks can produce blemishes on the finished
plaster.

*Even wetting* - Walls to receive setting should have been
evenly wet down. Uneven wetting can produce areas which dry
out quicker.

*Winds* - Often it is a good idea in hot weather to fit windows
and doors in rooms to prevent premature drying out.

*Wet walls* - In winter it is essential that "locking up"
does not take place too quickly after walls have been set.
If houses, etc., are enclosed too early sweating or condensation takes place on the walls, often causing fungus growths.
Cupboard areas are especially susceptible.

Areas which often cause problems or criticism of the finished
work are:

* flaring out of the setting along skirting lines
* build-up of setting in internal angles at the bottom of
  the wall and at the underside of the cornice
* reveals and returns often running out of square
* the tops of bullnoses flaring out at the tops.

An awareness of what causes the problems facing plasterers in
using this type of material should, while not making excuses for
bad work, provide an understanding of the problems which tradesmen
face in producing good plaster setting.

In summing up, it must be understood that ideal conditions are
necessary if a perfect finish is to be produced - something which
is not available on most construction sites. The plasterer relies
on the suppliers to furnish him with good quality materials, but
these vary from time to time and the quality control is often not
very effective - mainly because of the nature of the two materials.
**TYPES OF PLASTER AVAILABLE**

<table>
<thead>
<tr>
<th>Type</th>
<th>Uses</th>
<th>Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting plaster</td>
<td>Making plaster products, sheet, cornice, etc.</td>
<td>5 - 8 min.</td>
</tr>
<tr>
<td>Grouting plaster</td>
<td>Fixing plaster products, sheet, cornice, etc.</td>
<td>5 - 8 min.</td>
</tr>
<tr>
<td>Setting plaster</td>
<td>Small patching areas on walls and ceiling by the solid plasterer.</td>
<td>7 - 10 min.</td>
</tr>
<tr>
<td>Hardwall plaster</td>
<td>Large wall areas and ceilings. Used with the addition of lime putty.</td>
<td>1½ - 2 hrs.</td>
</tr>
<tr>
<td>Retarded plaster</td>
<td>Used to mix with sand for floating or vermiculite for spraying.</td>
<td>4 hrs. neat</td>
</tr>
<tr>
<td>Superfine plaster</td>
<td>Used to flush joint plaster sheet.</td>
<td>10 - 20 min.</td>
</tr>
</tbody>
</table>

**SAND FINISH**

This finish is a texture-type plaster finish. It can be used both internally and externally as a finish, and can be applied in either 1 or 2 coats.

It is a most durable finish which has certain advantages, in it is hard wearing, water resistant - and, at the same time, provides an attractive finish. It is usually finished these days with a sponge or, if required, left "off the float".

This particular finish can be used in some of the following areas:

- external walls on houses - to provide a water resistant finish, as a texture, to prevent fretting in brickwork
- internal - to provide a durable, hard wearing and attractive finish.

This finish can be used, therefore, in such areas as: cottages, factories, garages, workshops, external walls on buildings.

It has some disadvantages for normal cottage work.

**Rough** - The texture can cause minor injury if a person comes in contact with it.

**Hard to patch** - It is difficult to obtain the same texture.

**Hard to clean** - Dust and dirt are hard to clean off.

**Uses more paint** - The rough, porous surface absorbs more paint.

**Hard to wallpaper** - Modern homes require walls to which wallpaper can be fixed. Sand finish needs a backing paper first.

The main advantage of sand finish is that it requires little maintenance and is long lasting.
This finish was very popular during the years 1950 - 1965. It is still used on houses for garages, laundries and toilets. For one (1) coat finishes internally, 6 - 1 - 1 is a good ratio. Externally, $\frac{1}{2}$ - 1 - 1 is normally used. Variations on sand finish, such as splash texture, spanish bagging and bagging, and trowel textures, offer alternatives to the plain sand finish.

**GLASS FACE CEMENT - CEMENT DADO**

This finish provides a combination of all the advantages of setting and sand finish. It provides a smooth, hard wearing, durable, water resistant finish requiring little maintenance. It is easily cleaned and provides a hygienic wall finish.

It can be used in any area which requires constant cleaning down: e.g., operating theatres, food preparation areas, laundries, toilets, factories, dairies.

Its main disadvantage for cottage work is its cost. The base coat for this finish is 3 or 4 - 1 sand and cement. Normally this coat should not contain lime, but a small amount (e.g. 3 - 1 - 1/10th part lime) may be acceptable.

The second coat should be of a ratio of 1 sand 1 cement 1 lime but, depending on the sand, the ratio could be extended to 1 ½ sand 1 cement 1 lime.

This is a very hard surface finish which has a high cement ratio content, therefore some shrinkage can be expected.

This finish requires considerable trowelling to obtain the best finish with the normal setting time per wall of between 3 - 6 hours duration. The more trowelling, the more compaction of the surface and, therefore, a harder surface finish.

It is advisable to use lime putty in the surface material. Other methods of obtaining a similar finish have been tried but the success of the alternative methods relies heavily on the operative performing the task.

The surface of the base coat should be scratched with a serrated edged scratcher. Some keying for the second coat is thereby obtained, as well as assisting in water absorption. The surface is wet down prior to application of the second coat.

**FLOATING WITH SAND AND PLASTER**

Sand and plaster is an alternative method to the normal composition mortar for use as a float coat.

The use of plaster as the setting agent has some advantages as the product plaster (gypsum) is inert once it has set. This makes the plaster-sand mortar a most useful substitute for normal or accepted floating procedures.

It has only minor disadvantages which are:

- Setting time - because plaster has a time limit on its workability many plasterers steer away from it.
- Wet areas - some doubt may exist as to its ability to last under constant contact with moisture.

Neither objection is of major consequence as, with correct working procedures and selected use, both points can be overcome.
Depending on the area to be worked, several plasters could be used.

- Small patching areas up to 2 m² either casting, setting or grouting plaster and plastering sand. 2 sand - 1 plaster. 5 - 10 minutes working time.
- Areas above 2 m². Retarded or hardwall plaster and plastering sand. 2 sand 1 plaster. 1½ hours working time.

(Note: Lime and sand floating can be used if necessary).

The use of bricklaying or high clay content sand is not recommended as it:

- accelerates the setting time
- allows some shrinkage to occur.

Plaster and sand, once set, cannot be remixed. However, if using retarded plaster or hardwall, droppings may be remixed if more plaster is added, providing it is within 60 minutes (1 hour) of original mixing.

The working procedure is similar to ordinary floating with the same preparation as for general working.

**AREAS OF USE**

1. Patching or renovations of either 1 - 2 walls or 1 - 2 rooms. This allows for almost immediate setting to occur.

2. Concrete ceiling - either patching hollow areas or complete floating on ceilings.

3. Working onto bases such as plaster blocks - lathings which are rust resistant.

The main argument used by plasterers for not using plaster and sand are listed below:

- It is a little harder to spread and work; also, the finishing and filling of hollow areas of the wall (slacks) is more difficult.

- Cost. It may, by using straight sand-plaster mixes, cost a little more than conventional floating. This may be overcome by using a lime-sand-plaster mix on larger areas at a 4 sand 1 lime 2 plaster ratio.

The main benefit of sand and plaster is that it always adheres well to most bases.

**16.6 LATHINGS**

Plaster may be applied over many bases - usually these bases are solid types, such as bricks and concrete and stone. The bases are usually dictated by custom and the type of construction.

Where solid bases are not available, some other form of base must be provided. Primitive man used sticks, reeds and mud; the Romans used reeds as a reinforcement for much of their plastering.
This evolved to the use of timber or wood lathing - thin strips of timber over which a mortar was applied. These were known as split laths as the split occurred with the grain of the wood. From this the sawn lath evolved, and this method of plastering was continued until just prior to the Second World War (1938).

The first material used to replace this method was the gypsum lath or plasterboard sheet onto which mortar was applied. In Western Australia this type of sheet was referred to as stucco board, over which a sand and plaster material was applied.

In England, paper-covered plasterboard appeared called 'sackett board'. This was the original gyprock type of board. This is still used in England as a lathing. There are two types:

- with holes onto which mortar is applied
- similar to our own type of paper lining board, but a setting coat is applied

Metal lathing was first patented in England in about 1797, and was a type of netting material. The first actual use of metal plaster base occurred in England in about 1841. In 1890 metal lath was produced in Chicago by Mr. J.G. Golding.

Since those early years many types of metal lathings have been marketed. Among the more popular types which are still in use today are: diamond mesh, rib lath, woven wire lath, paper backed wire (K lath), expanded metal plus sheet lath.

In England, America, and also on the continent, metal lathing is used far more extensively than in Australia, as is paper board lathing.

The types of metal laths most commonly used locally are expanded metal or K lath. A new type to Western Australia is rib lath (expansion), which is possibly the easiest of all to work with.

In earlier days cow hair was mixed with the first coat of material to be applied, for two main reasons:

- to bind the material together so that when applied to the lathing the material would not push right through the slots;
- as a reinforcement or binder to the mortar.

The fixing of lathings, especially expanded metal, has caused some problems. The sheets must be stretched as tight as possible across the supporting timbers and nailed or stapled at every 150 mm. Each sheet should be lapped about 25 mm. On walls, the metal strips should run inwards and downwards.

It is normal on all types of lathings to apply 3 coats:

- 1st coat - 'pricking up' or scratch coat
- 2nd coat - floating or straightening coat
- 3rd coat - finish - any finish may be applied.

One of the biggest problems in using expanded metal is gaining a tight surface on which to apply the mortar. Several methods are used, such as:

- edges of the sheets are wired together every 150 mm.
wire is stretched in a criss-cross manner over the surface and wired to the metal lath to stop its upward or inward movement. There is normally a fair amount of movement on the wire when mortar is applied.

The new rib lath type material is far more rigid and easier to fix. Also, the application to this type of mesh is much easier, as no reinforcement is required in the first coat.

There are several areas where lathing can be used:
. exterior and interior walls
. ceilings
. columns and piers
. covering metal or timber beams
. fixing over old walls before re-rendering
. placing across severe cracks in masonry before patching.

OTHER TYPES OF LATHINGS

Wooden or timber laths, not used much these days, usually Oregon pine 6 - 10 mm thick 38 mm wide.

Colterro - A wire with clay nodules baked onto the wire at each intersection, not available at this time but quite a good lathing.

Chicken wire or bird wire - Spread over walls before plastering. Used with paper backing. Ferro-cement boats utilize chicken wire for the basic structure.

Plasterboard - As mentioned before. Can have either sand and plaster or even cement mortar applied.

Hessian - Not widely used. Normally a cement wash - then, when firm, an application of mortar.

GENERAL INFORMATION

Plaster material should not be applied directly to metal lath unless it is specially treated to stop rusting. 5% lime added to the first coat can prevent most rusting.

The first coat must be scratched well to ensure a bond between it and the second coat. A scratcher made of nails is usually the best method of roughing up the surfaces to provide the key.

The metal lath system is perhaps the most under-used method of plastering today. In both England and America this method is the most generally accepted base for plastering. In America, 80% of buildings have lathings as the external skin of the construction (stucco).

16.7 ASSESSMENT OF PLASTERING

The assessment of plastering is not an easy task. Even plasterers of many years' experience have difficulty in judging whether or not completed plastering work is satisfactory or fair.

Possibly, the more knowledge of plastering, the more reasons or excuses one can produce to explain why plasterers have not produced the ultimate in plastering finishes!
It is – of course – to be remembered that the plastering trade, although a finishing trade, relies heavily upon the operative and his hand skills or his ability to produce an acceptable standard of work.

As a guide to define what is acceptable in assessment, the following points should be considered.

**STRAIGHTNESS**

This applies to internal angles, external angles and returns, reveals to windows, skirting and ceiling lines.

All of these must be straight so that they are pleasing to the eye; also, to assist following tradesmen: e.g. carpenters, ceiling fixers, joiners.

**PLUMB, SQUARE AND LEVEL**

Applies to the above and also to sills, floors, columns and piers.

In general, the points mentioned above are of absolute necessity for the good appearance of the finished work. Again, this is important for the above trades.

Where columns and piers are placed along a building in line and number more than two (2), these must be in one plane or line.

**FINISH**

The general appearance of the finished work should be of the same colour and texture. Depending on the type of finish to be produced, the finish should be even. For example, plaster setting should be smooth all over with no blemishes, no water marks, no gaulls, no scratches or crazing. Sand finish should provide an even texture on the surface with no holes or slack areas. Corners (internal) should be sharp, with no scratches on the surface.

**CORNERS (external)**

As all external corners need to be finished by the plasterer, it is important that the following points be noted.

Three (3) acceptable methods may be adopted:

(a) Sharp arris

(b) Dulled arris

(c) Rounded (Bullnose)

(a) **Sharp arris** - Usually used on sand finish externally around windows or on beams. This is acceptable where these areas are not likely to be affected by passing traffic. When done correctly these look quite attractive. They should not have holes on the arris and must be left sharp.

(b) **Dulled or chamfered arris** - Used where a sharp or bullnosed arris is not preferred. They must be uniform. These types of finished arris, again, are normally used on the above finishes and similar areas. Columns, piers and nibs can be finished in this manner.
(c) Bullnoses - This is the normal method of finishing external corners both on sand finish and plaster setting; also cement dado (G.F.C.). Rounded or bullnose corners are subject to less damage than square or dulled arrises.

The most important point to be mentioned is that all the radii must be the same. When floating, a template should be used to obtain a constant size. The size can be varied from a small radius (pencil round) or to a large radius (up to 100 mm) as used in hospitals.

There are several major problems which occur continually in some areas of the trade.

. Flaring out in corners and bottoms of walls
  This occurs continually in the trade. The reasons are because of the natural methods of application and usage of the trowel. If care is taken this can be minimised but seems as though it will never completely be eradicated. In both occasions, if the floating has been prepared or completed correctly, this will assist in overcoming the problem. If the floating is incorrect, it will be accentuated by the application of the final coat.

. Angles and reveals
  The worst feature of these is usually that they are not square on the returns. It is only by continual checking and using the correct tools that this can be overcome. On reveals if the floating is run back slightly out of square it assists in obtaining an acceptable finish.

. Intersection of bullnoses and heads
  Again, this is a problem of flaring out at the point of intersection. It is accentuated by the use of an unsuitable tool. The same problem can occur at the bottom of the angle.

Other problems such as incorrect margins, finishing to frames (metal door frames), aluminium windows (quirks) and cutting away from timber frames are common. Cleaning along bottoms of walls, and cleaning out of electrical boxes are other jobs often overlooked.

OTHER GENERAL PROBLEMS

. Crazing or firecracking
  These are fine cracks which appear on the surface of finished walls.
  Causes: incorrect sand (bricklayers with high clay content)
  incorrect mortar (too much lime)
  not enough trowelling onto the surface
  drying too quickly (summer).

