Cement & Concrete Association of Australia

The Cement & Concrete Association of Australia is the major source of information on the many uses of cement and concrete in Australia's construction industry.

It is a non-profit organisation funded by its members: Australia's cement manufacturers.

The Association -

- publishes technical and promotional literature
  (such as this handbook)
- organises information seminars for, and presents information to the key groups in the building industry, including government authorities, builders, engineers, architects and building designers
- funds a range of research projects
- is represented on a number of Standards Australia technical committees including AS 2870 Residential Slabs and Footings - Construction
- is an active participant in many industry technical committees - trade and professional - committed to improving training opportunities and disseminating information
- maintains contact with international organisations and information sources to keep abreast of worldwide trends
- maintains an extensive library
- co-operates with allied industry organisations, which promote precast concrete, pre-mixed concrete, concrete masonry and steel reinforcement.

The Housing CONCRETE HANDBOOK
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The HIA supports the Cement & Concrete Association of Australia in producing The Housing CONCRETE HANDBOOK. HIA recognises the benefits of providing practical and accurate technical information to builders and sub-contractors in the housing industry, and has worked with the Association in releasing this handbook.
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PREFACE

This handbook was written, primarily, as a reference guide for house builders and tradespeople working with concrete and cement-based materials, although TAFE students and their instructors will find it a helpful reference; and design professionals too will find it informative.

It gives practical information about the use of concrete and cement-based materials – mortar and render, for example – in the construction of houses, driveways and paths, and small buildings.

It covers the essential subjects in enough detail to give the house builder all they need to know about good quality concreting, and to alert them to poor practices.

More comprehensive – and technical – information about the use of concrete in all forms of construction can be found in the Cement & Concrete Association of Australia – Standards Australia joint-publication: Guide to Concrete Construction.

Caution

Remember when working with cement, concrete, mortar and other cement-based materials or prefabricated products, always follow the manufacturer’s instructions, and seek advice from the manufacturer, WorkCover or Worksafe Australia about working safely with these products.

If you have any doubts about working with concrete or cement-based materials contact the Cement & Concrete Association of Australia before starting the work; or if you are unsure about the statutory approvals you will need contact the HIA before starting work.
GLOSSARY OF TERMS

Admixture
A substance—other than water, aggregates or cement—added to a concrete or mortar mix to improve or modify some of the properties of the mix, or of the resulting concrete or mortar. These include colouring agents, modifiers to slow or accelerate the setting time, plasticisers to increase workability, and water-reducing agents.

Aggregates
The granular ingredients of a concrete or mortar mix: natural sand, gravel and crushed rock. Aggregates make up to 80% of the volume of concrete.

Aliphatic alcohols
Evaporation retardants, which are applied over the surface to trap bleedwater, which in turn minimises the extent of plastic shrinkage cracking (see below) that would otherwise occur under hot and windy conditions. They do not affect the concrete’s structural performance, or limit the choice of finishing techniques. They should not be confused with curing compounds.

Cement
All types of portland and blended cements conforming to AS 3972.

Compaction
Consolidating the concrete mix: to fill the forms, surround the reinforcement, and expel entrapped air to achieve the strength, durability and quality of finishes specified.

Curing
Keeping the surface of concrete, mortar or render damp, after placement, to slow evaporation and to ensure enough moisture for optimum hydration and subsequent hardening. Proper curing during the early life (7-10 days) of concrete improves its strength, and reduces cracking and dusting of surfaces.

Efflorescence
Deposits of soluble salts that form on the surface of building materials such as bricks, mortar, and concrete. The salts are present in the material and migrate to the surface during evaporation.

Flatwork
Concrete floors and pavements.

Hydration
A series of chemical reactions after cement is mixed with water, resulting in the formation of new compounds. During hydration the cement paste progressively hardens, and the concrete grows in strength.

Laitance
A layer of weak, non-durable material brought to the surface by bleeding, and exacerbated by overworking the surface of wet concrete when finishing.

Matrix
The mixture of cement paste and fine aggregate (sand) that binds the coarse aggregates.

Pozzolans
Siliceous, or alumino-siliceous materials that have little or no cementitious properties but will, in the presence of lime and water, react with calcium hydroxide to form compounds with cementitious properties. Pozzolans are better known as ‘fly ash’ and ‘silica fume’

Segregation
An uneven distribution of fine and coarse aggregates in the concrete. The causes include excess water in the mix; concrete falling more than one metre into place; cement paste leaking from formwork; and poor—too little or too much—compaction.

Slump (slump test)
A standardised measure of the consistency of freshly-mixed concrete. It gives an indication of the water content, and the workability of the mix. Slump is one of the properties specified when concrete is ordered.

Water-cement ratio
The ratio of the mass (a scientific measure of the weight) of the water in the concrete to the mass of the cement in the concrete, mortar or grout. Adding water to a mix increases the water-cement ratio. The higher the water-cement ratio, the lower the strength and durability.

Workability
The degree of ease of handling, placing and finishing concrete or mortar. The greater the slump or water-cement ratio (see both terms above), the greater the workability.
1 CONCRETE PROPERTIES

Concrete is a versatile material with many uses. Good concrete, that which achieves its specified properties, depends first of all on the careful selection and proportioning of its constituent materials, and on effective methods for handling, placing, compacting, finishing and curing.

In its basic form, it is a mixture of cement, water, fine and coarse aggregates, which is plastic (can be worked and moulded) when first mixed, and hardens to a solid mass.

The properties of concrete, in its plastic and hardened states, are affected by the physical characteristics, the chemical composition, and the proportions of the ingredients in the mixture. In its hardened state concrete must be strong enough to carry the loads imposed on it, and durable enough to resist wear, weather and chemical attack. In its plastic state it must suit the methods of handling, placing, compacting and finishing.

The cement paste (cement and water) in the mixture lubricates the aggregates and allows them to move freely while the concrete is placed and compacted. Generally, the more cement paste in the mixture, the more workable the concrete. It is important that concrete delivered to site is sufficiently workable for it to be placed and compacted by the means available. If it is not properly placed and compacted, concrete will not achieve its potential strength and durability.

Addition of water increases the workability, but dilutes and weakens the cement paste. In this respect, cement paste is like any other glue: dilution will weaken it. It is the aim of concrete mix design, or proportioning, to strike a balance between the need for workability, so that concrete can be placed and finished, and the need for it to be strong and durable. Workability can also be improved by the use of chemical admixtures such as plasticisers.

Many of the characteristics of concrete, particularly its strength and durability, depend on the development of chemical and physical bonds: of the cement paste itself as it hydrates (see glossary), and between the cement paste and the aggregate particles as the concrete hardens. The chemical reaction between cement and water (hydration) takes time. Concrete must therefore be kept moist (cured) for a time to ensure that hydration continues and that the concrete achieves its potential strength and durability.

Technologists use a range of materials other than cement, water and aggregates to modify the properties of concrete. These include pozzolanic and other cementitious materials, chemical admixtures, and special aggregates.

2 CONCRETE MATERIALS

2.1 Cements and supplementary cementitious materials

The term ‘cement’ covers a wide variety of organic and inorganic binding agents. By far the most widely used are those known as portland cements—finely ground inorganic materials that have a strong hydraulic binding action. These binders, when mixed with water, will harden in the absence of air to produce a stable, durable product.

Hydraulic cements manufactured in Australia fall broadly into two classes, namely portland cements and blended cements, both produced to AS 3792.

Type GP — General purpose portland cement

Type GP cement is used as a general-purpose cement suited to all types of construction, including major construction projects and in precast concrete product applications. Type GP cement may contain up to 5% of approved mineral additions. Mineral additions include limestone, fly ash and blast-furnace slag.

Type GB — General purpose blended cement

Type GB cement incorporates supplementary cementitious materials (such as fly ash) used at rates greater than 5% and typically 10–40%. Due to the blending of ingredients, type GB cement has a wide range of construction applications for residential construction in concrete, grouts, mortars and renders. GB cements gain strength at a lower rate than type GP cements but 28-day strengths are similar.

Masonry cement

Masonry cement is a finely ground mixture of portland cement clinker, gypsum and suitable inorganic materials such as hydrated lime, limestone and pozzolans. It is characterised by producing mortars of high workability and high water retentivity, but which have a lower rate of strength development than those made from portland cement. These characteristics make masonry cement especially suitable for masonry work but unsuitable for any form of structural concrete.

Off-white and white portland cements

The grey colour of portland cement is due mainly to the presence of iron in the cement. By lowering the iron content, light coloured cements can be produced. Off-white and white cements are used principally for architectural applications. Australian-made off-white cements are produced to meet general requirements for type GP cement. Currently all white cements are imported. Generally, these would comply with AS 3972.

Supplementary cementitious materials (SCMs)

SCMs are defined as fly ash, blast-furnace slag and silica fume, which are added to concrete to improve its characteristics and properties. These additives are sourced from industry by-products.

Fly Ash is the fine residue extracted from the flue gases at coal-fired power stations. These particles are of spherical shape with a glassy appearance and are processed to meet the requirements of AS 3582.1.

Blast-furnace slag is a non-metallic material produced simultaneously with iron in a blast furnace and which is then granulated by the rapid quenching process. It possesses some latent hydraulicity but behaves as a cement in the presence of activators.

How do SCMs work in concrete?

When portland cement reacts with water, calcium hydroxide is produced. This material is soluble and adds little to the strength of concrete. Fly ash, however, reacts with the calcium hydroxide to form insoluble cementitious compounds similar to portland cement. Slag is also activated by calcium hydroxide and reacts with it.
Potential benefits of SCMs
- Improved workability
- Lower water demand for constant workability
- Reduction in bleeding
- Durable concrete
- More cohesive mix
- Longer setting period
- Higher ultimate strengths
- Reduced heat of hydration.

2.2 Admixtures

Admixtures are classified by the characteristic, or principal, effect on the concrete. Most concrete is described by the supplier as either a ‘summer-mix’ or a ‘winter-mix’, and will include admixtures that affect setting times to suit the prevailing conditions.

Air-entraining admixtures are added to general purpose concrete to improve its workability and cohesiveness and to reduce the water demand, thereby reducing bleeding and material segregation. Excessive amounts will reduce potential strengths.

Set-retarding admixtures slow the setting of concrete. They are useful during warm to hot weather, and when a concrete mix must be transported long distances.

Set-accelerating admixtures reduce the setting times of concrete. They are often used during cool weather.

Water-reducing admixtures disperse the cement particles and improve the workability of the concrete without the addition of water.

Superplasticisers increase fluidity of concrete; improving the workability for easier placement where, for example, reinforcement is congested or the formwork makes placement difficult. Working time depends on the type and dosage. Using superplasticisers does not remove the need for proper compaction.

2.3 Water

Most concrete specifications simply require that mixing water shall be potable, ie fit for drinking; or that it be clean and free from impurities harmful to concrete. Generally, water drawn from reticulated town-water supplies is suitable for making concrete.

3 SPECIFYING, ORDERING AND TESTING

3.1 Specifying

3.1.1 General

Australian Standard AS 1379 sets down a number of ways of specifying and ordering concrete to promote uniformity, efficiency and economy in production and delivery.

It refers to two classes of concrete:
- Normal-class, which is intended to cover most of the concrete delivered to building sites. Its specification and ordering has been simplified as far as practicable.
- Special-class, which allows for the purchaser to incorporate into the project specification any special requirements for the project.

3.1.2 Normal-class concrete

Normal-class concrete is specified by reference to basic parameters which describe the characteristics of concrete suitable for most purposes-
- the strength grade (N20, N25, N32, N40, or N50), or the corresponding characteristic strength (20, 25, 32, 40, or 50 MPa at 28 days)
- the slump required at the point of delivery (20–120 mm)
- the nominal maximum size of the coarse aggregate (10, 14 or 20 mm)
- the level of entrained air (if required)

In addition, the order for concrete should specify-
- the intended method of placement
- if the project assessment is to be carried out by the supplier

3.1.3 Special-class concrete

In general terms, special-class is concrete specified other than normal-class. It will be specified where the concrete will be used in harsh environments, particularly where corrosive elements are present (such as air-borne pollution or corrosive ground waters) or where the concrete will be used in the construction of liquid-retaining structures designed for holding substances that require a special, resistant concrete.

3.2 Ordering

For most housing projects, ordering normal-class concrete is simple.

A typical specification is-

<table>
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<tr>
<th>Strength</th>
<th>20 MPa</th>
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<tr>
<td>Aggregate size</td>
<td>20 mm</td>
</tr>
<tr>
<td>Slump</td>
<td>80 mm</td>
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The purchaser can ask for a higher slump to make the concrete easier to place. This will help when manual placement is necessary because of restricted access to parts of a project; or when an 80-mm slump might prove difficult to work, for example around congested reinforcement.

To produce a suitable mix, the supplier should always be advised of the task being undertaken, eg footings, floor slabs or driveways.

For example it would be essential to order a ‘block-fill’ mix (high slump and suitable aggregate sizes) in the case of a project that entails core-filling blockwork.

The timing of deliveries should be carefully planned. Traffic or site delays can result in several trucks waiting to discharge loads if successive deliveries are too close together. It may be
possible to alter the timing of the deliveries (or some properties of the concrete, notably slump) if, after placing has started, the original specification is found to be unsatisfactory.

3.3 Testing

3.3.1 General

 Builders will find it beneficial to have an understanding of the reasons and procedures for testing concrete. We explain here why and when tests are done.

Concrete supplied for floor slabs and driveways in particular, should be subject to slump and compression tests in accordance with Australian Standard AS 1379-1997 The specification and supply of concrete.

A slump test is carried out on plastic (freshly mixed) concrete, whereas a compression test is carried out on hardened concrete, usually at 28 days after placement. The slump test measures the mix consistency and workability, and gives an indication of the amount of water in the mix, which will affect the eventual strength of the concrete (see p1 Concrete Properties). The compression test measures the compressive strength of hardened concrete. The testing is done in a laboratory using a concrete sample made on site from a cylinder mould. Testing is a specialised procedure and should be carried out by experienced qualified people.

Builders have the choice of taking responsibility for testing or they can order pre-mixed concrete from a manufacturer that undertakes testing. Many suppliers of pre-mixed concrete have quality assurance systems that, among other checks, make periodical tests of the grades of the concrete they commonly supply. If builders order from a pre-mixed concrete manufacturer that undertakes testing it is important that they examine the delivery docket (referred to as an Identification Certificate in AS 1379) to ensure it matches their specifications. They should be sure that the docket indicates the four main attributes of a specification, namely class, strength, aggregate size and slump. They should retain this documentation for their records.

