

**BORAL CONCRETE**  
Build something great™



# CONCRETE

**THE BORAL BOOK OF CONCRETE**



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# 1. What is concrete?

## Cement and concrete – Are they the same?

Many people think that cement and concrete are the same product. They are not.

**Cement** is a dry powdered chemical that, when mixed with water, slowly reacts to form a hard, solid compound.

**Concrete** is a mixture of cement blended with water and various sizes of aggregates. The cement and water form a paste that glues the aggregates together when it hardens. Concrete, in its freshly mixed state, is a plastic, workable mixture that can be formed into almost any desired shape. It starts to slowly stiffen when mixed, but remains plastic and workable for several hours. This is a long enough period to allow it to be placed and finished. After initial set, it continues to gain strength for months and sometimes years if moisture continues to be present.

## Concrete has two components; aggregate and paste.

**Aggregates** generally are of two sizes; fine and coarse. Fine aggregates are those with particle sizes smaller than about 5mm, commonly known as sand, which can be natural or manufactured. Coarse aggregates are those with particle sizes greater than about 5mm. Gravel, crushed stone and blast furnace slag are among commonly used coarse aggregates.

**Paste** is composed of cement, ground granulated blast furnace slag, flyash, water and sometimes admixtures as required to achieve desired set times or air entrainment.

The cementing property of the paste results from a chemical reaction between the cement and water, called hydration. It is a reaction that requires time and favourable conditions of temperature and moisture. "Curing" is the provision of favourable temperature and moisture conditions over a period of time long enough to allow the hydration process to approach completion. With proper curing, hydration takes place very rapidly at first, and then decreases slowly for a long time. This allows the concrete to develop its strength and durability. Concrete needs continued moisture to develop its full potential. It should not dry out too quickly.

## Strength of concrete

The compressive strength of concrete is measured by how much force is required to crush it, this is important in the design of structures. In pavements and other slabs on the ground, the design is usually based on flexural strength, (i.e.; how much force the concrete can withstand in bending before it breaks). In either case, the principal factors affecting strength are the water-cement ratio and the extent to which hydration has progressed.

The addition of too much water to concrete (beyond the intended mix design) will reduce strength and durability of the concrete, even if it is properly placed, finished and cured.

## Properties of fresh concrete

Although freshly mixed concrete remains plastic for only a short time, its properties are important because they affect the quality and cost of the hardened concrete.

Concrete with suitable plastic consistency (medium slump) does not crumble as it is discharged, but flows without segregation of coarse aggregate from the finer material. Mixtures of such consistency are suitable for most work. The ease or difficulty of placing and consolidating concrete is called workability.

Concrete should be workable; it should not be so stiff or so wet that segregation occurs; nor should it bleed excessively. Bleeding is the movement of water to the surface of freshly placed concrete.

Excessive bleeding of water to the surface increases the water-cement ratio at the surface. A weak layer of poor durability may result, particularly if finishing operations take place while the excess water is present.

## What do you order?

Concrete is bought and sold by the cubic metre volume of the freshly mixed ingredients. Specifications for concrete normally include a requirement for a certain design strength level for test cylinders cured for 28 days, or they are based on a prescription of a specified cement content. Other characteristics such as slump and air content are also requested.

The Australian Standard; AS1379 – Specification and supply of concrete may be referenced for additional detail on the criteria and differences between Normal and Special Class concrete.

## What makes good concrete?

You do not need to be a concrete technologist. However, you should be aware that a certain quality is built into each mix design and you should be familiar with what constitutes good concrete:

1. Cement and water combine chemically to bond the sand and coarse aggregate together. Ground granulated blast furnace slag and flyash may also be used as cementing materials, but always in combination with cement. The volume of water added to a certain volume of cement determines, to a large extent, how strong the hardened concrete will be. Most concretes are designed with a certain cement content and enough water to make the mass workable. Providing workability is adequate, reducing the mixing water content makes the batch stronger and the addition of water makes the batch weaker.
2. Fine and coarse aggregate of a predetermined quality is added to the cement-water paste in the batch to give bulk to the batch. They contribute significantly to the quality of the concrete. If all fine aggregate (sand) is used to make a one cubic metre batch, a large amount of cement-water paste is needed to coat and bond the particles. By adding coarse aggregate to the batch instead of a portion of the sand, the mixing water demand can be kept lower. This works to produce better quality concrete at an economical cement content.

- 3.** Admixtures are used in concrete (often in combination) to impart specific qualities to the fresh or hardened concrete. Some admixtures make the concrete set faster or slower, or make it denser, or make it stronger or more durable.

The most common are water-reducing admixtures. They help produce a medium slump, workable concrete, requiring less mixing water. Air-entraining agents which develop millions of tiny air bubbles in the concrete are often used to improve durability and workability. Superplasticisers or high range water reducers can greatly increase slump with a relatively small dose. Once added to the concrete this slump increase will last up to two hours, with the concrete eventually returning to its original slump.

Typically, admixtures are incorporated into concrete design to assist with the plastic concrete consistency for uses such as:

- a)** Dry slump concretes (20 to 50mm) giving very low shrinkages due to reduced water content, but are difficult to work in their plastic state.
- b)** Normal slump concretes (60 to 100mm) giving suitable workability for general purpose applications.
- c)** Medium slump concrete (120mm to 160mm slump) for improved pumpability (130 plus metres high)
- d)** Flowing concrete (180mm plus slump) for ease of placement, labour savings and good off-form finish



## 2. The testing of concrete

### Technical service to the building and construction industries

Throughout Australia, Boral has established concrete testing laboratories staffed by qualified and experienced personnel to assist with the quality control of our product, and to act in a technical advisory capacity to the building and construction industry.

Each of our laboratories is registered with the National Association of Testing Authorities Australia (NATA), and as such our test reports bear the NATA endorsement; "Accredited for compliance with ISO/IEC 17025".

This NATA registration represents a safeguard and protection for the concrete purchaser, the architect and/or the engineer and the owner, that the testing procedures used have been in strict accordance with the relevant Australian Standards.

### Field testing services

Concrete testing services has been established as an extension of these facilities. Upon request one of the company's field testing officers will go to the job site, measure the slump of the concrete, cast cylinders for either compressive or indirect tensile (Brazil Test) strength, or cast beams for flexural strength, etc. The following day they will return to the site to collect the specimens and transport them to the laboratory for standard curing, testing and reporting.

### Concrete research and development laboratory

Boral maintains a dedicated construction materials research and development facility. It was at this facility that special concrete mixes were developed for many major projects across Australia.

Major project case studies may be reviewed on our web site at; <http://www.boral.com.au/major-projects/>

### Determining the consistency of concrete (AS 1012, Part 3) – the slump test

In many cases, the acceptance or rejection of a load of concrete depends upon a nominated (e.g. 15mm) variation to the specified slump. This much variation can be, and often is, caused by poor slump test practices.

If the slump test is to determine whether or not the concrete is to be accepted, the sample must be taken from the early part of the load. Never take the sample from the first concrete out of the mixer. Let out at least 0.2 of a cubic metre before taking a test sample.

If the test is to be representative of the entire load, samples should be taken from three well-spaced parts of the load by passing the bucket through entire discharge stream of concrete and remixing them on a non-absorbent surface.

## Conducting a slump test



**1.** Moisten the inside of the cone and place it on a flat, level and firm surface - a piece of steel plate, concrete or stone slab, sheet or metal pan etc. This support should extend 50mm beyond the base of the cone to provide space for the concrete to spread when the cone is removed later. Hold the cone firmly in place when putting concrete in it by standing on the foot lugs.



**2.** Fill the cone with one-third of the volume (approx. depth of 60mm) and rod the layer exactly 25 times with a round bullet-nosed steel rod of 15mm diameter, 600mm long. Rod uniformly over the entire concrete surface.



**3.** Fill the cone with the second layer until two-thirds full (approx depth of 150mm) and rod this layer 25 times uniformly over the entire concrete surface just penetrating into the underlying layer.



**4.** Fill the cone with the third layer until it slightly overflows and then rod this top layer 25 times uniformly over the entire concrete surface, just penetrating into the underlying layer.

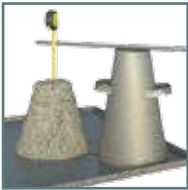


**5.** Strike off the excess concrete from the top with a straight edge so that the cone is exactly filled. Remove spilled concrete from around the bottom of the cone.





