SUMMARY - ELIMINATING CRACKS IN CONCRETE

HOW TO REDUCE CRACKING & SHRINKAGE MOVEMENT IN CONCRETE

The hydration reaction between water and cement, which, when mixed, thickens, sets and hardens to become the glue that binds the aggregates in concrete, is initiated when the cement and the water first come into contact. The subsequent reactions of stiffening, setting, hardening and gaining strength are part of a continuous evolution of changing properties which begins in the first few hours of the life of the concrete.

It has **now** been confirmed that shrinkage movement in concrete – including through coloured concrete - is also a continuous spectrum, starting soon after the addition of water to the cement. This is the finding of recent Australian research on concrete, both in the laboratory and in the field, arranged by Dr Peter Dux at the University of Queensland.

It has been found that early loss of moisture from fresh concrete – including through coloured concrete - can produce large shrinkage strains in the material, with differential shrinkage occurring between the top and bottom surfaces of a slab. Shrinkage strains can develop within the first few hours after mixing concrete.

Therefore, the use of:

- a shrinkage control admixture in the concrete such as Ability's 'EFFLOREIN®' Mark 2 powder,
- proper and thorough compaction to eliminate air bubbles,
- the use of sprayed liquid aliphatic alcohol as an evaporation retardant onto the concrete's surface whilst it is being finished by floating,
- the use of effective curing procedures including the application of a single pack, membrane (thick) liquid ready-to-use curing compound such as Ability's 'Duro-Seel' Clear, and
- early (sometimes ***within*** 8 hours) saw cutting of joints at 1.5 – 2 mitre centres to a depth of ⅓ of the concrete's thickness to prevent visual cracking

are procedures seen as ***highly*** important in reducing the propensity of concrete to crack – particularly watertight concrete that may leak due to full depth cracking.

MECHANISMS:

The mechanism for these shrinkage strains is capillary suction, when even mild loss of free water establishes a state of discontinuous free water within the concrete. Suction is **created** in the least saturated zone and the concrete contracts.

A small part of the water loss is caused by the hydration reaction itself, but the biggest loss is by evaporation of water to the atmosphere. These losses can occur to a significant degree even in mild drying environments, such as indoors, so efforts to protect all concrete from early moisture loss will pay dividends in reducing the effects of early and later shrinkage movement.

As freshly placed concrete begins to stiffen, its tensile modulus, (stiffness) increases more quickly than its tensile strength. Restraint to movement of set concrete, coupled with the existence of early strains can therefore lead to rapid development of stress at a time when all the concrete's mechanical strengths are low.

This process forms weaknesses and small surface cracks which may become full depth cracks at a later stage. Many of the cracks eventually blamed on drying shrinkage are after about 14 days actually initiated within the first few hours of the life of the concrete.

In practice, restraints to shrinkage movements are always present, in the form of embedded reinforcement, friction against formwork, and friction against the ground beneath the slab. There will always therefore, be some propensity for the formation of weaknesses within the concrete and this increases with increasing moisture loss.

SITE PRACTICES:

Rapid drying conditions will exaggerate this problem of early shrinkage strain, as the resulting differential drying can make the fresh concrete rigid enough to crack at the surface. The early appearance of such cracks is already well documented as shrinkage cracking.

MINIMISE MOISTURE LOSS:

It is thus vital that all concrete be protected from early drying, and that extra precautions are taken when the environment promotes rapid moisture loss. Adverse environmental conditions include high air temperature, low humidity, direct sunshine and drying winds (hot ***or*** cold air moving over the concrete's surface).

A number of precautions have been shown to be effective in minimising moisture loss, which causes plastic cracking (cracking before setting) including construction of windbreaks (or delaying the casting of concrete slabs until after the erection of surrounding walls), spraying the concrete with water from fog spray nozzles, covering the concrete surface with plastic sheeting, or (often preferably) applying (possibly several times) ***a film of liquid aliphatic alcohol*** which prevents cracking prior to the concrete setting, and finally, as soon as concrete sets, applying a thick single coat of an effective liquid film forming ***curing compound*** coating - all of which act as moisture evaporation retardants.

In rapid drying conditions, these precautions ***must*** be applied rigorously, and the concrete surface must ***not*** be left in an unprotected state between concreting operations such as placing and finishing, (screeding, floating, trowelling, brooming and so on). If using aliphatic alcohol, which forms a moisture retarding film but not a coating and is NOT a curing compound, ***the material should be sprayed onto the concrete surface AGAIN after each separate concreting operation*** in order to restore the protective film on the concrete's surface.