Builders taking responsibility for testing are advised to engage a testing laboratory accredited by the National Association of Testing Authorities, Australia (NATA).

We summarise, below, the testing procedures for the two tests should the builder want to undertake their own testing or witness the procedure and be sure that it has been done properly.

3.3.2 The slump test

Pre-mixed concrete manufacturers generally proportion the concrete mix with consideration to the travel time and ambient temperature so that the concrete meets the specification at the time of delivery. They are not required by AS 1379-1997 to carry out a slump test on site, unless water is added to the mix during the discharge of the concrete, in which case the concrete must be thoroughly re-mixed in accordance with the Standard and a slump test carried out on the remainder of the batch to ensure it remains within the tolerances of the specified slump. The tolerances of an 80-mm slump are plus/minus 15 mm. The amount of water added to the mix should be recorded on the delivery docket.

If a builder has serious concerns that the concrete mix is not the specified slump they should request an on-site slump test. If the builder undertakes the responsibility for slump testing, samples should be taken on site from concrete discharged directly from the agitator truck.

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The slump test is covered by AS 1012.3

The tools used are-

- Standard slump cone (see fig. 3.1)
- Small scoop/shovel
- Bullet-nosed rod (600 mm long x 16 mm diameter)
- Rule
- Steel float
- Slump plate (500 mm x 500 mm).

The method (see fig. 3.2) is as follows-

1. The clean slump cone should be dampened with water and placed on the slump plate. The slump plate should be clean, firm, level and non-absorbent.
2. Collect a sample from the batch of concrete. This should be done within 20 minutes of the concrete arriving on site and after the first 0.2 m³ of the load has been discharged.
3. Stand firmly on the foot plates of the cone and fill ⅔ the volume of the cone from the sample. Compact the concrete by 'rodding' 25 times.
4. Now fill to ⅔ and again rodding 25 times, just into the top of the first layer.
5. Fill to overflowing, rodding again, this time just into the top of the second layer. Top up the cone until it overflows.
6. Level off the surface with the steel float. Clean any concrete from around the base and top of the cone; push down on the handles and step off the footplates.
7. Very slowly lift the cone straight up, making sure not to move the sample.
8. Turn the cone upside down and place the rod across the upturned cone.
9. Measure the average distance to the top of the sample.
10. If the sample is outside the tolerance (ie the slump is too high or too low), another must be taken. If this also fails, the batch should be rejected.
3.3.3 The compression test

Compression testing may be a part of either production assessment or project assessment as described in AS 1379-1997. Production assessment requires the pre-mixed concrete supplier to take samples for testing at a designated frequency, and that records and reports of test results for each grade manufactured are retained by the testing organisation for at least 12 months. The supplier must make available certified copies for examination by the customer, namely the builder.

AS 1379-1997 also provides for builders who want to receive production assessment information from their supplier. Their project is registered with the supplier and reports relating to the concrete supplied during a particular production interval are sent to the builder or their nominee.

In the case of project assessment the builder takes responsibility for testing and reporting, and makes reports available to the supplier. Samples are taken from each 50 m³ of concrete at the project site before handling.

The making of compression-test cylinders is covered by AS 1012.9.

The tools used are:
- Cylinders (see fig. 3.4: 100-mm diameter x 200-mm high or 150-mm diameter x 300-mm high. The smaller cylinders are used for most testing because they are lighter).
- Small scoop
- Bullet-nosed rod (600 mm long x 16 mm diameter)
- Steel float
- Steel plate

Figure 3.2: Slump test

Figure 3.4: Cylinder-moulds for the two sizes for compression tests

Figure 3.3: Examples of slump

3.3.3 The compression test

Compression testing may be a part of either production assessment or project assessment as described in AS 1379-1997. Production assessment requires the pre-mixed concrete supplier to take samples for testing at a designated frequency, and that records and reports of test results for each grade manufactured are retained by the testing organisation for at least 12 months. The supplier must make available certified copies for examination by the customer, namely the builder.

AS 1379-1997 also provides for builders who want to receive production assessment information from their supplier. Their project is registered with the supplier and reports relating to the concrete supplied during a particular production interval are sent to the builder or their nominee.

In the case of project assessment the builder takes responsibility for testing and reporting, and makes reports available to the supplier. Samples are taken from each 50 m³ of concrete at the project site before handling.

The making of compression-test cylinders is covered by AS 1012.9.

The tools used are:
- Cylinders (see fig. 3.4: 100-mm diameter x 200-mm high or 150-mm diameter x 300-mm high. The smaller cylinders are used for most testing because they are lighter).
- Small scoop
- Bullet-nosed rod (600 mm long x 16 mm diameter)
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- Steel plate

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The method-
1 Clean the cylinder mould and coat the inside lightly with form oil and place on a clean, level and firm surface, ie the steel plate.
2 Collect a sample from the batch of concrete.
3 Fill the volume of the mould with concrete then compact by rodding 25 times.
4 Fill the cylinder to overflowing and rod 25 times first into the top of the first layer, then top up the mould until overflowing.
5 Level off the top with the steel float and clean any concrete from around the mould.
6 Place cap on cylinder, clearly tag the cylinder and put it in a cool, dry place to set for at least 24 hours.
7 After the mould is removed, the cylinder is sent to the laboratory where it is cured and crushed to test compressive strength (see fig 3.5).

4 FROM BATCHING PLANT TO FINISHED CONCRETE

4.1 Transporting

4.1.1 General

When water is added to cement it triggers hydration, setting begins and the concrete mix begins losing workability. Plan to avoid delays in deliveries from the batching plant, on the road and on the site. Delays reduce the amount of time to place concrete while it is still workable. Additional mixing of the concrete may be necessary on site, further delaying placement.

The setting process is also accelerated in high temperatures.

To avoid premature setting and difficult placement, adopt the following procedures-

- Select a pre-mix supplier close to the site to reduce travelling time.
- Provide good access for trucks to enter, and clear space for turning and manoeuvring, to allow for the quick discharge of the load.
- Ensure that adequate labour is on hand to reduce the unloading time for the concrete.
- Always try to finish the placement of all reinforcement, erection of formwork and site inspections at least 24 hours beforehand.
- Check that all mechanical appliances are in working order the day before placement to allow time for replacement or repair if needed.
- When pumping concrete, plan delivery schedules with enough time between loads to avoid delaying trucks.
- Consider using a pump if the weather is unpredictable. Overnight rain can limit access to the site and reduce the amount of time for placement.
- When access through a neighbouring property is necessary, ensure authorised passage beforehand to prevent delays arising from misunderstandings.
- Check that all underground services have adequate load bearing cover to prevent damage and rectification work.
- Where trucks must be driven over trenches, provide strong bridging to carry a fully laden vehicle. A loaded concrete truck bogged in a trench will cause long delays.
- If the soil-bearing capacity is in doubt, do not bring trucks in - pump only.
- Have all tools, equipment and materials at hand to avoid disruption.

4.1.2 The addition of water

Concrete will lose many essential properties if water is added to it on site. The addition of water will alter the water-cement ratio (see glossary), diluting and weakening the cement-paste, which is the essential ingredient that binds the mass.

Many concreting contractors mistakenly assume it is acceptable to add water on site to improve workability. The need to add water is often due to incorrect specification of the concrete mix or ordering details.

Adding unspecified amounts of water on site should be avoided. The correct way to adjust this is to add water and cement at rates that maintain the specified water-cement ratio. Always discuss these matters with the plant manager or batcher.

In certain situations, the addition of polypropylene fibres will reduce both the slump and workability of the concrete.
The table below summarises the properties affected by the addition of water.

<table>
<thead>
<tr>
<th>Property/performance</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump</td>
<td>Increased</td>
</tr>
<tr>
<td>Workability</td>
<td>Increased</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>Decreased</td>
</tr>
<tr>
<td>Incidence of shrinkage cracks</td>
<td>Increased</td>
</tr>
<tr>
<td>Chance of dusting surfaces</td>
<td>Increased</td>
</tr>
<tr>
<td>Chance of segregation</td>
<td>Increased</td>
</tr>
<tr>
<td>Volume of bleedwater</td>
<td>Increased</td>
</tr>
<tr>
<td>Value of compaction</td>
<td>Decreased</td>
</tr>
<tr>
<td>Value of curing</td>
<td>Decreased</td>
</tr>
<tr>
<td>Durability</td>
<td>Decreased</td>
</tr>
<tr>
<td>Permeability/absorption</td>
<td>Increased</td>
</tr>
</tbody>
</table>

4.2 Placing

4.2.1 General

Common placement methods, other than chute placement and pumping, require barrowing the concrete to position or manual shovelling; usually in successive placements. Barrowing concrete over reinforcement is often necessary. Prevent displacement of the reinforcement by supporting running boards above the reinforcement on blocks.

It is important not to over-handle the concrete as this can lead to segregation of materials (see glossary) and result in poor finishes.

The most important rule is to avoid segregation during placement. Concrete should be placed vertically and as near as possible to its final position. When it must be moved, it should be shovelled into position and not forced to flow into position.

Other techniques for avoiding segregation during placement depend on the type of element being constructed and on the type of distribution equipment being used.

For flatwork and slabs incorporating ribs and beams (shallow forms) the techniques shown in figure 4.1 should be adopted. For walls and columns (deep, narrow forms), problems occur when the concrete is dropped from too great a height and...
ricochets off the reinforcement and form-faces, resulting in segregation. The means of avoiding this vary with the type of distribution equipment being used (see fig. 4.2). The use of a tremmie could prove the most practical solution.

4.2.2 Placing in layers
To improve compaction of the concrete, place concrete in layers of a suitable depth for the compaction equipment. Layers that are too deep make it virtually impossible to adequately compact the concrete (see fig. 4.3), leaving entrapped air, which will create voids and blowholes in the surface of the concrete, and prevent it achieving its potential durability and strength.

4.2.3 Cold joints
Placing concrete in a continuous pour, if practicable, avoids the formation of cold joints. Cold joints are formed when fresh concrete is placed against the face of concrete that is about to set. The cracks resulting from cold joints will pass through the full depth of the slab.

Cold joints can be avoided by working ‘hot-on-hot’, which skilled paviours can do with enough labour at hand. When cold joints could occur—due to hot or windy weather, or delays for example—it is good practice to blend the faces by revibrating the concrete or to compact the joint with a shovel in a tossing motion to re-blend the faces.

Cold joints often occur when temporary internal formwork must be removed, which is common practice for internal step-downs and set downs. Good planning of formwork will avoid this.

4.3 Compaction and vibration

4.3.1 General
Compaction of concrete is undertaken to improve its overall performance. The most common form of compaction is vibration, undertaken with a poker or needle vibrator, but this is not the only method.

Proper compaction and expelling of entrapped air can greatly reduce the incidence of plastic settlement cracking over deep beams and fabric/bar reinforcement or restraints.

Properties improved by compaction—
• Strength and density
• Bond to fabric reinforcement and inserted structural anchors and hold-downs
• Hardness of wearing surface
• Reduced risk of plastic settlement cracking
• Off-the-form finishes.

4.3.2 Methods

Poker vibrators (see fig. 4.4) are good for expelling entrapped air in deep forms: beams, columns and walls. The poker will allow easy placement of what appears to be stiff concrete. Vibration will liquefy the mix and reduce demands for extra water.

They have an effective radius of between 100 mm and 600 mm depending upon the casing diameter and the specific amplitude of the device. They should be inserted quickly and removed slowly. They should not be dragged over the reinforcement but inserted vertically. Adequate compaction is signalled when the surface bubbling subsides.

Vibrating screeds (see fig. 4.5) are the preferred method for vibrating and compacting concrete flatwork for slabs up to 180 mm thick. Lower-slump concrete can be used if compacting this way. This method is often the most effective and economical option for long, continuous pours.

Tamping with the screed board on thin ground slabs is an effective method of compaction. In certain situations, tamping with wood floats and surface working closes up some types of cracking.

Rodding with a purpose-made rodding tool or equivalent, is effective for compacting piers or where pokers cannot be inserted; especially where fabric reinforcement is congested and space is limited. Shovels can be used for rodding at beam edges, around pipes and penetrations and at placement joints to re-work the old and new pours to prevent cold joints.

External vibration can be done simply (where other methods cannot be used) by using a hammer to tap the form or boxing. The concrete in contact with the form is vibrated and compacts, improving the surface finish.

4.3.3 Vibration hints

Under-vibration will cause serious defects in concrete and is the most common failing. Under-vibration will adversely affect structural properties, lower strength, increase permeability, lower durability and increase susceptibility to corrosive elements: both air-borne and contained in ground water.

Over-vibration, with grossly oversized equipment, may cause problems but ‘well-proportioned’ mixes are not likely to suffer any detrimental effects. Adding water to the mix can cause a problem with vibration, possibly leading to material segregation and poor surface finishes, such as those prone to dusting and flaking.
Re-vibration is used to blend cold joints, to close plastic shrinkage and plastic settlement cracking; to increase the potential strength of previously vibrated concrete; and to improve bonding to reinforcement when concrete is placed in layers (for example structural elements or deep beam sections).

4.4 Finishing

4.4.1 Screeding

Screeding is the operation of levelling the concrete after it is placed in the forms and roughly distributed with shovels. It is done by hand, or by means of vibrating-beam screeds, which work off the forms or guide rails. It should be done before bleedwater rises to the surface.

Hand screeding off edge forms involves the use of a screed board (or beam) to strike off the concrete to the required height. The striking surface of a screed board should always be straight and true. The surface is struck off by pulling the screed board forward, while moving it back and forth in a sawing-like motion across the top of the edge forms. A small roll or surcharge of concrete should always be kept ahead of the screed. Surface hollows created by aggregate 'roll out' or insufficient surcharge in front of the screed should always be filled immediately to prevent variations in floor levels.

4.4.2 Floating

The purpose of floating is to make the surface even and open in texture, ready for finishing.

Floating is working the surface of concrete with hand floats, bullfloats or with rotary finishing machines fitted with suitable floats or shoes. Generally, it should not begin until all bleed-water has evaporated from the surface, or has been carefully removed with a hessian drag or garden hose; and the concrete is hard enough to withstand foot traffic with only minor indentations in the surface. These indentations are removed by the floating operation.