6. Lift cone straight up slowly and gently, taking approximately 3 seconds to lift the cone, after filling, rodding and strike-off are completed. Never jar the concrete in any way until after the slump is measured in order to avoid possible incorrect results of the test.



7. Measure the slump as shown in the diagram. If the top of the slump is irregular, do not measure the high point or the low point. Try to get the average. The slump shall be measured to the nearest 5mm for slumps 100mm and less, and to the nearest 10mm for slumps greater than 100mm.

### Casting compression test specimen (AS 1012, Part 8)

The standard test specimen is a cylinder 100mm in diameter and 200mm long. These must “be of metal” with the ends “plane and perpendicular to the sides.” The moulds must be fitted “with lugs or other suitable means for the attachment of base plates”, the latter to be machined metal not less than 10mm thick.

The tolerance allowed on the machining of the base and cover plates is 0.05mm departure from the plane.

Before use, the inside surfaces of the mould and base plate should be thinly coated with a mineral oil to prevent adhesion of the concrete.



## Filling and compacting

The moulds (100mm diameter x 200mm high) are filled in “two approximately equal layers” and fully compacted usually by hand rodding for slumps of 40mm and above or by vibration for lower slumps down to 10mm.



**1.** By rodding – each layer shall be fully compacted using the standard tamping rod 15mm diameter, 600mm long, tapered for a distance of 25mm to a spherical shape end having a radius of approximately 5mm, the strokes being distributed uniformly over the cross-section of the mould. The bottom layer shall be rodded throughout its depth and for the upper layer; the first 10 strokes shall just penetrate into the underlying layer, with the number of strokes per layer being 25.



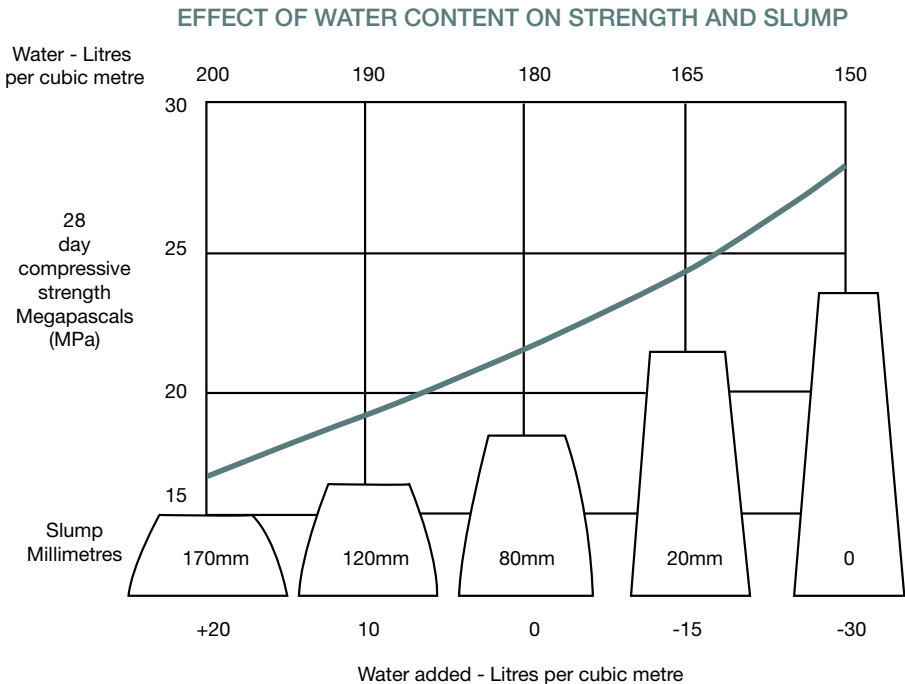
**2.** Compaction by vibration – for standard cylinders two approximately equal layers shall be used. All the concrete for each layer shall be placed in the mould before starting vibration of that layer. Vibration shall be continued only long enough to achieve full compaction of that layer. Over vibration should be avoided.



### 3. Mixing water in concrete

The use of too much mixing water in concrete is probably the most common abuse of concrete, and is often very costly. In a correctly proportioned concrete mix, only about half of the mixing water is needed to hydrate the cement. The remainder acts as a lubricant to produce workability. When more water than is actually needed for workability is added, the concrete is diluted, its density, strength and durability is reduced.

In terms of basic concrete technology, the compressive strength is proportional to the strength of the cement paste which is in turn dependent upon the amount of water present in the mix for a given quantity of cement, or the water-cement ratio. For the same quantity of cement, the more water used to produce a higher slump, the higher this ratio becomes and the lower is the resultant compressive strength. The effect on strength of increasing the slump on a truck load of concrete will be apparent from the graph below.



### **In addition to the loss in strength, other results of excessive mixing water include:**

- Excessive cracking resulting from high shrinkage and low tensile strength.
- Dusting and crazing of slabs caused by excessive bleeding bringing fines to the surface.

### **Remember:**

- Concrete with optimal water (lower consistency) is much less expensive when measured in man hours. It may require more labour initially to place, but it can be finished much sooner.
- Discharge concrete as soon as possible after it arrives on site. Prolonged mixing causes stiffening of concrete and may make it necessary to add water to maintain workability.
- Ensure that adequate manpower and equipment are available to place the concrete – place it rather than pour it.



## 4. Vibration of concrete

Concrete for any structure must have a degree of workability while in a plastic state, which will permit it to be placed into the final position where it will be allowed to harden.

Normally the plastic concrete flows around reinforcing in the forms, into corners and other areas. However, when the concrete is too heavily reinforced, with small clearances between the bars and forms, some mechanical aid is required to assist in the placing. Here vibration provides the best method for consolidation of the concrete.

### Advantages of consolidation by vibration:

- Efficient placement of stiffer concrete mixes which will give higher-strength, better quality concrete.
- Savings in time/costs through ease of placement.
- Greater density in the concrete.
- Greater homogeneity in the concrete - uniform consistency can be maintained throughout.
- Absence of voids, stone pockets and air traps.
- Improved bonds with reinforcement.
- More complete combination of successive layers.
- Reduces shrinkage in the setting concrete.

### Low-slump mixes

The higher strength and quality of concrete obtained by vibration result largely from the fact that a drier concrete can be placed.

Less free water, lower water-cement ratios, less volume change, all work for greater early and final strengths.

Vibration periods of five to 15 seconds are usually sufficient. The amount of vibration needed in one spot can be gauged by;

- the surface movement and texture of the concrete,
- the appearance of cement paste at the sides of forms,
- the approach of the sound of the vibrator to a constant tone, and
- the "feel" of immersion vibrators in the operators' hands.

## Over vibration

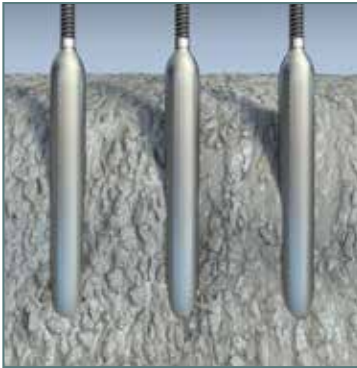
There is little likelihood of over vibration when the slump of the mix is as low as practicable.

When over vibration occurs the surface appears very wet and in fact consists of a layer of mortar containing little aggregate. Generally, the slump, and not the amount of vibration, should be reduced. Over vibration of wetter mixes may result in horizontal stratification, with loss of durability.

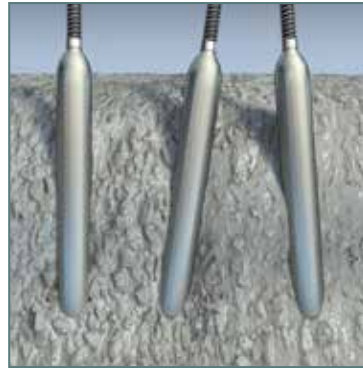
Air-entrained concrete mixes, or stiff mixes made with lightweight aggregates, should receive the minimum amount of vibration needed for consolidation.

Hand vibrators should not be used to transport concrete along a horizontal surface or to re-mix concrete in forms, as some segregation will occur.