. Drummy plaster
  This is plaster or mortar which has left the base on which it has been applied. When tapped it produces a hollow sound.
  Causes: lack of preparation of the base (little or no water applied)
  dust on surface of the wall (not washed or cleaned off)
  walls too dry or too wet (summer and winter)
  incorrect mortar.
Most problems encountered in the trade can be overcome. Lack of basic knowledge of the materials and general working procedures; time constraints applied by builders; lack of thought and poor attitudes - all of these reflect in the finished job.

As a general rule, the tradesman or operative who leaves the job clean, usually produces a neat and acceptable finish. The weather, job situation, ability of available tradesman - all must be considered in assessing the final finish. Cost must also enter into the question. Low prices encourage low standards.

There is no excuse for poor plastering work. However, while there remains no supervision, no set specifications and no form of control (registration) of the operative, poor standards of work will continue and the lower standards so easily become the accepted norm.

16.8 GENERAL INFORMATION ON PLASTERING

MORTARS

The mixing of mortar is important in that all gauges or mixes must be all the same. Most mortar mixes are not correctly gauged, there causing problems for the plasterer. These include:

- uneven suction for setting coats;
- cracks can appear on the walls where strong and weak coats join.

Shovel gauging is not likely to produce even mixes. Wet sand always gives larger shovel-fulls, whereas very dry sand gives smaller amounts.

Cement out of a full bag is more compact than a half-empty bag which has been "fluffed up". The same applies to lime.

The best method of gauging for mortar mixes is to use the volume method, or "buckets gauging".

MORTAR TO TIMBER FRAMES

Where mortar is to finish alongside timber frames, it is important to cut the material away from the frame. This is so that movement for any reason will not dislodge the plastering. Vibrations, timber swelling, etc., often cause plastering to go drummy.

PLASTER AND MORTAR

It may sometimes be necessary to patch up cement floated or rendered walls. It is not good plastering practice to mix plaster with cement mortar. The plaster sets, forcing the cement to harden prematurely. The cement then tends to soften after the plaster has set, killing the cement material.

Where patching up is to take place the following materials may be used:

- Plaster and sand - 2 sand 1 plaster
- Plaster and putty - setting plaster and putty

Cement mortar, if used to patch, must be left for at least 24 hours before covering.
SETTING TO CONCRETE CEILINGS

This method of finishing concrete in multi-storey buildings has become common over the last few years.
Where it is required, the following working procedure should be adopted:

1. Clean down ceiling with stiff brush; clean off dust.
2. Paint area to be plastered with a suitable masonry bonding agent.
3. Any areas which need to be straightened can be done with sand and plaster, 2 sand - 1 plaster (not hardwall and putty).
4. Apply hardwall and putty using the following working procedure:
   1st coat - scratch coat with setting trowel.
   2nd coat - apply with 450 mm long wooden float.
   3rd coat - laying down coat using setting trowel.
   Complete trowelling with water.

Plaster should not be re-mixed after it has been set.
Concrete does not provide suction; therefore, a strong plaster putty ratio is required - 70% plaster, 30% lime putty.

16.9 WALL AND CEILING LININGS

PLASTERGLASS - Reinforced plaster sheet (fibrous)

This internal lining board is manufactured by casting a flat sheet approximately 8 mm thick by mixing a slurry of casting plaster, pouring onto a flat smooth table or bench and fibreglass worked into the material.

Plasterglass is used as an internal lining board only, and provides a smooth fire-resistant (2 hour fire rating) surface.

FIXING METHODS - CEILINGS

Sheets are temporarily nailed and straightened (placed at right angles to ceiling joists). Where sheets are joined, the joints are between ceiling joists. The joints are cleated for support until grouted. When in position the ceiling is grouted.

A plaster called grouting plaster is mixed as a slurry and sisal or fibreglass dipped into the slurry. The sisal is impregnated with plaster and then placed over the ceiling joists and onto the ceiling board. These wads of sisal/fibreglass are placed every 450 mm. All joins are grouted to form a continuous sheet, nails are removed after approximately 30 minutes and nail holes stopped with superfine plaster. Joins are flush jointed - also with superfine plaster.

The cornice is usually placed into position and grouted at the same time.

WALLS

When only one side is to be done, the working procedure is as follows:
. Sheets run horizontal or at right angles to the studs.
. Galvanized nails are driven into the sides of the studs.
. Sheets are temporarily nailed - as for ceilings.
. Grouts are applied and draped around the nails.
. Vertical joints are joined on studs.
. Where possible, stagger joints on the walls.
. Finish as for ceilings.

Where both sides are to be done, one side is done as per above; the other side can be nailed, or stud adhesive may be used.

PATCHING

Depending on where or how big the area is, it is advisable to use superfine plaster. Sisal can be dipped in casting plaster or a piece of the same material. It is also a good idea to build up in coats, allowing the previous coat to set before laying another over the prior one. This stops hollowing out of the patched area. Keep the area to be patched moist to allow for better adhesion. Also, keep the surrounding area clean from excess material.

GYPROC LINING BOARD

Paper sandwich board or now known as plasterboard. The material should be used in areas not subjected to continual moisture. Areas such as shower recesses can be lined in Hardiflex-type material.

Gyprock is fixed in many ways, in a different manner to plaster-glass, and requires its own tools, fixing and jointing materials.

Gyprock sheets can be cut to any length to approximately 5.4 m and the product is available in 0.9, 1.2 and 1.35 widths. It can be a plain edge or recessed edge sheet. The most common is recessed edge sheet.

FIXING TO CEILINGS

(a) Gyprock stud adhesive is placed onto joints approximately 200 mm apart and 200 mm away from ends and sides. (See Figure 16.1).

(b) The sheets are run at right angles to the joists and nailed at the ends and edges (where sheets run the full length of the room). The next sheet is placed against the other with the recessed edges tightly together (use only special gyprock clouts).

(c) Where sheets are to be joined in the length of the sheet (butt joints), these need to be joined between ceiling joists by using a back block (a piece of gyprock 250 mm wide with adhesive GB100 spread onto the surface and placed evenly across the joint, half on each sheet. (See Figure 16.2).
FIG. 16.1
Courtesy of CSR Limited

First walnut 225 mm from edge
Locate walnuts at least 200 mm from nails
75 mm
Centre about centre line
1350 mm
1200 mm
900 mm
Walnuts of adhesive must never coincide with nailing points
Ceiling fixing detail

FIG. 16.2
Courtesy of CSR Limited

Gyprock back block

Strip nailed to stud.
50 mm maximum
GB8100 or Cornice Cement
Packing strip
Temporary batten
Back block set back 5 mm to 9 mm from face of stud and held with a skew nail into the stud

16.25
(d) Sheets are staggered where required. Temporary nails (only) are used to hold the centre of the sheets where adhesive is used. (See Figure 16.3)

FIG. 16.3
Courtesy of CSR Limited

JOINTING

- Fill the recess with GB100 (dry plaster mixed with water).
- Cotton tape is run over the joint and GB100 is pushed into the joint (use a 150 mm broad knife). (See Figure 16.4 (a)).
- Flush over with GB100 using the small curved trowel. Allow to dry or set. (See Figure 16.4 (b)).
- Apply GBRM topping to joints using large curved trowel. Allow to dry. (See Figure 16.4 (c)).
- Sand joint using the sanding float (do not scour paper sheet). (See Figure 16.4 (d)).

BUTT JOINTS

- Use the same working process but use a straight trowel and spread material the width of the trowel. Nail holes are filled at the same time but not sanded.
- Cornice is fixed last using cornice cement.
- Wall fixing - same system as ceilings except joints are on studs.
- Patching - Use the same process as described on ceilings; tape all joints.
Gyprock can be fixed to steel studs using the same system of adhesive, but is screwed to the steel using special gyprock screws.

Painting gyprock - recommended first coat using a paint roller. Brushes can be used after the first coat.

Gyprock is cut using a Stanley knife.

**FIG. 16.4**

*Courtesy of CSR Limited*

**GYPROCK LINING FAULTS**

Many of the failures with gyprock are a direct result of lack of training in the correct methods, and a large number of those erecting it have learned from untrained people, often with no building trade experience. A limited number undertook periodical courses of a week or so set up by C.S.R., but the time was too short to be of value and during the boom times anyone could and did tackle the job. Unfortunately, it is not such a simple matter to produce good work and, in fact, requires a good deal of knowledge and skill.

C.S.R. supply a manual laying down methods for their own contractors, but these are not available to the majority of fixers and few have ever seen them. They are good as far as they go, but do not deal with overcoming imperfect background or dealing with other types of problems. For instance, it is required to nail to every stud or joist on the perimeter of the board. This results
in the variation in timber sizes being reflected in the joints and cornice line, and the job is only as straight as the framing!

The board itself is sometimes the cause of bad joints: during the process of producing the recessed edge, a large bulge may be produced near the shoulder, which is itself a peak. Even when trowelled out for a considerable distance it can still be obvious.

At the recess there is considerably more thickness of wood laminate and, when this absorbs moisture from the cement, swelling occurs and with subsequent drying out distortion often results. All cut laminate (such as vent openings) require taping as, again, the swelling and shrinking of the laminate leaves hair cracks. With both gyprock and fibrous plaster, the joints are filled with a much stronger and denser material; this gives a variation in the absorption of the paint coat. This is very obvious with colours, and usually shows a dark band.

Sealing of both materials prior to painting is specified for both gyprock and fibrous plaster.

Back blocking of joints between joists is essential, as peaks are otherwise inevitable. In fact, back blocking of all joints is strongly recommended.

Ames tools, particularly the ones for joint finishing, make for a much better finish, but as these are only available on a hire system (which is fairly expensive) very few fixers use them. It surprises most people to know that victor board was used in South Australia extensively in the 1930s and also in this state, although it was not able to compete with fibrous plaster.

The methods of fixing and finishing were those employed on plasterboard today, and required no special tools. No great problems were experienced. This seems to indicate that a grouted joint could be superior to tapes.

Further study and experimentation needs to be done, but the fact that some manufacturers appear reluctant to accept any method except their own has discouraged this.

**FIBROUS PLASTER FAULTS**

When fibrous plaster was manufactured with sisal, a number of problems were involved. Being a vegetable material the sisal inevitably rotted over the years and the board became purely a biscuit of plaster; with ceiling joists at 450 mm or more, sagging occurred.

Good quality work could still be done by battening out to about 375 mm or less centres and thorough grouting, but this was more expensive. However, sagging has been largely overcome and well fixed work can last the life of the house.

Stains caused by green sisal and the rotting process were difficult to cover, and often found their way to the surface. With the introduction of fibreglass a big source of trouble was eliminated and a good tradesman can make a first class job, given the time. Possibly the introduction of sub-contracts was the worst thing to happen to good workmanship, particularly in the fibrous plaster and plastering trades. Prices did not warrant the expenditure of time to do a thorough job.

Care in fixing of boards is all-important, as bad fixing can only be disguised by flushing. Peaked joints, particularly, cannot be overcome. Time spent on fixing and grouting is, in fact, saved on the flushing process.
Board should be pinned and settled to a good line, with special care on joints, to ensure a perfect level or a slight dishing effect, but on no account to leave a peak, even if this entails hanging off bad joists 25 mm or so.

Cornices should be pinned at the correct projection and a straight line obtained, again hanging off high joints. The boards should be allowed to settle to the cornice and produce an even width of member to the ceiling angle.

A good tradesman has all mitres matching with the same design in each corner.

When all boards are pinned to a good flat surface, cornice and joins lined up, grouting can be undertaken. This is the main factor governing the life of the job and the maintenance it will require.

A job well grouted should not move under normal structural conditions and should, if done properly, not require maintenance. When completed, there should be no nails in the entire ceiling to cause cracks or pops.

Grouting can be from barely sufficient to well done, and this is a point which is seldom inspected by supervisors, as it entails climbing about in the roof space.

The most satisfactory method of grouting is to place nails in the sides of ceiling joints at not more than 450 mm and staggered each side of joists, placed on the line of the flush joints across joists, and grout attached. No flush joint or any joint should be on timber and, where they run in direction of joists, should be trimmed with 2 x 1 and grouted over the trimmer. Nails should always be placed in proximity to the front line of the cornice and grout used to tie both cornice and sheet together. Between joists the sheet and cornice should also be grouted together. On the wall line grouts need to be about 300 mm apart. All mitres and joins must, of course, be grouted so as to tie the whole to wall and ceiling.

Numerous small grouts are far better than a few great lumps. When a ceiling has just been grouted the damp spots show and some indication can be obtained of the care being taken in this important aspect.

Having fixed and grouted satisfactorily, the flushing depends on the skill with tools and thoroughness of the tradesman. All nail holes, scratches, etc., should be skimmed. Angles of cornice and ceiling should be sharp and not just plaster brushed into the cracks. Mitres should be treated properly and not merely wiped in with a finger and brushed. Vents, when fixed, should be square to the cornice line and not obviously cock-eyed, as is so often the case.

Where, as sometimes happens, the sheet is bowed up between the joists, giving a thicker appearance to the cornice line, these should be flushed out with the trowel.

With modern, low-pitched roofs, grouting is a difficult job and, in some cases, ceiling hangers make it impossible once all the boards are up. As there is still no satisfactory adhesive for fibrous plaster, nails are used in conjunction with those that are available, but grout is far preferable even if this entails fixing and grouting that section of the ceiling which is inaccessible first by means of a stick.
Staining today is usually caused by the use of dirty water, rusty buckets or tools, and stain from green timber carried through with the grout.

All in all, fibrous plaster ceilings can be most pleasing and serviceable, allowing great variety of design. It is unfortunate that other materials have taken over to a certain extent, with a consequent shortage of skilled fixers. However, fashion will probably cause a swing back to those ornamental ceilings of the past and fibrous plaster will again come into its own.
CHAPTER SEVENTEEN - TILING AND GRANOLITHIC CONCRETE TOPPING

17.1 TILING - INTRODUCTION

The tiling trade has grown tremendously over the last ten years and tiling now involves covering more areas in buildings than previously.

The methods of fixing tiles has also changed because of the improved technology of manufacture and fixing materials. The modern approach to tile fixing involves the use of adhesives, either P.V.C. type pastes or cement-based adhesives. Success in using adhesives is in using the right type in the right place! Some adhesives (paste types) have yet to prove themselves for their long lasting attributes.

The selection of tiles and the type of adhesive to fix them is also important to successful tiling.