Floating—
• embeds large aggregate particles beneath the surface;
• removes slight imperfections and produces a surface closer to the true plane;
• compacts the concrete and consolidates mortar at the surface, preparing it for finishing; and
• closes minor surface cracks, which might appear as the surface dries.

Bullfloating The bullfloat (see fig. 4.6) is a large float on a long handle, which is worked back and forth on the concrete in a direction parallel to the ridges formed by screeding. Bullfloating is useful as an initial floating operation to smooth the concrete surface immediately after screeding, and should be completed before bleedwater appears on the surface. A second use of the bullfloat may be required but care must be taken not to overwork the surface.

Floating by hand Three types of hand float are in common use: wooden, magnesium and composition.

The hand float is held flat on the surface and moved in a sweeping arc to embed the aggregate, compact the concrete, and remove minor imperfections and cracks (see fig. 4.7).

The surface may sometimes be floated a second time—after some hardening has taken place—to impart the final texture to the concrete.

Floating by machine (see fig. 4.8) Float blades are wider than trowel blades and are turned up along the edges to prevent them digging into the surfaces in the flat position. For this reason, floating with a trowelling machine equipped with normal...
trowel blades should not be attempted. The power-float should be operated over the concrete in a regular pattern, leaving a matt finish. Surfaces near to obstructions, or in slab corners, that cannot be reached with a power-float should be manually floated before power floating.

4.4.3 Trowelling

Trowelling is carried out some time after floating. The delay is to allow some stiffening to take place so aggregate particles are not torn out of the surface.

Trowelling by hand A trowel for hand finishing has a flat, broad steel blade and is used in a sweeping arc motion with each pass overlapping the previous one. For trowelling to be most effective, the timing of the operation calls for some experience and judgement, but in general terms, when the trowel is moved across the surface it should give a ringing sound.

For the first trowelling (often referred to as ‘breaking’), the trowel blade should be kept as flat against the surface as possible because tilting, or pitching, the trowel at too great an angle can create ripples on the surface. More trowelling increases the smoothness, density, and wear resistance of the surface. Successive trowelling operations should be made with smaller trowels at increasing pitches. This increases the pressure at the bottom of the blade and compacts the surface.

Later trowelling, after further hardening, will increase the density of the surface concrete, making it harder wearing. Successive trowelling operations should be at right angles to each other for best results.

Trowelling by machine The trowelling machine (power trowel or ‘helicopter’) is a common tool in Australia for all classes of work and consists of several (generally four) steel trowel blades rotated by a motor and guided by a handle.

Trowelling by machine should be carried out systematically over the concrete in a regular pattern. Corner areas, areas closest to obstructions and small irregularities should then be ‘touched-up’ with a hand trowel.

Edging Edging provides a quarter-round arris along the edges of footpaths, patios, curbs and steps. It is achieved by running an edging trowel along the perimeter of the concrete. Edging trowels are steel and incorporate a quarter-round forming edge. They are available in a variety of widths and with various diameter quadrants. Edging improves the appearance of many types of paving and makes the edges less vulnerable to chipping.

4.5 Curing

4.5.1 General

Curing is the procedure for retaining moisture in concrete for several days. It prolongs the chemical reaction of hydration (see glossary), which occurs when water and cement are combined to form cement paste.

Curing will:
- improve compressive strength
- reduce the incidence of drying shrinkage cracking
- reduce surface dusting
- improve protection of reinforcement
- increase the hardness of surfaces, and consequently their resistance to abrasion.

Curing should be maintained for a minimum period of 3 days for all types of housing concreting. It should begin no more than 3 hours after finishing, or the benefits will be markedly reduced.

4.5.2 Curing methods

Curing methods include:
- Curing compounds applied by spray or roller.
- Polythene sheeting placed and secured over the concrete to prevent evaporation.
- Formwork for edge beams and face panels left in place.
- Ponding water on the concrete surface where practicable.

The practice of intermittent wetting down morning and night is not curing and can cause greater harm to the concrete by causing expansion and contraction, increasing the incidence of shrinkage cracking – or craze-cracking.

4.5.3 Curing compounds

Curing compounds are liquids that can be sprayed, brushed, or squeegeed (usually sprayed, see fig. 4.9) directly onto concrete surface, which dry to form a relatively impermeable membrane that limits the loss of moisture from the concrete.

Their properties and use are described in AS 3799.

Use of curing compounds
- Easy to apply with either spray or roller
- Allow construction to continue unhindered
- Applied immediately after finishing
- Fugitive dyes assist in assessing coverage
- Rate of coverage is affected by the actual surface finishes, eg rough or broomed surfaces will require more as there is greater surface area
- Compatibility of compounds with intended adhesives should be checked as some compounds may require removal for glued-down floor coverings.

4.5.4 Plastic sheeting

Plastic sheets, or similar materials, are effective in limiting water loss, provided they are kept securely in place and protected from damage. Their effectiveness is reduced if they are not secure and wind can enter underneath.

Use of plastic sheeting for curing
- Plastic must be placed over the concrete and sealed and secured at the edges as soon as possible after finishing.
- Plastic must be lapped and sealed to prevent exposure to the drying effects of heat, wind or low humidity.
- Lightly coloured plastic sheeting will reflect the sun’s rays in hot weather and keep the concrete cooler during the summer.
- Black plastic, however, absorbs the heat but could be used in cooler regions, or in the winter months, to accelerate strength gain by raising the concrete temperature.
- The sheeting should not be lifted to add water to the surface. Additional water is not required.

Figure 4.9: Spraying on a curing compound
4.6 Effects of weather conditions

4.6.1 General

Experienced paviours are always aware of the effects that weather can have on concrete. Low workability, early setting times or plastic shrinkage cracking are not symptomatic of hot weather alone but can occur at all times of the year. Water is the catalyst for hydration of cement. Maintaining the water balance is important for full hydration, and to yield, ultimately, the properties of good concrete.

When the final finish does not meet expectations, the product is often wrongly blamed; when the most likely cause is a failure to adopt concreting practices suitable to the conditions.

In hot (above 30°C) and windy conditions concrete must be cured by covering with plastic sheeting, spraying with a liquid membrane curing compound or ponding of water on the top surface. (Building Code of Australia Volume 2 Housing Provisions: Clause 3.2.3.1d).

Weather factors to consider–
- Air temperature
- Relative humidity
- Prevailing winds and wind intensity

**Effect of weather conditions on concrete properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Hot</th>
<th>Cool</th>
<th>Dry/Windy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump</td>
<td>Decreased</td>
<td>Nil</td>
<td>Decreased</td>
</tr>
<tr>
<td>Setting time</td>
<td>Reduced</td>
<td>Increased</td>
<td>Nil</td>
</tr>
<tr>
<td>Strength gain</td>
<td>Increased</td>
<td>Decreased</td>
<td>Nil</td>
</tr>
<tr>
<td>- short term</td>
<td>Decreased</td>
<td>Increased</td>
<td>Nil</td>
</tr>
<tr>
<td>- long term</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workability</td>
<td>Reduced</td>
<td>Increased</td>
<td>Nil</td>
</tr>
<tr>
<td>Incidence of plastic shrinkage cracking</td>
<td>Increased</td>
<td>Reduced</td>
<td>Increased</td>
</tr>
<tr>
<td>Incidence of drying shrinkage cracking</td>
<td>Increased</td>
<td>Nil</td>
<td>Increased</td>
</tr>
<tr>
<td>Incidence of cold joints</td>
<td>Increased</td>
<td>Decreased</td>
<td>Increased</td>
</tr>
<tr>
<td>Period required prior to removal of formwork</td>
<td>Reduced</td>
<td>Increased</td>
<td>Nil</td>
</tr>
</tbody>
</table>

4.6.2 Hot-weather concreting

Hot weather increases the possibility of cracking. Temperature is not the only problem. Low humidity and high winds cause moisture loss and, in turn, shrinkage cracks.

Special attention to the following details will reduce the risk of poor quality work–
- Plan the job to avoid delays once the concrete pour has started.
- Provide shade and wind-breaks to work areas.
- Dampen the sub-base before placement of concrete (but do not leave surface water).
- Use a set-retarding admixture.
- Spray concrete with an aliphatic alcohol (see glossary) to reduce the rate of evaporation.
- Cure the concrete for a minimum of 3 days; 7 days is better. (If plastic sheeting is used, it should not be black.)

4.6.3 Cold-weather concreting

In cold conditions prolonged setting times can be shortened by adding a set-accelerating admixture. In exceptionally cold conditions, concrete can crack when the water in the concrete mass freezes and expands. In these conditions freshly placed concrete must be protected to prevent freezing. Formwork and sub-bases should be protected from frost, and concrete should never be laid on frozen ground. All materials should be kept warm, and while curing, the concrete should be kept warm where this is practicable.
5 FORMWORK AND REINFORCEMENT

5.1 Formwork

5.1.1 General

Accurate formwork construction is necessary to ensure correct levels and dimensions. Formwork joints should be tight to prevent cement paste leaks, which cause poor off-form finishes. Formwork should be coated with form oils to improve concrete finishes and aid the removal of the formwork.

Formwork is left in place, primarily, to protect the edges of the pre-hardened slab from mechanical damage during site works, and to avoid damage during the premature removal itself. Formwork is also an effective means of curing when it is left in place. If the formwork is stripped before 3 days have elapsed it is advisable to continue curing exposed surfaces with one of the methods described in 4.5 Curing.

Figure 5.1: Basic ground forms

5.1.2 Basic ground forms

Basic ground forms are suitable for paths and driveways on firm ground, up to 150-mm thick. The correct method of fixing forms to pegs is shown in figure 5.1.

5.1.3 Deep edge forms

In varying ground conditions formwork is often required for slabs up to 300 mm thick. Where the height of formwork exceeds 150 mm, it should be braced as shown in figure 5.2. Deep edge forms can be constructed from clean-faced ply with top and bottom walers. If solid timber forms (minimum 38 mm) are used, the bracing and formwork will be different. When depths exceed 200 mm, solid timber forms should be a minimum of 50 mm thick.

Illustrated in figure 5.3 are simple solutions to common problems when using deep edge forms.

Figure 5.2: Braced formwork for slabs more than 150mm thick

5.1.4 Edge forms with rebates

Many house slabs have rebates at the slab edge to allow an external skin of brickwork to sit on a damp-proof course (DPC) below the floor level. Figure 5.4 shows a typical construction method with timber formwork for raft slab construction; and figure 5.5 shows the method used for footing-slab construction. Edge forms are secured to greased 25 mm steel dowels placed into footing beams and removed after the slab has set.

Alternatively, the method depicted in figure 5.5 can be used without a rebated edge, with the brick veneer carried down to sit on the footing beam, leaving a 30-mm cavity between the veneer and slab.

5.1.5 Cantilevered formwork

A wider step-down is sometimes required, for example to accommodate steps at the slab edges. These are best constructed as shown in figure 5.6.

Figure 5.3: Solutions to common problems with deep edge forms

Figure 5.4: Formwork for raft slab with rebate
5.1.6 Other types of ground forms

Fabricated metal forms speed up ground slab construction and can be re-used. Several telescopic metal form systems are available and can be effective for highly repetitive construction. Ply and metal composite forms are suitable for applications with repetition and heavy working loads (deep beams).

5.1.7 Masonry formwork

Masonry formwork (brick or block) maintains the same face material below natural ground. It removes the need for a formworker but requires a two-part slab construction (see fig. 5.7).

5.1.8 Construction joints

At construction joints, where continuity of reinforcement is required, two-piece formwork is suitable for both fabric and bars as shown in figure 5.8.

Proprietary metal key-forms or timber forms are suitable for use as construction joint formwork to allow for the engaging of adjacent slab panels (see fig. 5.9).
5.2 Purpose of reinforcement

It is important to understand that incorrectly positioned reinforcement can reduce both the strength and durability of reinforced concrete, and greatly reduce the ability of reinforcement to control shrinkage cracking. We recommend a structural engineer be engaged for the design of reinforcement.

Concrete has high compressive strength but low tensile strength. Steel, on the other hand, has a very high tensile strength (and a high compressive strength) but is much more expensive than concrete. By combining steel and concrete, we are able to make use of both the high tensile strength of steel and the relatively low-cost compressive strength of concrete.

<table>
<thead>
<tr>
<th>Characteristics of concrete</th>
<th>Characteristics of steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High compressive strength</td>
<td>High compressive strength</td>
</tr>
<tr>
<td>Low tensile strength</td>
<td>High tensile strength</td>
</tr>
<tr>
<td>High fire resistance</td>
<td>Low fire resistance</td>
</tr>
<tr>
<td>Plastic and mouldable when fresh</td>
<td>Difficult to mould and shape except at high temperatures</td>
</tr>
<tr>
<td>Relatively inexpensive</td>
<td>Relatively expensive</td>
</tr>
</tbody>
</table>

The combination of concrete and steel in reinforced concrete is mutually beneficial—
- Upon hardening, concrete bonds firmly to steel rods, bars and wires so that, when loads are applied, the two act as though they are one. Any tendency for the concrete to stretch or crack in a zone of tension is counteracted by the steel embedded in that zone.
- When subjected to changes in temperature, concrete and steel expand or contract by similar amounts, and therefore remain firmly bonded.
- Concrete, having a relatively high resistance to fire, and a relatively low thermal conductivity, protects steel embedded in it.
- Concrete provides an alkaline environment to steel embedded in it, thus protecting the steel from rusting.

The principal types of stresses (see fig. 5.10) which develop in concrete elements are—
- Compressive stresses - those which tend to cause concrete to compact and crush.
- Tensile stresses - those which tend to cause concrete to stretch and crack.
- Shear stresses - those which tend to cause adjacent portions of concrete to slide across each other.

5.3 Types of reinforcement

Reinforcement is usually provided by steel bars or by steel wires welded together to form a mesh or fabric. Bars are normally associated with beams and columns, and fabric with floors and walls.

Concrete may also be reinforced with fibres, the main type being steel. Polypropylene fibres are also available but do not increase the tensile strength of a concrete member in the same way as steel bars fabric or steel fibres.

5.4 Fixing reinforcement

5.4.1 General

Fixing is more than just tying bars together. It should ensure that once the reinforcement has been placed in its correct position, it cannot be displaced during placing and compacting of the concrete and will remain in place until the concrete has fully hardened. A number of methods are used to locate reinforcement correctly.