Systematic vibration of each new layer is essential. The vibrator should be used at regular intervals of space and penetrate vertically about 50mm into the previous layer which should still be plastic. Penetration at haphazard angles, spaces and depths does not result in a monolithic combination of the two layers.



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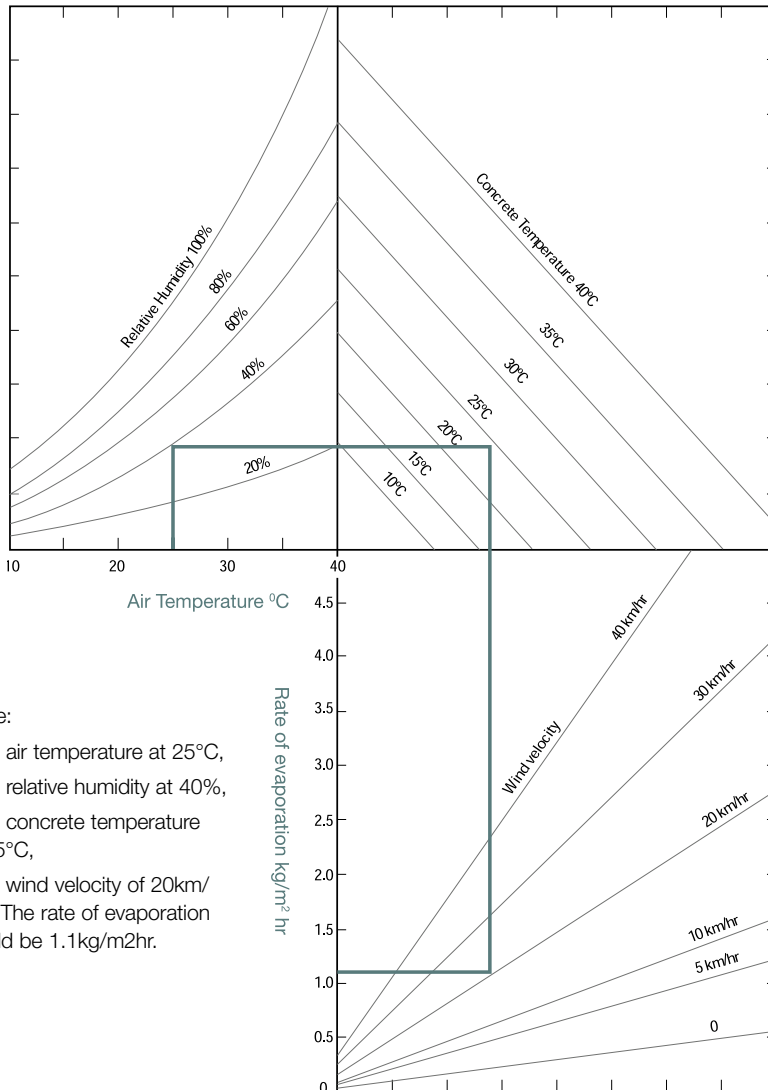


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## 5. Evaporation of bleed water from concrete

The chart below shows the effects of air temperature, humidity, concrete temperature and wind velocity together on the rate of evaporation of water from freshly placed concrete.



Example:

- With air temperature at 25°C,
- With relative humidity at 40%,
- With concrete temperature at 25°C,
- With wind velocity of 20km/hr, - The rate of evaporation would be 1.1kg/m<sup>2</sup>hr.



To determine the evaporation rate from the chart, enter the chart at the air temperature (in this case 25°C) and move vertically to intersect the curve for relative humidity encountered (in this case 40%). From this point, move horizontally to the respective line for the concrete temperature (in this case 25°C).

Move vertically down the respective wind velocity curve (in this case 20km/hr), and then horizontally to the left to intersect the scale for the rate of evaporation.

Trouble with plastic cracking is potentially in the making when the rate of evaporation exceeds be 0.5kg/m<sup>2</sup>hr.

When the evaporation rate exceeds 1.0kg/m<sup>2</sup>hr precautionary measures to prevent plastic shrinkage cracking, such as the use of aliphatic alcohols, are almost mandatory.



## 6. Curing of concrete

Concrete must be cured, whether as a test specimen or in the job. The following notes give some background to this necessity.

### What is hydration?

When cement is mixed with water it undergoes a chemical change that transforms it into “rock”. When it hardens into a mass similar to rock, it is said to have hydrated. Therefore, hydration is nothing more than a chemical combination of cement and water. First, the outside of the cement particle hydrates and a cement gel (glue) is formed. As water continues to soak through this cement gel, further hydration takes place in the cement particle. This process goes on for many years just as long as moisture is present. The process of keeping the concrete damp and at about 21°C is known as curing.

### Curing, why and how

Aggregate mixed with the cement becomes part of the “rock” mass. The process of transformation is most rapid during the first 28 days. Nothing can stop the transformation except a lack of water or subnormal temperatures. If concrete is allowed to dry out in the initial stages, it becomes permanently poor because water evaporated from the mix in the beginning cannot be forced back into the mix in time to prevent the cement gel from spoiling.

Similarly, low curing temperatures can adversely affect concrete strength as shown in a comparison between job site cured and standard cured test cylinders.

In this example, the job site curing was in a 200-litre drum with the temperature varying between 7°C and 9°C.

	Average compressive strength at 28 Days	
	MPa	%
27 Days standard curing	22.7	100
6 days site curing then standard curing in lab	19.7	86.7
7 days site curing then standard curing in lab	17.7	77.8
13 days site curing then standard curing in lab	16.7	73.5
17 days site curing then standard curing in lab	15.6	68.6
19 days site curing then standard curing in lab	15.0	66.2
27 days site curing then standard curing in lab	14.2	62.6

## Wearability

Since evaporation occurs more rapidly from the surface of concrete, the surface is affected by the length of curing time more than by any other single item. For instance, surfaces moist-cured for 28 days produce floors twice as hard as those protected only three days.

## Watertightness

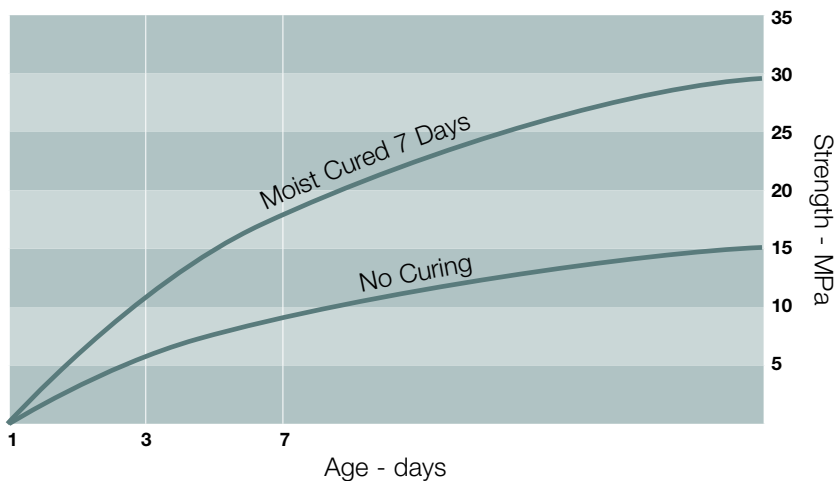
A well-proportioned and workable concrete mix generally contains about twice as much mixing water as is necessary for hydration of the cement. The reason is that one half of the water is used to make the concrete workable. As the cement and water hydrates, a gel is formed and the gel expands to fill the voids, which are left by the unneeded water as it bleeds through, and evaporates from the concrete. You can readily see what happens if curing is stopped at one of the intermediate stages. The voids that are normally filled by the gel are left at whatever stage curing is stopped, making the concrete porous.

## Curing of concrete

Concrete curing techniques fall into two groups:-

- those designed to prevent loss of water, such as the application of impermeable membranes, and
- those that supply moisture throughout the early stages of the hydration process, such as ponding or the application of wet sand or hessian.

### Curing of concrete



## Effects of curing

The longer concrete is moist cured the greater its strength.

If the concrete is to attain its potential strength and durability it must have:

- Sufficient water for hydration of the cement.
- A temperature conducive to maintaining the chemical reaction at a rapid, continuous rate.