17.2 METHODS OF FIXING

THE WET METHOD

The method which has been used for many years is known as the 'cement buttering' or 'wet method'. The wet method consists of using the following procedures:

1. The tiles need to be well soaked, and this is done by immersing them completely in water for approximately 30 - 40 minutes. The visual test is to wait until bubbles stop flowing to the surface of the water (new tiles absorb water quickly and emit
air bubbles in the absorption of water). Ceramic wall tiles laid dry will not adhere as well.

2. The tiles are then "drained" to remove excess moisture from the back. If water remains on the rear of the tile a good bond will not occur between the tile and the mortar. To drain tiles they are stacked on edge and separated for drainage and easy handling.

3. **Mortar** To adhere the tiles to the wall a "fatty" mortar is used. This ratio is normally 2 - 1 - 1 or 2½ - 1 - 1 mortar. The high lime ratio is designed to allow for easy manipulation of the tile; the mortar must have a high degree of plasticity for ease of use.

4. **Buttering** is the method of applying mortar to the back of the tiles. An even bed of mortar is spread on the tile and hollowed out to form a "well" in the centre. This allows the mortar to move inwards as well as outwards when pressure is applied to the face of the tile on application to the wall. If the mortar is not hollowed out there will be greater resistance to movement and if force is applied to the tile it may crack or break.

5. **Wetting** of the base to receive tiles in this manner is also of prime importance. If water is absorbed too quickly, the mortar sits hard and does not allow final adjustments to be made to the tiling job. These adjustments may have to be made up to 30 - 40 minutes after placing on the walls. Walls should be well dampened, but not saturated.

6. **The bases** which this method of tiling can utilize are: brickwork, concrete and lathings. No previous preparation of the walls is required for "buttering" tile onto, but walls which are rendered first can assist in making this method easier.

**THE DRY METHOD**

This is a fairly new method for fixing tiles and involves the use of adhesives or "fixatives". The working procedure is more simple than the previous method.

1. The tiles are always fixed using dry tiles (not wet).

2. The adhesive is spread onto the surface to be tiled, preferably with a 'notched' or 'serrated' trowel, and the tiles pressed onto the adhesive material.

3. Most adhesives allow for final adjustment up to several hours after their application (cement based only 30 - 40 minutes).

Some care should be taken in using adhesives and their selection should be based on the following criteria:

The base Cement type adhesives should only be used on hard straight bases, for example cement floating - concrete, asbestos (after priming).
The area Where water or moisture content is high a water-proof type of adhesive should be used. In special cases, acid-proof fixing and grouting may be specified.

Backgrounds for pastes. Usually softer type backgrounds, such as plaster setting, fibrous plaster, and gyprock can be used as bases for paste-type adhesives, although these pastes may also be applied to the harder bases if they are of a water-proof type or no moisture contact is expected. It may be necessary to apply a primer for some types of adhesives.

In all cases, application should be in accordance with the manufacturer's specifications.

When applying adhesive-type mortars or pastes, the following points should be noted:

. Dust – all bases must be free of dust of any type.
. Paints – where the surface has been painted, this must be treated in the following way:
   (a) Grinding or removing with paint stripper, and an application of a sealer or bonding agent.
   (b) Hacking with a sharp implement to roughen the surface may be required.

On floors which have been done for some time and which require tiles to be laid the following methods may be adopted:

Unpainted floors A wash with Spirits of Salts to "etch" the surface, followed by washing down to remove dust, etc. Coat with bonding agent or cement slurry, or both, then apply adhesive when surface is dry.

Painted surfaces Depending on the type of paint which has been applied, the following materials may be tried: paint stripper, turpentine, petrol or kerosene.
If none have any effect, apply bonding agent to seal the floor and apply the selected adhesive.

MOSAIC OR QUARRY TILE FLOORS (on new work)

A base of concrete should always be placed before tiling any area. This base should be a minimum thickness of 50 mm to approximately 75 mm.

The working procedure should be as follows:
1. Prepare floor by cleaning excess loose material and dust off the concrete.
2. Set up the levels or allow for falls if required.
3. Apply a bonding agent mixed with water or cement slurry to the concrete. Brush well into the concrete.
4. Apply the underlay (2 or 3 - 1 sand and cement) to the required level. The underlay should be of a semi-dry nature so that the tiles do not sink down.
5. A dusting of dry cement is applied to the surface so that a cement paste develops which assists in adhering the tiles to the underlay.
6. The tiles are applied to the surface and, when ready, are beaten down with the use of a float or block. This is done for two reasons:
   
(a) to force the tiles down into the underlay and at the same time compacting the base material, and
   
(b) to expel air pockets both underneath the tiles and in the underlay.

7. The tiles are cleaned off and grouted to requirements. The tile grout can be of either neat cement or sand and cement, which may be coloured with oxides. The grouting can be left until 24 hours after the tiles have been laid. This is often preferable if a first class job is required.

8. Tiles must be cleaned off the same day. Smears which are left are difficult to remove later.

POINTS TO WATCH

. The space between tiles is left to allow for expansion and contraction on the wall. Tiles should not be laid tight against each other for this reason. The space between tiles should be about the thickness of a match stick.

. All cuts should be either in a corner of a wall or at the bottom of the wall.

. All tiling should be level, plumb and square.

. Grouting should be applied to ceramic wall tiles with a squeegee. The trowel should not be used because it could scratch the face of the tiles.

. Steel wool should not be used to clean tiles as it may also scour the face of the tile and tends to discolour some tiles.

. Removing tiles - always start from the centre of the tile and work outwards. Take care to use a sharp chisel and not to chip surrounding tiles.

. Epoxy Resins. These are available for both fixing and grouting of tiles. This method of fixing is often used where acid-proof protection is required.

Joints

With most tiles only a small joint is required. Normally approximately 3 mm. Tiles which are regular in shape require a small joint. Tiles which are irregular such as Terra Cotta (clay) require a larger joint - approximately 10 mm.

17.3 GENERAL INFORMATION

TILES - WALL AND FLOOR

Very durable finish - a bit costly at first.
Advantages

- never needs paint
- easily cleaned
- very hygienic.

Tiles can be used practically anywhere.

TYPES OF TILES

(a) WALLS
Glazed body, plain colours and pattern.

Mosaic - walls
Do not use wall mosaic on floors. Mostly have net on back of the tiles, but some have paper on the face.

Quarries - (unglazed)
A distinct group of their own.

Ferrolite - (acid resistant)
A very hard wear-resistant surface, non-absorbent tile.

Non Vitreous - (made from brick clays)
Incorrectly referred to as terra cotta. A very absorbent surface, non-slip, but wears very quickly.

(b) FLOORS

Mosaic
Long lasting and a large variety of patterns available.

Quarries - (unglazed)
These tiles are coarse in texture, and are hard and dense. They are made from natural clays in red, black, brown and cinnamon.

Ferrolite - (acid resistant)
A very hard, wear-resistant surface, non-absorbent tile. Easily cleaned and available in plain colours only.

Non Vitreous - (brickclay types)
They vary in size, shape and colour. They're very absorbent and usually laid with a 10 - 12 mm joint.

Faience
These are glazed terra cotta blocks. In pottery, faience is a term denoting a superior kind of glazed earthenware. Often referred to as a construction tile.
**Encaustic**
These tiles are slightly absorbent, but hard. They are usually made in reds, browns, chocolate, buff and black.

**Terra Cotta**
These tiles are made of fine clay and a fine colourless sand, and are baked to a stoney hardness. They are of a yellow-brown to brownish-red colour. Often referred to as a construction tile.

**TYPES OF FIXING**

(a) **WALLS**

**Mortars**
Generally compo, cement and sand may be used, but must be treated with caution.

**Adhesive**
Cement based, P.V.A., Latex, Epoxy.

**Bitumen - (Flint-Kote)**
On special applications.

**Acidproof Cement**
Where there are acids.

**FIXATIVES - INTERNAL WALLS**

**Compo Mortar**
Either over a rendered background or onto brickwork. A mix of approximately 2½ sand, 1 cement, 1 lime putty, depending on the base and weather conditions.

**P.V.A. (Ceramafix)**
Generally they stand up to water. Set quite hard.

**Cement based - (Cerama-C-Ment)**
Set hard, available in 25 kg bags.

**Latex - (Hornex, Hydrolox)**
Be cautious where there is water: for example, shower recesses and swimming pools. Good for "acid" applications with epoxy grout.

**Epoxy**
Seldom used for housing work. For areas where there is acid, water. Also food processing and abattoirs. Resistant to bacteria.
Bitumen - (Flint-Kote)
Will stand up to water, soaps, etc. Good in very cold areas. Will dissolve with kerosene, petrol, turps.

Acidproof Cement
Seldom used for housing work except on special occasions.

(b) FLOORS

Mortars
Sand and cement. Some tiles are using granite dust and cement, and compo mortars.

Adhesive
Cement base, P.V.C. or Latex. Epoxy fixatives are available.

Flint-Kote - (Bituminous type of material)
For extremely wet areas.

Acidproof Cement
Only used where there are acids.

FIXATIVES - FLOORS INTERNAL

Cement Types
Available in a thick bed for uneven surfaces. One of the popular types; withstands water fairly well.

P.V.A. - (Ceramafix)
Proved to be reliable over the years. It is clean and easy to use, and stands up to water fairly well. Be cautious of dust; requires a strong background.

Latex Types - (Hornex, Hydrolux)
Be cautious where there is water: for example, shower recesses and swimming pools. Good where there are acids if attached with epoxy grouting. Contains sand, fondu cement and latex.

Suitable for timber floors

Flint-Kote
Mostly over timber floors. A mix of granite dust, white sand, Flint-Kote and a little cement. Softer under foot and much quieter to walk on. The surface does not feel as cold and it withstands low temperatures. Dirty to use. May be used neat. It is water soluble while in the plastic state.
FIXATIVES - EXTERNAL

Compo Mortar - (Render)
Better suited for our extreme temperatures. There is a trend
to use these mortars for floors.

Cement Mortars - (Render)
Likely to crack and craze, especially strong mixes such as
2½ - 3 sand, 1 cement. These strong mixes provide a waterproof
coat to withstand the penetration of water.
Usually wall tiles are laid in compo mortars over a rendering.
It is usually a fatty mix of about 1½ - 2 sand, 1 cement,
1 lime putty, employing either the screed or buttering method
of fixing.

Adhesives
Those able to withstand the extreme change of climate.

BASES - INTERNAL

Rendering
Must be strong enough to take surface tiling and dense enough
to stop the passage of water: e.g. roman baths.

Plaster Boards - (Plaster Glass)
Plaster-faced surfaces.
Avoid using cement-based adhesives on these surfaces, unless
a sealer is used first: e.g., Bondcrete, Keycrete, Weldcrete,
Rendakee.

Paper face boards - (Gyprock Stramit)
Do not wet surface area. Cement based, P.V.A., Latex and
Flint-Kote seem to bond without any apparent problems.

Plaster setting - (75% lime putty, 25% setting plaster)
DO NOT TILE OF THIS SURFACE unless it is at least 5 years
old, unpainted and the tiles are light in weight.

Setting - (75% Hardwall plaster, 25% lime putty)
On good floating or rendering, the surface may be tiled
providing it is a dry area.

NEVER TILE ON ANY TYPE OF SETTING IN WET AREAS

Setting, Ultrahard
Providing it has not been adulterated with lime putty and has
a good background, it may be tiled in a dry area.

Setting - Titan
This plaster must be used neat. If it is over a good floating
or rendering it may be tiled.
Glass Face Cement - (Cement Setting, Dado)
Any adhesive can be used over this surface. Be cautious of wall trowelled with kerosene. Will withstand water.

Cement Sheeting - Asbestos, Hardiflex)
Any adhesive. With some adhesives, the surface may need priming first.

Chip Boards
Do not use cement-based adhesives. Prime surface first and be cautious. If possible, face with cement sheeting before tiling.

GROUTING

Neat Cement
Usually white; about the cheapest. Colour may be added and will withstand water. Sets very hard.

Patent Grouts
Readily available in pack form and have large range of colours to match tiles. Sets very hard and withstands water.

Epoxy

17.4 GRANOLITHIC CONCRETE TOPPING

Granolithic concrete flooring is composed of Portland cement and granite, whinstone, or other hard aggregate mixed with sufficient water to give a suitable workability and plasticity for laying and compacting. A typical mix is 1 part Portland cement to 1 part of sand to 2 parts of 10 mm - 15 mm aggregate, free from dust.

The base concrete may be either freshly laid or matured concrete, but matured concrete must be well cleaned, hacked and wetted to secure a good bond, and Portland cement grout should be brushed over the surface immediately before the granolithic concrete is laid. On matured concrete the topping should be laid to a thickness of 40 mm, and it is advisable to divide the finish into bays not larger than about 15 m² laid either in alternate strips or alternate bays.

Ideally, the topping should be laid 'monolithically' on fresh base concrete (i.e., within 3 hours). The topping should be 20 mm thick, but rather larger bay sizes (up to 30 m²) may be used with slabs with a total thickness of 150 mm or more. Skilled operatives must be employed in order to ensure that successive trowellings are applied at the appropriate times. Good trowelling is of prime importance; its purpose to close up the finish after the excess water has bled to the surface and evaporated. Excess laitance should be removed before the final trowelling. Curing for at least seven days - using a plastic membrane, building paper or hessian - is essential.
Granolithic concrete may be coloured by the use of pigmented Portland cement. It is generally slip resisting unless polished, though abrasive aggregates may be incorporated to improve slip resistance where this is particularly important.

Provided the flooring is properly laid on a carefully prepared base, granolithic topping possesses good resistance to chipping, cracking and abrasion but, if unsuitable materials are incorporated or if workmanship is poor, granolithic concrete is liable to dust. A solution of calcium chloride may be added to the mix at laying, or a solution of sodium silicate or other surface hardener may be applied to the surface, to retard dusting. Granolithic concrete made with Portland cement is resistant to water, alkalis, and mineral oils and greases on the surface, although it is attacked slowly by weak acids, and animal and vegetable oils. Resistance can be increased by the use of high alumina cement. Granolithic concrete is laid extensively in factories, warehouses, schools, storerooms, toilets, kitchens and utility rooms. It may be washed and scrubbed with hot water, scouring powders, washing soda and alkaline detergents.

GRANOLITHIC SPRinkle FINISHES

The general qualities and characteristics of granolithic sprinkle finish flooring are similar to those described for monolithic concrete toppings, though the wearing layer is thinner.

Concrete floor slabs are brought to the finished floor level and while still plastic - within 3 hours of laying - they are sprinkled with a mixture of 1 part Portland cement to 2 parts granite, whinstone or other hard aggregate graded from 5 mm down, mixed dry and applied at the rate of 7.5 kg/m². The whole is tamped in with a wooden float and trowelled twice with a steel trowel to produce a smooth finish as for toppings.