5.4.2 Bar chairs and spacers

Bar chairs and spacers support bar or fabric reinforcement above horizontal surfaces, and provide adequate clearances to vertical formwork and/or excavation facings. They are available in a variety of shapes and may be made from wire, plastic or concrete (see fig. 5.11). They are also manufactured in a range of sizes, each of which provides a specific thickness of concrete cover.

Factors to consider in the suitability of a chair or spacer—
- Cover A bar chair or spacer should be selected to provide the correct cover, not one ‘close to’ that required.
- Membrane damage Bar chairs which could puncture damp proof membranes during placing operations should be avoided, or supported on purpose-made ‘saucers’.
- Stability Some types of bar chairs and spacers are easily displaced or knocked over during concrete-placing operations.

5.4.3 Tying

Reinforcing bars may be tied together, or to stirrups (ligatures), to form a ‘cage’ that helps maintain the bars in position during the subsequent concreting operations. The cage must be strong enough to achieve this and sufficient ties used for the purpose.
5.4.4 Splicing (joining)

Lengths of reinforcing bar or fabric may be joined or ‘spliced’ together in a variety of ways. The most common method is simply to lap the bars or mesh. The lapped portion of the bars or mesh must always be in contact and tied unless otherwise indicated on the drawings.

The requirements in Section 5.3 in AS 2870 Requirements for Lapping of Reinforcement are summarised—

- Fabric mesh should be lapped a minimum of two cross wires to both side and end laps.
- Trench mesh should overlap a minimum of 500 mm and be tied and secured.
- Trench mesh at T and L-intersections should be overlapped by the full width of the mesh.
- Bars used in reinforced footing cages should be lapped a minimum of 500 mm at T and L-intersections (see fig. 5.12).

5.5 Cover to reinforcement

The cover to reinforcement (the minimum thickness of concrete between the outside of reinforcement and the nearest concrete surface) is provided basically to give protection against corrosion (rusting).

Section 5.3 in AS 2870 gives the minimum cover to reinforcement in house construction.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Cover (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top cover to fabric for shrinkage control internal surfaces</td>
<td>20</td>
</tr>
<tr>
<td>Top cover to all reinforcement in slabs or paths members exposed to weather</td>
<td>40</td>
</tr>
<tr>
<td>Bottom cover to all reinforcement in beams and slabs protected by vapour barrier</td>
<td>30</td>
</tr>
<tr>
<td>Bottom cover to all reinforcement in members cast directly against non-aggressive ground</td>
<td>40</td>
</tr>
</tbody>
</table>

Important considerations for reinforcement

Where penetrations occur, cut away the fabric to prevent fouling the penetration and interfering with the penetration alignment. Check with the engineer that extra reinforcement is not required to maintain structural strength.

Horizontal penetrations to footings and beams are permitted in the middle third of the beam depth. Localised deepening to the beam section and additional reinforcement may be needed.

With any reinforced concrete projects—
- Do not hook mesh into position (use bar chairs).
- Place bar chairs for general work at a maximum 900-mm spacing.
- Do not ‘walk’ the mesh into the pour during placement.
- Prevent mud being walked onto reinforcement.
- Stack materials on skids off the ground.
- Do not allow trucks to drive over reinforcement.
- Adequately splice and secure reinforcement. For fabric, a good standard is to secure each third wire lap and stagger tying off line. For bar splicing and overlaps, double splice along the length of the lap and secure all overlapping bars.

5.6 Inspections

Items to be inspected and checked where applicable—
- Number, size and spacing of bars, or the sizes of fabric. Refer to specifications and project drawings.
- Number, size and spacing of fitments (in beams).
- Height and distribution of chairs to maintain required bottom and side covers.
- Distance of cut-off ends of bars from support faces.
- Extension length of bars and fabric past support faces.
- Location and lengths of lap splices.
- Location of service pipes, conduits, openings and outlets with respect to conflict with bar on fitment locations.
- Trimming of bars around openings in slabs at re-entrant corners.
- Effectiveness of tying (bars to bars, bars to fitments, lap splices, chairs to bars or fabrics).
- Remove tie wire offcuts, particularly where slabs/beam soffits will be exposed.

Supports and ties are intended to support only the weight of the reinforcement and the concrete over them and, together with tie-downs, to prevent the reinforcement being accidentally displaced during concrete placement. They are not intended to support general construction traffic. It is therefore important that, once the reinforcement has been placed, fixed and checked, independently supported plank runs are provided to keep personnel and equipment off the reinforcement. If this is not done, all the previous good work and effort in correctly positioning the reinforcement will have been wasted.
6 CRACKS AND CRACK CONTROL

6.1 General

Cracks can occur in concrete construction for a variety of reasons. Some cracking is inevitable because concrete, like most other building materials, moves with changes in temperature and its moisture content. Specifically, it shrinks as it loses moisture. Cracking can be controlled, but not entirely prevented.

Cracking in concrete falls into two categories–
• Cracking prior to set
• Cracking after set

6.2 Cracks prior to set

6.2.1 General

Cracks in concrete prior to final setting are not always recognised since they can be temporarily closed up by bullfloating or may be hidden by surface bleedwater. The two common forms of pre-setting cracking are plastic shrinkage cracking and plastic settlement cracking.

6.2.2 Plastic shrinkage cracking

Plastic shrinkage cracking is caused by rapid drying of the surface in dry, windy conditions or in cooler, low-humidity weather conditions. It can occur at any time of the year. It occurs after placement, compaction and screeding as the bleedwater evaporates, exposing the fresh concrete to the elements and causing the surface to shrink before it has any strength. Concrete cracks in much the same way as clay soils.

Polypropylene fibres can be added to the concrete mix to reduce the incidence of plastic shrinkage cracking.

Prevention–
• Erect wind breaks to direct drying winds away from the surface.
• Dampen the ground to reduce absorption (or if suitable to conditions, place a vapour barrier).
• Use a continuous fine mist spray to fog the surface of the concrete.
• Spray evaporation retardants such as Antivap, Eucovap or Confilm over the freshly screeded concrete surface. The addition of a fugitive dye will show the evenness of the coverage. In extreme conditions, re-application of retardants may be necessary after trowelling.
• Use physical remedies such as revibrating the concrete, vigorous wood floating over cracks or extended use of power trowelling to close up the cracks to the full depth.

6.2.3 Plastic settlement cracking

This is caused when concrete settles under its own weight, often because of inadequate compaction.

It occurs over reinforcement, in deep section beams, and steps in formwork such as in a waffle floor (see fig. 6.1).

Cracking in the hardening mass occurs over restraints, and may leave voids under reinforcing bars.

Prevention–
• Fill any deep beam sections to the level of the bottom of the slab before placing the concrete in the slab.
• Always ensure adequate compaction.
• Revibrate surface where there is more than a 300-mm depth of concrete below top bars.
• Ensure all formwork can withstand expected working loads and that the formwork stays in place to support the concrete until it is self-supporting.

Figure 6.1: Settlement cracking

6.3 Cracks after set

6.3.1 General

Cracking in concrete after setting also occurs for a variety of reasons. The two most common forms of after-set cracking are crazing and drying-shrinkage cracking.

6.3.2 Crazing

This is best described as a network of very fine cobweb-like or alligator-skin cracks, which are usually evident when the concrete has been subjected to periods of wetting and drying while it is still ‘green’. They are, however, more common in surfaces with a highly polished, steel-trowelled finish.

The main causes of this form of cracking are–
• Trowelling bleedwater into the surface of the concrete.
• Steel travelling the concrete before the water sheen has gone.
• Using cement as a drier to remove excess water.
• Overworking the surface and bringing excess mortar to the surface.
• Adding extra water to the mix.
• Inadequate or inconsistent curing.

Crazing is not detrimental to anything other than the appearance.

Prevention–
• Do not work the bleedwater into the surface.
• Drag excess bleedwater off with a hose.
• Do not repeat power trowelling unnecessarily.
• Avoid excessive ‘wet wiping’ of the surface.
• Do not use cement, oxides or colour hardeners to mop up bleedwater.
6.3.3 Drying shrinkage cracks

These are caused by concrete shrinking; the result of moisture loss. This is not a major problem if the concrete is free to move, but, if restrained, tensile stresses can develop in the concrete and cause it to crack. The water content of the mix is the major factor influencing drying shrinkage. Shrinkage, however, is not the only cause. Restraints, detailing geometry and construction practices may also affect the probability of cracking in hardened concrete.

Prevention–
• Do not add any water to concrete on site.
• Provide adequate reinforcement and ensure correct placement.
• Place joints in correct location and ensure proper construction.
• Place concrete correctly.
• Compact the concrete adequately.
• Start curing promptly and correctly.

6.4 Joints

6.4.1 General

Joints serve a number of purposes, but they fall into two broad categories–
• Those that allow no relative movement of the concrete on either side of the joint.
• Those that do allow such movement.

The first, referred to as construction joints, make a monolithic bond between the sections of concrete either side of the joint. The second, referred to as control joints, allow for lateral movement of the concrete. In some cases dowels, isolated from the concrete, are embedded in the concrete to maintain vertical alignment of adjoining sections of concrete.

Because house slabs are comparatively small in area, joints are not commonly needed in their construction. However where they are needed, their location and detailing should be in accordance with the design and instructions of the geotechnical or structural engineer. Joints are not suitable for some slab types - this is often not understood. Providing joints in a house slab without expert advice can cause structural problems that may be expensive to fix.

A house slab is often placed directly on the ground and is therefore subject to ground movement. Without careful consideration and construction, joints can become a hinge in the slab and exaggerate ground movement, sometimes resulting in damage.

6.4.2 Construction joints

Construction joints (see fig. 6.2) are concrete-to-concrete joints that prevent any relative movement across the joint. They are commonly used when there is discontinuous placement of concrete and successive pours are allowed to harden beyond the initial set; or at the end of the working day. They may also be necessary if unforeseen events (for example delays in delivery or bad weather) interrupt a pour.

Most house slabs are placed and finished in the course of a day obviating need for construction joints.

6.4.3 Control joints

Types of control joints–
• Contraction joints: allow shrinkage movement at designated locations.
• Expansion joints: allow the concrete to expand (and contract) with changes in temperature, and changes in the concrete’s moisture content.
• Isolation joints: allow concrete sections to move independently of walls, columns, posts and penetrations.

Contraction joints allow two concrete panels to move apart as a result of shrinkage, or temperature changes. The joint is a line of least restraint and induces a controlled crack under tension, relieving tensile stresses across the surface of the concrete, and minimising the incidence of uncontrolled cracking. Contraction joints are essential in both reinforced and unreinforced concrete flatwork.

Fabric reinforcement is placed in the top 1/3 of the concrete to control and reduce shrinkage cracking. In unreinforced concrete, extra contraction joints are provided to control cracking.

Keyed joints allow horizontal movement and restrain vertical displacement of adjoining slabs. A series of steel dowels with one end fixed in the concrete and the other isolated do the same.

Expansion joints allow concrete elements to expand and push against each other (without damage), with changes in temperature or moisture content. There is some argument about the need for expansion joints in concrete structures because shrinkage is usually greater than thermal expansion. However, there is no argument about their value in exposed

**Figure 6.2: Construction joint in slab**

**Figure 6.3: Isolation joint between slab and wall**
concrete flatwork, particularly in large and long sections.
Expansion joints, with flexible sealants, prevent edge spalling, slabs riding up and joint peaking, all of which are detrimental to slab performance and appearance.

**Isolation joints** allow for the independent movement of slabs between walls, around columns, posts or ground fixtures such as kerbing or access holes. They allow free movement, and are often used in combination with other types of joints to allow maximum panel movement caused by shrinkage, temperature changes and seasonal variations. Compressible, cellular materials are commonly used to fill these joints (see fig. 6.3).

6.4.4 Forming control joints

Control joints can be made at any of three stages during construction–
- During placement, a pre-moulded strip is embedded into the concrete to create a line of weakness. Examples include preformed plastic strips and metal strips in terrazzo.
- During finishing, a groove can be formed in the surface with a suitable jointing or grooving tool, which creates a line of weakness that induces a crack as the concrete hardens.
- Soon after the concrete has hardened, a joint can be sawn in the surface (see fig. 6.4). It should be made just before drying shrinkage occurs–when the surface is hard enough it will not chip, spill and collapse on the cutting blade (sometimes referred to as ravelling). If it is deferred, drying shrinkage could cause random cracking. The sawn joint is filled with a flexible sealant to keep out dirt. Unsealed joints fill with dirt and do not function effectively (see clause 6.4.8).

6.4.5 Joint locations

In concrete flatwork the layout of joints is very important. Joints, of various details, can be transverse and longitudinal, but are predominantly transverse in residential work, such as paths and driveways.

6.4.6 Joint spacing

Joints are generally not needed in floor slabs because of the amount and layout of reinforcement.

In unreinforced slabs – perhaps a path – transverse joints are usually placed at intervals of 2.5 – 3.0 m. When a slab is reinforced this distance can be increased, depending on the type and amount of reinforcement.

Longitudinal joints are generally provided when the slab is wider than 4 metres, for example driveways or terrace pavements.

6.4.7 Slab proportions

Where it is possible, concrete slab sections are best formed, approximately, as squares. For rectangular slabs, the longer side should be no more than 1½ times the shorter side.

This rule, in addition to the joint spacings recommended above, ensures correct spacing of joints to minimise cracking.

6.4.8 Joint maintenance

The long-term performance of joints is crucial to long-life pavements. Dirt must be kept out of the joint's groove – by sealing with a flexible sealant – because a build-up can result in joint peaking, edge spalling and edge rupturing. Joint spacers should be stopped about 10 mm below the surface to allow for sealing.

![Figure 6.4: Sawn joint in concrete pavement](image)
7 FOOTING TYPES

7.1 General
A variety of standard designs for footing systems are provided in Section 3 of AS 2870. The choice of footing system can be one of preference based on local experience, or it may be based on particular site conditions. Geotechnical or structural engineers undertake an increasing number of designs.

The term ‘slab-on-ground’ is adopted in AS 2870 (and in this handbook) and refers to concrete slabs supported by the ground and incorporating integral edge beams. ‘Stiffened raft’, ‘waffle raft’ and ‘stiffened slab with deep edge beam’ are all types of slab-on-ground.

7.2 Stiffened raft (see fig. 7.1)
A stiffened-raft floor slab is placed at the same time as the external and internal beams, all of which are reinforced. Internal beams are not necessary on stable sites, however for reactive soil conditions the beam sizes and quantity of reinforcement are varied accordingly.

