Silica Fume - Marine Concrete

SILICA FUME MARINE CONCRETE

Corrosion commences when chloride reaches the reinforcement and breaks down the natural passivity. The principal penetration mechanism is diffusion. Sorptivity plays a relatively minor role during the first few months. Provided sufficient oxygen is available at the cathode, and it usually is, the subsequent corrosion rate is controlled by the concrete resistivity. A design model based on these mechanisms (fig 2) comprises calculating the structures life (fig 3) as the sum of:-

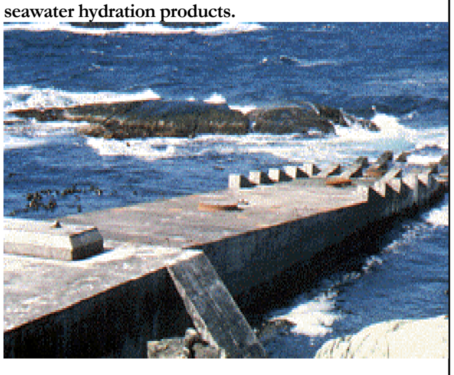
- t_o – the time taken for chlorides to reach the steel as controlled by chloride diffusion
- t_1 – the time taken for sufficient corrosion product to form to cause spilling as controlled by resistivity

The chloride diffusion rate of Silica Fume Marine Concrete is approximately 5-10 times lower than OPC concrete (fig 4) and the resistivity is about 5-10 times higher (fig 5). Hence the life expectancy, based on theory, would be increased by 5-10 times.

In practice, as shown from studies over 8 years on a Norwegian structure (fig 1), the pore structure of the concrete is so fine that seawater reaction may cause total blockage to penetration after the first few years in service. Chloride diffusion and resistivity testing can be difficult and time consuming to undertake. A rapid test that is dependent on these two factors was developed about 20 years ago and has found wide acceptance as a guide to concrete's corrosion resistance. Figure 6 shows that Silica fume marine concrete meets the requirement of less than 1000 Coulombs as stipulated by ASTM and AASHTO versions of a specification using this test.

Silica fume marine concrete is used to provide increased life expectancy or to enable reduced cover for the same performance. Figure 7, showing results of laboratory tests indicates 20mm of silica fume concrete is equivalent in performance to 50mm of an OPC, 50MPa concrete or 25mm of spun concrete.

Figure 1 - Karmoy Immersed tubes. The fine pores in the silica fume concrete became totally filled by the seawater hydration products.



SILICAFUME™ MARINE CONCRETE BENEFITS.

LONG LIFE

- 5x longer life than OPC concrete
- Indefinite life for low w/c ratio concrete

LOW COVER

- Cover up to 5x lower than OPC concrete
- Low dead weight of beams and columns

HIGH STRENGTH

- High early strength
- Early stripping of props and formwork
- Short curing required
- Use thin elements (results from reduced cover and high strength)
- Low temperature rise
- Low cost
- High abrasion resistance

LOW COST

- And maintenance compared to cathodic protection
- And risk compared to inhibitors

MARINE CONCRETE

Figure 2 - Corrosion Mechanisms. Chlorides diffuse to the reinforcing breaking down passivity. The ensuing corrosion rate is controlled by the concrete resistivity.

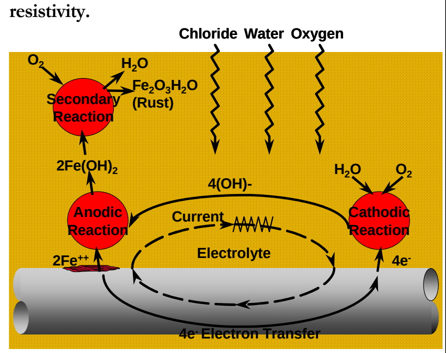


Figure 3 - Design model based on key corrosion mechanisms. T_0 is the time taken for chlorides to reach the steel and T_1 is the time taken to form sufficient corrosion product to cause spalling. Use of CSF extends both timeframes

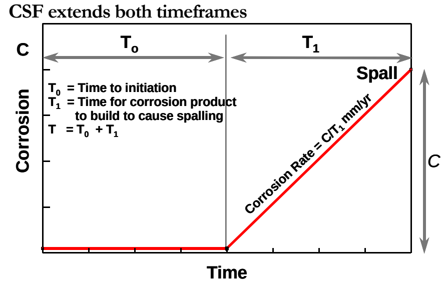
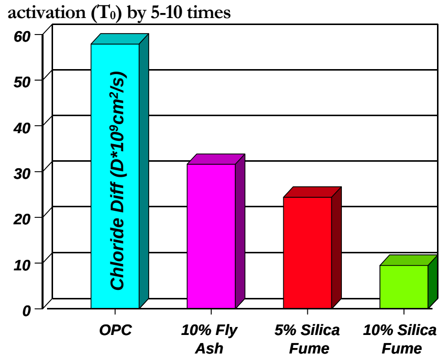


Figure 4 - Silica fume concrete (ref Gautfall 1986) has a chloride diffusion coefficient 5-10 time lower than an OPC concrete. This increases the time to activation (T_0) by 5-10 times



