# TB-0702 — The Use of FORCE 10,000D® for Sulfate Resistance Concrete Technical Bulletin

In areas where soils and ground water have high sulfate contents, or structures in a marine environment, concrete must be designed to resist sulfate attack. Solid sulfate salts do not attack concrete, but when present in solution they can react with hardened cement paste. When sulfates permeate concrete, expansive reactions occur with the cement hydration products: $Ca(OH)_2$ (calcium hydroxide) and calcium aluminate and silicate hydrates. Rapid disintegration of the concrete can result. Three common forms of sulfates are calcium, sodium and magnesium. Calcium sulfate attacks only calcium aluminate hydrate, while sodium sulfate attacks the calcium aluminate hydrate and the $Ca(OH)_2$. Magnesium sulfate attacks the calcium aluminate and silicate hydrates and the $Ca(OH)_2$. Under certain conditions, attack by magnesium sulfate is more severe than by other sulfates. Concrete can be designed for a long service life in an aggressive sulfate environment with the incorporation of silica fume. Silica fume protects against sulfate attack in two ways. First, it decreases concrete permeability, which prevents the ingress of the sulfate solution. Secondly, silica fume chemically binds some of the free $Ca(OH)_2$ in the paste preventing future reaction with sulfates. ACI 234 states that silica fume concrete has good resistance to sodium sulfate attack but does not work as well against magnesium sulfate.

Common preventive measures also include reducing the water/cement ratio to decrease permeability and providing air entrainment to allow room for expansive reaction by-products. The use of Type V cement, which is low in C3A (tricalcium aluminate), as a replacement for a higher C3A Type I cement, greatly increases sulfate resistance. However, the availability of Type V can be a problem. In addition, chloride resistance may be sacrificed when Type V cement is used. C3A chemically binds chloride ions leaving fewer ions available to attack embedded steel. In a concrete produced with Type V cement, less C3A is present to bind chloride ions than in Type I cement, and the potential for corrosion of reinforcing steel is increased. There are several references available showing superior sulfate resistance with the inclusion of silica fume in concrete. Research conducted by Rasheeduzzafar et. al., published in the ACI Materials Journal, March–April 1990, shows that Type I cement used with 20% silica fume provides more sulfate resistance than Type V cement. In these tests, cement paste cubes were immersed in a 5% sodium sulfate solution and tested for compressive strength at various ages over a 300-day period. Strength decreases measured the degree of sulfate attack. The conclusion of the work is that the use of Type I cement with silica fume can offer maximum protection against sulfate attack.

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