17.5 TERRAZZO

DESCRIPTION AND PROCEDURE

Terrazzo, sometimes called Venetian mosaic, is essentially a decorative concrete in which the aggregate consists of marble chippings and the matrix is either white or coloured cement. It was originally used in Venice and surrounding districts where there was an abundance of marble chippings resulting from extensive marble and masonic work. These chippings are now mainly exported from Italy to all parts of the world, and terrazzo has become increasingly popular not only for floor surfacing, but the walling, partitions, door frames, columns, staircases, and counter and bench tops. A great variety of pleasing colours and effects can be produced by blending or contrasting different coloured and graded aggregate and cements.

Great care should be taken in mixing in order to get uniformity. There is a special machine available for mixing terrazzo which prevents segregation by means of blades which lift as well as rotate. This machine produces far better results than can normally be obtained by hand, but the machines are relatively costly.

The usual thickness of terrazzo topping is 20 mm; this is on a 16 mm layer of 3:1 mortar screed over the base.
The movement joints should be taken through the screed and, if ebonite or metal jointing strips are used, these should be fixed before the screed is laid. After the terrazzo has been laid it is tamped to ensure consolidation, and the surface is lightly trowelled to obtain a flat surface. Do not over-trowel; this may bring too much cement to the surface.

After laying, the terrazzo must be matured under damp conditions. To obtain the polish, the first grinding with coarse carborundum brick or disc should be carried out about three days after laying. After grinding, the area is washed to remove slurry and then grouted with a fine mixture reserved from the original mix. The second grinding, after a further five days, is made with a finer grained stone or disc. This may be sufficient to produce the required polish, or it may have to be repeated. The whole is washed with hot water and pure soft soap after the final grinding. When the surface has dried it may be treated with wax.

New floors should be washed and waxed as previously mentioned, every week for several months.

MAGNESIUM OXYCHLORIDE (MAGNESITE COMPOSITION FLOORING)

Magnesium Oxychloride flooring is composed of burned magnesite mixed with fillers, such as wood flour or sawdust and ground silica, powdered limestone, powdered asbestos or sand, and is gauged with a solution of magnesium chloride.

The precise grading of the mix varies with different floor-laying firms. It is important that the dry components be thoroughly mixed and that there is no excess of magnesium chloride, or severe sweating of the floor surfaces may result. Any reduction in the magnesite content, while cheapening the floor, will also impair wear resistance and lead to failure of the flooring.

The flooring may be laid in one or two layers; single layer work being from 13 to 19 mm and double layer work, 13 mm undercoat with a 6 mm topping, totalling 19 mm.

Any rigid and dry sub-floor is suitable provided it is not too porous. Concrete in contact with the ground must have a damp-proof membrane, and any embedded metal must be protected with a material such as bituminous paint against the corrosive action of magnesium chloride.

It is made in many colours including buff and white, and has a good appearance; it is moderately warm, but is hard and rather noisy. It may become slippery when polished. When properly laid and mixed, it has a good resistance to cracking and abrasion, especially if finished with an oiled surface. It is not affected by mineral oils, fats and greases, but should be protected against water by oiling or waxing. It should not be used in positions where it is likely to come into contact with chemical solutions. It is produced in two grades: normal and heavy duty, and is used extensively in hospitals and schools, light factory work, offices and domestic work.

Where the flooring has an oiled finish, it should be treated once a week for the first three months with raw linseed oil and this continued thereafter once a month. Where the floor has no wax or oil treatment, it should be washed regularly with warm water without soap for the first month, but a non-caustic soap may be used thereafter. It is essential that skilled layers be employed.
CHAPTER EIGHTEEN - PAINTING

18.1 REASONS FOR PAINTING

18.2 CONSTITUENTS OF PAINT

18.3 TYPES OF PAINT
   OIL PAINTS
   ALKYD-BASED OIL PAINTS
   SYNTHETIC RESIN EMULSION PAINTS
   METALLIC OR ALUMINIUM PAINTS
   VARNISHES
   LACQUERS
   STAINS
   ALTERNATIVE FORMS OF CLASSIFICATION

18.4 PAINT MANUFACTURING PROCESS
   THE SIX STEPS OF PAINT MANUFACTURING

18.5 SURFACE PREPARATION - NEW AND OLD
   PREPARING NEW SURFACES
   PREPARING OLD SURFACES

18.6 TYPICAL PAINTING SPECIFICATIONS
   SPECIFICATIONS AND SCHEDULES
   PAINT SYSTEMS
   FURTHER POINTS

18.7 PAINTING DEFECTS - CAUSE AND CORRECTION
   LIABILITY
   CAUSES AND TREATMENTS

The Experimental Building Station NOTES ON THE SCIENCE OF BUILDING, numbers 147 and 148 should be read in conjunction with the material given in this Chapter, prepared to cover the following sequence of topics:

- Reasons for Painting
- Constituents of Paint
- Types of Paint
- Paint Manufacturing Process
. Surface Preparation - New and Old
. Typical Painting Specifications
. Painting defects - Cause and Correction

18.1 REASONS FOR PAINTING

Paint is essentially defined as a colouring matter applied to a surface either by a dipping process, or more commonly, by brush, spray or roller.
A paint may be applied for one or more of the following reasons:
. The colour may be required to decorate or identify.
. Paint may provide for the preservation or protection of the material to be painted.
. For sanitary reasons, paint may seal and provide an impervious surface which can be washed and kept clean.
. Special intumescent paints may be applied to increase the fire resistance of combustible materials.

18.2 THE CONSTITUENTS OF PAINT

Naturally the constituents of specific paints or varnishes will vary to meet the required properties of the finished products, but most paints will contain forms of the basic constituents shown in Figure 18.1

![Diagram of the constituents of paint](image)

**FIG. 18.1**

(a) **BASE, PIGMENT AND EXTENDERS**

The base and pigment provides the substance and the colour of the paint film and affects the properties of flow, gloss, durability, corrosion or fire resistance of the paint. It consists of fine particles suspended in the vehicle or paint solution. These may be mixed with similar materials called extenders which improve certain characteristics of the paint or reduce the cost of the product. Zinc or iron oxide are examples of base pigments and calcium carbonate is a common extender.
(b) VEHICLE OR PAINT SOLUTION

The vehicle is the liquid part of the paint which carries the base and, as shown in the preceding layout, is composed of the binder and the solvent.

(c) BINDER OR FILM FORMER

This constitutes the final dry paint film binding the pigment particles and consists of resins or polymers which determine the paint type, such as oil, alkyd or acrylic. For example, linseed oil may be the binder dissolved in a turpentine solvent of an oil paint, or a polyvinyl acetate (P.V.A.) resin may be the binder suspended in a water diluent of a latex or plastic paint. Properties such as the gloss, the drying time, adhesion and durability of the paint are largely determined by the type of binder used.

(d) SOLVENT, DILUENT, THINNER OR MEDIUM

These are the liquids, often volatile, in which the binder is either dissolved or suspended, regulating the consistency of the paint and providing ease of application.

(e) ADDITIVES OR AGENTS

These consist of various materials which may be added in small quantities to improve particular properties of the paint, such as the drying time, or to induce even-flow or non-drip qualities. An oxide of lead or terebene are examples of dryer additives.

18.3 TYPES OF PAINT

Specific paints are manufactured to meet the property requirements best suited to each painting situation. Properties required of a particular product may relate to the resilience, durability, adhesion, corrosion or fungicidal resistance of the final paint film.

Today, each manufacturer may produce a range of over fifty different products and many of these may each be available in a further range of surface appearances or colours.

The builder must have a sufficient knowledge of this vast range of products to competently supervise the application and ensure that the work conforms to the painting specifications. An appreciation of this range of paint 'types' may be simplified by a primary classification which is found to be governed by one or more of the following factors:

- Type based on the materials from which the solution has been formulated. e.g. oil, alkyd, epoxy or acrylic resin paints, varnish, lacquer or french polish.

- Type based on the situation or material for which the solution has been formulated. e.g. paving, roofing or road marking paints.

- Type based on the purpose for which the product was formulated. e.g. stains, sealers, primers or undercoats.
. Type based on the special characteristics of the finished product. e.g. enamels, luminescent or intumescent paints.

A further sub-division or specification of these type classifications may then be made on the basis of the required surface appearance and colour of the final paint film. For example, a paint initially classified as a synthetic resin emulsion may be further specified as being 100% acrylic, flat or semi-gloss finish and of a mission brown colour.

Descriptions of the following main product types, based on materials of formulation, will be given here to assist in distinguishing between the many proprietary products currently available:

- Oil paints
- Alkyd-based oil paints
- Synthetic resin emulsion paints
- Metallic or aluminium paints
- Varnishes - natural or synthetic
- Enamels - natural or synthetic
- Lacquers
- Stains

Each product type will be outlined under the sub-headings:

(i) Composition
(ii) Properties
(iii) Use
(iv) Thinners
(v) Cleaning solvent

**OIL PAINTS**

(i) A metallic oxide such as white lead or zinc oxide suspended in an oil and turpentine vehicle with colouring and drying agents added.

(ii) Has excellent adhesive, preservative and protective properties and good durability in most situations.

(iii) Can be formulated to be used in most situations as primer, undercoat or finish in oil-based paint systems for internal or external timber, timber product or metal surfaces.

(iv) Generally mineral turpentine.

(v) Mineral turpentine or white spirit.

**ALKYD-BASED OIL PAINTS**

(i) An alkyd resin formed by neutralising a drying oil (linseed) and an acid (phthalic anhydride) with an
alcohol to form a polymerised base to which required agents and solvent are added.

(ii) A fast drying paint or gloss enamel with excellent adhesion and water or mould growth resistance.

(iii) Used as undercoat or enamel finish coat in alkyd paint systems to internal or external timber or metal surfaces and to walls and ceilings of humid or wet areas.

(iv) White spirit thinner.

(v) White spirit or hot water and detergent.

SYNTHETIC RESIN EMULSION PAINTS

(i) Generally referred to as plastic or latex paints as all are based on an emulsion of a synthetic resin binder, and a base such as lithopone suspended in water with a defoaming agent. Paint names refer to the resin used such as P.V.A. (polyvinyl acetate) or acrylic.

(ii) Has high alkali resistance (e.g. to lime) and 100% acrylics have good adhesion, weather resistance and flexibility.

(iii) Essentially for flat or satin finish to internal or external masonry, plaster or asbestos and acrylic gloss to masonry, plaster, asbestos or metal surfaces.

(iv) Thin with water.

(v) Clean up with water.

Note: Most of the two-pack epoxy resin paints are included under this section.

METALLIC OR ALUMINIUM PAINTS

(i) Contain a pigment of finely ground metal particles such as aluminium, zinc or bronze which are suspended in a varnish, lacquer or bituminous based vehicle, with appropriate thinners and dryers added.

(ii) Most metallic paints possess special decorative, heat resistant or reflective properties.

(iii) Used as a primer, as a decorative paint to wrought iron work or as a reflective finish to pipes or roofing.

(iv) Thinner must be compatible with the vehicle used.

(v) To suit thinner used.

VARNISHES - NATURAL OR SYNTHETIC

(i) May be a natural varnish having a body of natural resin heated and dissolved in a linseed or tung drying oil and turpentine vehicle; or a synthetic varnish with a synthetic resin (such as the polyurethanes) suspended in an oil and turps vehicle; or in a synthetic or liquid alkyd vehicle.
(ii) Most varnishes have transparent properties which provide a clear, tough, satin or gloss protective surface to dressed timbers.

(iii) Used internally where a hard clear finish is required to timber joinery, mouldings or flooring, with special long-oil marine varnishes used in wet or exposed situations.

(iv) Thin all natural varnishes with turpentine but thinners to the synthetic varnishes must be compatible with the particular vehicle used.

(v) Clean up with turpentine or recommended solvents.

ENAMELS - NATURAL OR SYNTHETIC

(i) Natural oil-based enamels are prepared by adding a pigment to a clear natural varnish vehicle. Synthetic enamels may be either alkyd enamels in which a pigment is added to a synthetic alkyd varnish or lacquer enamels in which a pigment is added to a clear synthetic lacquer vehicle.

(ii) Most enamels provide a dense hard wearing washable gloss finish coat although some alkyd enamels will give a similar but matt or satin finish.

(iii) Used as a finish coat on timber, metal or dense material surfaces or to internal surfaces of kitchens, bathrooms and doors etc. Subject to constant wear and cleaning. Baked synthetic enamels provide the surface finish to many household appliances.

(iv) Turpentine is generally used to thin most natural or alkyd enamels but specific highly volatile thinners such as the alcohol ethyl or hydrocarbon benzol will be nominated for lacquer enamels.

(v) Cleaning solvents will be the same as or compatible with the respective thinners used.

LACQUERS

(i) A wide range of clear or tinted, dipping, brushing or spraying lacquers is formulated from synthetic materials such as cellulose nitrate in conjunction with synthetic resins and plasticisers, and complex solvents and highly volatile thinners (such as ethyl or benzol).

(ii) Rapid evaporative drying lacquers produce a tough satin or glazed surface which will withstand extremes of temperature and frequent washing.

(iii) Used to provide a durable gloss finish to internal or external dimensionally stable timber, timber product or metal surfaces of furniture, pressed metal products or appliances.

(iv) Highly volatile thinners such as the alcohol, ethyl, or hydrocarbon, benzol, will be nominated by the manufacturer.
(v) Cleaning solvents will be the same as the respective thinners.

STAINS

(i) Stains may be water, spirit or oil based, depending on the vehicle in which the dyes have been dissolved. Water stains consist of powdered dyes dissolved in hot water. Spirit stains consist of alcohol soluble powdered dyes in solution and oil stains are made by dissolving oil soluble dyes in solvents such as benzol.

(ii) Most stains have penetrating colouring properties and impart colour without obscuring the natural figure of the material. However, the fade resistance, bleeding or grain raising properties of each stain type would govern selection in each situation.

(iii) Used to change or make uniform the colour of timber or timber products without concealing natural grain, and prior to applying a clear protective varnish or lacquer finish.

(iv) The thinners will depend on the type of stain used as they must be compatible with the particular stain vehicle.

(v) Cleaning solvents must suit the respective thinner of the stain used.

ALTERNATIVE FORMS OF CLASSIFICATION

Before leaving the topic of paint classification, mention should be made of those alternate forms of classification previously noted earlier in this Chapter. These forms, often used by manufacturers, do specify the use for which the paint was prepared, but often give no indication of the base materials from which the paint was formulated.

For example, a paint may be advertised as a roofing paint, a primer or a gloss enamel, but further information would be required before using these respective paints in a particular oil based or synthetic resin based paint system.

The various paint systems are discussed in the recommended reference, NOTES ON THE SCIENCE OF BUILDING, number 148.