A stiffened raft is often placed in one pour. They are cost-effective, and provide a strong footing that can be supported on bulk concrete piers if placed on uncontrolled fill.

Figure 7.1: Stiffened raft

7.3 Waffle raft (see fig. 7.2)
Waffle rafts are constructed on level sites using cardboard or polystyrene void formers to produce a closely-spaced grid of reinforced concrete ribs. Site preparation is minimised because the concrete is placed on surface forms rather than in excavated trenches. This system avoids occasional, unintended, over-excavation when trenching, allowing more accurate measurement of the quantities of concrete and reinforcement. Waffle rafts can be designed for support with piers.

Figure 7.2: Waffle raft

7.4 Stiffened slab with deep edge beam (see fig. 7.3)
This is suitable for sloping sites where cut and fill excavation is not practicable. The system uses deep perimeter beams for stiffness. These beams can incorporate reinforced masonry.

Figure 7.3: Stiffened slab with deep edge beam

7.5 Footing slab (see fig. 7.4)
The footing slab is cast on ground in two stages: the edge footings first, followed by the slab. This method reduces the length of time excavations are open and does not require extensive formwork. The footing-slab system can be adapted well to sloping-site applications.

Figure 7.4: Footing slab

7.6 Strip/Pad footings (see fig. 7.5)
Strip footings are rectangular in section and are used for continuous support of walls. Pad footings are used to support piers, columns or stumps. Strip and pad footings can be used together to support a range of suspended flooring systems for sloping sites. Floor slabs between walls - on strip footings - can be supported on controlled fill.

Figure 7.5: Strip/pad footings
7.7 Pier/Pile and slab (see fig. 7.6)
On highly reactive sites, and areas of collapsing or uncontrolled fill, piers or piles can be used to support a concrete slab-and-beam floor system.

Piers are poured, after excavation, whereas concrete piles are driven into the ground to a specified depth or until reaching a specified level of resistance. The piles are cut off at the required level to suit the floor system.

8 PATHS AND DRIVEWAYS

8.1 General
The primary function of concrete paths and driveways is to provide trafficable access to a property, however they are also important to the general appearance of the property, and for control of surface rainwater.

Prior to undertaking construction, a number of aspects need to be considered -
• The type of subgrade (soil) the pavement is to be constructed on.
• The loads/traffic the pavement will be expected to carry.
• The area of pavement to be concreted.
• The finished levels of the work.
• The level of the damp proof course in adjoining buildings.
• Termite control.
• Drainage requirements.
• The type of surface finish required.
• Reinforcement requirements and the spacing/location of joints.
• Method of curing.
• Safety.

8.2 Grade and thickness of concrete
The loads that the pavement can be expected to carry determine the correct concrete grade and thickness. In typical domestic situations, the following are recommended -

<table>
<thead>
<tr>
<th>Application</th>
<th>Concrete thickness (mm)</th>
<th>Strength grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footpaths</td>
<td>75</td>
<td>20</td>
</tr>
<tr>
<td>Patios/Garden-shed floors</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>Cars and other small-vehicle traffic (less than 2t)</td>
<td>100</td>
<td>20/25</td>
</tr>
<tr>
<td>Light trucks</td>
<td>150</td>
<td>32</td>
</tr>
</tbody>
</table>

8.3 Selecting reinforcement
Selecting reinforcing fabric depends on the thickness of the concrete. The type and extent of reinforcement also has a bearing on the spacing of joints.

Polypropylene fibres can be added to the concrete mix to control plastic shrinkage cracking.

In typical domestic situations, reinforcement as shown in Table 8.2 is suitable.

<table>
<thead>
<tr>
<th>Concrete Thickness (mm)</th>
<th>Reinforcement fabric</th>
<th>Max. joint spacing (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>RF52</td>
<td>2000</td>
</tr>
<tr>
<td>100</td>
<td>RF62</td>
<td>3000</td>
</tr>
<tr>
<td>150</td>
<td>RF82</td>
<td>4500</td>
</tr>
</tbody>
</table>

8.4 Construction

8.4.1 Planning for concreting
Before ordering concrete, careful planning will ensure the
8.4.2 Soils
Subgrades for slabs must have adequate strength after compaction with a plate compactor or a vibrating-drum roller.
Prepare the subgrade by first removing topsoil containing roots and grass, and levelling the subgrade. Backfill over service trenches and fill isolated hollows or soft spots, then compact to the level of natural ground.
Note Clay soils need to be moist for optimum compaction.

8.4.3 Sub-base
A sub-base is required to build up areas or adjust falls or levels. Sub-base materials should be free-draining, and capable of being compacted in layers of no more than 100-mm deep.
Correct sub-base and subgrade preparation ensures the concrete pavement alone does not carry the service loads.
Unstable, or filled sites with inadequate compaction, should be thoroughly investigated by a geotechnical or structural engineer before design and construction.

8.4.4 Formwork
Formwork should be strong and true to line. The accuracy of the formwork will be reflected in the finished line of the hardened concrete. By placing the top edge of the form boards at the finished level of the pavement surface, screeding can be efficiently done using the form edge as a guide. Form boards should be thick enough and securely fixed so they do not bend or move when placing concrete. Formwork should be constructed with care so it is easily removed when the concrete has hardened. A light coating of form oil before pouring will make removal easier.
It is good practice to leave formwork in place for a minimum of 3 days - depending on weather conditions - to allow concrete to harden and become self-supporting.

8.4.5 Reinforcement
Reinforcement should be located in the top half of the slab as close as possible to the surface but keeping a minimum cover of 30 mm. This is done by supporting the reinforcement on bar chairs or concrete blocks arranged in a 500-mm square grid.
When two or more sheets of reinforcing fabric are necessary the sheets are lapped so that the two outermost transverse wires of one sheet overlap the two outermost wires of the other. They are tied together (spliced) with wire. See clause 5.4.4.

8.4.6 Polypropylene fibres
Polypropylene fibres are used, primarily, to reduce the incidence of plastic shrinkage cracking. They also reduce bleeding of water in the mix.
They resist shrinkage of the surface (in its plastic state) under conditions that cause rapid evaporation, notably hot, dry and windy weather. Plastic shrinkage cracks can impair freshly placed concrete, are unsightly and difficult to fix (especially in coloured work), and induce larger uncontrolled cracks as the concrete dries.
In drying conditions, the use of polypropylene fibres, together with evaporation retardants (aliphatic alcohols) and effective curing methods reduce the incidence of plastic shrinkage cracking, and the likelihood of repairs.

Note that polypropylene fibres are no substitute for steel reinforcement, which is also used to counteract drying shrinkage in addition to its structural purpose. If steel reinforcement is omitted, then the spacing of joints should be the same as for unreinforced concrete.

8.4.7 Skid resistance
When deciding the surface finish consider if a non-slip surface would be advisable given the use of the pavement, its steepness, and the effectiveness of its surface drainage.
Skid resistance can be improved with simple techniques. For example, textures can be made with a broom, wood float, stipple roller or a hessian drag, or by exposing aggregates with a wash-off finish (see clause 8.7.3). Incorporating silica dust or carborundum dust in an applied sealer is another technique.

8.4.8 Protection against staining
Sealers, clear and tinted, prevent most stains penetrating the concrete surface. Coloured paints, suitable for the concrete and the conditions, can also be applied to the surface.
Concrete surfaces, however, are often subject to the abrasion of tyres and foot traffic. Sealers or paint coatings may need to be applied repeatedly for continuing surface protection, and to keep them looking good.

8.5 Coloured concrete
8.5.1 Introduction
Colours can be readily applied to concrete.
Durable colour is achieved when mineral oxide pigments are added to concrete while it is in a plastic state: that is at the time of placement. They can be added to the mix to produce integrally-coloured concrete and coloured toppings, or broadcast onto the surface of pre-hardened concrete as a dry-shake topping.
Hardened concrete pavements - new and old - can be enhanced with purpose-made paints and coatings, however they may need to be reapplied some time later to keep them looking good.
The colours of aggregates - sand and stones - can provide permanent colour in exposed-aggregate finishes, but the range of colours will be limited by the available aggregates. Exposed aggregate finishes are discussed in part 8.7.

8.5.2 Integral colouring (with mineral oxide pigments)
Mineral oxides occur naturally in soil and rock. Synthetically produced oxides, however, are more pure, uniform and stronger colouring agents. They are suitable for concrete because of their resistance to the alkalies in cement, their chemical inertness, and their resistance to fading under exposure to weather and UV light. They are produced as a fine powder, a tiny fraction of the size of cement particles. Unlike a dye, which colours by staining, mineral oxide powders are insoluble in water, and colour by masking the cement matrix. They are produced in a range of colours: blues, greens, red and yellow ochres, grey and black.
Integrally-coloured, or colour-through, concrete refers to colouring of the entire mass of the concrete. Mineral oxide powders or liquids are added at the batching stage, and thoroughly dispersed through the concrete mix. In correct proportions, oxides do not have a significant effect on the strength of concrete. The amount of oxide powder required will generally be 5-8% of the weight of the cement in the mix. For best results, follow the recommendations of oxide suppliers.
After placing, the concrete surface is struck, floated and finished in the same way as ordinary concrete, and particular care should be taken with curing to produce the best finish.

For uniform colour, a consistent mixing procedure is crucial, whether it is done at the batching plant or in the barrel of a pre-mix truck. Results are improved if the concrete mix design, the proportions of water and oxide powder, and the method of mixing do not vary. Sample panels are useful to find the right mix, and provide the basis for quality control. Borders, of different colours or concrete pavers, can be used to divide large areas into smaller sections—which can be placed in a single pour—making less obvious the colour variations of different sections that might result with different batches.

8.5.3 Dry-shake toppings

Dry-shake toppings are commercially available products containing cement, sand, and mineral colour oxides, and in some cases, special hardeners to increase the strength of the surface of finished concrete. They are sometimes referred to as ‘coloured surface hardeners’ because of this. They come in a range of colours: blues, greens, red and yellow ochres, grey and black, and are often used in conjunction with stencilled and stamped pattern finishes (described below).

Dry-shake toppings can also be made on site from similar materials. The usual blend is 1 part cement: 2 parts clean sand; and mineral oxide pigment measured by weight in the ratio of 1 part pigment to 10 parts cement. The powdered pigment is first blended with dry cement before combining with the sand.

The dry powder is cast by hand over the surface (hence the term ‘dry-shake’ see fig.8.1) of fresh concrete and worked into the surface by trowelling. All traces of bleedwater must be allowed to evaporate before applying the powder. Using the powder to soak up bleedwater is bad practice, and invariably results in a much weaker surface, which will wear quickly, and may delaminate or chip. The rate of application of a dry-shake topping for flatwork will typically be a minimum of 2 kg per square metre.

The manufacturers of coloured surface hardeners state that correct use of coloured surface hardeners produces 40 to 60-MPa surface strengths. They are cement-based products and must be finished and cured like any concrete work to achieve the strengths advertised by manufacturers.

When using dry-shake toppings it is important to protect adjacent surfaces, with plastic sheeting for example, because splashes are difficult to remove.

Application of dry-shake toppings:

- Evenly broadcast the dry-shake topping (coloured surface hardener) over the surface in two stages to ensure uniform colour and thickness. Usually two thirds is applied for the first coat, and one third for the second, which should be applied in a direction perpendicular to the first coat. Each coat is thoroughly worked into the surface by trowelling.
- Apply topping colour, or highlight flecking, while the surface is still plastic to ensure bonding.
- For dark colours such as charcoal (black), it may be advisable to apply a third coat for more even colour distribution.

8.5.4 Chemical stains

Chemical stains can be applied to hardened concrete. They are commercially available liquids that soak into the surface and react with the chemicals in the concrete. The variations in colour of the pre-treated concrete are reflected in a mottled finish after staining. They do not, generally, produce even colour. The use of two or more colours, however are often used to produce mottled finishes resembling stone.

8.6 Patterned concrete

8.6.1 Introduction

Stiff-bristle brooms, wood floats and sponges have been used for many years to create surface textures and patterns. More recently, purpose-made metal dies have been developed to stamp impressions in the concrete surface; and cardboard stencils are used to produce many patterns when dry-shake toppings are sprinkled over them.

The techniques are simple, but must be well planned to take advantage of the short period when concrete is workable. Ordering ‘low-bleed’ concrete shortens the waiting time for bleedwater to evaporate, in effect giving more time for finishing. Consider the addition of polypropylene fibres, which help bind a mix and reduce bleeding.

Good curing practice is crucial to the appearance, and the service of the pavement.

8.6.2 Stencilling

Cardboard stencils are temporarily embedded in the wet surface of the concrete. The coloured surface hardener is sprinkled over and trowelled into the surface. When the concrete stiffens the stencil is removed (see fig. 8.2) producing a coloured pattern with grey joints—the colour of the base concrete.
The procedure for stencilling—

**Place the concrete slab**
Place, screed, bullfloat and trowel the concrete to its finished level.

**Embed the stencils**
Points to note—
- Where applicable, stencils are placed in the following sequence: features such as Rosettes or motifs, borders and finally the main (general area) stencil are cut in.
- Carefully work the stencil into the surface with a roller or a trowel.
- Stencils can become deeply embedded in concrete that is too wet. They will be difficult to remove and will result in varying 'joint' depths.
- If the concrete has become too stiff, the stencils may not be fully embedded or in full contact with the concrete. The coloured topping will stick to the edges of the stencils causing ragged lines; or if the coloured topping gets under the stencil it will stain the 'joints'.
- When placing and aligning stencils it is good practice to lift them, rather than drag them into position.
- Drying-shrinkage control (contraction) joints in stencilled concrete are 'wet-formed' such as inducement-strips and key joints, or sawn joints (see clause 6.4.4). Wet-formed joints are placed under the stencil and aligned with a 'joint' so they are not repeatedly trowelled over.

**Apply coloured surface hardener**
See 8.5.3: Dry-shake toppings

**Apply surface texture**
Surface textures, if specified, are made while the surface is still plastic. Common finishes include steel-trowel, broomed, wood-float, sponge, and hessian-drag.

**Remove the stencils**
Lift the stencil when the surface has stiffened and remove residue with a leaf blower, not a high-pressure hose. At this stage avoid walking on the concrete with heavy, patterned-soled boots. If necessary the leaf blower can be attached to a long pole for greater reach.

