DATAsheet

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COLD-WEATHER Concreting

In some locations in Australia, the temperature ranges experienced in winter can present problems with concrete placement that need to be managed. AS 1379[1] requires that concrete temperatures at the point of delivery be within the range 5 to 35°C. When the air temperature falls below 10°C, while the concrete may be in no danger of freezing, it is usually recommended that precautions be taken firstly to ensure an acceptable minimum concrete temperature at the point of delivery and, secondly, due to the increase in time required for the concrete to gain the specified strength.

This Data Sheet provides guidance on the effects of low temperatures on the properties of concrete, on minimising those effects, and the precautions that should be taken against a sudden drop in air temperature at the time of placement. These effects and precautions are particularly significant in thinner concrete elements.

EFFECTS OF LOW TEMPERATURES

Low temperatures have a number of effects on the behaviour of the concrete; most of these are related to the reduction in the rate of cement hydration.

- **Extended Setting Times** The lower rate of cement hydration at low temperatures increases the setting times as shown in **Figure 1**. Combined with the increased time for bleed water to evaporate in low temperatures, concrete finishing operations will be delayed, and this may add cost. If the concrete is finished prematurely, problems may be experienced with delamination (or flaking) and weak, dusty surfaces. The practice of adding cement or cement/sand mixtures to the surface of the slab to use up excess water and allow finishing to proceed should be avoided as it will inevitably lead to poor wear resistance.

PRECAUTIONS should be taken against a sudden drop in air temperature at the time of placement.

CEMENT CONCRETE & AGGREGATES AUSTRALIA

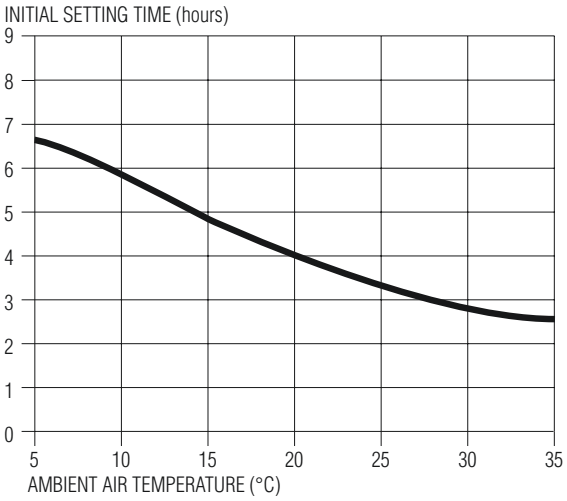

Figure 1: Typical influence of air temperature on setting times of concrete made with Type GP cement

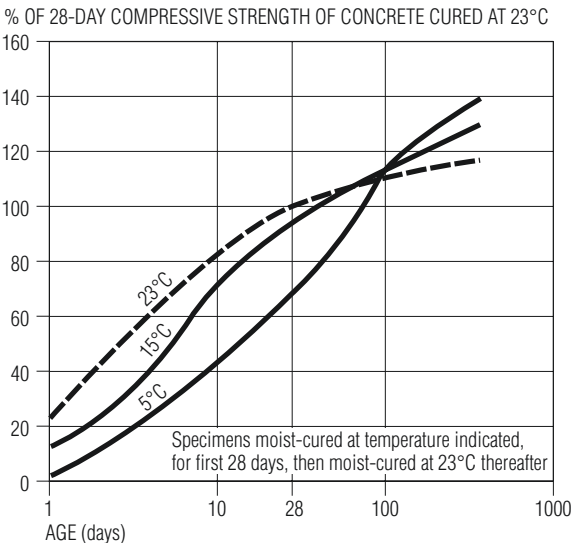

Figure 2: Typical effect of low temperatures on concrete compressive strength

Table 1 Stripping/removal times (based on AS 3600[2])
From *Guide to Concrete Construction*[3]

Average ambient temperature over the period, T (°C)	Period of time before stripping of formwork from reinforced slabs continuous over formwork supports – normal-class concrete (days)	Period of time before removal of all formwork supports from slabs and beams not supporting structures above – reinforced members only (days)
T > 20	4	12
20 ≥ T >12	6	18
12 ≥ T > 5	8	24

Note: Where the average ambient temperature over the period is less than 5°C or the superimposed construction load is greater than 2.0 kN/m^2, the periods will need to be increased (see Clauses 19.6.2.4 and 19.6.2.5 in AS 3600[2] for further details).

- **Slower Strength Gain** As **Figure 2** indicates, at low temperatures the gain in concrete strength is considerably slower than at normal temperatures; this will delay the removal of formwork. **Table 1** gives guidance on the minimum periods for which formwork and formwork supports must be left in place depending on the average ambient temperature over the period.
- **Cracking** The extent of cracking may also be increased, as the lower concrete strength may be inadequate to resist the drying shrinkage stresses and /or thermal stresses. The latter may result from the temperature difference between the inside and the (cold) surfaces of the element, particularly in thick sections.
- **Freezing** Freshly placed concrete is vulnerable to freezing conditions both before and after it has set. **As a general rule, concrete must be protected from freezing for at least 24 hours after placement.**
  If there is a possibility that freezing can occur prior to setting, precautions should be taken to protect the concrete elements or the concrete should not be placed.
  If allowed to freeze after setting (ie sudden drop in temperature overnight), the expansion of the water as it freezes will cause damage to the pore structure of the cement paste, thus reducing the potential strength of the concrete. The extent of the damage will depend on its age and strength when frozen.

