ASH DEVELOPMENT ASSOCIATION

# HOW TO REDUCE SHRINKAGE AND THERMAL CRACKING IN CONCRETE

*By W. Barry Butler, CemConSult International*

FLY ASH TECHNICAL NOTES

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Photograph of saw cut concrete slab edge which includes a significant crack.

## INTRODUCTION

Cracking in concrete is unsightly and can cause significant durability problems. Exposure of the reinforcement to the ingress of water is a likely result, with the potential for corrosion and long term structural failure.

The use of fly ash in the concrete works in a variety of ways to reduce both the likelihood and the potential severity of cracking.

## MECHANISMS OF CRACKING

The strength of concrete is lowest when it is subjected to tension. Cracking in otherwise sound concrete is normally the result of excessive tensile stress. Such stresses may result from a deficiency in the structural design or its implementation. More commonly though, the stress will be caused by some form of shrinkage that has not been considered in the design.

## SHRINKAGE

Two of the major causes of shrinkage-induced tensile stress in concrete, are known to respond favorably to the inclusion of fly ash in the mix. The first of those causes is based on excessive water content in the concrete. The second is based on the thermal effects of cement hydration.

### 1. Water-related shrinkage

Within this area there are also several ways in which cracking may occur. All of the effects are related to the quantity of water which is used to ensure thorough mixing of the ingredients of concrete.

In fact, the unit water content of the concrete is one of more easily controllable factors influencing drying shrinkage. Other factors such as the aggregate type or source might not be so easy to vary. The use of quality fly ash in a concrete mix allows a reduction in water demand and hence reduces the shrinkage potential.

When concrete is placed, there is first a dormant period when surplus water in the concrete tends to bleed to the surface and evaporate. This process leaves water pockets under the larger aggregate particles and leads to settlement of the remaining material.

Settlement cracks then commonly appear in line with the bars of the top reinforcement.

As the setting process proceeds, further loss of moisture, by evaporation or absorption into the subgrade, can lead to plastic shrinkage cracks. Characteristically these are straight cracks with some slumping at the edges. They may be in the body of the concrete or may develop from settlement cracks. Once the cracks have occurred there is no quick fix.

### What about curing?

An important aspect in reducing the impact of cracking is the quality of curing achieved. To maximise strength, particularly in tension, it is important to slow the rate of drying out of the concrete.

Moisture is the best form of curing. As an alternative, curing compounds seal the surface to reduce the loss of water by evaporation. Whilst not as good as moist curing, in many cases this is the only practicable method.

A surface spray of aliphatic alcohol (curing compound) should normally be used between initial and final finishing. Aliphatic alcohol must be applied as soon as the concrete has been screeded to be useful.

In addition, the concrete should be shielded from drying winds and hot sun. Curing should never be ignored, since cracking is almost inevitable unless the concrete develops its strength potential.

In the longer term, after setting is complete, the concrete continues to dry out, inducing drying shrinkage stresses. Whether or not the concrete cracks will depend upon the level of stress and the tensile strength that has been achieved.

As with the early onset forms of shrinkage, the unit water content is the most easily controlled factor that influences the long term drying performance. As such, incorporation of fly ash (reducing water demand) into concrete together with an appropriate level of curing will both reduce the shrinkage stresses and increase the tensile strength. Both ways, the likelihood and severity of cracking are reduced.

## 2. Thermal Stress

The process of cement hydration generates heat. That heat rises to a peak which usually occurs during the first 24 hours. Heat generation is particularly significant in thick sections such as columns and major raft slabs. It is closely related to the cement content in the concrete with the higher strength grades being more susceptible.

Large structures can develop significant surface cracking due to the temperature differeantial between the hot interior and the cool surface. That differential leads to a build up of tensile stress in the surface of the concrete. In addition, the ultimate strength potential of portland cement concrete is reduced by this heating.

Fly ash was first used in concrete in gravity dams in USA in the 1930s to overcome these problems. The use of fly ash allows a reduction in the cement content of the concrete, thus reducing the potential heat generation. In addition, the fly ash reacts with the hydration products at a reduced rate to limit the temperature increase. This reduces the potential for differential expansion.

The differential expansion can also be caused by surface cooling of a concrete structure. Unreinforced pavements in particular, if left unprotected from cold night air can be vulnerable to thermal cracking in the early period. Such cracks usually go right through the slab.

As with shrinkage cracking, curing to protect the concrete from rapid cooling and drying during the first few days, is recommended to allow the concrete to develop tensile strength.

## DESIGN FACTORS.

One further area from which cracking commonly arises (particularly in residential slabs) is the positioning of reinforcement.

Where the designer has called for steel mesh to be within 30mm of the concrete surface it is important that the constructor achieves this. There is no benefit from reinforcement that ends up somewhere near the bottom of the slab. Control of surface cracking is lost. Clearly the appropriate steps need to be taken during the set up for the pour, to ensure that this possibility is excluded.

Changes in the width or thickness of concrete elements will lead to areas of increased stress. The designer will pay particular attention to key areas such as boxed out sections. Potential cracking in these areas is often addressed by incorporation of additional reinforcement or by joint placement to reduce the likelihood of crack formation.

## CONCLUSIONS

Cracking in concrete is undesirable and generally is the result of inadequacies in either design or construction. Fly ash may help in certain areas as described here, but it can never eliminate cracking completely. That can only be done through good design and attention to detail during construction.

*Further Reading*

Other Technical Notes and Reference Data Sheets are available from the Ash Development Association or your local representative.

ASH DEVELOPMENT ASSOCIATION OF AUSTRALIA
GPO Box 5257, SYDNEY, 2001 AUSTRALIA

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