**Cure the concrete**
A sealer (see below) is often used to slow evaporation because conventional curing methods are unsuitable for this type of finish.

Do not confuse curing with drying. See section 4.5: Curing.

**Seal the surface**
Sealers are applied to protect the surface from stains (for example oil) because they are difficult to remove using cleaners or solvents without affecting the colour.

Most sealers cannot be applied to moist concrete without problems—usually the sealer turns a milky-white. Special same-day sealers are available which can be applied to the 'set' surface of the concrete while, underneath, the concrete mass is still moist. They are generally not as effective as normal sealers or curing compounds for retaining moisture in the slab, but are a satisfactory alternative.

The use of same-day sealers should be followed with an application of the final sealer when the surface has dried to its final set. Although this is not the best curing regime, it minimises initial moisture loss and surface strength loss.

8.6.3 Stamped concrete
Purpose-made metal moulds (dies), rollers, or rubber mats, are pressed into the surface of the wet concrete (see fig. 8.3). The patterns produced are not unlike - and often simulate - brick paving, cobblestones, setts, slate or natural stone.

Figure 8.3: Stamping concrete

The dies are usually a metal 'grid' with an attached shaft.

**Place the concrete slab**
Place, screed, bullfloat and trowel the concrete to its final level.

**Note** the thickness of a stamped concrete slab is determined as the thickness from the bottom of the impression to the underside of the slab. In driveways for example, if the thickness needs to be 100 mm, and a 15-mm deep stamp is used, the formwork will need to be set at 115 mm, to ensure the minimum thickness is achieved.

**Apply coloured surface hardener**
See 8.5.3: Dry-shake toppings

The use of integrally-coloured concrete as the base colour may give the paviour more time to apply highlight colours, and stamp the surface, which is helpful in drying conditions.

**Apply surface release agent**
After working in the coloured surface hardener, a release agent is applied. The reason for the release agent is twofold. Firstly, it prevents concrete sticking to the stamping mould and spoiling the appearance. Secondly, it can be a highlight colour, creating a variety of two-tone effects. Release agents come in a range of colours to complement coloured surface hardeners. Stamping with sufficient pressure will ensure good bonding of the release agent to the surface, which is why the highlight effect generally occurs in deeper joints and depressions. The surface release agent is not a curing agent.

A thin film (about 1.0mm) of clear polythene plastic can be used as an alternative bond breaker. It is placed over the prepared concrete before stamping, preventing the concrete sticking to the moulds.

**Stamp pattern**
Before stamping, plan the layout of the pattern to finish against walls and around fixtures. In many cases it will be necessary to use hand tools (jointing/ironing tools) or small moulds to complete the pattern up to the edge.

**Cure the concrete**
The surface release agent does not allow the use of curing compounds.

Cover the surface with plastic (polythene) sheeting but make sure it is in complete contact with the surface of the concrete, or colour variations may occur. Polythene sheeting may produce some dark or mottled areas because of condensation under the plastic, which will become less noticeable as the concrete dries.
8.7 Exposed-aggregate finishes

8.7.1 Introduction

Exposed-aggregate finishes can be produced by ‘seeding’ the surface of the concrete with selected stones; or by ordering a special mix (for the full depth of the slab or for a topping) which contains selected stones. They are exposed when the thin layer of cement paste on the surface is washed away soon after the concrete stiffens. Aggregates are available in a range of colours including white, black and green quartz, dark grey basalt, brown and red gravels. The concrete can be coloured (see section 8.5) to complement or contrast with the grey basalt, brown and red gravels. The concrete can be finished level, ensuring even paste coverage over the selected stones.

Sample panels are recommended to assess techniques, surface finish, distribution of stones and, if applicable, consistency of colour.

These finishes should be done under the supervision of a paviour experienced in these techniques.

8.7.2 Seeded aggregate

The procedure–
• Place the concrete, screed and bullfloat the surface to the finished level.
• After the bleedwater has dissipated, sprinkle the selected aggregate over the surface. An aggregate size of 8–12 mm is recommended for ease of placement although sizes up to 20 mm can be used.
• The selected aggregates are fully embedded by tamping and by repeatedly working the surface with wood floats.
• Aggregate exposure begins when the surface can bear the weight of the paviour without making surface impressions deeper than 2 mm. Use a medium-bristle broom, together with a continuous water spray, to wash away the cement paste. Do not broom the surface repeatedly. This will weaken the paste and dislodge aggregates.
• The use of water-based surface set-retarders should be considered. Those that are developed especially for this technique slow the setting time of the surface of the slab to a predetermined depth without affecting the set of the mass of the concrete. This ensures consistent depth of exposure. They are very useful when drying weather conditions would otherwise limit the time available for aggregate exposure.
  • After exposure, cure the surface by covering it with plastic sheeting for a minimum of 3 days (7 days is preferable).
  • An acid-wash treatment is usually necessary to brighten up the stones by removing the fine cement film from the surface. Thoroughly rinse the surface with clean water to remove all residues and apply a surface sealer if desired.

8.7.3 Wash-off finish

The procedure–
• Order the special mix of concrete from the concrete supplier, containing specified aggregate sizes and types, and colour pigments.
• Place the concrete, screed and bullfloat the surface to the finished level, ensuring even paste coverage over the aggregate on the surface.
• Follow the steps for exposing the aggregate and curing in clause 8.7.2.

8.7.4 Bonded topping

Bonded toppings are placed on the structural slab while it is in a plastic state. The slab and topping harden together, making a monolithic bond. (An unbonded topping is placed on a hardened slab with a bond-breaker between the two).

The procedure–
• Place the base slab and screed it to a level 25–40mm below the finished level.
• Prepare a topping mix in the proportions 1 part sand: 1 1/2 parts cement: 3 parts aggregate (and colouring pigments if required) and just enough water for workability—or order a special pre-mixed concrete mix.
• Use a surface set retarder on large jobs (or in drying conditions) to allow more time to place and finish toppings.
• Wait until the surface bleedwater has evaporated from the base slab before placing the topping.
• Screed and float to ensure consolidated and complete bonding.
• Follow the steps for exposing the aggregate and curing in clause 8.7.2.

8.7.5 Stamped exposed-aggregate

Aggregate exposure (by either the seeding or wash-off method) and the stamping technique described in clause 8.6.3 can be combined to produce other finishes.

8.7.6 Environmental considerations

Environmental issues, particularly water run-off, must be considered with coloured and exposed-aggregate finishes. Flushing cement paste, coloured surface hardeners, oxides and release agents into stormwater drains affects the water quality in natural water systems and may be prohibited by local authorities.

To prevent this–
• Provide filters at strategic points using sand as a sediment-control barrier and remove from site.
• Use hessian wraps to divert run-off to surface catchment or into excavated silt traps. Overflow from silt traps can be diverted to a surface catchment with excavated channels.
• Temporarily cap all drainage inlets.

Joints
Points to note–
(Refer also to section 6.4: Joints)
• Plan the layout of control and construction joints so they correlate with the grooves in the pattern.
• Wet-formed contraction joints can be tooled after stamping is finished, while the surface is still plastic; although this is difficult if the stamping makes deep impressions.
• Form key joints before placement. Key joints may interfere with stamping of deeper patterns.
• Install isolation joints against abutting structures before placement. Installing them after will probably damage the finish.
• Sawn joints should be cut no later than 24 hours after finishing.

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• Temporarily cap all drainage inlets.
8.8 Topping existing pavements

8.8.1 General
Existing slabs can be sprayed with coloured and textured finishes (varying in thickness from 3 – 5 mm), however, the success of any topping depends on the bond to the substrate.

8.8.2 Materials
Spray-on toppings are available as cementitious or acrylic-based materials. They can look similar but their life expectancy may vary. Consult the supplier about suitability and performance of materials.

8.8.3 Preparation
Clean the existing pavement to remove grit, paint, oil, and other substances that will affect the bond and finish. Use high-pressure water cleaning, acid etching (a mild solution of 1:25) and – where severe surface deterioration has occurred – the use of concrete grinding or dustless shot blasting to produce a clean, even and sound substrate.

8.8.4 Repairs to substrate
Cracks can be filled with a cementitious or epoxy grout, how- ever, this will not prevent continued cracking due to thermal or ground movements. These cracks will again appear in any new topping or coating, though narrower and less noticeable.

Different levels of adjoining slabs (caused by tree roots, expansive soils, moisture problems and subsidence) can be made flush with a topping or purpose-made levelling compound. Prepare and apply strictly in accordance with the manufacturer’s specifications. The cost of levelling compounds may be prohibitive. Moreover they are not recommended externally because of the possibility of warping and delamination. Where there is a serious case of subsidence, and the slab has lost support, an alternative to replacement is the injection of grout under the slab (‘slab jacking’). This is expensive but may be necessary in some cases.

Broken corners can be repaired by fixing a new section of concrete to the existing. The fixing may be a reinforcing bar (or a stainless steel pin if enough concrete cover is not possible) epoxied into the existing concrete.

Joints are difficult to repair because movement may cause failure of the repair.

Spalling is usually caused by rusting reinforcement. Exposed bars are cut back to give the required cover, before patching with a repair mortar. Before proceeding, a structural engineer should be consulted to determine the structural implications of removing reinforcement.

Surface defects that are shallow can be filled with a spray-on topping material. A purpose-made repair mortar can be used for deeper depressions.

Note repairs should be carried out by specialists. If extensive repairs are necessary, consider replacing with a new slab. The total cost of repairs and a sprayed finish may be greater than the removal and replacement.

8.8.5 Joints
Contraction joints fall under the general heading of control joints. They control (do not resist) movement and minimise random cracking by inducing an acceptable crack at the joint itself, which relieves the stresses resulting from drying shrinkage. They should not be filled and sealed over because movement of the pavement could cause the joint to rupture and the topping to spall. As a general rule, joints in a new topping, or coating, should correspond with existing joints. This may govern the direction of any surface patterns. It may be worthwhile to cut new joints in existing pavements to allow controlled movement, or when existing joints have failed to control joint peaking or spalling.

In certain situations, isolation joints may be needed to relieve stresses around structures (posts and walls) adjoining the slab.

8.8.6 Protection of adjoining structures
Protect adjoining surfaces from over spray or splatter. The fine oxides and topping powders stain.

8.8.7 Bonding products
Bonding agents can be used to increase the strength of the bond of the topping to the existing substrate. They are usually supplied with the application kit, which will include specifications.

8.8.8 Base coats
A base (or primary) colour coat is applied over the bonding agent; this becomes the colour of the ‘joints’ in the stencilled pattern. Base coats are fairly workable and can be levelled with trowels, broad floats, cumalongs or squeegees. The condition of the slab, existing falls and depths of any depressions will however, influence the choice of slump. After the base coat has dried (a period specified by the manufacturer) smooth the surface with fine sanding, light grinding or rubbing over with open-mesh rubbing blocks to remove minor imperfections. Remove dust and grindings from the immediate area so it is not walked onto, or blown back onto the pavement.

8.8.9 Stencil application
Stencils are usually self-adhesive for fixing directly to the base coat or prepared surface. They are available in a wide range of patterns, similar to those available for standard stencil applications. Stencils with special patterns can be made to order.

8.8.10 Topping coats
The final coloured coat is mixed according to the manufacturer’s directions. This may include additives sold with the application kit. Varying the slump and viscosity of the topping can produce different textures. A more fluid topping (with a high slump) will produce a smooth finish; a drier mix (lower slump) is used to produce rough textures. Increase the slump by adding both fluid and binding materials - not only fluid. The colour can be applied through a dual-line feeder or handheld hopper with a gravity feeder. An even application is crucial. A second coat is usually applied the following day (weather permitting) and allowed to dry in accordance with the manufacturer’s recommendations. A third, or highlight coat (with an iron-oxide fleck for example) can be applied. After the surface is set, the stencils are removed and the residue is blown off.

8.8.11 Sealing
A same-day sealer can be applied for immediate protection, however two coats of a high-quality sealer are recommended to ensure lasting serviceability of a spray-on surface finish.
9 MORTARS, RENDERS AND ROOF-TILE BEDDING

9.1 Mortars for masonry

9.1.1 General

Mortars for concrete, clay or calcium silicate masonry perform similar functions, whether veneer, double, or single-leaf construction.

The design of masonry including the requirements for mortars are covered by Australian Standard AS3700.

Mortar—
• Provides an even bedding for masonry units, and takes up the dimensional variation of units.
• Transmits compression loads.
• Bonds the units together so they resist tensile and shear forces.
• Seals the joints from the weather.
• Holds damp proofing and flashings in place.
• Is essential to optimum acoustic performance and fire resistance of masonry units.

9.1.2 Materials

Cement

For normal brick and blockwork general-purpose cement (Type G P or Type GB) or masonry cement are suitable. The proportioning of the mortar, however, varies with the type of cement, see Table 9.1. To avoid on-site confusion, it is preferable if only one type of cement is used on a project.

Cement has a limited shelf life and should be stored off the ground in a dry environment.

Lime

Hydrated lime suitable for hard plastering should be used. Lime is added to make the mortar creamier or more workable. It also helps to minimise cracking as the mix dries out. It is good practice to soak the lime in an equal volume of water for 24 hours prior to use to improve its performance in the mix.

Sand (fine aggregate)

Sand is the fine aggregate in mortar. Fine sands are preferred. Sands with high clay content should not be used, nor should ‘fire clay’ or ‘brickies’ loam’ be added to the mortar. (Loam is commonly referred to as ‘fatty’ sand.)

Sand with a high clay content degrades the mortar, markedly reducing bond strength and lowering durability.

Water

Should be clean, fresh and free of impurities. Mains water or water suitable for drinking is usually satisfactory.

Admixtures

Chemical additives should not be used to replace lime. Use in strict accordance with the manufacturer’s instructions.

Powdered pigments – or oxides – for colouring, should not exceed 10% of the weight of cement in the mix and should be thoroughly mixed with the other materials prior to the addition of water.

Liquid colour additives should be measured and used in accordance with the manufacturer’s instructions.

A sample of coloured mortar should be made and allowed to dry before starting work, to ensure the right colour is achieved.

9.1.3 Mixes and applications

Mixes should be varied to suit the particular exposure conditions and location (see Table 9.1). Mix proportions are expressed as ratios, eg 1:1:6, 1 part cement to 1 part lime to 6 parts sand by volume.

