DATAsheet

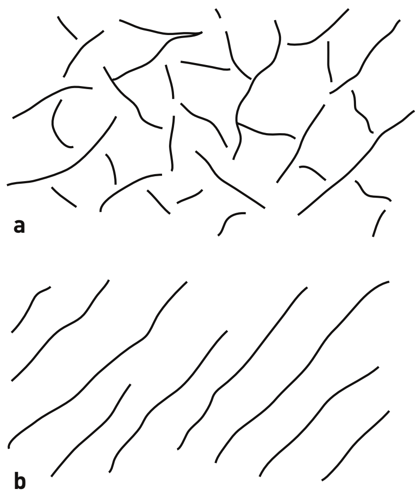
JUNE 2005

PLASTIC SHRINKAGE Cracking

WHAT ARE PLASTIC SHRINKAGE CRACKS?

Plastic shrinkage cracks are so-called because they form while the concrete is still plastic, ie has not set. Rapid drying of the surface of the plastic concrete causes it to shrink and crack, but the cracks are not always evident during finishing operations and may not be discovered until the next day.

Plastic shrinkage cracks may form in a random manner or be roughly parallel to each other. The cracks are often almost straight, ranging in length from 25 mm to 2 m but are usually 300 to 600 mm long, **Figure 1a and 1b**. They rarely occur near the edges of a slab as at those locations the concrete is usually free to move. They can be up to 3 mm wide at the surface but usually taper quickly over their depth but may penetrate right through a concrete element. These cracks form a weakness in the concrete and will be widened and/or extended by subsequent drying shrinkage and thermal movement.



Figures 1a and 1b: Typical shrinkage cracking

PLASTIC SHRINKAGE cracks may form in a random manner or be roughly parallel to each other.

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WHAT CAUSES PLASTIC SHRINKAGE CRACKS?

Simplistically, plastic shrinkage cracking occurs when the rate of evaporation of moisture from the surface exceeds the rate at which moisture is being supplied to it (via bleeding from the concrete). The concrete surface dries out and shrinks at a time at which it has little strength and hence it cracks. It can be likened to the cracking that occurs in clay soil as it dries.

Water is lost from the concrete mass in two main ways:

- **Drying from the top** Moisture rises to the top surface of a concrete element during placement – a process known as bleeding. Bleed water dries out mainly from evaporation; when the rate of evaporation exceeds the rate of bleeding, the surface dries and tends to crack.
- **Drying from the base** Water in a concrete slab may be absorbed into the subgrade or ground below. In addition to affecting bleeding this could significantly increase settlement of concrete and the risk of associated cracking.

The rate of evaporation from the surface is dependent on environmental factors such as temperature, relative humidity and wind speed. It is not just a hot weather phenomenon, as the combination of these factors may provide the worst conditions in cool weather with low humidity and wind.

Mix design sets the bleed capacity of the concrete. This may be changed from hot to cold conditions to suit the finishing operations and crack-control requirements. Concretes with low bleed potential (eg those containing a high proportion of fine material such as silica fume, fine aggregate, low slump) are more prone to plastic shrinkage cracking. However, mixes with high bleed characteristics are not recommended as a solution as they give rise to other problems (eg increased risk of plastic settlement cracking, crazing, delays in finishing processes, greater long-term shrinkage). Retarded concrete is also more prone to plastic shrinkage cracking because of the increased time that it remains in a plastic state.

The processes of screeding and finishing can also have an impact on the formation of plastic shrinkage cracks. Slower screeding rates and delayed trowelling can reduce the extent of plastic cracking.

Controlling the rate of drying of the surface (evaporation rate) is the key to avoiding plastic shrinkage cracking.

The evaporation rate can be determined from the relative humidity, air temperature, concrete temperature and wind velocity using the nomograph in **Figure 2**, or the equation developed by Uno[1]. Cracking is most likely to occur when the environmental conditions give an evaporation rate in excess of 1 kg/m^2/h. It is recommended that precautions be taken when the anticipated evaporation rate is likely to exceed 0.5 k/m^2/h.