18.4 THE PAINT MANUFACTURING PROCESS

Nowadays, paint manufacture is a complex process employing all the advanced principles of industrial chemistry and technology in the formulation and production of a vast and changing range of products from traditional and recently developed synthetic materials. Each manufacturing process will be designed and developed to suit the specific materials used and the product required.

The traditional paint manufacturing process may be conveniently divided into six general procedural steps, as outlined graphically on the flow diagram shown in Figure 18.2.
THE SIX STEPS OF PAINT PROCESSING

FIG. 18.2
THE SIX STEPS OF PAINT MANUFACTURING

STORAGE

Step 1 involves the acquisition or manufacture and the subsequent refining and storage of the range of raw materials.

MIXING

Step 2 refers to the initial mixing of the base pigment, extender and part of the vehicle in the form of a paste.

GRINDING

Step 3 is the mechanical process of pigment dispersion which involves the breaking down of the pigment into primary particles and the wetting of these in the presence of part of the vehicle to form the 'mill base' of the paint. This 'mill base' is produced by one of the five following methods:

- The roller mills method in which the paste is sheared between the rotating surfaces of three rollers.
- The ball mill method in which the paste is sheared between steel balls moving inside a revolving drum.
- The attritor method in which the paste is rubbed between steel balls in a drum due to the action of a revolving stirrer shaft and side arms.
- The sand grinder method in which the paste is sheared by sand particles in a drum with high speed shaft and disc stirrer.
- The high speed disperser method in which the paste is sheared between discs on an exceedingly high speed impeller shaft.

THINNING

In Step 4, the 'mill base' paste is brought to the correct paint consistency by stirring in the balance of the vehicle and the required thinners and additives.

STRAINING

In Step 5 the finished product is filtered through to final holding tanks.

PACKAGING

In Step 6 containers are filled, labelled and stored ready for despatch.
18.5 SURFACE PREPARATION

Painting specifications will usually contain a clause stating that: "the contractor shall ensure that all background surfaces are suitably prepared and are in a satisfactory condition to receive the specified applied finishes". Adequate surface preparation is an important and essential pre-requisite part of the application of surface finishes. Poor adhesion, peeling, blistering, efflorescence or bleeding of the applied finish can be the direct result of neglected or incorrect surface preparation.

SURFACE PREPARATION OF NEW SURFACES

TIMBER SURFACES

Timber surfaces may require rubbing down with glass paper, dusting off, cleaning off grease or resins with turpentine and the final 'knotting' of knots or gum veins with shellac. Further stopping of nail holes or torn grain may be necessary after the primer has been applied.

ASBESTOS CEMENT

Asbestos cement, masonry or plaster surfaces should be dry, dusted down and have loose fragments removed and holes or cracks cut back and stopped up as necessary.

FERROUS METAL

Ferrous metal surfaces must have all surface corrosion and scale removed and then be cleaned and degreased with an appropriate solvent compatible with the primer to be applied.

GALVANIZED OR ZINC COATED STEEL SHEET

Galvanized or zinc coated steel sheet surfaces may be left to 'weather' for a period of time, but should be dry, wiped down, degreased with a solvent, and etched with either vinyl etch, calcium plumbate or acrylic primer prior to painting.

PREPARATION OF PREVIOUSLY PAINTED SURFACES

TIMBER SURFACES

Timber surfaces in good condition can be rubbed down with glass paper and cleaned off with a solvent damped cloth. Any bare timber can then be re-primed before stopping holes and cracks. Where the existing paint is blistering, cracking or flaking, burn or grind off the defective paint then glass paper and dust clean. Any chalking or powdering paint must be papered back to a sound surface.

ASBESTOS CEMENT

Asbestos cement, masonry, concrete or rendered surfaces in good condition may only require rubbing down with a medium glass
paper and dusting off. Holes must be patched and bare sections sealed before applying a new paint system.

For surfaces in poor condition, remove all flaking or powdery material with a stiff bristle or wire brush and wash down where necessary.

A tie sealer may then be required to tie back porous material which cannot be removed, before repainting.

FERROUS METAL

Ferrous metal surfaces in good condition may only require rubbing back and dusting clean followed by the spot priming of bare sections before repainting. If in poor condition, all old paint, scale and rust should be removed, and a rust neutralising solution applied prior to the metal primer of the new paint system.

GALVANIZED OR ZINC COATED STEEL

Galvanized or zinc coated steel surfaces still in good condition should be lightly sanded and dusted down before repainting. Remove all powdered or flaking paint from surfaces in poor condition, then clean back and neutralise any rust affected areas before applying the metal primer when repainting.

18.6 TYPICAL PAINTING SPECIFICATIONS

SPECIFICATIONS AND SCHEDULES

Painting specifications and colour schedules nominate the paint types, systems and finish colours to the various different surfaces to be painted in a particular contract. Most painting specifications will state that all materials used are to be in manufacturers' containers and that the surface preparation, sequence of coats and manner of application will conform to the manufacturer's recommendations.

Each manufacturer prepares 'Product and Standard Specifications Manuals', which are available to architects, specification writers, builders, supervisors and contractors to guide them in their respective tasks. These manuals provide detailed information on surface preparation, product descriptions, paint systems and standard specifications to suit the various previously or newly painted surfaces. A typical manufacturer's product description may read as follows:

**RED LEAD PRIMER**

**DESCRIPTION:** a linseed oil and red lead based primer for wood.

**USES:** for all new or burnt off wood work, dry or weathered timber, particularly where primed work will be left exposed to the weather for some time.

**REMARKS:** use only in accordance with the health regulations. It should only be used on commercial and industrial work.
COLOUR: orange

COVERAGE: approximately 14 m² per litre.

APPLICATION: stir thoroughly and apply by brush straight from the can.

THINNING: thin sparingly with mineral turpentine.

DRYING TIME: touch dry in 4 - 6 hours, leave 48 hours before recoating.

PAINT SYSTEMS (refer NOTES ON THE SCIENCE OF BUILDING No. 148)

To each painting situation there will be a number of alternate paint systems which could be used and the specification writer will select and nominate that system believed to be the most appropriate to each situation.

A paint system is an outline of the type and number of paint coats required to protect a given substrate surface, and to illustrate this, examples of two alternate systems for the protection of external timber are provided here:

<table>
<thead>
<tr>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st coat</td>
<td>a lead free, linseed oil</td>
</tr>
<tr>
<td></td>
<td>based, pink primer</td>
</tr>
<tr>
<td>2nd coat</td>
<td>a general purpose</td>
</tr>
<tr>
<td></td>
<td>pink primer</td>
</tr>
<tr>
<td>3rd coat</td>
<td>an oil based</td>
</tr>
<tr>
<td></td>
<td>exterior undercoat</td>
</tr>
<tr>
<td>3rd coat</td>
<td>an exterior plastic</td>
</tr>
<tr>
<td></td>
<td>(acrylic) gloss</td>
</tr>
<tr>
<td></td>
<td>an exterior plastic</td>
</tr>
<tr>
<td></td>
<td>(acrylic) gloss</td>
</tr>
</tbody>
</table>

SPECIFICATIONS: FURTHER POINTS

The builder is required to have an understanding of the various paint types, product descriptions, paint systems and specification clauses as it is his responsibility to ensure that all painting, carried out by his subcontractors, is strictly in accordance with the specifications.

A typical painting specification will contain clauses which stipulate the materials to be used, the standard of workmanship and the various paint systems to be applied.

The example provided here would be typical of a standard painting specification to cottage construction:

**PAINTING SPECIFICATION**

**Materials:** Shall be ready mixed first quality shelf lines manufactured in Australia in accordance with relevant standards, delivered to site in the manufacturers' labelled and unopened containers.

**Colours:** All vents above roof shall match roof. Down pipes, vents, piping and meter box shall match the colour of the surface to which they are fixed. All other colours will be in accordance with the colour schedule nominated by the architect.
Workmanship: Refer to 'General Conditions of Contract'. Remove and replace hardware as required and protect all unpainted surfaces with masking or dust sheets. Prepare all surfaces prior to painting by removing all grease, wax, dust or loose particles, rubbing down with glass paper where required, sealing back knots and resinous patches and stopping all holes and cracks. Apply coats evenly to produce a uniform finish and observe manufacturers' recommended drying times when re-coating.

PAINT SYSTEMS:

Interior Walls and Ceilings: To all wet areas, prepare, prime with sealer and apply 2 coats of semi-gloss 100% acrylic plastic paint. To all other rooms, prepare and apply 2 coats of semi-gloss 100% acrylic plastic paint.

Interior Woodwork: To all clear finished work, prepare surfaces, uniformly stain with one coat of oil-based wood stain and apply 2 coats of clear polyurethane satin plastic. To all other interior wood work, prepare and apply one coat of timber primer, one undercoat and one full gloss alkyd enamel finish coat.

Interior Metalwork: Clean back and prepare surfaces, apply one coat of metal primer, one undercoat and one full gloss alkyd enamel.

Exterior Claddings: Wall claddings to be prepared and given 2 coats of exterior gloss 100% acrylic paint. Eaves and exterior ceiling linings to be prepared and given 2 coats of exterior flat 100% acrylic paint.

Exterior Sawn Timbers: Prepare and give 2 coats of low gloss 100% acrylic timber finish.

Exterior Dressed Timber: Prepare and apply one coat of pink primer, one exterior undercoat and one coat of full gloss alkyd enamel.

Exterior Metalwork: Prepare and apply one coat of metal primer, one undercoat and one coat of full gloss alkyd enamel.

Exterior Masonry, Render or Concrete: Remove efflorescence with stiff brush and apply 2 coats of exterior flat vinyl acetate-acrylate paint.

18.13
COMPLETION: Allow to touch up or replace damaged surfaces before practical completion. Provide architect with a record schedule of the brands of paint used on the respective surfaces painted.

18.7 PAINTING DEFECTS

DEFECTS LIABILITY

Most building contracts will nominate a Maintenance or Defects Liability period which is a mutually agreed period of time (e.g. 6 months) commencing from the date of practical completion of the works. During this period, any defects evident and found to be due to inferior materials or workmanship, must be made good, prior to the issue of the final certificate of payment. The builder should be familiar with common painting defects, respective causes and treatments so that he can supervise any necessary maintenance and assess the painter's liability before advancing final payment to this sub-contractor.

CAUSES AND TREATMENTS

An outline of the probable cause and treatment of some painting defects is provided here.

"BLEEDING" FROM DYES AND STAINS

<table>
<thead>
<tr>
<th>Cause</th>
<th>Prevention or Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>When surfaces have been previously stained with dyes or coated with a material containing a dye pigment, the original dye colour will often appear through the successive coats of paint. Red is a common bleeding pigment.</td>
<td>To hold back this &quot;bleeding&quot;, as it is termed, a coating of some impervious material must be applied to the stained areas. Materials in general use for this purpose are knotting, proprietary spirit-thinned sealers, and aluminium paint. The application of two thin coats of the selected material is advisable.</td>
</tr>
</tbody>
</table>

TAR OR BITUMEN

Dissolve and remove all possible tar or bitumen, using turpentine or benzol. When dry, apply two thin coats of a proprietary tar and bitumen sealer.

BLISTERING

<table>
<thead>
<tr>
<th>Cause</th>
<th>Prevention or Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blisters occur in impervious paint films when trapped moisture or grease is vapourized by heat.</td>
<td>For gloss oil paints and enamels: . The surface must be thoroughly dry and</td>
</tr>
</tbody>
</table>
BLOOMING (OPAQUE CLOUDY FILM)

Cause

The result of a sudden and considerable drop in temperature after a varnish is applied, is called "bloom-ing".

Blooming may also be caused by damp atmosphere.

Prevention or Treatment

Varnish only when temperatures are steady and moderate, and avoid dampness.

Slight bloom can be removed by polishing the surface with equal parts of raw oil and vinegar.

In severe cases, rub down and re-varnish under more favourable conditions.

CHALKING (Prematurely)

Cause

Insufficient binder.

A very porous surface may have absorbed too much of the binder.

An inferior or unsuitable paint may have been used.

Prevention or Treatment

Make sure that paints, particularly water paints, are sufficiently bound.

Stop suction in porous surfaces with an appropriate size or primer.

Before repainting chalking surfaces, sand and dust off surplus loose material.

CISSING

Cause

Oil paints and enamels, as the result of their own surface tension, will often withdraw themselves from a glossy or greasy surface.

Prevention and Treatment

Wipe the surface with a benzine rag or a rag moistened with limewater.

A dusting or rubbing with dry whiting is effective in many cases.

In extreme cases, wet sand the surface, using weak lime-water.
CRACKING, ALSO TERMED CHECKING AND CROCODILING

**Cause**

The most general cause is the application of hard-drying paint, enamel or varnish films over relatively soft undercoats.

**Prevention and Treatment**

Priming and intermediate coats should dry hard to give a secure foundation for the finishing coat, which should remain relatively elastic.

DISCOLOURATION

**Cause**

This occurs mostly when painting over surfaces which contain lime traces.

The alkali in cement, brick and plaster will discolor certain pigments, such as prussian blue.

**Prevention and Treatment**

Avoid the use of white lead in proximity to laboratories and stables, where acids and acid fumes may be present.

Avoid the use of alkali-sensitive paint and pigments on active cement, plaster, or brick surfaces.

The alkaline action can be subdued in active surfaces with a wash of zinc sulphate.

FADING

**Cause**

Fading occurs almost invariably as the result of using a fugitive pigment in an exposed position.

**Prevention or Treatment**

The fault is one of wrong selection. Only permanent pigments should be used outdoors.

FAILURE TO DRY, AND TACKINESS

**Cause**

Oil paints and enamels which normally would be dry overnight, may remain wet or tacky almost indefinitely if non-drying oil, wax, or grease finds its way into the paint.

A sudden drop in temperature, such as occurs in a frost, may also seriously interfere with the drying of a paint.

**Prevention or Treatment**

All traces of wax, non-drying oils, or greases must be removed from surfaces before painting.

Paint should always be mixed in clean pots and applied with clean brushes.

Surfaces which remain tacky but are otherwise dry can be rubbed down with a warm alkaline solution: for example, washing soda 226g to 2.25 litres of water. This is afterwards washed off with warm water and, when dry, can be repainted.
FLAKING AND CHIPPING

Cause

When excessive coats of P.V.A. or other materials have been applied, the build up becomes so thick, that it begins to flake. Particularly on hard plaster surfaces.

In oil paints and enamels flaking and chipping is generally due to faulty adhesion. This is particularly so on galvanized iron.

Flaking and chipping is most likely to occur as the result of using paints made with hard-drying pigments, such as zinc oxide.

Prevention or Treatment

Wash off old water paint before repainting. If there is any reason why this cannot be done, apply a coat of oil or varnish size or a proprietary sealing paint.

Do not use glue size.