## Methods of curing

We have given some of the reasons why it is necessary to cure concrete. The table below lists some of the methods to cure concrete. All the methods have advantages and disadvantages. The method chosen should be the one that will be the cheapest and most effective for the particular conditions under which the concrete is to be placed.

## Methods of curing

Methods	Advantage	Disadvantage
Sprinkling with water or covering with wet hessian	Excellent results if constantly kept wet	Likelihood of drying between sprinklings. Difficult on vertical walls
Straw	Insulator in winter	Can dry out, blow away or burn
Curing Compounds	Easy to apply, inexpensive	Sprayer needed – inadequate coverage allows drying out; film can be broken or tracked off before curing is completed unless pigmented, can allow concrete to get too hot
Moist Sand	Cheap	Can dry out, removal problem
Waterproof Paper	Excellent protection prevents drying out	Cost can be excessive. Must be kept in rolls, storage and handling problem
Plastic Film	Absolutely watertight, excellent protection. Light and easy to handle	Should be pigmented for head protection. Requires reasonable care and tears must be patched, must be weighed down to prevent blowing away

## Mechanical barriers absorptive covers

The use of waterproof building papers or plastic film (polyethylene sheeting) will also prevent the evaporation of moisture from concrete.

An absorptive medium such as sand, hessian or canvas will hold water on the concrete surface while curing progresses.

Plastic sheeting also has advantages of flexibility. It is easy to drape over complex shapes; and the progress of curing and conditioning of the concrete can be checked easily at any time.

## To sum up the advantages of careful control of moisture concrete and temperature in curing

- The strength of concrete increases with age if curing conditions are favourable (the compressive strength of properly cured concrete is significantly greater than the strength of concrete which has not been cured at all).
- Properly cured concrete surfaces wear well.
- Drying shrinkage is greatly reduced and cracking is avoided.
- Greater watertightness of constructions is assured.

## Points to keep in mind when curing

- Start the curing operation as soon as possible after finishing is complete.
- For proper curing concrete needs moisture.
- Continuity in curing is a must, alternations of wetting and drying may promote the development of cracking.
- If during curing the concrete is allowed to dry out – as may happen in hot weather – the chemical change stops right at the point where the concrete loses its moisture.
- The ideal curing temperature is a constant 21°C.
- Cure concrete for at least seven days.



## 7. Hot and cold weather concreting

### Hot weather concreting

The main things to consider during hot weather concreting are:

1. minimising the early loss of water from concrete;
2. preventing early setting through too-rapid drying.

### If these problems are not anticipated, there may be:

- Strength reduction.
- Shrinkage cracks.
- Crazeing or cracking.
- Finishing difficulties.

### In very hot conditions the following steps should be undertaken:

- Thoroughly moisten the subgrade, reinforcing steel and wooden forms before placing the concrete.
- Avoid delay in placing the concrete. Have sufficient labour and equipment on hand to perform the placing quickly.
- Try to shade the concrete from direct sunlight during placement in very hot weather.
- Use wet coverings until final finishing can be completed.
- If a float finish is required, uncover only a small section immediately ahead of the finishers. Cover again at once after final finish.
- Keep covers wet.
- Start curing as soon as possible using a method that will keep temperature of the covered concrete at or about a constant 21°C.
- Discharge concrete from waiting trucks as soon as possible. Heat builds up in mixer drums if this is not done.
- In very hot weather shade concrete from sunlight or use wet coverings until finishing can be completed.

*Remember: Plan work in advance and have adequate labour available so that concrete can be handled rapidly.*

## Cold weather concreting

Few areas in Australia experience temperatures low enough to warrant elaborate and expensive protection of freshly placed concrete. But frosts, abrupt drops in ambient temperature and/or prolonged periods of cold weather, are common in our winter seasons. Harmful effects of these conditions on new concrete can be avoided by relatively simple measures in ordering, placing and curing.

Placed concrete undergoes a “gel” formation that hardens over a period of weeks. Generally, the lower the ambient (surrounding) temperature, the slower the rate of hardening.

At an ambient temperature just above 0°C the development of strength in unprotected freshly placed concrete is very slow. If the ambient temperature drops to or below 0°C some of the water in the concrete may freeze, setting will virtually stop until it thaws and this interruption of hydration increases porosity and reduces final strength and durability.

Because some heat is generated during the hydration process, ordinary concrete has a minor inherent resistance to the freezing of its water content after placing. But when the temperature of the concrete surface itself falls below freezing point, the water content near the surface will solidify in an almost instantaneous surge, increasing its volume by about 10 percent and causing tensile pressure as high as 210 MPa in concrete that is no longer plastic. Scaling or spalling will follow, and will become more severe if several freezing/thawing cycles occur.

The use of aggregate of high porosity in concrete can increase scaling/spalling problems. The aggregate particles near the surface will expand when frozen. Moreover, as most porous aggregates have poor abrasion resistance, the damage will be intensified by separation of particles from the cement paste.

Air-entrained concrete mixes have excellent resistance to surface scaling or bursting after freezing because, as ice crystals begin to form, residual water under pressure moves into the millions of small air cells in the concrete, thus relieving stress. The addition of any air entrainer increases slump, the obvious answer will be to reduce the amount of water in the mix and thus derive an even greater benefit in terms of increased durability.

An interesting comparison can be provided between:

1. An ordinary concrete mixed and cured at 5°C and
2. An identical concrete mixed and cured at 21°C.

The three day strength of the first concrete (5°C) could be expected to be only 30 percent of the three day strength of the second concrete. At seven days the relative strength of the low temperature concrete might be 50 percent and at 28 days 80 percent.

Ordinary concrete mixed at 21°C but placed in an ambient 5°C will gain strength fairly rapidly if the surrounding temperature increases.

## 8. Cracks in concrete

Concrete, when placed, is a mass containing more water than is required for hydration of the cement it contains and for subsequent curing. When the concrete hardens and starts to lose the excess water, shrinkage begins. Unrestrained concrete should not experience cracking due to drying shrinkage, however, it is virtually impossible to support a structure of any appreciable size without some restraint.

The cracking phenomenon is complex and depends upon a number of things – rate and amount of drying, drying shrinkage, tensile strength, tensile strain, creep, elasticity, degree of restraint and other factors. In the laboratory, drying shrinkage tests are the most easily and most frequently performed tests in relation to shrinkage/cracking problems. However, there is sometimes too much emphasis on the drying shrinkage of hardened concrete as the criterion of susceptibility to cracking.

### Types and causes

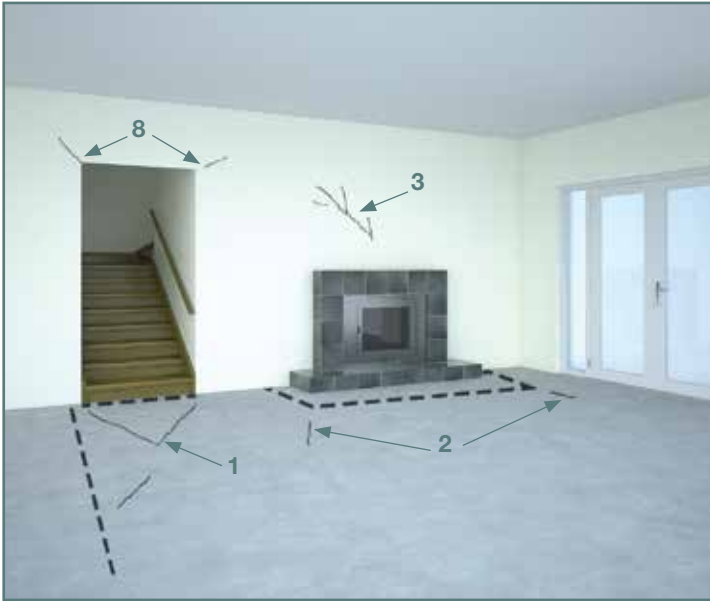
- Cracks and causes, can be divided into three broad categories:
- Cracks occurring before and during hardening.
- Cracks occurring after hardening of concrete.
- Cracking resulting from structural design or accident.

