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:

- $t_0$ – 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 spalling 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. Additionally, silica fume marine concrete can be specified by including the following:

**SILICA FUME 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

**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.
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

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.

### Table: Deemed to Comply Mix Designs for Various Seawater Exposures

<table>
<thead>
<tr>
<th>General Environment</th>
<th>Cover (mm)</th>
<th>Fume CSF %</th>
<th>Silica Fume %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submerged</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both Faces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Close to water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Face</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splash/Tidal</td>
<td>50mm</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>40mm</td>
<td>7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30mm</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**


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**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.