New galvanized iron should be etched with hydrochloric acid (mild) or coated with a self-etching primer.

A paint film showing a tendency to chipping and flaking must be removed before further applications of paint to a surface.

FLASHING

Cause

Laying off a paint after it has begun to set will cause uneven gloss where the brush marks overlap.

Uneven suction in a surface will cause both sheariness and flashing.

Prevention or Treatment

Do not continue brushing after the paint begins to set. Paints and surfaces must be free from grease and moisture. Glossy paint surfaces must be sanded before applying further gloss coats.

Flashing and sheariness due to faulty brushing or uneven suction can be overcome by re-coating when dry.

SHEARINESS

Cause

Sheariness will result from either water or grease in the paint, or from applying a gloss oil paint on a gloss paint surface.

Prevention or Treatment

If moisture or grease has seriously affected the paint film, those sections may have to be removed.

SOFTENING

Cause

Softening (saponification) of oil films may occur as the result of alkaline activity in the presence of moisture on lime, plaster, and cement surfaces.

Prevention or Treatment

Old films on these surfaces which have been affected by alkali must be removed before repainting.
19.1 TYPES OF GLASS

GLASS
TOUGHENED GLASS
LAMINATED GLASS
WIRED GLASS
COATED GLASS

19.2 METHODS OF GLAZING

PUTTY
BEADING
GLAZING TECHNIQUES

19.4 SAFETY AND THICKNESS

THICKNESS

19.5 MULTIPLE GLAZING

19.6 BY-LAWS AND REGULATIONS

19.7 LIGHT

Glazing is the fixing of glass or a similar material in a framework or opening to admit light, but to exclude weather. Rules for the selection of the type and thickness of glass, glazing techniques; and unframed toughened glass assemblies, are laid down in Australian Standards: AS 1288 parts 1 to 3 - 1979. For the purpose of selecting a particular glass type, it is necessary that terms and definitions used are clearly understood. The following are commonly used glazing terms.

19.1 TYPES OF GLASS

(a) GLASS - a hard brittle, non-crystalline substance produced by fusion and usually consisting of mutually dissolved silica or silicates that also contain soda and lime. It may be transparent, translucent or opaque.
(b) **TOUGHENED SAFETY GLASS** - glass which has been converted to a safety glass by subjection to a process of pre-stressing so that, if fractured, the entire piece disintegrates into small, relatively harmless particles.

(c) **LAMINATED SAFETY GLASS** - glass consisting of two or more sheets of glass bonded together by one or more sheets of plastic "interlayer".

(d) **SAFETY WIRED GLASS** - a single sheet of glass with wire completely embedded in the glass.

(e) **SAFETY ORGANIC - COATED GLASS** - a glazing material consisting of a piece of glass coated and bonded on one or both sides with a continuous polymeric coating sheet or film.

### 19.2 METHODS OF GLAZING

Detailed recommendations are contained in AS 1288 SAA Glass Installation Code.

The methods of fixing glass in sashes are:

(a) Putty glazing without beads - by bedding the glass in glazing compound and securing with sprigs (in timber frames) or springs clips (in metal frames), and building up a front angle of glazing compound.

Where applicable, the glass should be set in position using setting blocks as required at quarter points. (See Figures 19.1 and 19.3)

(b) With beads - for windows, the glass is set in glazing compound and beads are either pinned or screwed to the frame. External beads are difficult to make and keep weather-proof, and must be bedded in compound, but internal beads do not require bedding. (See figures 19.2 and 19.4).

### GLAZING TECHNIQUES

In timber and metal frames the thickness of the back putty should not be less, than 2 mm and 4 mm respectively, whether front putty or glazing beads are used.

The minimum depth of rebate will depend on the size of the glass to be used.

The width of the rebate must be such as to allow for 12 mm front putty for timber frames, and 16 mm front putty for metal frames. Where glazing beads are utilized, 4 mm front putty should be used for both timber and metal frames.

In all cases except for small panes - say, up to 0.2 m² in area - the glass should always be set on small blocks of resilient material to locate the pane properly within the surround. These blocks are known as *setting blocks* and can be made from lead, hardwood, nylon or unplasticized P.V.C. Each block should be wider than the glass and, generally, 25 to 75 mm long. Figure 19.5 shows the suggested positions for setting blocks.
FRONT PUTTY AND GLAZING DETAIL TO TIMBER FRAME
FIG. 19.1

BEAD GLAZING DETAIL TO TIMBER FRAME
FIG. 19.2

BEAD GLAZING DETAIL TO METAL FRAME
FIG. 19.3

FRONT PUTTY GLAZING DETAIL TO METAL FRAME
FIG. 19.4
19.3 THERMAL EXPANSION

It is always necessary to allow clearance between the edge of glass and the surrounding frame to allow for fitting, fixing and thermal movement. It is suggested that 3 mm edge clearance be allowed for glass up to 4 m², and 6 mm for areas up to 8.4 m². For areas over 8.4 m², consultation should be made with the manufacturer.

19.4 SAFETY AND THICKNESS

The thickness of glass for a given area of glass, or the maximum area of glass for a given thickness of glass, can be calculated using the tables in AS 1288 and reproduced below.

For rectangles of glass supported on all sides, dimensions shall be obtained by reference to Figure 19.6 for aspect ratios up, to and including, those shown on the graph. For higher aspect ratios, Figure 19.7 shall be used, the shorter side of the rectangle being deemed the span.

The aspect ratio of rectangles is defined as the length of the long side divided by the length of the short side.
GLAZING SIZES FOR RECTANGLES OF SHEET, FLOAT OR PLATE GLASS WITH ALL SIDES SUPPORTED AND ASPECT RATIOS LESS THAN OR EQUAL TO VALUES SHOWN

FIG. 19.6
GLAZING SIZES FOR RECTANGLES OF SHEET, FLOAT OR PLATE GLASS SUPPORTED ONLY ON TWO OPPOSITE SIDES, AND ALSO FOR RECTANGLES OF HIGH ASPECT RATIO SUPPORTED ON ALL SIDES

FIG. 19.7
Example 1 - to find the thickness of glass 1.70 x 1.10 m; that is, 1.87 m², required for a design wind pressure of 2.1 kPa.

Lines on Figure 19.6 at 1.87 m² and 2.1 kPa intersect at R.

The thickness of glass required is the next highest on the graph - that is, 6 mm - and this holds for aspect ratios up to 6.3, well above the aspect ratio of the glass under consideration, that is 1.5.

Example 2 - to find the thickness of glass 4.40 m x 0.62 m - that is, 2.73 m² - required for a design wind pressure of 1.3 kPa.

Lines drawn on Figure 19.6 at 2.73 m² and 1.3 kPa intersect at Q.

The thickness of glass next highest on the graph is 6 mm and this holds for aspect ratios up to 6.3. However, the aspect ratio in this case is 4.40/0.62 = 7.1, which is greater than 6.3 and, therefore, Figure 19.7 must be used.

Lines drawn on Figure 19.7 at 0.62 m and 1.3 kPa intersect at T. The thickness of glass next highest on the graph is 5 mm, and this is the thickness - to be used.

19.5 MULTIPLE GLAZING

Because air is a poor conductor of heat, double-glazed windows consisting of two sheets of glass separated by an air space, provide light but restrict heat flow. Double glazing is mainly used to prevent heat loss from buildings in winter and restrict heat gain in buildings in summer. The advantage of this is a reduced running cost for air conditioning units.

The sheets of glass for double glazing are set from 5 mm to 12 mm apart, with the internal air dried to prevent condensation, and the whole unit hermetically sealed.

Double-glazed units are set into frames in a similar way to single glazing that is, putty or beaded.

19.6 BY-LAWS AND REGULATIONS

The size of a room will determine the minimum size of a window and the amount of the window which must be openable to provide ventilation.

Building by-laws state that natural light shall be provided to all habitable rooms for domestic buildings. The extent of this natural lighting shall be at least one tenth of the floor area of the room concerned.

Building by-laws also state that natural ventilation shall be provided to all habitable rooms for domestic buildings. The extent of this natural ventilation shall be at least one twentieth of the floor area of the room concerned.
In fact, what this means is that at least half the area of the minimum sized window must be openable to provide ventilation. Frequent consultation of the building by-laws and regulations will ensure that any recent amendments are not overlooked.

19.7 LIGHT

Specific tasks require a certain amount of light so that the operator or person performing the task can do so safely and comfortably. Australian Standards 1680 gives the minimum quantity of light required for various tasks.
CHAPTER TWENTY - ELECTRICAL INSTALLATIONS

20.1 TEMPORARY SUPPLIES

20.2 METER

20.3 CUSTOMER'S POLE AND SERVICE BRACKET

20.4 UNDERGROUND RESIDENTIAL DISTRIBUTION
   DEVELOPER
   OWNER-BUILDER
   ELECTRICAL CONTRACTOR
   CONSUMER'S MAINS
   DEPTH OF LAYING

20.5 GENERAL ELECTRICAL HARDWARE
   CABLES
   CONDUCTORS
   SWITCHES
   POWER POINTS
   FUSES
   LAMP HOLDERS

20.6 GENERAL PURPOSE OUTLETS AND LIGHTS
   SAMPLE TABLE
   GUIDELINES FOR LIGHTING

20.7 DOMESTIC LIGHTING
   DIRECT LIGHTING
   INDIRECT LIGHTING
   DIFFUSED LIGHTING
   DIRECT/DIFFUSED LIGHTING

20.8 SIMPLE SINGLE ELECTRICAL LAYOUT
Electrical installations in buildings should only be carried out by subcontractors who are licensed to do electrical work by the regulating authority, the State Energy Commission. All work undertaken by electricians must comply with the rules and regulations of the supplying authority, which includes the Wiring Rules of the Standards Association of Australia.

In the various states, local regulations may in some cases modify these wiring rules, and state sub-committees generally make interpretations where required.

The builder, electrician and owner each have responsibilities to ensure work proceeds in the manner required and that connection is effected without delay.

The builder engages the electrical subcontractor to perform the work usually on a supply and fix basis. Consultation between builder, electrician and owner will ensure that the owner gets the number of power outlets and light points in the positions required by the owner. The electrician must submit a form 14 - "Notice of commencement of works" - 48 hours prior to commencing work.

When the electrician has completed his work he submits a form 15 - Notice of Completion of Works. When the inspector receives his copy of the 15 he inspects the work, passes it or gives instruction for modifications. The owner must make application for connection and pay all necessary fees. Connection will only be made when the SEC has received both the inspection report endorsed by the inspector and the application for connection. When both of these forms are to hand, a meter is installed and connection is made.

20.1 TEMPORARY SUPPLIES

Where there are existing electricity mains, the SEC can make available to the builder a temporary supply for construction purposes.

A builder’s private pole, which will carry the meter, box containing the meter, switch gear and fuses, should be located at the front of the site in a position approved by the inspector. The pole is normally 150 x 150 mm sound jarrah or galvanized tubular steel. (150 mm diameter)

The meter box should be of the standard size for single tariff, and positioned 1350 mm from ground level.

When it is time to transfer power from the temporary pole to the building, the SEC will disconnect the temporary pole and connect the power to the building, and install the meter to the building meter box.

20.2 METER

The service to a property is metered immediately on entering the premises, with equipment supplied and installed by the Commission.

The position and design of a meter enclosure must be approved by the Commission. In domestic construction, the meter box may now be approved on the front wall of a building, or up to one metre from the corner on the side walls. Combined gas and electricity meter enclosures can be obtained from the Commission, together with details for installation.
Fig. 20.1(a)
(Courtesy State Energy Commission of Western Australia)
COMBINED GAS-ELECTRIC METER BOX

FIG. 20.1(b)

(Courtesy State Energy Commission of Western Australia)
FIG. 20.2

(Courtesy State Energy Commission of Western Australia)
Meter enclosures must be accessible at all times, and shall not be positioned behind screen walls and gates or under carports. (See Figure 20.1(a) and (b)).

In domestic situations, several different methods are employed in distributing single and three-phase electric current. The different categories of tariff require meter enclosures of varying sizes and shapes, in specified positions on buildings. The sizes and details of standard sheet metal meter enclosures are detailed on Figure 20.2, including the combined gas and electric meters box.

20.3 CUSTOMER POLES AND SERVICE BRACKETS

These are utilised within a customer's premises for the support or termination of the Commission's service lines.

A customer will be required to erect a pole within his boundary in the following situations: (See Figure 20.3).

(a) To maintain a clearance across a roadway of 5.5 metres from the crown of the road to the service lines.

(b) When the span from the Commission mains pole to the point of attachment exceeds the following distances (See Figure 20.4):

- standard service bracket - 30 metres (Fig. 20.4(a));
- standard raiser bracket - 18 metres (Figs. 20.4(b) and (c));
- long span raiser bracket - 30 metres (Fig. 20.4 (d)).

(c) Where the service line cannot be taken directly from the Commission's main pole owing to obstructing buildings, trees or passage over adjacent property.

(d) Where the customer's mains are to be installed underground in a normally overhead reticulated area.

Steel poles must be a minimum size - 114 mm diameter x 4.88 gauge galvanised pipe, 5.2 - 7.0 metres above ground.

Wooden poles should be of a suitable type: hardwood or CCA treated round pine, minimum sizes 150 mm x 150 mm sawn timber or 250 mm butt diameter x 150 mm head diameter round pole; height 5.2 - 7.0 metres above ground.
APPLICATION OF CUSTOMER POLES

FIG. 20.3

(Courtesy State Energy Commission of Western Australia)
CUSTOMER POLES & SERVICE BRACKETS

FIG. 20.4

(Courtesy State Energy Commission of Western Australia)

20.8
20.4 UNDERGROUND RESIDENTIAL DISTRIBUTION (U.R.D.)

The following guidelines are set out to ensure builders, electrical contractors and developers maintain a standard approach when undertaking projects in an area serviced by a U.R.D. scheme. It is important that owners, builders and developers of properties to be serviced in these areas are aware of the differences involved in being supplied from underground mains in comparison with the more conventional methods of overhead distribution.

DEVELOPER

The Commission arranges installation of the underground street mains and provides service pillar units at appropriate locations from which supply may be taken for each property. Street installations are laid in accordance with the Commission's specifications and project developers are required to contribute to the cost.

OWNER/Builder

The prospective customer is responsible (directly or through the builder/developer) for the supply and installation of the consumer's mains from the supply point to the main switch board. The supply point is within the service pillar unit, located near the property boundary. (See Figures 20.5 and 20.6).

TYPICAL LAYOUT

FIG. 20.5

(Courtesy State Energy Commission of Western Australia)
ELECTRICAL CONTRACTOR

The electrical contractor is responsible for the installation of the consumer's mains from the supply point to the main switchboard.