### Types of Cracks

1. Shrinkage cracks – avoid by cutting contraction joints along dotted lines.
2. Shrinkage cracks caused by stress concentration at corners – prevent by placing expansion joint along dotted line, or by using reinforced steel.
3. Settlement crack caused by movement of subgrade or footings.
4. Cracks due to heaving under slab through poor drainage of subgrade.
5. Expansion cracks – prevent by placing expansion joints at dotted lines.
6. Shrinkage cracks in feathered sections. Narrow feathered sections should be avoided.
7. Plastic shrinkage cracks, due to quick loss of water to subgrade or the atmosphere.
8. Shrinkage cracks at door or window corners – avoid by using reinforced steel or (in solid concrete walls) by careful placement of low slump concrete.



### Types of Cracks



inside

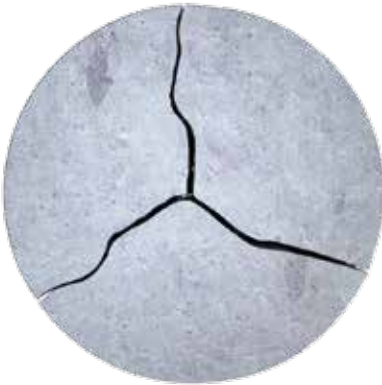


outside

## Cracks before and during hardening

Plastic shrinkage cracks occur when wind velocity, low relative humidity, high air temperature, or a combination of all three, cause water to evaporate from a concrete surface faster than it can be replaced by bleeding to the surface. The rapid evaporation that causes this cracking can be minimised by windbreaks, shading and efficient curing.

## Cracks after hardening

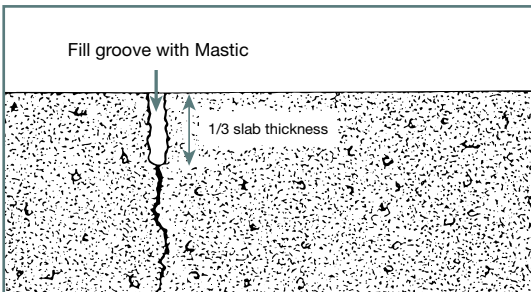


This category covers the performance of concrete after its form can no longer be altered without damage. It includes the cracks caused by the later stages of drying shrinkage, as well as those which result from the moisture movements which take place in almost all materials undergoing alternate stages of wetting and drying.

Contraction joints cut one third the depth of the slab permit concrete expansion and contraction and help establish direction of any cracking.

**Diagram at left:** Typical three-branch plastic shrinkage crack, caused by rapid loss of water soon after concrete has been finished.

Typical three-branched crack resulting from drying shrinkage.



## Grooves and joints

Shrinkage cracks cannot always be prevented, but they can be controlled by making planes of weakness to establish the direction of cracking when contraction occurs. This is done by cutting grooves one third the thickness of the slabs, and is done as soon as the concrete is hard enough to resist damage by the saw.

### In Summary:

The majority of cracks occur within 72 hours after concrete has been placed. These are preventative measures that will minimise cracking in this period.

- See that the subgrade is well compacted.
- Check that form work is firm.
- Ensure that subgrade and form work are moist before placing concrete.
- Do not add water to ready-mixed concrete at the point of placement.
- Adequately compact the concrete.
- Cut sufficient contraction joints to allow for shrinkage and/or provide crack inducers to control location of cracking at early ages.
- Provide expansion joints where necessary.
- Start curing as soon as possible.
- Maintain proper curing for an adequate period.



## 9. Concrete delivery requirements

At Boral we regard the safety and welfare of our people as our most important responsibility. We are committed to operating our businesses in a manner which ensures that our employees, contractors, visitors and the communities in which we operate are free from harm.

In seeking to meet our zero harm goal, Boral is committed to ensuring the safe delivery of our products and would like to formally draw your attention to our specific concrete delivery requirements set out below:

### Traffic Management

Our Drivers	Our requirements – for Customer planning
<p>Must be satisfied that they have a safe &amp; legal area for the truck to park &amp; discharge the load.</p>	<p>Authorised traffic control is to be in place if:</p> <ol style="list-style-type: none"> <li>1. the truck has to face oncoming traffic while discharging.</li> <li>2. the driver has to discharge the load on a main road or is in a hazardous position (e.g Bend or over the crest of a hill). In this case, barriers &amp; witches hats are required.</li> </ol>
	<p>Safe &amp; legal access for pedestrians:</p> <ol style="list-style-type: none"> <li>3. The customer must ensure that when the footpath is crossed or blocked by the trucks discharging that there is safe &amp; legal access for pedestrians.</li> </ol>
	<p>A spotter available at all times to guide the truck into position for discharge.</p> <ol style="list-style-type: none"> <li>4. Customers will need to ensure that the spotter is wearing Hi-Vis clothing, is at a safe distance from the truck and is visible to the driver at all times.</li> </ol>

### Environmental

Our Drivers	Our requirements – for Customer planning
<p>Have the right to refuse to enter any site if they believe that the truck will illegally drag contaminates offsite onto a public road upon their departure.</p>	<p>Cleaning facilities:</p> <ol style="list-style-type: none"> <li>5. Customers to provide a wheel wash, pressure washer or other means of cleaning wheels and a area to clean any contaminates from the truck before the truck leaves the site.</li> </ol>
<p>Are not to wash onto street where contaminates could enter storm water drains.</p>	<p>Wash down of chutes:</p> <ol style="list-style-type: none"> <li>6. customer to provide a skip or alternative.</li> </ol>



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# Power Lines

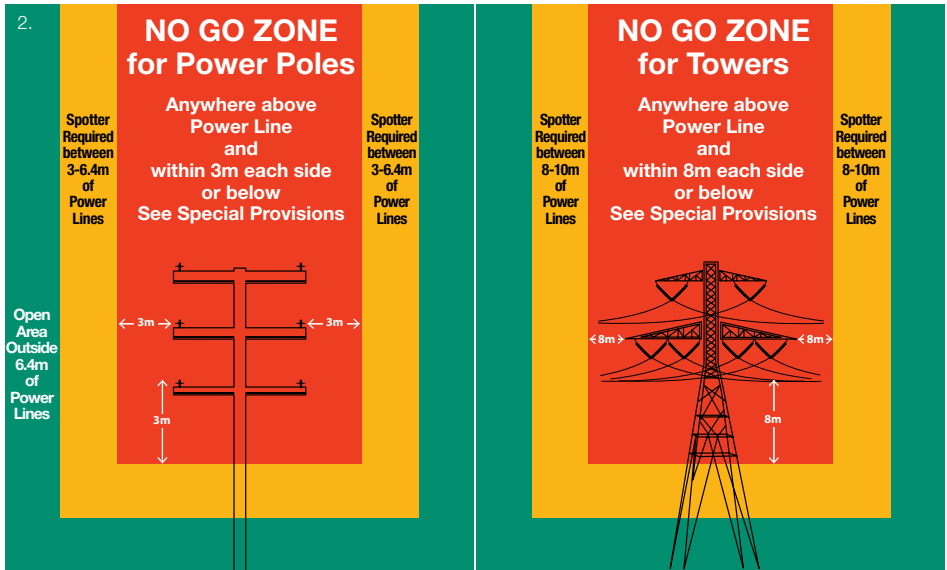
## Approach distances for work performed by ordinary persons

Phase to phase a.c. voltage (volts)	Approach distance (metres)
Up to 33,000 volts *	0.9
33,000 to 132,000	3.0
132,000 to 330, 000	6.0
Above 333,000	8.0

\*Note: the 0.9 separation distance relates to the following activities:

- Vehicles driving under power lines
- Trucks discharging while parked under power lines
- Vehicles and personnel under power lines that connect a domestic house to the power lines.

The separation distance increases to a minimum 3m for all other activities.



