SULPHATE ATTACK ON CONCRETE - What it is and how to stop it.

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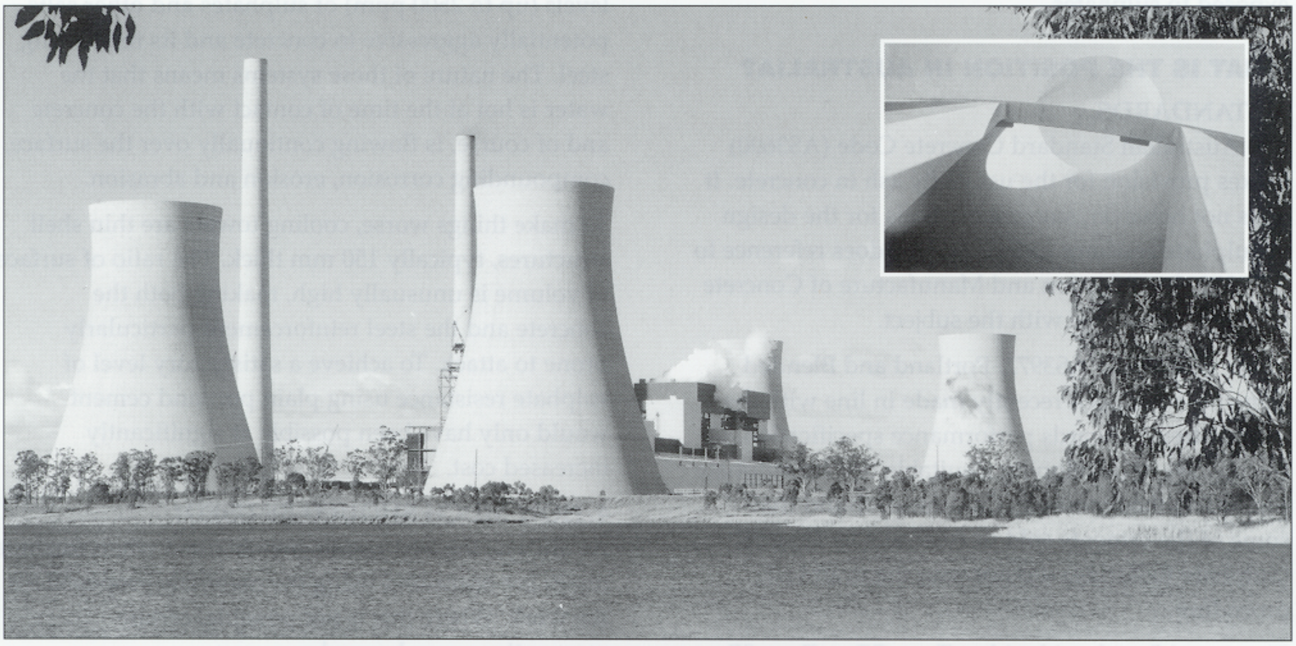

INTRODUCTION

Sulphate attack on concrete has the potential to cause serious damage or structural failures. Structures in potentially aggressive environments must be designed to recognise the risk of sulphate attack, and specific precautions taken in the design process to manage that risk.

The use of fly ash is well documented as a sound and economical method of achieving sulphate resistance.

HOW DO SULPHATES ATTACK CONCRETE?

Cured concrete in the presence of moisture can be susceptible to attack by sulphates. Those sulphates may be present in groundwater, seawater or from other sources. Attack occurs when the sulphates are able to react with the free lime released during hydration of the portland cement and with calcium aluminates present in the cement.

This reaction results in the formation of a range of sulphate compounds including sulphoaluminates. Because these compounds occupy a greater volume than the original concrete components they cause expansion and eventual failure of the concrete.

HOW TO PREVENT SULPHATE ATTACK ?

The key to prevention of sulphate attack is to tie up the free lime and calcium aluminates to eliminate the possibility of ongoing reactions.

As far back as 1908, Jewett reported the use of natural pozzolans (fly ash is a manufactured pozzolan) to combat sulphate attack in concrete. Dikeou, 1970, prepared the US Bureau of Reclamation Research Report No. 23 "Fly Ash Increases Resistance of Concrete to Sulfate Attack." In that report Dikeou found that all of the bituminous coal fly ashes (the type available in Australia) greatly improved the resistance of concrete to sulphate attack regardless of the type of cement used.