9.1.4 Site-mixed mortar

When site-mixing, it is important to carefully measure the material by volume in a suitable container, not by the shovelful.

Mechanical mixing is usually done in a concrete mixer. A small amount of mixing water is placed in the mixer followed by the sand, cement and lime. Water is slowly added to create a thick creamy mixture. Each batch should be thoroughly mixed for two to three minutes for uniform consistency.

Hand Mixing should be done in a clean wheelbarrow or on a mixing board to avoid contamination. The dry materials should be combined and mixed to an even colour before slowly adding water as the mix is constantly turned until a thick creamy mortar is made.

Mortar should be used within half an hour of mixing. Mortar that has stiffened should not be retempered by the addition of water.

9.1.5 Pre-mixed mortar

Factory-blended, ready-to-use, general-purpose mortars are available in bags from most cement retail outlets. They only need the careful addition of water (and colour additives if required) for mixing.

9.1.6 Mortar mixes for particular environments

See Table 9.1

M2 applications–
• Above DPC in interior environments not subject to wetting and drying.
• Above DPC in other than marine environments.
• Above DPC and protected by a waterproof coating, flashed junctions and top covering.
• Below DPC or in contact with ground but protected from water ingress by waterproof coating.
• In domestic barbecues and incinerators.

M3 applications–
• Above DPC in interior environments but subject to non-saline wetting and drying.
• Above DPC in marine environments (100 m–1km of non-surf coast or 1 km–10 km of surf coast).
• Below DPC or in contact with non-aggressive soils.
• In fresh water.

M4 applications–
• Above DPC in interior environment but subject to saline wetting and drying.
• Above DPC in severe marine environments (within 100 m of non-surf coast or 1 km of surf coast).
• Below DPC or in contact with aggressive soils.
• In saline or contaminated water, including tidal and splash zones.
Table 9.1 Mortar mixes for masonry
(based on Tables 5.1 and 10.1 in AS 3700)
Mix proportions (parts by volume)

<table>
<thead>
<tr>
<th>Mortar</th>
<th>Type GP Cement</th>
<th>Type GB Cement</th>
<th>Building Lime</th>
<th>Masonry Cement</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1+ water</td>
<td>thickener</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M4</td>
<td>1</td>
<td>0-1/4</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1/2</td>
<td>41/2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0-1/4</td>
<td>21/2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1+ water</td>
<td>thickener</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: these mortars are not suitable for autoclave aerated concrete (AAC) units. For calcium silicate units use only the mixes with added water thickener.

9.2 Renders
9.2.1 General
Cement-based renders, on internal and external walls improve: waterproofing, fire rating and the appearance with the use of coloured or textured renders.

To get the best results from a render—
• The mix should be suited to the background surface.
• It should be properly applied in the correct number of coats, and to correct thicknesses.
• It should be properly cured.

9.2.2 Materials
Cement
General Purpose (Type GP or Type GB) cement is normally used, but where a light or coloured finish is required an off-white cement may be used.

Lime
Hydrated lime suitable for hard plastering should be used. Lime is added to make the render creamier or more workable. It also helps to minimise cracking as the mix dries out.

It is good practice to allow the lime to soak in an equal volume of water for 24 hours prior to use. This will improve its performance in the mix.

Sand
Sand is the major ingredient of the mix and should be of good quality. Plastering sands and finer washed concrete sands – commonly referred to as ‘sharp’ sand - are available from builders’ suppliers. In general, coarsely graded sands are more suitable for undercoats, and a finer grading is more suitable for finishing coats.

Water
Should be clean, fresh and free from impurities. Mains water or water that is suitable for drinking is usually satisfactory. Use just enough water to make the mix workable.

Admixtures
Generally, admixtures are not required in render. However, if they are added they should be used strictly in accordance with the manufacturer’s instructions.

Pigments, added to colour the render, should not exceed 8% of the weight of cement in the mix and should be thoroughly mixed with the other materials prior to the addition of water. Liquid pigments should be measured consistently and added in accordance with manufacturer’s instructions.

A sample of coloured render should be made and allowed to dry before starting work, to ensure the right colour is achieved.

9.2.3 Mixes and applications
A variety of render mixes can be used, and depend on the background surface and the conditions the rendered surface is exposed to.

Table 9.2 Render mixes

<table>
<thead>
<tr>
<th>Mix (cement:lime:sand)</th>
<th>Internal/External</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:¾:3</td>
<td>Internal</td>
<td>Single coat Undercoat work (two part)</td>
</tr>
<tr>
<td>1:¾:5</td>
<td>Internal</td>
<td>Finish coat work (two part)</td>
</tr>
<tr>
<td>1:½:4½</td>
<td>External</td>
<td>Strong mix for strong backgrounds</td>
</tr>
<tr>
<td>1:1:6</td>
<td>External</td>
<td>Moderate strength mix for porous and weaker backgrounds</td>
</tr>
<tr>
<td>1:2:8</td>
<td>External</td>
<td>Final coat for weak backgrounds in sheltered conditions</td>
</tr>
</tbody>
</table>

Site-mixed renders
When site-mixing, it is important to carefully measure the material by volume in a suitable container, not by the shovelful.

Mechanical mixing A small amount of mixing water is placed in a concrete mixer followed by the sand, cement and lime.

Water is slowly added until a stiff mix that will ‘sit up’ on the trowel is made. Each batch should be thoroughly mixed for two to three minutes to ensure uniform consistency.

Hand mixing is done in a clean wheelbarrow or on a mixing board to avoid contamination.

The dry materials should be combined and mixed to an even colour before the addition of water, which is slowly added and mixed in until a stiff creamy mix ‘sits up’ in the barrow.

Renders should be applied within half an hour of mixing. Render mix, which has stiffened, making it difficult to apply, should be discarded and not retempered by the addition of water.
**Pre-mixed renders** Factory-blended, ready-to-use, general-purpose and special-purpose renders requiring only the addition of water are available in bags from most cement retail outlets and decorative-coating manufacturers.

### 9.2.4 Applying render

#### Surface preparation

The background surface should be free from paint, oil, dust and any dirt or other loose material that may prevent a good bond. Purpose-made bonding agents, applied in strict accordance with the manufacturer’s instructions, can also be used to improve adhesion.

Table 9.3 indicates the preparation treatment necessary for a number of background surfaces prior to rendering.

#### Table 9.3 Background Preparation

<table>
<thead>
<tr>
<th>Background</th>
<th>Building material</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth, strong</td>
<td>High-strength concrete</td>
<td>Scabbled surface and apply dash coat or fix metal lath clear of surface</td>
</tr>
<tr>
<td>Fibre-cement</td>
<td>Sheet</td>
<td>Fix metal lath clear of surface</td>
</tr>
<tr>
<td>Strong/porous</td>
<td>Standard bricks, blocks, concrete</td>
<td>Rake joints and apply dash coat</td>
</tr>
<tr>
<td>Weak/porous</td>
<td>Lightweight concrete, Render undercoat</td>
<td>Dampen surface</td>
</tr>
</tbody>
</table>

#### Surface dampening

After initial preparation, the background surface should be dampened and allowed to dry back to a surface-dry condition immediately prior to rendering. This reduces suction but still enables a bond to be achieved.

#### Dash coat

Dash coats are used to provide a high-strength bond between the background and the subsequent render coat. Site-mixed dash coats have the proportions of 1 part cement: 1–2 parts sand. The dash coat is flicked and splattered over the background to produce a rough finish. This open-textured layer is not trowelled level or smoothed out, but left rough to ‘key’ with the render.

#### Number of coats

This will depend on the condition and the uniformity of the background, the conditions it is exposed to, and the type of finish required. Usually, one or two coats are all that is required for most work. Single coats should never exceed 15 mm in thickness.

A minimum of three days should be allowed between coats.

**Undercoats** are normally applied by trowel to a minimum thickness of 10 mm and a maximum of 15 mm. When the render is firm, it should be raked or scratched to provide a key for the next coat.

**Final coats** are normally applied by trowel to a maximum thickness of 10 mm over the undercoat.

#### Decorative finishes

A variety of decorative effects can be achieved using different finishing techniques on the final coat.

The application of decorative render finishes can be difficult and application by a competent tradesman is recommended.

**Trowelled finish** can be achieved by skimming the final coat with a wood float to produce a smooth, dense surface or using notched trowels to produce a variety of finishes.

**Bagged** or patterned finish can be obtained by rubbing a ball of damp hessian into the surface with different patterns being produced depending on the action used.

**Sponge** finish can be achieved by mopping or sponging the unhardened surface with a damp sponge. Water should not be allowed to run down the wall.

**Roughcast** The final coat is thrown and flicked onto the surface and no retouching is done.

Textured surfaces can be achieved through the use of coarser aggregate in the final coat.

#### 9.2.5 Control joints

Cement-based renders can crack as a result of shrinkage as they dry, or because of movement in the background material. With the careful placement of control joints, this cracking can be minimised.

Control joints should be formed in the render to coincide with all joints in the background and locations in the structure where movement is likely to occur.

#### 9.2.6 Curing and protection

All render coats, including undercoats and dash coats, should be kept damp for 3 days or until the next coat is applied. Render should not be allowed to dry out quickly and should be protected from hot weather, drying winds and rain.

Rendering in direct sunlight or exposed windy areas should be avoided.

Plastic sheeting should be used to protect fresh render for the first 3 days after application. (The plastic sheet should not be allowed to touch the finished surface or it will lead to discolouration.)

Protection is not normally necessary for internal renders if the building provides protection from drying weather conditions.

### 9.3 Roof-tile bedding

#### 9.3.1 General

Ridge and hip cappings should be laid on a mortar bed.

Mixes recommended by AS 2050-

- Composition mortar 1 cement:1 lime: 6 sand
- Cement mortar 1 cement:4 sand

Measurement of the ingredients should be made using a gauge box or bucket not a shovel. A good bricklayers’-sand should be used. The lime in the composition mortar will produce a more workable mix.
9.3.2 Pointing

Pointing cappings provide a weather seal. The use of wet mixes prone to excessive shrinkage cracking should be avoided.

Pointing of the joints between ridge and hip cappings, should be done using a 3:1, sand:cement mortar.

Where tiles converge at a valley (or steep roof pitches), it is often essential to point under the cut tiles in the valley line to prevent the up-wash of roof water under the opposing tile edge.

Pigments are usually added to pointing-mortars to match the colour of roof tiles. Some trials will be required to achieve a good match. In all cases, the pigment used should be no more than 10% by weight of the cement in the mix. Pigments should be used strictly in accordance with the manufacturer's recommendations.

When pointing, the mortar should be lightly brushed or wiped after the initial set to remove loose particles. All tiles adjacent to the ridge tiles should also be cleaned and brushed free of loose mortar particles.

10 TROUBLESHOOTING AND REPAIRS

10.1 Defects—Prevention and repair

10.1.1 Dusting

Dusting is a condition where a fine powder comes off the surface of the concrete.

Cause: Concrete with high water content (often the case when water has been added on site) will bleed more easily and bring fines to the surface. When the surface is worked prematurely, these fines become dominant and the cement paste is diluted. With little cement binder available, the surface dusts. Another cause is rain on fresh concrete surfaces before the concrete has set. A deluge of rain will flood the surface and wash out or dilute the cement binder. The failure to undertake proper curing may also cause dusting.

Prevention: Do not work the surface too early while bleedwater is present. Avoid adding water to concrete. Do not overwork the concrete because this will also bring fine material to the surface. When rain threatens, take decisive action to protect the surface. Do not attempt to broom the surface when wet because this will drag away the cement paste and create rutting in the surface. Always adopt a good curing procedure as early as possible.

Repair: Dusting can be rectified in the majority of cases by the application of a sealer that penetrates the concrete (and reacts with the lime in the concrete, effectively case hardening the surface). It also bonds the thin, weak layer on the surface to the base concrete below. More-severe cases will require the complete removal of the weak top layer with a concrete grinder.

10.1.2 Crazing

A crazed concrete surface is a network of very shallow fine cracks across the surface. They are obvious when the concrete is damp.

Cause: Crazing is caused by minor surface shrinkage in rapid drying conditions (ie low humidity and high temperatures), or alternating wetting and drying. Other contributing factors include having the mix too wet and the lack of adequate curing. Crazing also results when driers such as neat cement are used to soak up excess water and are trowelled into the surface.

Prevention: Adopt a good curing regime and start it early. Do not use cement (or coloured surface hardeners) to soak up water, and limit the trowelling of the concrete. Avoid the addition of water to the concrete. Do not work the surface too early when bleedwater is present.

Repair: Repair may not be necessary because crazing usually will not weaken concrete. If it is visually unacceptable, then a surface coating of paint or other overlay sealer can be applied to cover and/or conceal the cracks.

10.1.3 Blistering

Blistering are hollow, low-profile bumps on the concrete surface filled with either air or bleedwater. Under traffic (both vehicle and foot traffic) these blisters crack and the surface mortar breaks away, exposing the concrete underneath.

Cause: The concrete surface was sealed too early by trowelling, trapping water, which continued to rise, causing the blistering under the surface during finishing. This can occur particularly in thick slabs or on hot, windy days when the surface is prone to premature drying.

Prevention: The use of an evaporation retardant in hot, dry or windy weather will reduce this problem. Other means of reducing rapid drying include windbreaks and sunshades, and placing at cooler times of the day. If blisters are forming,
delay trowelling as long as possible and take steps to reduce evaporation.

Repair: Grind off the weakened layer to an even finish. Place a topping layer to remedy badly damaged surfaces.

10.1.4 Uneven colour of plain concrete

There is sometimes colour variation in adjoining sections of concrete, and sometimes in the slab itself.

Causes: The amount of water in concrete affects its colour. The more water (and therefore bleeding), the lighter will be the concrete. Changing the supplier of the concrete or changing the cement brand may also affect colour. Finishing practices such as early trowelling of wet surfaces will lighten the concrete and extended hard trowelling will darken the concrete. A steel trowelled surface will be lighter in appearance than a broomed finish. Curing will darken the concrete and inadequate or inconsistent curing methods can result in mottled surfaces. Curing compounds that are not evenly applied, and plastic sheeting that is not fully in contact with the surface will result in lighter patches.

Prevention: Adopt a standard and consistent procedure for ordering, placing and finishing. Do not add water, use the one supplier, trowel after bleedwater has dissipated, trowel the surface evenly and implement good curing techniques.

