Silica Fume - Sulphate Resistant Concrete

Ideal Alternative To Low C_3A Cement

INTRODUCTION

Research[2,6] over the last 10-15 years has shown several technical problems with the use of low C_3A cements (SRPC or type V cement). These problems are depicted in Table 1

Table 1 - Comparison SRPC and OPC+CSF

Silica fume SRC	SRPC (Low C_3A Cement)
High performance in all normal sulphate conditions	Poor performance at low sulphate concentrations
High rebar corrosion protection	Prone to rebar corrosion
Low chloride diffusion	High chloride diffusion
Very high resistivity	Low Resistivity
High 28 day strength	Low 28 day strength
Low cement content	High cement content
Economic design	High total cost
Low heat	High heat of hydration
Readily available	Special production often required
Moderate cost	High unit cost
Small storage volume with long shelf life	Large storage volume

SRPC (TYPE V CEMENT) HAS LOW SULPHATE RESISTANCE IN MODERATE EXPOSURES

Of particular concern is the fact that low C_3A cement based concrete may provide poor protection in moderate sulphate environments. The reasons for this low protection are that SRPC:-

- has a poor permeability due to the interconnected interfacial layers. Hence, the contaminating fluid penetrates the concrete quickly
- provides low resistance to the acidic form of attack that predominates when sulphates are not consumed in forming ettringite (fig 1)

Accelerated tests that are normally undertaken on concrete show SRPC provides high sulphate resistance. However, the effects of penetrability are not apparent and the form of attack is different to that at moderate concentrations in this rapid test.

Tests in moderate sulphate environments (fig 2 & 3) show that OPC outperforms the SRPC mix.

Various leading authors have ratified this alarming fact over the last 8 years.

BENEFITS OF SILICA FUME SULPHATE RESISTANCE CONCRETE

- Sulphate resistant at low and high sulphate concentrations
- Resistant to chloride ion penetration and corrosion propagation (NB chlorides are often present with sulphate)
- Silica fume represents a low proportion of the cementitious system making it
  - easy to store
  - low cost in relation to SRPC in some locations
- High strength leading to
  - low cement content low heat
  - low cost
- High early age strength for early formwork and propping removal
- Can be used for waterproofing

SRPC HAS LOW CORROSION RESISTANCE

Another major problem with low C_3A cements is that they increase the risk of corrosion.

C_3A binds chlorides to form Friedal salts. The chemically bound chlorides cannot penetrate so the total amount of chloride available for penetration is reduced. Hence in low C_3A cement concretes chloride ions diffuse to the steel rapidly exacerbating the corrosion problem.

SRPC GIVES LOWER STRENGTH THAN OPC AND HENCE HIGHER HEAT OF HYDRATION

Due to its chemical nature SRPC gives a lower 28 day strength than OPC. This leads to a high cement content, higher cost and higher heat of hydration than an OPC concrete of equivalent strength.

Fig 1 – Different mechanisms attack the concrete at different sulphate concentrations. Accelerated testing of low C_3A cement concrete may tell us nothing about performance at moderate sulphate concentrations (ref Mehta, 1982).

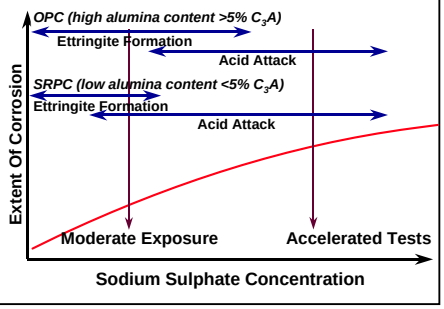


Fig 2 – At moderate sodium sulphate concentrations OPC concrete performs better than low C_3A sulphate resisting cement. Silica fume SRC performs far better than either of them (ref Fidjestol, 1990)

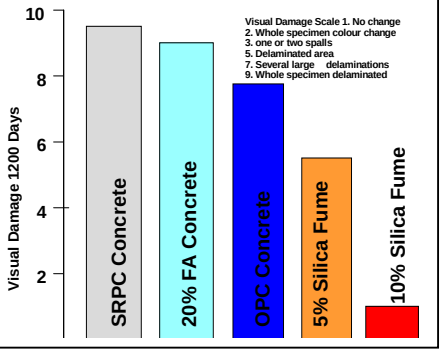
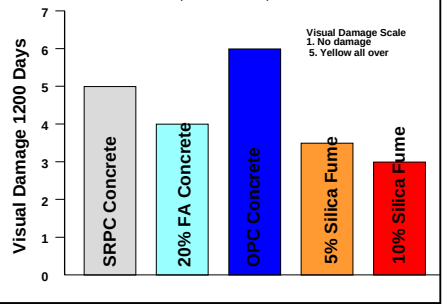


Fig 3 – At moderate magnesium sulphate concentrations low C_3A sulphate resisting cement performs better than OPC. Silica fume SRC performs far better than either of them (ref Fidjestol, 1990)



SILICA FUME SRC OUT PERFORMS ALL OTHER CEMENT SYSTEMS

Silica Fume SRC out performs other cementitious systems significantly in terms of:-

- Sulphate resistance in moderate environments
- Sulphate resistance in aggressive environments (figures 4 & 5)
- Corrosion Resistance
- Low heat of hydration

The excellent performance of silica fume SRC results from:-

- Dilution of the lime and C_3A reducing the amount of ettringite that can form.
- Lime consumption reduces the amount of gypsum available for formation of ettringite.
- Low permeability reduces the penetration of attacking sulphate. Of particular significance is the elimination of the transition zone which has been shown to be the main ingress path for sulphates.
- The formation of analogs of mono sulphate hydrate that are resistant to sulphates -

Silica fume SRC can be used to give protection against other sulphates and chemicals. Your silica fume Concrete supplier can obtain advice on this for you and provide suitable specifications.