IMPORTANT FINAL PROCEDURE :

When all concrete finishing operations have been completed, the important final procedure – the ***curing procedure*** - should be implemented immediately. This could take the easy form of applying a lasting clear liquid film forming single pack membrane curing compound such as Ability's 'Duro Seel' Clear.

Ponding with water to cover the concrete with a 30-50mm thick water bath or covering the concrete with ***continuously*** wetted woven material such as burlap or hessian cloth, or covering it with thick (150μm - 200μm) plastic sheeting are also procedures that may be used to cure concrete.

Whichever method of curing has been chosen, it is important that it be applied as soon as this can be done without harming the concrete surface. Since aliphatic alcohol is ***not*** a curing compound, it cannot be relied upon to reduce moisture loss once the concrete has set and the hardening reactions proceed.

AVOID AIR BUBBLES – COMPACT WELL :

Another vital aspect of concreting site practices which could have a large effect on cracking behaviour is the quality of compaction of the concrete to remove air voids. The presence of voids in concrete promotes cracking via stress concentrations when shrinkage strains occur.

Poor compaction leaves voids or air bubbles in concrete, thus allowing stress concentrations to form. Unfortunately, these voids conjointly:

- ✪ increase the strains due to early suction effects and
- ✪ reduce the tensile strength of the concrete.

In fact, the presence of voids in concrete reduces its tensile strength to a greater degree than its compressive strength, making crack initiation far more likely in poorly compacted concrete than in properly compacted concrete.

IDEAL SAW CUTTING :

The introduction of saw cuts in concrete flatwork creates new, stress-free boundaries and hence alleviates the effects of restraint. Saw cutting at approximately 1½ metre centres to the ideal depth of one third (⅓) of the thickness of the slab at an early stage of the concrete's strength development, preferably within 8-12 hours of setting, thus provides the best control of visual crack initiation, whereas delayed saw cutting will promote cracking.

SPECIFICATION OF SHRINKAGE:

It should be noted that current shrinkage models and tests used in Australian and many international Codes and Standards do ***not*** take account of this earliest shrinkage movement of concrete. Similarly, early age effects are not measured in standard shrinkage tests on concrete specimens.

Thus the earliest age shrinkage strains and their adverse effects discussed here will occur in any case and are best countered by the use of improved site practices, particularly the procedures of:

- ❁ ideal compaction,
- ❁ protection against moisture loss prior to setting,
- ❁ the easiest, promptest curing procedure to be commenced ***immediately*** after setting, or if the concrete's surface will not be damaged – just before the setting occurs, and
- ❁ early ideal saw cutting.

The use of tighter shrinkage limits when specifying concrete at current ages does ***not*** guarantee a more successful outcome. The adverse effects of poor site moisture retaining practices on the concrete ***far outweigh*** any advantage of later reduced drying shrinkage movement.

The test for 'drying shrinkage' is conducted on concrete which is cured under water for seven (7) days and then allowed to dry in air for a further seven (7) days.

The 'drying shrinkage' properties of N Class (normal class) pre-mixed concrete should suffice in most cases, whilst the specification of tighter limits should be based on the engineering needs for the structure, ie: don't specify a 'drying shrinkage' strain of 600 micro-strains when 1000 micro-strains will do.

SUMMARY OF RECOMMENDED GOOD SITE PRACTICES:

- ❁ Ensure proper compaction of the concrete as it is placed.

- ❁ Protect the concrete from early loss of moisture prior to it setting. This could involve multiple applications of a moisture evaporation retardant such as aliphatic alcohol.

- Initiate the chosen curing procedure immediately after completion of the last concrete casting operation, such as floating or broom finishing provided that the concrete's surface is not damaged by the procedure.

- Form sawn joints ***as soon*** as these can be done without producing rough edges on the saw cuts. **NOTE:** That at concrete temperatures above 29°C this might be as rapidly as only 4 to 6 hours after the concrete sets.

Could this summary above be the basis for *CHANGING* your current specification for concrete construction?

FURTHER INFORMATION:

For additional data, call Ability on (03) 9457 6488 or toll free on 1800 337 324, or email us at service@abilityproducts.com.au and speak to Anna, Dorothy, Bea, Michael, Peter or Robert, or go to our website www.abilityproducts.com.au.

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