CONSUMER'S MAINS AND ENCLOSURE

Acceptable types of consumers mains for U.R.D. areas are:

(a) Elastomeric or thermoplastic insulated and sheathed cables installed in non-metallic enclosure - Cat A (PVE) Underground Enclosures - AS C183.

(b) Other types of cables or enclosures are subject to approval by the commission.

Cat. A (PVC) underground enclosure is orange in colour. Appropriate bends and fittings are to be used and the enclosure should not be bent.

DEPTH OF LAYING

The minimum depth of laying of consumer's mains is to be 900 mm. The enclosure should terminate approximately 900 mm from the pillar unit, and approximately 2,500 mm of cable is to be coiled in the ground for connection to the pillar unit. (See Fig. 20.7)

It is important that the electrical contractor, while installing the consumer's mains, gives due consideration to future back filling and levelling of the property, to ensure that mains are not buried to an excessive depth.
20.5 GENERAL ELECTRICAL HARDWARE

The following are items of general electrical hardware.

(a) ELECTRICAL CABLES

A cable is an insulated conductor (solid or stranded), or two or more such conductors laid together either with or without base conductors, fillings, reinforcements, or protective coverings.

TPI (or thermoplastic insulated) cables have a single layer of coloured insulation (PVC) over copper conductors. TPI cable is also known as "building wire". As these cables are single insulated, they must be protected from damage by enclosing them in a conduit or duct. See Figure 20.8(a). TPS or thermoplastic sheathed cables have an insulated core or cores and these are surrounded by an outer layer or sheath of insulation. TPS cable is available with a single core, several insulated cores, or two more insulated cores with an earthing conductors. (See Figure 20.8(b)).

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(Attribution: By CC BY 4.0)
THERMOPLASTIC SHEATHED CABLES

FIG. 20.8(b)

SINGLE POLE SINGLE THROW (sp st) SWITCH

FIG. 20.8(c)

GENERAL PURPOSE OUTLET (power point)

FIG. 20.8(d)

(b) CONDUITS

Conduits to carry electrical cables can be either metal or PVC. The size of the conduit for domestic construction ranges from 16 mm to 25 mm diameter. The standard colour is grey, unless it is used underground, when it is coloured orange. These are a variety of fittings available to use in conjunction with the conduits, such as elbows, tee's, junction boxes, etc.
(c) SWITCHES

A switch is a devise for opening or closing (making or breaking) one or more electrical circuits. Some switches are operated manually, while others, such as time switches and pressure switches are automatic. There is a wide variety of switches available, as well as a range of colours for the cover plates. The most common switch used is domestic construction is the single pole, single throw SPST switch. See Figure 20.8(c).

(d) POWER POINTS

Power points or "general purpose outlets" are the source of electrical supply to portable electrical applications. The usual location of these is either in the skirting board (must be flush mounted if they are within 0.15 m from the floor) or at about 900 mm from floor level. Special regulations apply to power points located in kitchens, bathrooms and laundries, and these are stated is the SAA WIRING RULES. All power points must be earthed. See Figure 20.8(d) for a sample wiring diagram. Single-phase power points must be connected so that the active is on the LEFT when the socket or base is viewed from the front.

(e) FUSES

A fuse is a wire, on a porcelain insulator, that will easily melt when the electrical circuit is overloaded. It is placed in each circuit. The size of fuse wire used for lighting circuits is 8 Amps and 16 Amps for power circuits. When a fuse "blows" (the wire burns out due to an overloading), the wire has to be replaced. To overcome this problem, circuit breakers can be used. These tip when overloaded and then can be re-set manually by pressing a button or a switch.

(f) LAMPHOLDERS

The most common type of lampholders fitted to new houses is the Batten holder. There is a variety of batten holders available on the market today. The main point to remember when installing fixed lamp holders, is that they should have provision to attach on earth wire. It will depend on the actual type of light fitting used, whether the earth connection has to be used.

20.6 GENERAL PURPOSE OUTLETS AND LIGHTS

The number of general purpose outlets or power points installed in a domestic residence is normally divided upon by the builder and the owner by mutual agreement. There is however an accepted minimum requirement. The following table lists each room and gives the normally accepted number of power points for that room.
<table>
<thead>
<tr>
<th>ROOM</th>
<th>TYPE OF POWER POINT</th>
<th>QTY.</th>
<th>USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>Single</td>
<td>1</td>
<td>Refrigerator</td>
</tr>
<tr>
<td></td>
<td>Double</td>
<td>1</td>
<td>Toaster, Kettle Etc.</td>
</tr>
<tr>
<td>Laundry</td>
<td>Single</td>
<td>1</td>
<td>Washing Machines</td>
</tr>
<tr>
<td>Bathroom</td>
<td>Single</td>
<td>1</td>
<td>Shaving, Hairdryer</td>
</tr>
<tr>
<td>Lounge</td>
<td>Single</td>
<td>2</td>
<td>T.V., Radio, Table Lamp</td>
</tr>
<tr>
<td>Dining</td>
<td>Single</td>
<td>1</td>
<td>Portable Hot Plate</td>
</tr>
<tr>
<td>Family</td>
<td>Single</td>
<td>2</td>
<td>T.V. Radio, Table Lamp</td>
</tr>
<tr>
<td>Games</td>
<td>Single</td>
<td>1</td>
<td>Table Lamp, Vacuum Cleaner</td>
</tr>
<tr>
<td>Master Bed</td>
<td>Single</td>
<td>2</td>
<td>Side Lights, Electric Blanket</td>
</tr>
<tr>
<td></td>
<td>or Double</td>
<td></td>
<td></td>
</tr>
<tr>
<td>En Suite</td>
<td>Single</td>
<td>1</td>
<td>Shaving Etc.</td>
</tr>
<tr>
<td>Bed 2,3 Etc.</td>
<td>Single</td>
<td>1</td>
<td>Side Light, Electric Blanket</td>
</tr>
<tr>
<td>Garage</td>
<td>Single</td>
<td>1</td>
<td>General Purpose</td>
</tr>
</tbody>
</table>

**TABLE 20.1**
GUIDELINES FOR LIGHTING

The first step in home lighting is to decide between incandescent and fluorescent light. Incandescent lighting is preferred for domestic use because of its flexibility but fluorescent does give a high-efficiency light for the bathroom or kitchen or a continuous light for a pelmet, for example. However it is a matter for individual taste.

Suggestions to help make practical as well as decorative use of lighting:

**PORCH**
Provide enough light to make a home appear welcoming to guests and to reveal the keyhole and hazards. Also, illuminate attractive plants and shrubs where possible.

**ENTRANCE HALL**
Have a ceiling and wall light for effect; also a floor light that can be left on all night if there are young children in the house.

**LOUNGE**
Provide a ceiling light for decorative purposes; for example a chandelier, with lamps for atmosphere, and concentrated light for reading or sewing.

**DINING ROOM**
This needs soft, warm light focused on the table, adjustable if possible. Candlelight for atmosphere.

**BEDROOM**
Soft ceiling light should be supplemented by lamp light on either side of the bed. Make sure the lamp-shades are wide enough to give a flow of light across the bed.

**KITCHEN AND BATHROOM**
Use highly-efficient shadowless light. Have a separate light over stove and work bench. Another separate light is needed over the bathroom mirror, so that illumination falls on the face as well as on the mirror.

Kitchen and Bathrooms - 200 Lux
Sewing and Darning - 400 Lux
Home Work and Sustained Reading - 300 Lux

20.7 DOMESTIC LIGHTING

TYPES OF ARTIFICIAL LIGHTING UNITS, OR LUMINARIES

There are four principal categories of luminaries or light fittings, which determine the type of light emitted, and the direction of illumination:

(a) Direct

(b) Indirect
(c) Diffused

(d) Direct - diffused

(Refer to Figure 20.9)

(a) DIRECT LIGHTING

Direct Lighting has the advantage of providing the maximum number of lux for any given wattage, but produces both direct and reflected glare. The illuminance comes direct from a globe or tube, without passing through any diffusing medium, and may be direct downwards by an open reflector.

(b) INDIRECT LIGHTING

Indirect Lighting is ideal for tasks involving fine detail and concentration, but produces only about 33% of the illuminance of obtained by the same wattage of direct lighting. Open reflectors direct most of the light upwards, to be reflected from the ceiling in a soft light, free from glare and almost eliminating shadows.

(c) DIFFUSED LIGHTING

Diffused lighting passes through an enclosed bowl of diffusing material, or "egg crate" cover, to radiate in all directions. The value of illuminance is approximately 30% less than for the same wattage of direct light, but glare is reduced, and softer shadows are produced.

(d) DIRECT/DIFFUSED LIGHTING

Direct/diffused lighting is achieved by a combination of direct and diffused methods, using an open-type reflector over a diffusing bowl. The efficiency of illuminance is midway between the two systems, or approximately 85% value of direct lighting.

NOTE: Direct lighting is emitted towards a work situation, with only a fraction of the illumination (approximately 10%) being reflected from the ceiling.

Indirect light in the reverse of the above, with most of the illuminance (90% approximately) coming as reflected light.

Intermediate situations produce approximately equal amounts of direct and reflected light, and may be termed direct-indirect fitting.
20.8 SIMPLE SINGLE ELECTRICAL LAYOUT

Figure 20.10 shows an average domestic dwelling with the layout of the power points and lights indicated. Table 20.2 shows the electrical location symbols used.

Figure 20.11 shows a simple single electrical layout. The board shown on the diagram is wired for three phase, but only single phase is used for the circuits.

The system is shown earthed, including the light circuit. All power circuits have to be earthed, so that if a leakage occurs it will feed back through the earth wire, rather than through the person operating any appliance.
## Electrical Location Symbols

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main switch board</td>
<td>![MSB]</td>
</tr>
<tr>
<td>2</td>
<td>Luminaire</td>
<td>![O]</td>
</tr>
<tr>
<td>3</td>
<td>Luminaire-fixed to wall</td>
<td>![a]</td>
</tr>
<tr>
<td>4</td>
<td>Luminaire-with 3 x 60 W lamps</td>
<td>![O3x60W]</td>
</tr>
<tr>
<td>5</td>
<td>Luminaire-built in switch</td>
<td>![O]</td>
</tr>
<tr>
<td>6</td>
<td>Luminaire-for emergency lighting</td>
<td>![X]</td>
</tr>
<tr>
<td>7</td>
<td>Lamp with reflector</td>
<td>![O]</td>
</tr>
<tr>
<td>8</td>
<td>Luminaire - for fluorescent</td>
<td>![H]</td>
</tr>
<tr>
<td>9</td>
<td>Switch - one way</td>
<td>![S]</td>
</tr>
<tr>
<td>10</td>
<td>Switch - triple pole</td>
<td>![S]</td>
</tr>
<tr>
<td>11</td>
<td>Switch - pull type</td>
<td>![S]</td>
</tr>
<tr>
<td>12</td>
<td>Switch - two way</td>
<td>![S]</td>
</tr>
<tr>
<td>13</td>
<td>Switch - intermediate</td>
<td>![S]</td>
</tr>
<tr>
<td>14</td>
<td>Light dimmer</td>
<td>![S]</td>
</tr>
<tr>
<td>15</td>
<td>Time switch</td>
<td>![S]</td>
</tr>
<tr>
<td>16</td>
<td>Motor</td>
<td>![M]</td>
</tr>
<tr>
<td>17</td>
<td>Clock-battery operated</td>
<td>![J]</td>
</tr>
<tr>
<td>18</td>
<td>Socket outlet (G.P.O.)</td>
<td>![G]</td>
</tr>
<tr>
<td>19</td>
<td>Multiple socket outlet for 2 plugs</td>
<td>![G2]</td>
</tr>
<tr>
<td>20</td>
<td>3 phase socket outlet</td>
<td>![G3]</td>
</tr>
<tr>
<td>21</td>
<td>Telephone outlet-wall</td>
<td>![G]</td>
</tr>
<tr>
<td>22</td>
<td>Thermal fire alarm detector head</td>
<td>![M]</td>
</tr>
<tr>
<td>23</td>
<td>Electric bell</td>
<td>![M]</td>
</tr>
<tr>
<td>24</td>
<td>Electrical appliance (hot water service)</td>
<td>![HWS]</td>
</tr>
</tbody>
</table>

**Table 20.2**
SIMPLE WIRING DIAGRAM
FIG. 20.11
CHAPTER TWENTY ONE - VENTILATION AND HEATING

21.1 NATURAL VENTILATION

INTRODUCTION
VENTILATION REQUIREMENTS
FORCES PROMOTING VENTILATION
UTILIZATION OF BREEZES
WINDOWS
OBSTRUCTIONS
DESIGN CONSIDERATIONS

21.2 HEATING OF BUILDINGS

HEAT TRANSFER
SPACE HEATING
ELECTRICITY
GAS
OIL
SOLID FUEL
SOLAR

21.1 NATURAL VENTILATION

INTRODUCTION

The term, "natural ventilation," is intended to apply in this context to the movement of air into and out of a building under the action of natural atmospheric forces. Such air movement serves several useful purposes; for example, it reduces the concentrations of bacteria, odours and other airborne contaminants within a space, doing so in the interests of good health. In summer, particularly, it helps to cool the body, and induce a sensation of freshness in the air.

VENTILATION REQUIREMENTS

Human beings are able to live healthily even though the quantity of fresh air introduced into their environment is astonishingly low by common standards. Measures aimed at effecting a desirable dilution of odours have figured largely in determinations for minimum rates of air supply to buildings, but conclusions reached on this basis require comparatively liberal rates of air change, which are somewhat inconsistent with fuel economy if comfortably warm conditions are to be maintained in winter. Further, when conditions of light
breeze or calm prevail outdoors, such rates of air change will not normally be automatically given by the customary permanent wall vents or ventilation openings required by building regulations. It is logical, therefore, that ventilation openings should be adequate, but adjustable at will.

However, the mere removal of what may be regarded as requisite quantities of air and the introduction of equal amounts of fresh air is not sufficient in itself. The process may well give rise to uncomfortable draughts in winter, when air movement exceeding 8 to 12 metres per minute should be avoided, or it may take place in a manner that fails to move air at satisfactorily high rates for personal needs. Thus, the provisions which might satisfy health needs may be entirely inadequate or even unsatisfactory for physical comfort. It is important, therefore, that due regard should be paid to the proper utilization of moving air, as well as to the magnitude of its flow.

FORCES PROMOTING VENTILATION

The two principal agencies which promote ventilation by natural means are temperature difference, and wind action.