Class	SO_4	Mg	CSF/Type1 Kg/m³	W/c
1	<300		Refer Code	
2	300-1200		-	0.50
3	1200-2500	<1000	7.5%	0.50
4a	2500-5000	<1000	7.5%	0.45
4b	2500-5000	>1000	10%	0.45
5	>5000	<3000	10%	0.45
5b	>5000	>3000	Corrocem	0.40

Table 1:Design guide for SFSRC

GENERAL

Scancem Materials are able to provide technical support related to most aspects of the use of concrete in construction. This 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 detail the design methods and assumptions used for any analysis undertaken and includes published papers supporting the use of these design methods.
- Use of computer models to calculate dosages of special additives.

Fig 4 – In the ASTM C1012 expansion test Silica fume SRC out performs low C3A cement. OPC performs very poorly in these high (5%) sulphate concentration tests (ref Hooton, 1993).

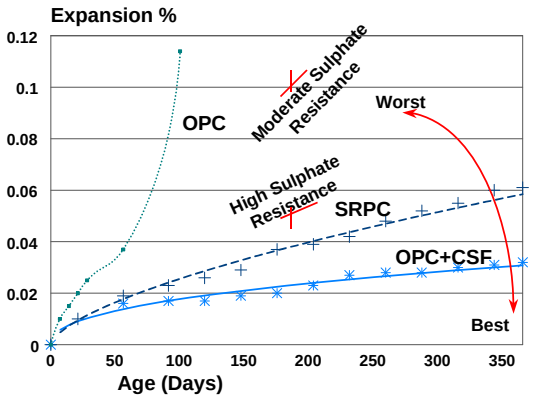


Fig 5 – In strength loss tests Silica fume SRC out performs low C3A sulphate resisting cements. OPC performs very poorly in these high (5%) sulphate concentration tests (ref Rasheeduzzafar, 1994)

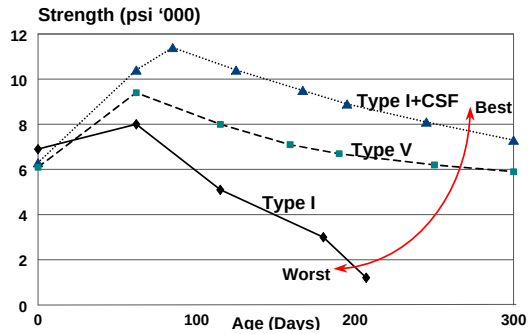
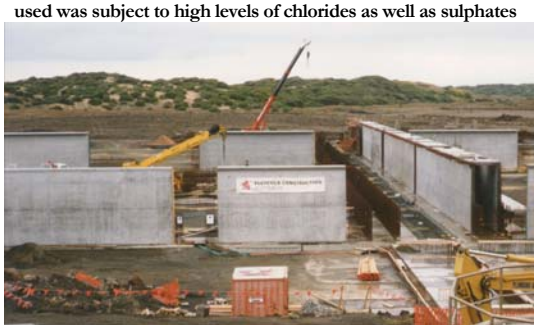


Fig 6 – Silica fume SRC was used for Blackrock sewage works. With the fascility only 500 metres from Bass Strait, all concrete used was subject to high levels of chlorides as well as sulphates



SUGGESTED READING

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2. Mather, K., "Current Research in Sulfate Resistance at the Waterways Experiment Station", Proceedings, George Verbeck Symposium on Sulfate Resistance of Concrete, SP-77, ACI, Detroit, 1982, pp 63-74.

3. Hooton, R.D., "Influence of Silica Fume Replacement of Cement on Physical Properties and Resistance to Sulfate Attack, Freezing and Thawing, and Alkali Silica Reactivity", ACI Materials Journal, Vol 90, No 2,1993, pp 143-161.

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6. Fidjestol, P., "Concrete For Low Sulfate Concentrations", Concrete Institute of Australia, Concrete for the Nineties, Leura, NSW, 1990.

7. Al-Khaja, W.A., Rasheeduzzafar, W.A., Al-Sayed, M.H., and Al-Khoder, A.A., "Sulfate Resistance and Chloride Penetration Characteristics of High Strength Concrete", High Performance Concrete, Proceedings ACI International Conference, Singapore 1994.

8. "Reinforcement Corrosion-Resisting Characteristics of Silica Fume Blended Concrete", ACI Materials Journal, Vol 89, No4, ACI 1992.

SCANCEM MATERIALS

Products For Engineered Concrete

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