Uno gives the following equation to calculate evaporation rate

$$E = 5([T_c+18]^{2.5} - r[T_a + 18]^{2.5})(V + 4) \times 10^{-6}$$

where

E = evaporation rate (kg/m^2/h)
r = relative humidity/100
T_a = air temperature (°C)
T_c = concrete (water surface) temperature (°C)
V = wind velocity (km/h)

NOTE: Temperature, humidity and wind velocity need to be measured on site to give a realistic picture of the evaporation conditions.

Both the nomograph and the equation are based on evaporation from a water surface and do not hold true after bleed water has disappeared from the surface, ie after the water sheen has disappeared.

IMPACT OF PLASTIC SHRINKAGE CRACKING

Plastic shrinkage cracking rarely impairs the strength of a concrete element. However, it will have a dramatic impact on the appearance of the concrete; where it penetrates full depth it may lead to water penetration problems.

PRACTICES TO MINIMISE PLASTIC SHRINKAGE CRACKING

To minimise the incidence of plastic shrinkage cracking:

- Dampen the subgrade and formwork, ensuring that any excess water is removed prior to placing concrete.
- In hot weather**,** lower the temperature of the fresh concrete by using chilled mixing water or replacing some of this water with crushed ice. See Data Sheet – *Hot Weather Concreting*[3].
- Protect concrete surfaces from drying out.
  - Erect wind breaks to reduce wind velocity over the concrete surface. This is often impractical, but can be accomplished when frames or walls are erected prior to a floor being placed.
  - Apply aliphatic alcohols over the surface immediately after screeding and while there is plenty of bleed water on the surface; repeat the application in severe conditions. These products reduce the rate of evaporation from the surface. They are not a substitute for curing.
- Commence curing regime promptly after finishing and continue for the specified period.
- The use of sufficient proportions of synthetic or steel fibres in concrete can provide improved control of plastic cracking[4].