Dikeou explains "Increased sulfate resistance of concrete containing fly ash may be explained by the reaction of silica, alumina and ferric oxide found in fly ash with calcium hydroxide liberated during the hydration of portland cement to form relatively stable cementitious compounds."..."Greater impermeability of fly ash concrete reduces penetration of sulfate solutions and results in improved resistance to sulfate attack".

The British Building Research Establishment Digest 363 (July 1991) entitled "Sulphate and Acid Resistance of Concrete in the Ground" is strongly recommended for further reading on the impact of sulphates and precautions which can be taken. Recommended options for most levels of exposure include blends of various types of portland cement with fly ash. This technique is claimed to be effective particularly when the proportion of fly ash is between 25 and 40 percent of the total cementitious material.

The American Concrete Institute Guide to Durable Concrete (ACI 201-2R) also recommends the use of Class F (bituminous) fly ash as an aid to the prevention of disruptive expansion of concrete exposed to sulphates.

WHAT IS THE POSITION IN AUSTRALIA?

1. STANDARDS.

The Australian Standard Concrete Code (AS3600) makes provision for the use of fly ash in concrete. It does not however, suggest methods for the design of sulphate resistant concretes. Nor does reference to AS 1379, Specification and Manufacture of Concrete offer any assistance with the subject.

Major changes to AS3972, Portland and Blended Cements have been recently made in line with the current trend towards performance specification. In the process of developing a suitable test for sulphate resistance, the Standards Committee found that some of the cements sold in Australia as Type SR (Sulphate Resisting) did not pass the draft test procedure.

The use of fly ash with either Type GP or Type SR cements however will give assurance to the specifier of an increased level of sulphate resistance, to meet performance specification requirements.

2. LOCAL RESEARCH.

The Ash Development Association of Australia has sponsored research in progress at the CSIRO Division of Building and Construction Engineering at North Ryde. Interim results on mortars containing fly ash indicate that all of the commercial fly ashes tested provide significant reduction in expansion under sulphate exposure.

Strengths of exposed mortar specimens containing fly ash are significantly higher than those containing only the control cement. This result is found despite the fact that cement has been replaced directly by mass. Even better concrete may be achieved through replacement of a portion of the fine aggregate with fly ash. This portion would be in addition to the cement replacement.

Total binder proportions including 20% fly ash have produced more durable concrete than use of the control cement alone. Binder comprising 40% fly ash has given even better results again.

3. LOCAL EXPERIENCE.

Around Australia, the list of structures successfully protected from sulphate attack by the inclusion of fly ash in the mixture is too large for inclusion here. One example only will be mentioned, being fully documented.

At Bayswater Power Station in NSW the hyperbolic cooling towers were designed and constructed with concrete containing fly ash. The structures (which are 130 m high) have now been in service for over ten years with no signs of attack.

Closed circuit cooling systems quickly build up high levels (up to 2500 ppm) of sulphates and other salts potentially aggressive to concrete and its reinforcing steel. The nature of these systems means that the water is hot at the time of contact with the concrete and of course, is flowing continually over the surface, compounding corrosion, erosion and abrasion.

To make things worse, cooling towers are thin shell structures, typically 150 mm thick. The ratio of surface to volume is unusually high, making both the concrete and the steel reinforcement particularly prone to attack. To achieve a satisfactory level of sulphate resistance using plain portland cement would only have been possible at significantly increased cost.

4. HOW MUCH SHOULD BE USED?

As always, the best results are obtained when concrete mixes are optimised using the materials proposed for the work. Where this is not possible, certain assumptions may be made.

1. Any amount of fly ash in the concrete is likely to be better than none.
2. From the literature, a binder containing 40 % by mass of fly ash is commonly favoured. Given that enough cement must be present to ensure adequate early strength and long-term durability total binder content will vary depending on application. For a total binder content of 350 kg per cubic metre this would imply 140 kg of fly ash.
3. Where the size or importance of the works justify a full appraisal, the mix assessment described in Reference Data Sheet No. 1. should be adopted.

5. FURTHER READING

Most Fly Ash Technical Notes are supported by Reference Data Sheets giving detailed descriptions and references for the supporting data. Ask for these from your local ADAA member.

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