Class F Fly Ash

INCREASES RESISTANCE TO SULFATE ATTACK

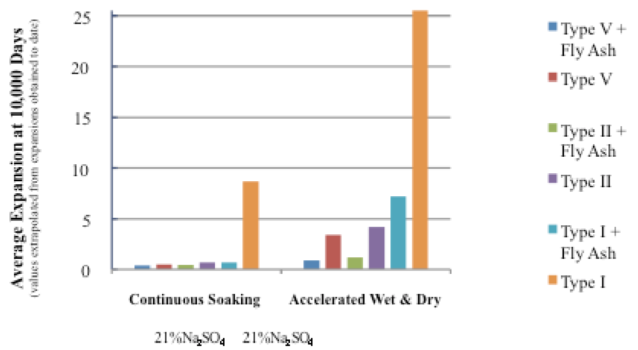
Sulfate Attack Is A Two-Phased Process
Sulfates combine with calcium hydroxide generated during cement hydration to form calcium sulfate (gypsum). The volume of this gypsum is greater than the sum of its components causing internal pressure and expansion, which fractures the concrete. Aluminate compounds from portland cement react chemically with sulfates and calcium to form a compound called ettringite (calcium sulphoaluminate). Ettringite formation destroys the concrete in the same manner as gypsum formation.

Fly ash effectively reduces this sulfate deterioration in three important ways:

1. Fly ash chemically binds free lime in cementitious compounds, rendering it unavailable for sulfate reaction.
2. Fly ash activity reduces concrete permeability keeping sulfates from penetrating concrete.
3. Replacing a portion of portland cement with fly ash reduces the amount of reactive aluminates, in particular tricalcium aluminate, available for sulfate reaction.

Studies by the United States Bureau of Reclamation (USBR) show that properly proportioned concrete utilizing up to 35% Class F fly ash will withstand sulfate attack far better than conventional portland cement. Concrete mixes, with and without fly ash, using Type I, moderate sulfate resisting Type II, and sulfate resisting Type V cements were compared under standardized conditions of exposure to sodium sulfate. In all instances, Class F fly ash concrete dramatically outperformed conventional portland cement concrete.[1,2] These tests clearly demonstrate that Type II cement with Class F fly ash was more resistant to sulfate attack than Type V cement alone.

Further USBR work correlates the chemistry of a given fly ash with its ability to resist sulfate attack through a mathematical equation called the R factor, formulated below:[3,4]



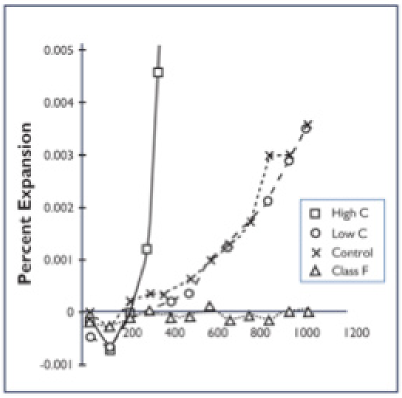
For more information or answers to questions about the use of fly ash in specific applications, contact your nearest Boral Resources Technical Sales Representative or call 1-770-684-0102

Revision Date: 1.15.18

Class F Fly Ash

INCREASES RESISTANCE TO SULFATE ATTACK

$$R = \frac{CaO-5}{Fe_2O_3}$$



Von Fay, Kurt and Pierce, James S., "Sulfate Resistance of Concrete with Various Fly Ashes", ASTM Standardization News, Dec. 1989.

R factor requirements are currently used in USBR concrete specifications. The limits established by the USBR requiring progressively lower R values as sulfate attack severity increases are as follows:

R Limits*	Sulfate Resistance***
<0.75	Greatly improved
0.75 to 1.5	Moderately improved
1.5 to 3.0	No significant change**
>3.0	Reduced

* R=(CaO-5)/Fe2O3 percentage from the fly ash oxide analysis. For very severe cyclic conditions of wetting and drying or for MgSO4, reduce the R value by 0.50.

** Slightly improved to slightly reduced.

*** Compared to a Type II cement control at 0.45 w/c2.

The Portland Cement Association (PCA) reports that the use of Class F fly ash improves sulfate resistance, while Class C fly ash is less effective in improving sulfate resistance and may even accelerate deterioration.4

ACI 232.2R-96 (Use of Fly Ash in Concrete) reports that fly ash with CaO content less than 15% will generally improve sulfate resistance. Fly ash with greater CaO content should be evaluated for use per ASTM C1012 or USBR test 4908.

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

1 Dikeou, J.T., "Fly Ash Increases Resistance of Concrete to Sulfate Attack", United States Department of the Interior, Bureau of Reclamation, Research Report No. 23, US Government Printing Office, 1975.

2 Dunstan, E. R., "A Spec Odyssey-Sulfate Resistant Concrete for the 80s", United States Department of the Interior, Water and Power Resources Service, March 1980.

3 Dunstan, E. R., "Fly Ash and Fly Ash Concrete", US Bureau of Reclamation, U.S. Government Printing Office, May 1984.

4 Helmuth, R. "Fly Ash in Cement and Concrete", Portland Cement Association, Skokie, IL, 1987.