MINIMISING THE EFFECTS OF LOW TEMPERATURES

Most methods to minimise the effects of low temperatures involve increasing the rate at which concrete gains strength under these conditions in the important early stage after placement. These include:

- **Cement Quantity** Increasing the quantity of cement (ie using a higher-strength concrete) can significantly increase the rate of strength gain. Note that there is little or no impact on the setting time.
- **Cement Type** High-early strength cements (Type HE) will gain strength more rapidly than general purpose portland cements (Type GP). Their use also results in heat being generated more rapidly within the concrete, thereby increasing its temperature. There is no significant difference in the setting times between the two types.
- **Lower Slump** Having less water in the mix will increase the rate of strength gain.
- **Reduced Time Between Mixing and Placing** This will minimise the drop in temperature of the concrete.
- **Admixtures** The addition of an accelerating admixture (non-chloride) to the concrete reduces the setting time and accelerates the rate of strength gain by increasing the rate at which the cement hydrates.
  Note that the use of admixtures containing chlorides should either be avoided, or their chloride content limited to comply with the requirements of AS 1379 and AS 1478.1[4].
- **Hot Water** Using hot water in the mix will raise the temperature of the concrete, which in turn accelerates the rate at which the cement hydrates. The temperature of mixing water should not exceed 70°C and mixing should ensure consistency in the temperature of the concrete delivered to site.
- **Air Entrainment** It may be possible to provide some protection against the effects of sudden freezing by incorporating an air-entraining admixture into the concrete. These admixtures create minute air pockets/spaces into which pore water can move as it expands during freezing.

ON-SITE PRECAUTIONS

It is desirable to take precautions against damage to the concrete by a sudden and unexpected frost or whenever the air temperature drops below 5°C. Precautions include:

- **Protection from the Cold** (including cold/frozen ground, winds and frosts). In some situations, the provision of a heated enclosure (light frames covered with tarpaulins and the use of hot-air blowers) to completely encase the concrete element may be required. Note that care should be taken to prevent the drying out of the concrete when using this approach.
- **Insulated Formwork** During the first 24 hours, hydrating cement generates a significant amount of heat which, if retained within the concrete by insulation, will protect it from freezing.
  Timber formwork is a reasonable thermal insulator and will probably suffice for moderately cold conditions. Additional insulation will be required for more-severe conditions, or for prolonged periods or freezing weather. Metal formwork offers little or no protection and should be insulated.
  Insulating materials should themselves be waterproof, or be protected to keep them dry, as many materials are excellent insulators when dry, but ineffective when wet. Note that expanded polystyrene sheets are relatively unaffected by moisture.
- **Delayed Stripping of Formwork** It is recommended that the formwork be left in position for as long as practical to protect the concrete from frost.
- **Curing** All concrete should be cured to ensure that it achieves its maximum potential strength and durability. During prolonged periods of freezing conditions this can pose particular problems as moist or water curing is rarely appropriate.
  Common solutions include use of an insulation blanket or covering, particularly where concrete has been placed in insulated forms. When formwork is removed, the member should be further cured by covering it with plastic sheeting, or tarpaulins, properly lapped at joints and secured to ensure wind-tightness.
  Note that concrete newly released from insulated formwork or heated enclosures should never be saturated with cold water. Rather, care should be taken not to suddenly expose warm concrete surfaces to cold conditions. The temperature of surfaces should always be allowed to fall slowly to avoid thermal cracking due to a temperature differential between the surface and interior of the element, particularly larger/thicker elements.

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SPECIFYING CONCRETE

Acceleration of concrete hardening can be assisted by the specification of one or more of the following concrete mix options.

- Higher cement content (or specification of a higher strength concrete)
- Lower slump
- Non-chloride accelerator
- Hot water batching where possible
- Winter admixtures and non-retarding superplasticisers
- Air-entrainment.

REFERENCES

1 AS 1379 *Manufacture and supply of concrete* Standards Australia, 1997.

2 AS 3600 *Concrete structures* Standards Australia, 2001.

3 *Guide to Concrete Construction (T41/HB64)* Cement & Concrete Association of Australia and Standards Australia, 2002.

4 AS 1478.1 *Chemical admixtures for concrete, mortar and grout, Part 1 Admixtures for concrete* Standards Australia, 2000.

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CCAA OFFICES

SYDNEY OFFICE:
Level 6, 504 Pacific Highway
St Leonards NSW Australia 2065
POSTAL ADDRESS:
Locked Bag 2010
St Leonards NSW 1590
TELEPHONE: (61 2) 9437 9711
FACSIMILE: (61 2) 9437 9470

BRISBANE OFFICE:
Level 14, IBM Building
348 Edward Street
Brisbane QLD 4000
TELEPHONE: (61 7) 3831 3288
FACSIMILE: (61 7) 3839 6005

MELBOURNE OFFICE:
2nd Floor, 1 Hobson Street
South Yarra VIC 3141
TELEPHONE: (61 3) 9825 0200
FACSIMILE: (61 3) 9825 0222

PERTH OFFICE:
45 Ventnor Avenue
West Perth WA 6005
TELEPHONE: (61 8) 9389 4452
FACSIMILE: (61 8) 9389 4451

ADELAIDE OFFICE:
Greenhill Executive Suites
213 Greenhill Road
Eastwood SA 5063
POSTAL ADDRESS:
PO Box 229
Fullarton SA 5063
TELEPHONE: (61 8) 8274 3758
FACSIMILE: (61 8) 8373 7210

EXTRACTIVE INDUSTRIES OFFICE
PO Box 243
Henley Beach SA 5022
TELEPHONE: (61 8) 8353 8151
FACSIMILE: (61 8) 8353 8151

TASMANIAN OFFICE:
EXTRACTIVE INDUSTRIES OFFICE
PO Box 246
Sheffield TAS 7306
TELEPHONE: (61 3) 6491 2529
FACSIMILE: (61 3) 6491 2529

WEBSITE: www.concrete.net.au

EMAIL: info@ccaa.com.au

LAYOUT: Helen Rix Design