Source:  
 1] Work Cover New South Wales - Work Near Overhead Power Lines Code of Practice 2006.  
 2] [www.worksafe.vic.gov.au/\\_data/assets/pdf\\_file/0014/21704/ngz\\_overhead\\_power\\_lines.pdf](http://www.worksafe.vic.gov.au/_data/assets/pdf_file/0014/21704/ngz_overhead_power_lines.pdf)

## Cranes, Kibbles and Booms

### Approach distances for work performed by ordinary persons

Our Drivers	Our requirements – for Customer planning
<p>Must comply to all PPE requirements and ensure that Kibble is not overfilled.</p>	<p>Dogman or Spotter – Our Drivers must not be used as a dogman or spotter.</p>
<p>Are not to wash onto street where contaminants could enter storm water drains.</p>	<p>Loading Kibble -</p> <ol style="list-style-type: none"> <li>1. Customer to ensure truck driver is directed into position for discharging loads.</li> <li>2. The loading area must be clearly defined and kept free of obstructions and trip hazards.</li> </ol>
	<p>Slewing kibbles – Slewing of mobile cranes or booms cannot pass over truck - Kibble is to be raised above Agitator height and slewed away from personnel.</p>



# Open Trenches & Ramps

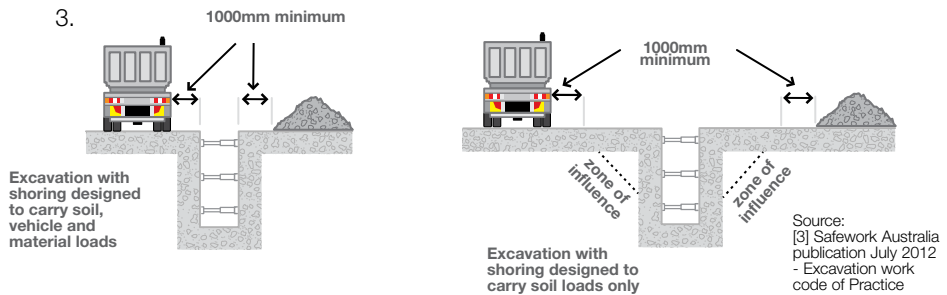
## Our requirements – for Customer planning

The minimum width for access road should be 3 metres clear of any building materials or debris:

1. The customer should consider extra width if there are any turns on the access road. The minimum distance any part of our truck must stay away from an open trench is the depth of the trench plus 1 metre.

This means for example:

1. If the trench depth is 500mm deep the truck must stay 1500mm away.
2. If the trench depth is 1 metre deep the truck must stay 2 metres away.
3. If the trench depth is 1.5 metres deep the truck must stay 2.5 metres away.



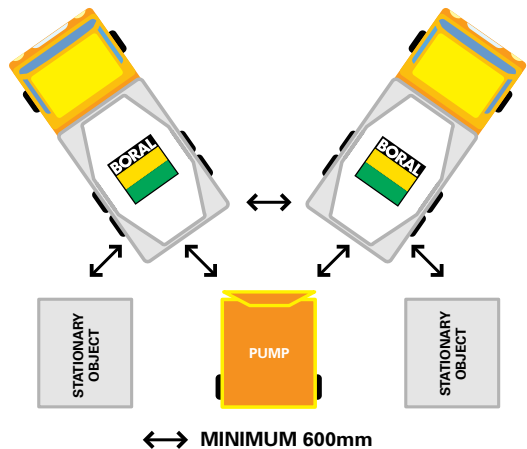
Source:  
[3] Safework Australia publication July 2012 - Excavation work code of Practice





# Pumping

Our Drivers	Our requirements – for Customer planning
<p>Must stand well clear of pump lines and couplings where practicable.</p>	<p>The concrete pumping area should be:</p> <ol style="list-style-type: none"> <li>1. reasonably level, solid and free of obstructions, with careful attention paid to positioning of the pumping equipment and any stabilising devices.</li> <li>2. clear of excavations, trenches or holes in the ground.</li> <li>3. clear of inadequately compacted or soft ground.</li> <li>4. clear of cellars, basements, pits or back-filled ground, to allow for the safe discharge of the concrete delivery trucks.</li> </ol>
<p>Must wear all required personal protective equipment:</p> <ol style="list-style-type: none"> <li>1. Safety Helmet</li> <li>2. Safety glasses</li> <li>3. Ear plug/muffs</li> <li>4. Hi-Visibility vest or shirt</li> <li>5. Work gloves</li> <li>6. Steel capped boots</li> </ol>	<p>The emergency stop should be visible to the driver and operational crew.</p> <p>We also require there to be a 600mm clearance between two trucks simultaneously feeding into pump hopper as demonstrated in the diagram below.</p>



Source:  
 [4] Cement Concrete & Aggregates Australia - Concrete Pump Delivery Industry Guidelines - page 13 - [http://www.ccaa.com.au/imis\\_prod/documents/CCAA\\_Concrete\\_Pump\\_Delivery.pdf](http://www.ccaa.com.au/imis_prod/documents/CCAA_Concrete_Pump_Delivery.pdf)

## Pumping cont.

Our Drivers	Our requirements – for Customer planning
Must never reverse without a spotter in place.	A spotter to assist reversing trucks must be provided by the contractor or pump operator.
	We require the provision of a safe location for the spotter, pump operator and truck drivers to prevent them from being caught between the reversing truck and the pump hopper, other trucks or stationary objects.
Must never stand on the pump truck or straddle between the concrete truck and the pump truck.	Our customer must ensure they have a competent person reversing trucks onto the receiving hopper at all times.
	The primary chute on concrete trucks should only be moved when the truck is stationary. It is preferable for the truck driver to perform this task. If another worker performs this task then the permission of the driver should be obtained.
	The concrete receiving hopper should be at a height that allows a gravity flow of concrete into the hopper.
	The pump must be fitted with a secure hopper grate constructed of parallel bars. A grill must be provided to prevent access to dangerous moving parts such as feed or agitator mechanisms and valve gear.

**NO ONE SHOULD EVER BE ALLOWED OR ABLE TO STAND BETWEEN A REVERSING TRUCK AND THE PUMP OR OTHER NEARBY STATIONARY OBJECT**

## Blowback – importance advice notification

- Blowback into a concrete truck can only occur if;
  1. a risk based process has been documented, and
  2. approval has been given by Boral.
- Allowing concrete to be blown back into the agitator barrel is an inherently dangerous procedure unless it is carefully controlled. Air pressure can cause anything inside the pipeline to act as a high velocity projectile.
- Blowback must occur via a well secured fixed line to prevent “whipping”. The steel pipe must extend 600 mm inwards beyond the barrel drip ring.
- Appropriate work platforms must be provided to fit the blowback line
- The pump operator is responsible for fitting the line.
- The driver is to be positioned forward of the pump truck cabin.

## Road Surfaces & Gradients

- Forward road gradients are not to exceed 1 metre high for every 10 metres in length (1:10)
- Cross slopes are not to exceed 1 metre high for every 10 metres in width (1:10)
- The road surface are to be compacted (or able) to sustain;
  - 23 tonnes (6 wheeler concrete truck)
  - 28 tonnes (8 wheeler concrete truck)
  - 32 tonnes (10 wheeler concrete truck)
- Self draining (free from pooled water)
- One way roads are to be 1.5 times the width of the concrete truck with passing bays (a minimum of 16 metre in length and 4 metres wide)
- Two way roads are to be 2.5 times the width of the concrete truck.