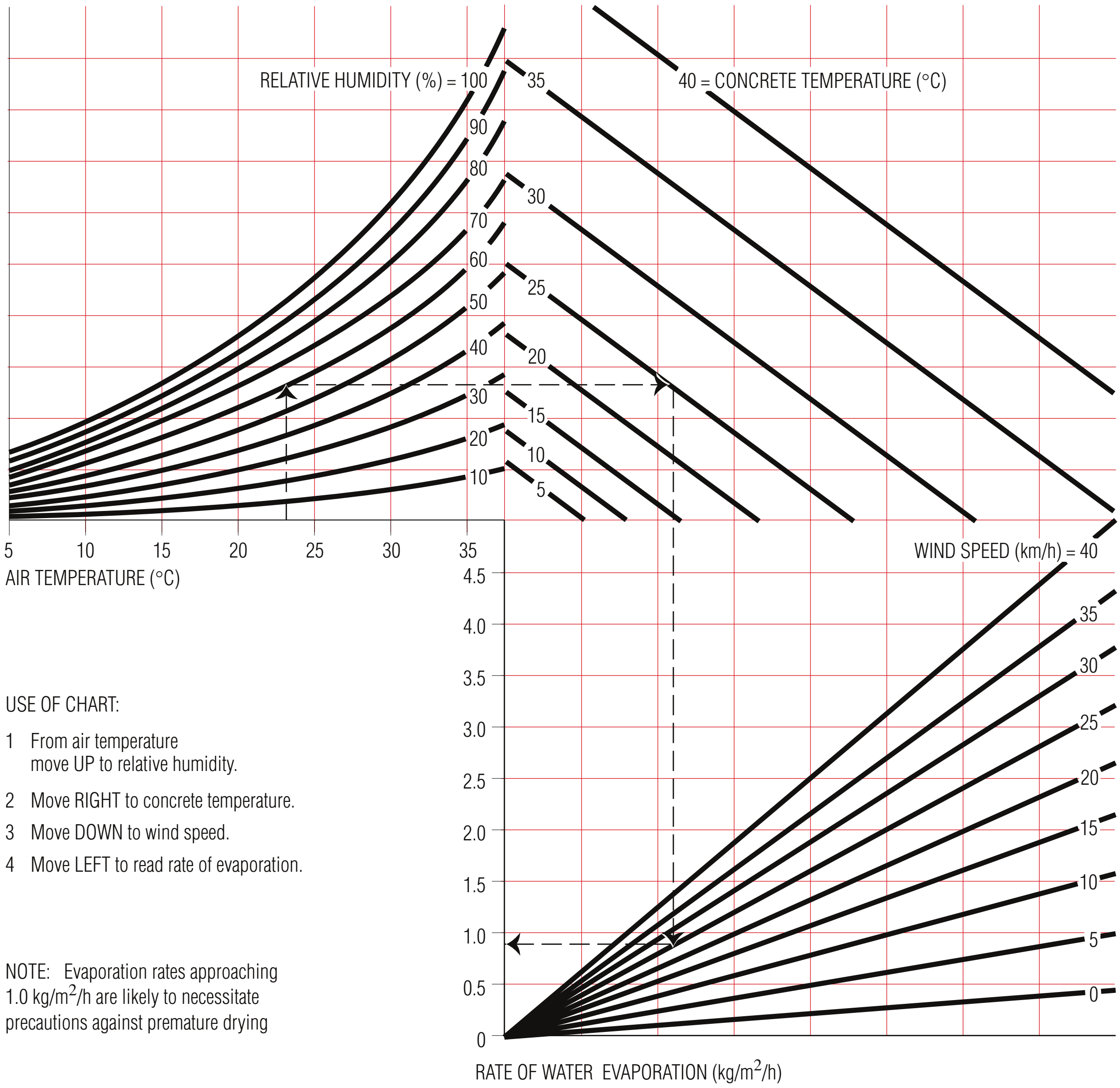

Figure 2: Effect of ambient conditions on rate of evaporation ACI 305[2]

REPAIR OF PLASTIC SHRINKAGE CRACKS

In pre-hardened concrete It is preferable to prevent plastic shrinkage cracking or to identify them while the concrete is still plastic and the surface can be re-worked to close the cracks, rather than rely on repair techniques.

Surface vibrators can be used to close the cracks over their full depth and the surface finishing can then be completed as specified. Careful timing is essential to ensure the concrete re-liquefies under the action of the vibrator and that the cracks close fully. Caution needs to be exercised in the use of re-trowelling alone since it may just form a skin (which can fracture with subsequent shrinkage, thermal or traffic impacts) over the cracks but not close them. If used it must be done as soon as the cracks become evident

Note: Additional working of the surface may change the colour and texture of the surface in that area.

In hardened concrete Once the concrete has hardened there is little that can be done. If the cracks are not wide at the surface then it may be best to tolerate them. Where they are of concern for watertightness or protection of the reinforcement, or 2 mm or wider, the cracks should be filled with a suitable proprietary filler. The object of such treatment is not to camouflage the cracks but to improve the performance of the concrete and ensure that the durability and wear characteristics of the surface are not impaired.

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REFERENCES/FURTHER INFORMATION

1 Uno, P 'Plastic Shrinkage Cracking and Evaporation Formulas' *ACI Materials Journal* Vol 95, No 4, July–August, 1998, pp 365–375.

2 ACI Committee 305. 'Hot Weather Concreting' *ACI Manual of Concrete Practice, Part 2: Construction practices and inspection, pavements* American Concrete Institute, Farmington Hills, USA, 2005.

3 CCAA Data Sheets:
Hot Weather Concreting
Plastic Settlement Cracking
Early Age Concrete Shrinkage
Download from **www.concrete.net.au**.

4 Naaman A E, Wongtanakitcharoen T and Hauser G *Influence of Different Fibers on Plastic Shrinkage Cracking of Concrete* ACI Materials Journal Vol 102, No. 1 January–February 2005, pp 49–58.

5 Dux P F *Mechanisms and Significance of Cracking in Concrete* Paper presented at Concrete Institute of Australia Symposium, Brisbane, September , 2000.

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

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