SPECIFICATION

Where silica fume concrete is to be used the general specification clauses outlined on the "Silica Fume Concrete" brochure shall be included in the concrete specification. Additionally silica fume marine concrete can be specified by including the following clauses in the standard concrete:-

1. Silica fume marine concrete shall be supplied with the following corrosion resistant properties:
   - Max rapid chloride permeability at 28 days = 1000 Coulombs
   - Min resistivity at 28 days = 20,000ohm cm
   - Max sorptivity at 28 days = $0.1mm/min^{0.5}$
2. Test reports showing that the proposed mix design has met these requirements in laboratory tests shall be provided to the Engineer before placing any silica fume marine concrete. Thereafter, the mix design shall not be changed without submitting details of the proposed alternative, together with RCP, resistivity and sorptivity results, which show compliance with the above.
3. The silica fume marine concrete mixes listed in the table below shall be deemed to comply with the requirements of clauses 1 and 2 provided $w/c < 0.4$.
4. Where concrete is to be placed on a flat slab, every precaution shall be taken to prevent plastic cracking.

Deemed to Comply Mix Designs for Various Seawater Exposures

General Environment	Min Cover (mm)	Min Silica Fume CSF (%)
Submerged		
Both Faces	-	-
Both Faces but close to water surface	-	8%
One Face	-	8%
Splash/Tidal	50mm	5%
	40mm	7%
	30mm	10%

Based on a design life of 50 years. The life of an OPC Concrete with 50mm cover is 19 years.

TECHNICAL SUPPORT

MARINE

Design life based on chloride diffusion and resistivity can be calculated using standard design formula. These are available on spreadsheets for engineers to make their own assessment of corrosion protection requirements.

GENERAL

Scancem Materials, are able to provide technical support related to most aspects of the use of concrete in construction. The support takes the form of:-

- Meeting with the Owner, Architect, Engineer and/or Contractor to develop a cost effective and technically appropriate silica fume concrete option that invariably offers advantages to all parties; "the win, win, win approach".
- Presentation to interested parties on the mechanisms by which silica fume concrete provides solutions to construction problems
- Report preparation that details the design methods and assumptions used for any analysis undertaken and include published papers supporting the use of these design methods.
- Use of computer model to calculate
- dosage of special additives.

SUGGESTED READING

1.Gautefall, O., "Effect of Condensed Silica Fume on the Diffusion of Chlorides through Hardened Cement Paste", ACI SP-91, Malhotra, V.M. (Ed), CANMET/ACI, Second International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Madrid, Vol II, Detroit, ACI, 1986.

2.Byfors, K., "Influence of Silica Fume and Fly Ash on Chloride Diffusion and pH values in Cement Paste", Cement and Concrete Research, Vol 17, No 1, January 1987, pp 115-130.

3.Berke, N., "Resistance of Microsilica Concrete to Steel Corrosion, Erosion and Chemical Attack", Proceedings CANMET/ACI Third International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Trondheim, Ed. VM Malhotra, SP-114, Vol 2, American Concrete Institute, Detroit, pp 816-886, 1989.

4.Vennesland, O., and Gjorve, O.E., "Silica Fume Concrete-Protection Against Corrosion of Embedded Steel", Proceedings CANMET/ACI Third International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Trondheim, Ed.

VM Malhotra, SP-79, Vol 2, American Concrete Institute, Detroit, pp 719-730, 1989.

5.Perraton, D., Aitcin, P.C., and Vezina,D., "Permeabilities of Silica Fume Concrete", Permeability of Concrete, Ed D Whiting and A Walitt, SP 108, American Concrete Institute, Detroit, pp 63-84 1988.

6.Baweja, D., et al, "High Performance Australian Concretes for Marine Applications" American Concrete Institute, Singapore, 1994.

Figure 5 - Resistivity of silica fume concrete exceeds the 20,000ohm cm limit set by Browne to provide a negligible corrosion rate (ref Baweja 1994).

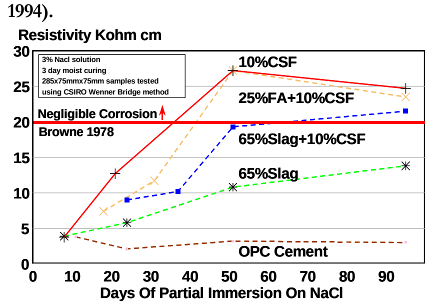


Figure 6 - Rapid chloride permeability results indicate that silica fume concrete meets the ASTM requirement of 1000 Coulombs.

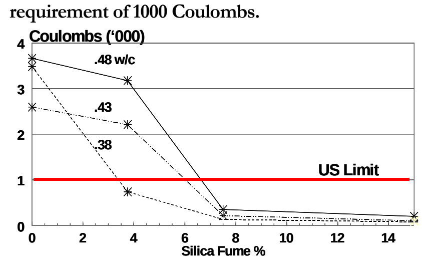


Figure 7 - AS3600 cover provisions for 50Mpa concrete and spun concrete are extrapolated for silica fume concrete based on chloride diffusion measurements of all three concretes