FLY ASH INCREASES RESISTANCE TO SULPHATE ATTACK

Soluble sulphates which exist in soils, ground waters and sewage waste corrode and eventually destroy Portland cement concrete *unless it is designed with fly ash to maximise sulphate resistance.*

SULPHATE ATTACK

Sulphate attack is a two-phased process:

1. Sulphates combine with soluble calcium hydroxide, generated from the hydration of Portland cement, to form calcium sulphate or gypsum. The volume of the resulting gypsum is greater than the sum of its components, causing internal pressures which fracture the concrete.

2. Aluminate compounds from Portland cement are attacked by sulphates forming a compound called ettringite. Ettringite formation ruptures the concrete in the same way gypsum formation does.

Fly ash has been found to be most effective in reducing this deterioration in two important ways:

1. The pozzolanic activity of the fly ash binds it to free lime (calcium hydroxide) released in the hydration of Portland cement. The fly ash and calcium hydroxide combine in cementitious compounds trapping the calcium hydroxide so that it is no longer available for reaction with sulphates. This prevents the formation of gypsum.

2. The cementitious compounds formed when fly ash and calcium hydroxide bond block bleed channels and capillary pores in the concrete making it impervious to aggressive dissolved sulphates. Since the sulphates cannot combine with cement aluminates, ettringite cannot occur.

Studies by the Bureau of Reclamation show that properly proportioned concrete utilising up to 35 percent fly ash will withstand sulphate attack far better than conventional Portland cement. The Bureau compared plain mixes and fly ash mixes using regular Type I cement, moderate sulphate resisting Type II cement and sulphate resisting Type V cement. Exposure conditions ranged from the normal test of continuous soaking in sodium sulphate to the severe test of alternating wet and dry exposure to sodium sulphate. In all instances, fly ash concrete dramatically outperformed conventional Portland cement concrete. These tests clearly demonstrated that Type II cement with fly ash outperformed Type V cement alone and that Type V cement with fly ash was the most resistant to sulphate attack.

Further work has correlated the chemistry of a given fly ash with its ability to resist sulphate attack through a mathematical equation called the R factor. The formula for determining R factor is as follows:

$$R = \frac{CaO - 5}{Fe_2O_3}(\%)$$

By this formula, as CaO (calcium oxide) increases and/or Fe_2O_3 (iron oxide) decreases, sulphate resistance decreases due to fly ash chemistry.

Limits have been established by the Bureau of Reclamation, requiring progressively lower R values as sulphate attack severity increases. These values are outlined in the following table:

R Limits[1]	***Sulphate Resistance[3]***
< 0.75	*Greatly improved*
0.75 - 1.5	*Moderately improved*
1.5 - 3.0	*No significant change[2]*
> 3.0	*Reduced*

Notes:
1. *For very severe cyclic conditions of wetting and drying or for $MgSO_4$ reduce the R value by 0.50.*
2. *Slightly improved to slightly reduced.*
3. *Compared to a Type II cement control at 0.45 W/C.*

Although R factor is an important criteria for selecting a fly ash for use in sulphate resistance, another fly ash property may enable a higher than desirable R factor to be used successfully. A high quality fly ash acts as a

strong water reducer and aids in reducing water/ cementitious ratio. Lowering water/cementitious ratio significantly can lead to more sulphate resisting concrete.

To ensure the most durable concrete possible, fly ash is an essential ingredient when the project will be vulnerable to attack by sulphates or other aggressive compounds.

ASTM CEMENT TYPES

The ASTM types of Portland cement are defined as follows:

Type	*Description*
I	*For use when the special properties specified for any other type are not required*
II	*For general use, more especially when moderate sulphate resistance or moderate heat of hydration is desired*
III	*For use when high early strength is desired*
IV	*For use when a low heat of hydration is desired*
V	*For use when high sulphate resistance is desired*

REFERENCES

1. Dikeon JT, "Fly Ash Increases Resistance of Concrete to Sulphate Attack", United States Department of the Interior, Bureau of Reclamation, *Research Report No 23*, US Government Printing Office, 1975.

2. Dunstan ER, "A Spec Odyssey - Sulphate Resistant Concrete for the 80's", United States Department of the Interior, *Water and Power Resources Service*, March, 1980.

3. Elfert RJ, "Bureau of Reclamation Experiences with Fly Ash and other Pozzolans in Concrete", Third International Ash Utilization Symposium, 1973.

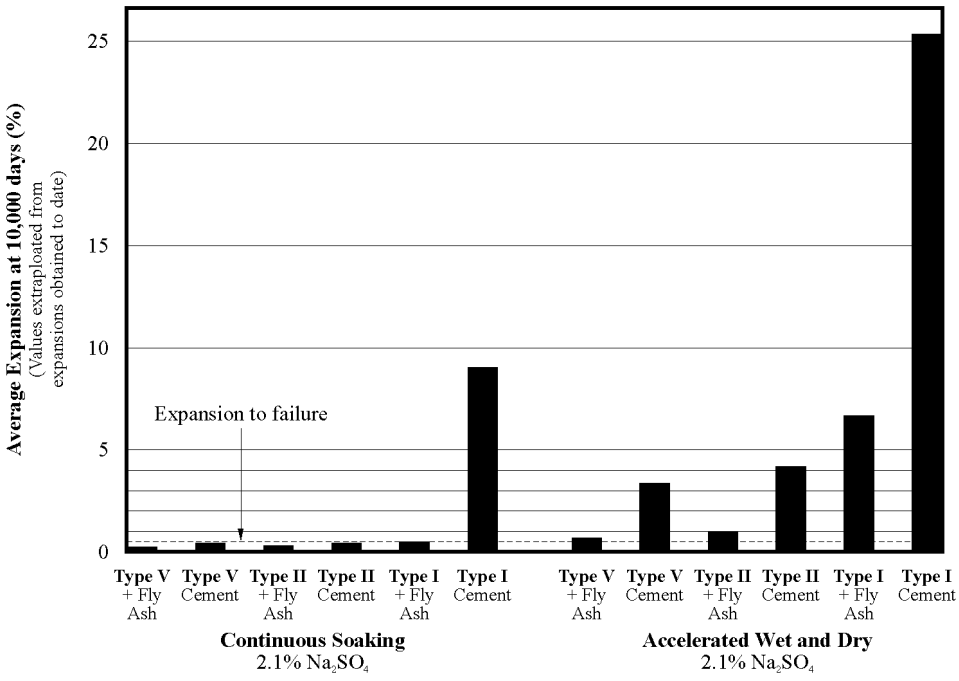

Figure 1: *Reduced expansion of concretes containing 30% fly ash illustrates improved sulphate resistance afforded by fly ash use*