Repair: The application of a stain available from concrete chemical supply companies may lessen the colour variations. A trial, on a concealed section of the slab, is advisable.

10.1.5 Rain damage

Causes: Heavy rain while concrete is setting, or rainwater being allowed to run across the concrete surface.

Prevention: Prevention is far better than any cure in this case. If caught out, cover the concrete and channel run-off away from freshly laid concrete.

Repair: If concrete has not hardened and damage is only slight, the surface can be refloated and re-trowelled, taking care not to overwork excess water into the surface. If concrete has hardened, it may be possible to grind or scrape away the surface and place a topping layer of new concrete, or repair compound, over the top. This may not always be possible and should be done only with expert advice.

10.1.6 Efflorescence

Efflorescence is a white crystalline deposit sometimes found on the surface of concrete soon after it is finished.

Causes: Mineral salts are sometimes present in the water used to make the concrete. These salts collect on the concrete surface as water evaporates. Excess bleeding can also result in efflorescence.

Prevention: Use clean, salt-free water and washed sands. Prevent excessive bleeding by avoiding the addition of water to the mix on site. Use a vapour barrier to separate ground-water, which would otherwise soak into the concrete and possibly bring salts to the surface.

Repair: Remove salt deposits with a stiff-bristle broom. If the result is not satisfactory, scrub with clean water then lightly rinse the surface. To remove any remaining deposits, the concrete can be treated by acid etching and flushing.

Efflorescence is not a permanent discolouration and without treatment will eventually fade away.

10.1.7 Honeycombing

Commonly occurring on vertical faces of edge beams, staircase and verandah soffits, it appears on the surface as a coarse texture of interconnecting voids and stones.

Causes: One or more factors including incorrect placement of the concrete, delays between placement of concrete layers, inadequate vibration, and the loss of cement paste through unsealed formwork joints. Surface voids may also indicate a mix that has segregated because of the addition of water, or concrete that has been dropped into place from a height greater than one metre. Poor surface formwork, poorly oiled forms, or damaged form faces restrict the movement of the concrete during placement.

Prevention: Compact and vibrate as close as possible to formwork and, if necessary allow for external vibration of forms. Vibrate more frequently. Use good formwork that has not been damaged. Do not add water to the concrete. Do not drop the concrete into forms from excessive heights. Ensure that all formwork joints are tight (tape joints if necessary) to avoid mortar leakage. Place all concrete continuously and ensure that when placed in layers, concrete in one layer is vibrated to blend with the lower layer.

Repair: Honeycombed surfaces can be rendered. If honeycombing is much deeper than the surface layer, it may need to be removed and replaced with a repair mortar.

10.1.8 Blowholes

Blowholes are individual, spherical voids in the surface, usually less than 10 mm.

Causes: Air voids are trapped against the form face, usually because insufficient vibration (compaction) has not brought them to the surface. Blowholes often occur with impermeable forms.

Prevention: Ensure forms are rigid, with a thin, even coat of form oil (referred to as ‘pickling’). The workability of the mix should be suitable for the application. Ensure careful and thorough internal vibration.

Repair: Use repair mortars.

10.1.9 Wavy or uneven surfaces

Causes: Common causes include-

• Poorly built formwork that has uneven guide rails for screeding
• Improper methods of screeding and trowelling
• Loading a pre-hardened slab with workers’ foot-traffic and power trowelling machines, resulting in humps and hollows in the concrete. Paviours—intent on finishing the surface—can be deceived about the hardness of the slab when hot weather conditions dry out the surface prematurely, while the concrete mass underneath is still plastic and can be deformed.

Prevention: Always keep a uniform surge of concrete ahead of the screed board and take accurate levels. To avoid the premature set of the surface, use evaporation retardants to control rapid drying. Maintain a constant slump; do not add water, which will vary the set of different concrete loads.

Repair: Use self-leveling floor compounds or repair mortars. Alternatively, grind the surface evenly.

10.1.10 Spalling

Spalling is when fragments of concrete are detached from the concrete surface.

Causes: Heavy loads or blows from a hammer. Corrosion of reinforcement, which forces off the surface concrete. Entry of hard objects—such as stones—into joints, can cause spalling when a slab expands and pushes against the object. Poor compaction of concrete at joints is another cause.

Prevention: Ensure sufficient cover of reinforcement. Remove formwork carefully, to avoid hammer blows or point loads to
new concrete. Design joints carefully. Keep joints free of debris. Keep heavy loads away from the joints and edges until they have properly hardened. Ensure proper compaction.

Repair: Scrape, chip or grind away the weak areas until sound concrete is reached. Then refill area with new concrete or repair mortar. Make sure the old concrete is brushed clean of any loose material. Compact, finish and cure the new patch carefully. For larger areas, seek expert advice.

10.1.11 Coloured decorative concrete defects

Stamped concrete
- Colour appears to be lifting, exposing a pale, tinged concrete base. This is caused by the incomplete removal of the release coat.
- The depth of the stamped impression tapers down to a minimal imprint. This is the result of undertaking the stamping when the concrete has hardened too much.
- The surface has small craters over much of the pattern. Often the concrete has been too wet when stamping begins, or the concrete was re-wetted (or 'wet wiped') to make imprinting easier, and the excess surface water has created suction on the stamping mould.
- The colour is fading, although it is not in a high-traffic area. The colour applied was not sufficient, or only one coat of base colour was applied and the release coat was applied at the same time as the second colour. This will also indicate that the sealer is allowing the weather to break down the pigments. Colour may have been poorly worked into the concrete.
- The colour surface has crusted and begun to delaminate and flake off. Causes include the use of cement or a dry-shake topping to mop up bleedwater, or the application of the colour topping after the concrete has set, resulting in a poor bond with the base slab.

Stencilled concrete
- The edges of the 'joints' of the pattern are rough and variable. The stencil was not fully embedded in the concrete, consequently the colour topping has stuck to the stencil and been torn away when the stencil was removed.
- The joints are stained with colour. The colour has bled under the stencil due to poor adhesion with the surface. The stencil was not sufficiently worked into the surface, or the concrete had begun to dry when the stencil was placed, resulting in a weak bond.
- The depth of the joints varies. The stencil was placed too early, when the concrete was too wet, and was embedded too deeply into the soft surface.
- The pattern is out of alignment. The alignment of stencils was unplanned or the project was comprised of separate pours and care was not taken to align stencils.
- The pattern is distorted. This is often caused by dragging the stencil into alignment across the surface. When aligning stencils, always hold them off the surface and lay down into position.

10.2 Crack Repair

10.2.1 General

The following factors should be taken into account:
- Before any repair is undertaken the cause of the cracking must be ascertained. This may require the services of a suitable expert or consultant.
- Whether the crack is live or dormant. Will it continue to move–open or close–or has it stabilised?
- The width and depth of the crack.
- Whether or not appearance is a factor.

Dormant cracks are usually repaired by cutting a groove over them and filling with a cement grout or mortar. Other materials are also available for crack repair.

Live cracks are filled with a flexible sealant to allow movement. A wide variety of purpose-made materials are available.

There is a large range of repair products. It is not possible, in the scope of this handbook, to give detailed instructions about their use. The following is only a guide–detail information should be sought from the manufacturers of particular products.

10.2.2 Live cracks

Live cracks should be sealed with a flexible material that allows movement, particularly in seasonal cycles.

Flexible epoxy resins allow a small amount of movement but mastic sealants, such as silicone and polyurethane, are more commonly specified. Cracks are repaired by cutting a groove (or chase) over them and filling with the sealant.

10.2.3 Dormant cracks

Dormant cracks range in width from 0.05 mm (crazing) to more than 5 mm. The materials and methods for repair depend on the width of the crack.

Very fine cracks, for example crazing, are very difficult to repair effectively. In many cases it is best to do nothing. If the problem is one of appearance (dirt collecting in very fine cracks accentuates them), a solution may be to rub down the surface with a carborundum stone before sealing with a water-repellent material, such as sodium silicate.

Fine cracks (up to about 1 mm in width) can often be sealed against water penetration by simply rubbing in a cement grout or slurry. Injecting an epoxy-resin into them can also seal them.

Repairing fine cracks is often unnecessary and can sometimes detract from the general appearance of the surface finish.

Epoxy grouts are widely used because:
- they adhere strongly to both fresh and hardened concrete;
- formulations are available which will adhere to most surfaces and harden even under wet conditions;
- they have good mechanical strength and low shrinkage; and
- they are resistant to a wide range of chemicals, including the alkalies in concrete.

For cracks wider than 2 mm, a cement grout may be the most satisfactory, and is often preferred because of its total compatibility with the parent material, and its ability to maintain an alkaline environment around reinforcement.

Other materials, such as polyester resins and synthetic latexes, have also been used satisfactorily to seal fine cracks. They can have lower viscosities than epoxies and hence can penetrate more easily. However, they may not achieve the same bond strengths and may be less reliable in damp or wet conditions.

Always refer to the information supplied by the manufacturer of the products to be used in a particular situation.
10.2.4 Wet-crack repair
In some situations, a crack in a concrete slab can allow moisture to rise through to the surface, possibly due to hydrostatic pressure. Often, moisture is present from seepage or a broken or damaged water pipe under a slab. As the concrete may be very dry, the slab acts as a wick and can draw up any moisture present. Products are available which react with the moisture present to seal cracks in a moist environment.

10.3 General repairs
10.3.1 General
Concrete needs minimal maintenance if correctly placed. However, minor repairs may be necessary in some instances to improve its appearance and performance. Serious defects may require a complete topping over the whole concrete surface. Some of the simpler repairs are outlined below.

A variety of purpose-made products are available for repair and treatment of concrete. It is essential to obtain the manufacturer's advice and instructions on the product's application.

10.3.2 Mortars
The filling of chips or gouges is best done with a repair mortar available from concrete chemical supply companies. A variety of products are available and the product selected should suit the particular application. The manufacturer's instructions should be followed carefully.

10.3.3 Acid etching/cleaning
Acid etching is an effective method in some instances to clean or lightly texture concrete surfaces.

Extreme care is required when handling acids. When diluting hydrochloric acid always add the acid to the water, never the reverse. Ensure good ventilation and avoid contact between the acid and the reinforcement.

Use only diluted acid to clean or etch the concrete surface. The recommended proportions are 1 part hydrochloric acid to 20 parts water. Always saturate the surface with water before applying the dilute acid solution. When applying the solution, ensure that the surface is moist but without any free water being present.

The applied solution should be allowed to react on the concrete surface for 10 to 15 minutes. The surface should then be thoroughly rinsed and scrubbed with lots of clean water. Repeat rinsing at least twice or until all traces of the acid solution has been removed.

The process may be repeated if necessary to produce the required surface finish.

10.3.4 Slippery concrete surfaces
Smooth concrete surfaces that have become slippery may be made coarse by using a high-pressure water blaster or by acid etching the surface.

If a high-pressure water blaster is used, it should be capable of delivering pressure between 6.9 and 8.3 MPa (1000 and 1200 psi). The use of such equipment to achieve surface texturing can be difficult and specialised use by a competent tradesman is recommended. If the clean concrete surface is sealed (once dry), it will resist dirt and grime.

10.3.5 Topping existing concrete
General
A damaged or worn concrete surface can be revitalised by the application of a topping.

A variety of applications are available, ranging from new concrete toppings (which may be either bonded to the existing concrete or unbonded), to the application of pre-packaged proprietary levelling compounds. The alternatives have different advantages and applications for different situations.

It is crucial to consider the locations of joints in a topping to avoid cracking. Generally, the area should be limited to 15-m² sections and control joints formed to align with existing joints. The thickness of a topping will depend on the product, and intended use of the floor, including abrasion requirements, service and dead loads and exposure to corrosive substances or environments.

Cracks in the existing concrete should be repaired, because it is likely they would appear in the topping, especially in thin bonded toppings.

New concrete toppings show fine surface cracks because of drying at the surface of the topping, and the bond of the topping to the existing base.

After curing, the topping can be used by foot traffic, heavier loads, however, should be deferred for 28 days.

Bonded toppings
Bonded topping slabs are between 20 and 50 mm thick and consist of 1 part cement; 1½ parts clean sharp sand; 2 parts of 7 to 10-mm aggregate mixed with a minimal quantity of water necessary for workability.

Toppings are placed on a rough surface, which is clean and sound. Old concrete surfaces, which are disintegrating, ie dusting or spalling, should be chipped until a sound surface is obtained. Smooth concrete should be chipped or scabbled to provide a key for the new topping. Water blasting or captive shot blasting is preferable, because chipping tends to produce a weak base layer. On a prepared surface the coarse aggregate should be showing.

Hose and scrub with a stiff broom to remove all dust and foreign matter before placing the new concrete. A suitable bonding compound should be used.

Generally, reinforcement is not used when the topping thickness does not exceed 50 mm.

F42 fabric can be positioned 20 mm from the top of the slab and supported on bar chairs will help control shrinkage cracking. Polypropylene or steel fibre reinforcement may also be used.

All joints in the original slab should be duplicated in the topping slab to maintain movement control.

The topping should be cured for a minimum of 3 days, preferably 7 days.

Unbonded toppings
If the topping slab is 50–75 mm thick, a separate unbonded reinforced topping should be considered with a plastic membrane separating the old concrete from the new. Toppings that exceed 75 mm in thickness should be regarded as new concrete slabs and designed and reinforced accordingly.

N32 grade concrete with a maximum slump of 80 mm should be specified. F52 reinforcing fabric is positioned 20 mm from the top of the slab and supported on bar chairs to help control shrinkage cracking.

The topping should be cured for a minimum of 3 days, preferably 7 days.

Levelling compounds
Proprietary levelling compounds and toppings are typically less than 10 mm thick. They are mixed with water and screeded onto the concrete surface. Levelling compounds
can be applied in thicknesses as thin as 1 mm. Some self-levelling products require little finishing. It is essential to follow the manufacturer’s advice and instructions about the product’s application.

APPENDIX

Relevant standards

AS 1379 Specification and Supply of Concrete
AS 2050 Installation of Roof Tiles
AS 2870 Residential Slabs and Footings - Construction
AS 3582 Supplementary Cementitious Materials for use with Portland Cement
  3582.1 Fly Ash
  3582.2 Slag - Ground Granulated Iron Blast-furnace
AS 3727 Guide to Residential Pavements
AS 3799 Liquid Membrane-forming Curing Compounds for Concrete
AS 3972 Portland and Blended Cements
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