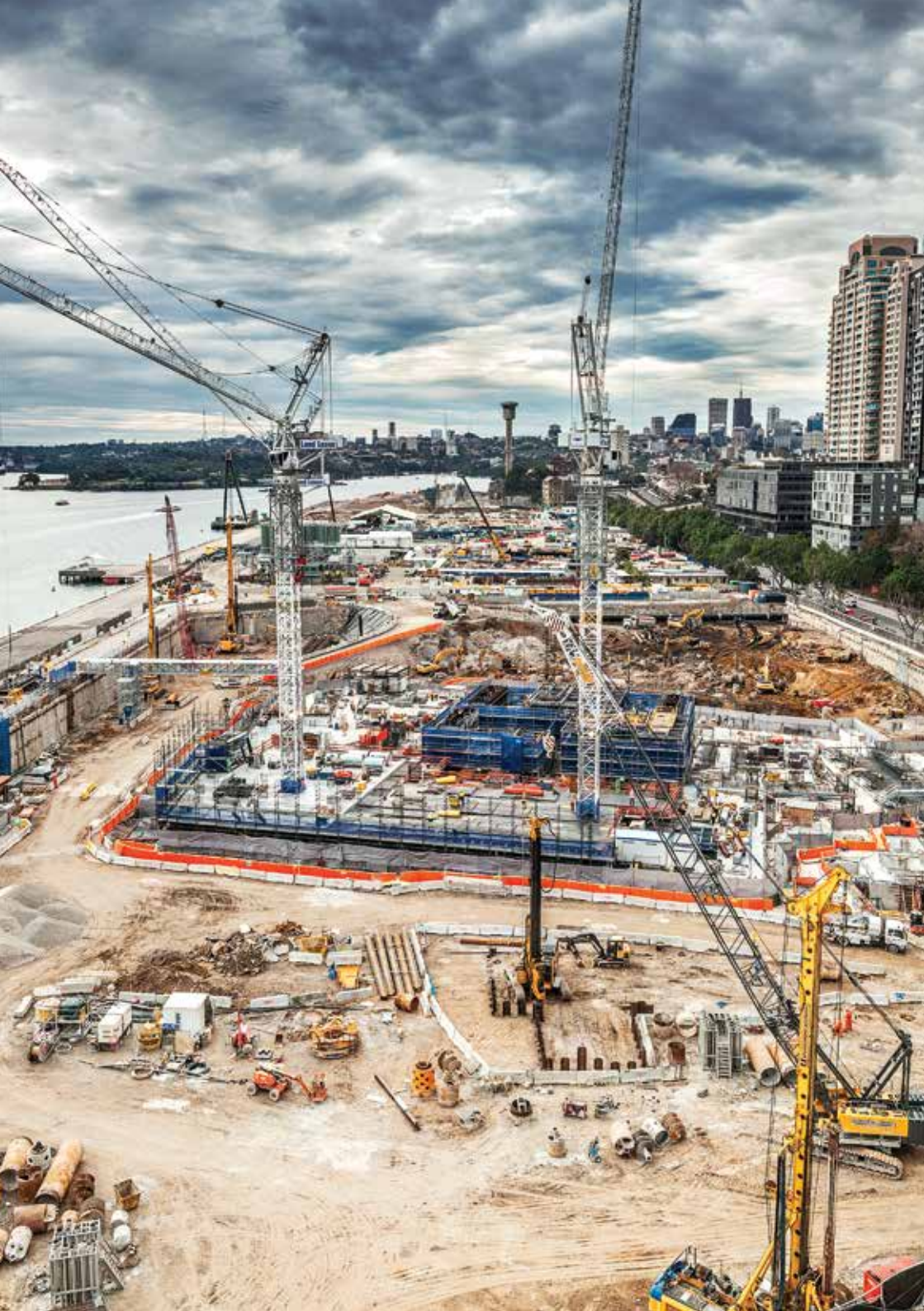
## 10. Safe handling of concrete

Concrete is a very alkaline material and if not handled properly, and with the appropriate personal protective equipment (PPE), caustic burns may be experienced.

Boral's Concrete Safety Data Sheet (SDS) can be viewed at; <http://www.boral.com.au>

The page '1 of 7' of the referenced SDS is included below;

BORAL CONCRETE Safety Data Sheet		
<a href="http://www.boral.com.au">www.boral.com.au</a>		
<b>1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER</b>		
<b>1.1 Product identifier</b>		
<b>Product name</b>	BORAL PRE-MIXED CONCRETE	
<b>Synonym(s)</b>	BORAL COLOR® • BORAL EXPOSE® • BORALSTONE® • ENVISIA® • GROUT • READY-MIXED CONCRETE • WET-MIX CONCRETE	
<b>1.2 Uses and uses advised against</b>		
<b>Use(s)</b>	CONCRETE • WET MIX CONCRETE	
	Boral Pre-mixed Concrete is used for a wide variety of applications in building and civil engineering.	
<b>1.3 Details of the supplier of the product</b>		
<b>Supplier name</b>	BORAL CONSTRUCTION MATERIALS LTD.	
<b>Address</b>	Level 3, 40 Mount Street, Nth Sydney, NSW, 2060, AUSTRALIA	
<b>Telephone</b>	(02) 9220 6300	
<b>Email</b>	<a href="mailto:sds@rmt.com.au">sds@rmt.com.au</a>	
<b>Website</b>	<a href="http://www.boral.com.au">www.boral.com.au</a>	
<b>1.4 Emergency telephone number(s)</b>		
<b>Emergency</b>	1800 555 477 (6.30am – 5pm WST)	
<b>Emergency (A/H)</b>	13 11 26 (Poisons Information Centre)	
<b>2. HAZARDS IDENTIFICATION</b>		
<b>2.1 Classification of the substance or mixture</b>		
CLASSIFIED AS HAZARDOUS ACCORDING TO AUSTRALIAN WHS REGULATIONS		
<b>GHS classification(s)</b>	Skin Corrosion/Irritation: Category 2 Serious Eye Damage / Eye Irritation: Category 2A	
<b>2.2 Label elements</b>		
<b>Signal word</b>	WARNING	
<b>Pictogram(s)</b>		
<b>Hazard statement(s)</b>		
H315	Causes skin irritation.	
H319	Causes serious eye irritation.	
<b>Prevention statement(s)</b>		
P264	Wash thoroughly after handling.	
P280	Wear protective gloves/protective clothing/eye protection/face protection.	
<b>Response statement(s)</b>		
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.	
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.	
P321	Specific treatment is advised - see first aid instructions.	
P332 + P337 + P313	If skin or eye irritation occurs: Get medical advice/ attention.	
P362	Take off contaminated clothing and wash before re-use.	
<a href="http://www.boral.com.au">www.boral.com.au</a>		
Page 1 of 7		SDS Date: 2 June 2015 Version No: 1



## 11. Products

### General Purpose Concrete

Boral provides a range of concrete products are designed for general purpose applications such as slabs on ground, footpaths, foundations and general paving, and are able to for every day applications.

### Special Purpose Concrete

With more than 100 years in concrete manufacturing, Boral's team of technical specialists have formulated a wide range of concrete products for special purpose applications to help you deliver your project on time. These products include, but are not limited to;

- high durability
- post-tensioned
- high pumpability
- pool mix
- piling concrete
- no-fines (permeable concrete)
- lightweight, etc.









## Decorative Concrete

Boral's Decorative Concrete category consists of Boralstone®, Exposé®, Colori® and the ingredient brand Luminesque® (glow in the dark aggregate) which can be sold as a complementary product. All category ranges incorporate the functionality and strength with design flair and aesthetic appeal.

## Boral's Advanced Concrete Range

Developed with the assistance of Boral's highly respected concrete research and development laboratory, Boral's high performance concretes have been used in many highly technical and demanding projects around Australia.



## 12. Glossary of terms

Term	Definition
<b>Admixture</b>	A material other than water, aggregate and cement, used as an ingredient of concrete to alter its basic characteristic.
<b>Accelerator</b>	A chemical which, when added to concrete shortens the time of set, or increases the rate of hardening or strength development.
<b>Aggregate</b>	Granular material such as sand, gravel, stone and slag, which when bound together by portland cement paste forms concrete
<b>Aggregate – Heavyweight</b>	A heavier than normal aggregate such as barite, magnetite, limonite, illemenite, iron or steel used to produce extra heavy concrete.
<b>Aggregate – Lightweight</b>	A lighter than normal expanded aggregate made from basic materials such as clay, slate, fly ash, vermiculite, pumice or scoria used to produce lightweight concrete.
<b>Air Entraining Agent</b>	An admixture for concrete which causes air to be incorporated in the form of minute bubbles in the concrete during mixing, usually to increase its workability and frost resistance. Normally expressed as AEA.
<b>Amorphous Silica</b>	A very fine pozzolanic material composed mostly of non-crystalline silica; commonly referred to as 'silica fume'.
<b>Batch Plant</b>	An installation of equipment including bins, batchers and/or mixers as required for batching or for batching and mixing concrete materials; also called mixing plant when equipment is included.
<b>Bonding Agent</b>	A substance applied to an existing surface to create a bond between it and a succeeding layer as between a sub-surface and a terrazzo topping.
<b>Broom Finish</b>	The surface texture obtained by stroking a broom over freshly placed concrete.
<b>Bush Hammer Finish</b>	A finish on concrete obtained by chipping off the surface mortar