The term, "temperature difference", is applied - for the sake of brevity - to the phenomenon in which heated air rises through a main body of air at a lower temperature, and seeks to escape from the space. Advantage is often taken of this behaviour of heated air; canopies with associated flues are frequently erected over heat-producing plant and equipment, for the purpose of entraining and removing the heated air and any associated fumes before the heat or fumes affect the space generally. As the force which causes the air to rise is often small in relation to that of the cross-currents within the space, an exhaust canopy with its flue must be properly designed and installed with due regard to prevailing conditions, if the arrangement is to be effective in service. This is particularly true with respect to domestic cookers: the housewife is likely to leave a kitchen window open during favourable weather, with the result that the inflowing breeze will blow hot gases from beneath the canopy and render it largely ineffective, irrespective of the merits of its design and installation. (See Figure 21.1).

Cross ventilation reduces efficiency of canopy

FIG. 21.1

21.2
UTILIZATION OF BREEZES

When a breeze blows against a building it establishes, broadly, a zone of positive pressure against the windward wall and roof slopes, and corresponding zones of reduced pressure on the leeward side of the building. If these induced pressures are able to communicate themselves to the air contained within a building, because of the presence of suitably placed windows or other openings, it follows that air will be forced inwards through openings on the windward side, and be drawn out of openings on the leeward side. Clearly, the rate at which air will enter and flow through a building will increase with the speed of the wind and the extent of the suitably placed openings. The flow of air is further increased if the total area of openings within the zone of reduced pressure exceeds that of openings within the zone of increased pressure.

Openings in walls parallel to the direction of the wind are largely ineffectual for purposes of inducing air movement.

Although large volumes of air might be induced to flow through a particular building, as a result of providing large areas capable of being thrown open, it does not follow that the rate of air movement through the building, and particularly at working level, will necessarily be high. For example, in an industrial-type building, extensive use is made of openings in roof-lights, or in the roof itself, but it is possible for most of the air movement to take place ineffectually, that is, above working level. It follows, therefore, that ventilation openings should preferably be placed low, so as to serve the working area effectually; high openings in a leeward wall will cause an air stream within the building to rise well before it reaches the wall, and deprive the nearby working area of the potential benefit, and high inlet openings will fail to improve working conditions at the outset.

Where it is necessary that there should be partitions or other obstructions to the indoor flow of air, there usually remains the opportunity in principle to utilize moving air to good effect, even though the speed of movement may be reduced by the obstructions. Here again, high-level openings should preferably be avoided if effective air movement is required at working level, and opposite openings of limited extent in opposite walls are undesirable; high-level openings on the one hand will promote air movement essentially at their own height, and opposing small openings on the other hand will limit the lateral extent of the air stream. It is clearly desirable that windows and doorways should be so arranged as to ensure that air flowing between them and other openings is caused to traverse the space as fully as is reasonably possible.

A practice common in hot, humid regions is that of supporting partitions clear of both floor and ceilings, for the purpose of improving ventilation conditions in, say, sleeping quarters. While such provisions may at times aid natural ventilation when it is assessed in terms of rate of air change, the practice can be expected to detract from the effective utilization of the air; in the circumstances, air can escape laterally from a cubicle or room, instead of being obliged to traverse the space as it must do if the partitions extend from floor to ceiling.
It has already been noted that in order for high rates of air movement to be induced indoors, windows or other openings must be located to face the breeze to be utilized, and corresponding openings provided in leeward walls to permit the air to escape. As windows of various types have different ventilation characteristics, brief notes follow on this aspect.

**DOUBLE-HUNG WINDOWS**

This is the type of window in which two sashes are adjustable vertically. In windows of this type the sashes always obstruct at least half the available opening. This disability of permanent obstruction is, of course, common to all sliding-sash types of window, whether the sashes move vertically or horizontally. However, it may not be great, particularly in dwellings, where either the ventilation openings provided may in any case be adequate, or the occupants are able to place themselves to gain the greatest benefit from the inflowing air. In fact, the obstructive action of the sashes of a double-hung window can be put to good purpose; if, when calm conditions prevail outdoors, both the top and bottom sashes are opened partially, heated air can flow outward at the top, and cool air inward over the sill, because of the temperature difference which usually prevail over the height of the window.

A double-hung window can be adjusted also to provide a high-level opening only for ventilation, as may be desirable during cool weather, or when it is raining. (See Figure 21.3).

**FIG. 21.2**

![Disposition of openings affects ventilation](image1)

**FIG. 21.3**

![Double-hung windows are useful in calm conditions](image2)

**CASEMENTS**

An open casement window provides a free airway nearly as great as the available opening, but this advantage cannot be sustained for admitting air unless the wind is blowing somewhat directly
into the opening. A special feature of casement sashes is that they can be adjusted to entrain, and deflect horizontally, the incoming air stream. Because no vertical deflection of the air stream is possible, desirably, sills should be low.

ADJUSTABLE LOUVRES

Adjustable louvres, too, offer little obstruction when fully open but, in contrast to casements, they can deflect air in a vertical plane; they will not deflect it laterally. On this account, it is desirable that in common with sliding sash windows they should be well distributed in the wall of the room or space to be ventilated. (See Figure 21.4).

![Louvres deflect breeze vertically](image1)

**FIG. 21.4**

![Horizontally hinged sashes provide ventilation in wet weather](image2)

**FIG. 21.5**

HORIZONTALLY PIVOTED SASHES

Windows in which the sashes are horizontally pivoted are generally favoured in regions where the climate is hot and humid, and rain falls frequently in the absence of strong wind. Such windows offer little obstruction to inflowing air, and the sashes, if they are top-hung and swing outwards, serve to protect openings against the entry of rain. In other respects, the ventilation characteristics of horizontally-pivoted sashes are similar to those of adjustable louvres. (See Figure 21.5).

EXTERNAL DOORS

Natural ventilation can usually be improved materially by opening external doors or French windows. These openings are large in relation to other ventilation openings and, as they extend to floor level, they induce air movement at low levels; this type of movement is necessary for anyone who may be reclining. However, external doors need to be carefully located so as to be protected from driving rain and cold winds.

PERMANENT OPENINGS

Permanent openings can be beneficial for ventilation in summer, particularly if they face the prevailing breeze, but they will need to be weathertight and be so placed that they will not be
disadvantageous in winter by admitting cold winds. Because of the natures of the seasonal wind patterns, it may often be desirable to avoid permanent openings from the viewpoints of both weather-tightness and avoiding winter draughts.

Similar problems are associated with doors to loading docks, and the like, which must be kept open for lengthy periods, and they highlight the need for careful placement of all such openings.

EFFECTS OF EXTERNAL OBSTRACTIONS

Obstructions such as a line of trees or wooded country are largely permeable to air movement, and their effect, principally, is to reduce the wind velocity near the ground. Buildings, on the other hand, abruptly obstruct the wind, and so deflect it about them as to create zones of reduced air pressure in their lees; these zones persist, at progressively reducing intensities, for considerable distances behind the obstructing buildings. It therefore follows that the windward wall of a building may well be subjected to reduced air pressure, instead of to increased air pressure, because of the air disturbances set up by another building to the windward of it. The effect in the obstructed building would then be the induction of low-speed air movement in a direction contrary to that of the wind.

No concise rules can be set down to provide guidance on the problem of obstructions and their effects on ventilation conditions in other buildings. However, it can be suggested broadly for industrial-type buildings, for example, that a separation of 30 to 45 m should normally suffice to reduce to small proportions the shielding of one building by another, and that if the separation cannot exceed about 9 m, the buildings should be located as close together as possible, and preferably to abut.

It is also not possible to state generally how buildings will obstruct each other when they are not in line with the prevailing breeze, but broad conclusions can often be drawn from diagrams developed for specific circumstances, showing roughly the zones of increased and reduced air pressure. A desirable condition is that buildings should reinforce the zones of reduced air pressure in their lees. Such a state can be established, say, by a two-storey building beside the leeward end of a lower building; ventilation conditions in the latter building can be expected to be improved, under prevailing winds, by the presence of the former building. (See Figure 21.6).

![The influence of an obstruction](image)

FIG. 21.6
DESIGN CONSIDERATIONS

No special comment is offered regarding natural ventilation for winter conditions; provisions now commonly made are usually adequate, or even excessive. Summer requirements often cannot be met so readily, and special measures are frequently necessary to produce the desired effects.

The main considerations which apply broadly to most problems involving natural ventilation are as follows:

1. Ascertain the directions of the prevailing cooling summer winds, so that these winds may be utilized to the best advantage indoors.

2. Ascertain the directions of the prevailing winter winds, with a view to excluding them.

3. Locate openings in windward and leeward wall (with respect to cooling summer winds) to ensure, in conjunction with appropriate types of windows with low sills, a reasonable distribution of air indoors.

4. Endeavour to locate partitions, and openings in them, so as to encourage the natural flow of air and, at the same time, ensure good distribution of air movement throughout the entire space.

5. Apply whatever corrective measures appear to be justified because of the presence of external obstructions to the normal passage of the wind.

21.2 HEATING OF BUILDINGS

Space heating is normally required in winter to make conditions comfortable for human occupation. The heating provided may be either continuous or intermittent. For lowest running costs thermal insulation improves efficiency and reduces the time to reach comfortable conditions when intermittent heating is used. Heat transference may be by conduction, convection or radiation, with various combinations of convection and radiation being most common.

HEAT TRANSFER

When a temperature difference or gradient exists across a body of solid, liquid or gas medium, heat will flow from the high temperature area to the low temperature area.

CONDUCTION

Conduction is the direct transmission of heat through a material. The rate of conduction (i.e., conductivity) depends partly upon the density of the material. Metals have a high conductivity, wood has low, and gases have even less conductivity.
**CONVECTION**

Convection is the transmission of heat in fluids and gases by circulation. When a liquid or gas is heated it is displaced by the colder more dense liquid or gas around it, and it tends to rise. In doing so it will impart some of its heat to anything in its path. The greater the movement, the greater the speed of transfer.

**RADIATION**

Radiation is the transferrence of heat from one body by radiant energy through space to another. All bodies emit radiant energy. The temperature of the body defines the wavelength and the rate of emission depends on the temperature and the nature of the surface. When radiant energy reaches an opaque body, part of it is reflected and the remainder absorbed and converted into heat.

**SPACE HEATING**

There is a wide range of space heating appliances available for domestic use. Basically, the choice of the unit will be determined by the choice of fuel to be used as the heating medium. Fuels generally available are:

- electricity
- gas
- oil (or kerosene)
- solid fuels (coal, timber).

**ELECTRICITY**

With the exception of solar heat, electricity is the cleanest fuel type. It produces no pollution at the house; though, of course, the generation of power by burning oil or coal or nuclear fuels causes some pollution at the source.

The simplest type of electric appliance is the bar radiator, which ranges in price and capacity from a few dollars for a single bar 750 watt output to somewhere around a hundred dollars for an elaborate three-bar 2900 watt appliance.

The electric bar heater has the attraction of low initial cost but the encumbrance of high running costs. There are no problems with fuel storage and 95% of the electrical energy consumed is converted to heat, making the unit very efficient. However, being a radiant-type heater, assisted by a polished reflector, the most benefit is gained by those in a direct line with the heater.

Oil-filled column radiators are electrical heaters which function when a sealed element in the radiator heats the special oil in the columns. As the oil heats, convection currents distribute heat through the whole unit. Convection currents are set up on the outside also and the warm air is distributed throughout the room. Prices for this type of heater range from $150 to $250 (1983).

A simple popular type of electric heater is the fan-assisted blower heater, which is able to produce a large heat output from a very small appliance. This is blown over the heated element, cooling it as it passes. This enables a higher wattage to be used and, consequently, more heat is emitted.
GAS

A range of heating appliances use gas as a fuel and many are similar in the transfer of heat to electrical appliances.

A new type of socket fitting known as a "bayonet fitting" allows the heater to be moved from room to room and plugged into the gas outlet. Because of their transportability these gas units are unflued and are therefore restricted in size. The largest unit currently permitted to be used unflued is 25 megajoules.

When unflued gas heaters are used, the room must be adequately ventilated. Local S.E.C. regulations require 10 cm² of ventilation top and bottom to the room for each megajoule of output.

The flued gas space heaters are permanently fixed in position (usually on a wall) with the flue either internal, external or hidden in the cavity of brick wall construction. The fixed gas space heater is usually equipped with an electric fan to set up convection currents, thus increasing the efficiency of the heater by using both radiation and convection as mediums of heat transfer.

Gas heaters are very efficient (about 90%) and are reasonably economical to operate; however, initial purchase and installation is a greater cost compared with electrical heaters already mentioned.

OIL

Heating appliances which operate on oil are similar to gas, with the exception that all are fixed in position and must be flued or ventilated to the outside. Oil is supplied to the appliance from a tank which is installed outside the building and reasonably close to the proposed position of the heater to help save on the installation costs of pipework.

Oil heaters which are used intermittently require servicing to clean up clogged burners. This should be done at the start of each winter.

With the present high cost of oil fuel, oil heaters are waning in popularity. When assisted with a convection fan the efficiency of an oil heater can be increased from 60% to 80%.

Another type of heater that uses a liquid fuel is the kerosene heater. These can be similar to the oil heater, in that they are in a fixed position and supplied by a tank situated nearly on the outside of the house. Another type is the portable kerosene heater. These are a radiant-type heater, assisted by a polished reflector, and like the electric bar heater, the most benefit is gained by those in a direct line with the heater.

SOLID FUELS

With the high cost of fuels there has been a big demand for solid fuel heating units. Such units can be open fire places built in as the house is built or be free-standing units such as pot bellied stoves, or even free-standing fire places. An added benefit of solid fuel heaters is that they can be fitted with a hot water coil to heat water and feed it into the hot water storage unit, thus reducing running costs of the hot water unit, or increasing the winter efficiency of solar water heating units.

The fuel burnt is usually wood or coal, although paper, sawdust and coke may be used with excellent results. The efficiency
of the solid fuel pot-bellied stove is said to be as high as 80%, while an open fire place is about 50% to 60%.

The operation of fire places - and particularly chimneys - is very susceptible to external conditions such as prevailing winds, adjacent buildings and surrounding high trees.

The proportions of a fire place must be carefully calculated to provide adequate ventilation and efficient burning. These proportions can be found in the Chapter dealing with brickwork.

SOLAR HEATING

As explained in an earlier Chapter, solar heating is being researched as a means of supplying cheap heating for domestic purposes. Considerations are given to the design of the house, placing of windows, heat absorbing walls and floors, to take as much advantage of the winter sun as possible. Any method that can be used to absorb as much heat as possible from the winter sun during the day, store this heat and then give it up during the night, would assist in the general heating of the house.
BUILDING CONSTRUCTION
Volume 1

DESCRIPTION
Topics include: Site Selection and Preparation; Concrete; Bricks and Brickwork; Timber; Sanitary Plumbing; Electrical Installations. This text is used with Study Guides 28-018 Building 1A and 15-835 Building Identification.

CATEGORY
Building and Construction