<b>Cement Content</b>	Quantity of cement, fly ash and ground granulated blast furnace slag contained in a cubic metre of concrete.
<b>Cement – Expansive</b>	A special cement, which when mixed with water, forms a paste that tends to increase in volume at an early age used to compensate for volume decreases due to drying shrinkage.
<b>Cement – High Early Strength</b>	Cement characterised by producing earlier strength in concrete than regular cement.
<b>Cement – Hydraulic</b>	A cement that is capable of setting and hardening under water, such as normal portland cement.
<b>Cement – Portland</b>	Hydraulic cement obtained by combining and burning limestone and clay to form amounts of gypsum, is then ground to produce a powder.
<b>Central Mixed Concrete</b>	Concrete that is completely mixed in a stationary mixer before it is transported to the job. It can be transported in mixer trucks, agitators or dump type trucks.
<b>Chute</b>	A rounded trough or tube for sliding concrete from a higher to a lower point.
<b>Compressive Strength</b>	The measured maximum resistance of a concrete specimen to compressive loading expressed in megapascals (MPa).
<b>Concrete</b>	A composite material which consists mainly of aggregate, portland cement and water, normally weighing 2100-2300kg per cubic metre.
<b>Concrete – Foamed</b>	Concrete made very light and cellular by the addition of prepared foam or by generation of gas within the unhardened mixture.
<b>Concrete – Lightweight</b>	Concrete made with lightweight aggregate; the unit weight of the resulting concrete is in the range of 800 to 2000kg per cubic metre.
<b>Concrete Pump</b>	An apparatus that forces concrete to the placing position through a pipeline or hose.
<b>Concrete – Reinforced</b>	Concrete construction that contains mesh or steel bars embedded in it.
<b>Construction Joint</b>	A normally keyed joint formed by a bulkhead between successive placements of concrete.

<b>Contraction Joint (Control Joint)</b>	A joint or deep groove separating concrete in a structure or pavement designed to prevent formation of cracks elsewhere in concrete.
<b>Conveyor</b>	A device for moving materials; usually a continuous belt, system of buckets, a confined screw or pipe through which material is moved by air or water.
<b>Core Test</b>	Compression test on a concrete sample cut from hardened concrete by means of a core drill.
<b>Corrosion</b>	Disintegration or deterioration of concrete or reinforcement by electrolysis or by chemical attack.
<b>Craze Cracks</b>	Fine, random cracks or fissures caused by shrinkage that may appear in a concrete surface within a few days of placement.
<b>Curing</b>	Maintenance of moisture and temperature of freshly placed concrete during some definite period following placing, casting or finishing to provide enough moisture and the proper temperature level to promote continued hydration within the hardened concrete.
<b>Drum Speed (RPM)</b>	The various rates of rotation of the drum of the mixer when used for charging, mixing, agitating or discharging. These various drum speeds are usually outlined on the mixer rating plate.
<b>Drying Shrinkage</b>	Contraction caused by moisture loss from hardened concrete sometimes resulting in cracks in the concrete occurring days, weeks, or months after placement.
<b>Dusting</b>	A defect in a slab surface; the powdering of the surface under foot or vehicle traffic. Usually caused by over trowelling wet concrete.
<b>Efflorescence</b>	A deposit of salts, usually white, formed on a surface, the substance having emerged from below carried by water vapour.
<b>Entrained Air</b>	Microscopic small air bubbles intentionally incorporated in concrete during mixing to improve durability and workability.
<b>Entrapped Air</b>	Large air voids in concrete that are not purposely entrained; generally larger than 1mm and are usually due to incomplete consolidation.

<b>Expansion Joint</b>	A separation in the concrete filled with compressible material to allow room for the expansion of the concrete in hot weather or movement due to other causes.
<b>False Set</b>	Premature stiffening of freshly mixed portland cement concrete. Plasticity can usually be regained by further mixing with no additional water.
<b>Flash set</b>	The rapid development of rigidity in freshly mixed portland cement concrete, usually building up considerable heat. Rigidity cannot be dispelled nor can the plasticity be regained by further mixing without addition of water.
<b>Flexural Strength</b>	The ability of concrete to withstand bending measured by breaking a test beam.
<b>Float</b>	A tool, usually of wood, aluminum or magnesium, used in finishing operations to impart a relative even (but not smooth) texture to a fresh concrete surface immediately after placement and strike off.
<b>Fly Ash</b>	The fine ash resulting from the burning of powdered coal in electric utility plants, sometime used as a mineral admixture.
<b>Ground Granulated Blast Furnace Slag (GGBFS)</b>	A glassy granular cementitious material resulting from the rapid chilling of molten iron blast-furnace slag.
<b>Grover (Jointing Tool)</b>	A tool used to form grooves or weakened lane joints in a concrete slab before hardening to control crack location.
<b>Gross Vehicle Load</b>	The weight of a vehicle plus the weight of a load thereon.
<b>Grout</b>	A mixture of cement and water with perhaps some fine material used to fill cracks and voids in concrete or to prime concrete pumps.
<b>Hardener</b>	A chemical applied to concrete floors to reduce wearing and dusting
<b>Hairline Cracking (Crazing)</b>	Small cracks of random pattern in a concrete surface caused by too rapid surface drying.
<b>High Early Strength Concrete</b>	Concrete that, through the use of high-early-strength cement or admixture, is capable of attaining specified strength at an earlier age than normal concrete.

<b>Mineral Admixture (Pozzolan)</b>	A fine powdered material such as fly ash that may be used to improve workability or strength characteristics of concrete.
<b>Mixer capacity</b>	The volume of concrete permitted to be mixed or carried in a particular mixer or agitator.
<b>Mortar</b>	Usually consisting of cement, water and sand; no coarse aggregate.
<b>Plastic Shrinkage Cracks</b>	Cracks that appear in fresh concrete during or just after finishing. They are often at an angle to side forms but parallel to each other.
<b>Pile</b>	A long slender timber, concrete or steel structural element driven, jetted or otherwise embedded on end in the ground for the purpose of supporting a load or of compacting the soil.
<b>Retarder</b>	An admixture which delays the time of set of concrete.
<b>Rubber Finish</b>	A finish obtained by using an abrasive to remove surface irregularities from concrete walls or columns.
<b>Schmidt Hammer</b>	(Trade Name), Swiss Hammer, or Rebound Hammer – a device used to estimate the compressive strength of hardened concrete by measuring surface hardness.
<b>Screed</b>	A tool for striking off the concrete surface.
<b>Segregation</b>	a) separation of the coarse aggregate from the mortar portion of the concrete, or b) improper balance of the aggregate sizes from stockpiles or bins resulting in stony or sandy mix.
<b>Self-Compacting Concrete</b>	Concrete that is able to consolidate under its own weight, without the need of vibration.
<b>Slump</b>	A measure of consistency or wetness of freshly mixed concrete.
<b>Slurry</b>	A wet mixture of water and portland cement (and pozzolans); usually containing no aggregate.
<b>Spalling</b>	A chipping or peeling off of concrete surface or corners.
<b>Superplasticizer</b>	A high range water-reducing admixture used to achieve very high slumps / spread of plastic concrete.

<b>Swirl Finish</b>	A non-skid curving texture imparted to a concrete surface during final finishing.
<b>Topping</b>	a) a layer of high-quality concrete placed to form a floor surface on a concrete base, or b) a dry shake application of a special material to produce particular surface characteristics.
<b>Truck-mixed Concrete</b>	Concrete, achieved by mixing in a truck mixer.
<b>Vibrated Concrete</b>	Concrete compacted by vibration during and after placing.
<b>Water Reducing Admixture</b>	A material that either increases workability of freshly mixed concrete without increasing water content or maintains slump with a reduced amount of water.
<b>Wet-mixed Concrete</b>	Concrete partially mixed in a plant mixer to intermingle the materials and to attain consistency; it is then discharged into a truck mixer where mixing is completed.







# ZERO HARM TODAY

Boral is a major player in the construction materials industry, with around 12,000 employees operating across more than 700 sites in Australia, Asia and North America.

Working as one global team, we are developing new products and better ways of getting them to our customers across the world.

We are playing a key part in creating a sustainable future for our industry.

In Boral we strive to deliver Zero Harm wherever we operate. Employees, contractors and everyone involved in Boral's operations should expect to go home at the end of their working day in the same condition in which they started work.







## Discover More

Boral products at [www.boral.com.au](http://www.boral.com.au)

Specific concrete information visit [www.boral.com.au/concreteproducts](http://www.boral.com.au/concreteproducts)

Concrete plant locations [www.boral.com.au/concretelocations](http://www.boral.com.au/concretelocations)

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