# Elkem Microsilica®

CONCRETE

## Performance of Triple Blend Microsilica Concrete

C3-08
Properties

*Figure 1. The Tsing Ma bridge in Hong Kong is built in triple blend concrete*


### Summary

This data sheet is a review of a major trial, initiated in early 1991, that compared nine different concretes in terms of both physical characteristics and durability performance. The overall period of the trial was three years. The tests and the results obtained were all supervised, scrutinized or conducted by the British consultants Messrs. Sandberg.

**The findings indicate that the concretes using the microsilica blends out-perform the 'plain' concretes and give greatly increased durability.**

The full "Sandberg Report" is available from Elkem Materials or Messrs. Sandberg.


### Introduction

The purpose of the trial was to produce real-size batches of concrete, using standard UK materials in a readymix plant and to test these concretes for performance over an extended period of time. The scale of production and testing would also eliminate a number of the difficulties encountered when relating "lab tests" to the real world.

All the mixes were based on reference mixtures with 400 kg cementitious material to which would be added 10% micro-silica for comparison.

Water/cementitious ratios and workabilities were kept similar in all the concretes.
The general mix details are set out in Table 2, using the designations in Table 1. Quartzitic gravel was used in all the mixes except C and D as shown.

| | | |
|---|---|---|
| **Mix A** | OPC | (gravel aggregates) |
| **Mix B** | OPC/MS | (gravel aggregates) |
| **Mix C** | OPC | (limestone aggregates) |
| **Mix D** | OPC/MS | (limestone aggregates) |
| **Mix E** | OPC/GGBS | (50% ggbs) |
| **Mix F** | OPC/GGBS/MS | (50% ggbs) |
| **Mix G** | SRPC | |
| **Mix H** | as Mix A | (with Harex steel fibres) |
| **Mix I** | as Mix B | (with Harex steel fibres) |

*Table 1. Mix designations*

### Test programme and procedures

All testing was carried out according to the appropriate British Standard or equivalent, depending on the criteria examined. Any modifications made to a procedure for its use in this trial are noted in the listing below. Full test procedures are found in the complete report.

All the tests were not performed on all the concretes. Testing of the durability was restricted to mixes A, B, E, F and G.

The concrete was produced in 1 cubic metre batches in a pan mixer at a readymix plant. The concrete was then tested in the fresh state and cubes, cylinders, beams and prisms cast as required by the test regime. Excess concrete from each batch was cast

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| Mixes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Material** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| **OPC** | 405 | 395 | 415 | 405 | 200 | 200 | 405 | 400 | 395 |
| **GGBS** | - | - | - | - | 200 | 190 | - | - | - |
| **Microsilica** | - | 40 | - | 40 | - | 40 | - | - | 40 |
| **Coarse 5-20mm** | 1120 | 1210 | 1120 | 1250 | 1145 | 1215 | 1125 | 1115 | 1200 |
| **Sand** | 695 | 565 | 745 | 575 | 660 | 545 | 695 | 690 | 565 |
| **Water** | 175 | 177 | 186 | 178 | 192 | 191 | 184 | 179 | 191 |
| **Plasticiser** | - | 1.2 | - | 1.2 | - | 1.2 | - | - | 1.2 |
| **Steel Fibres** | - | - | - | - | - | - | - | 25 | 25 |
| **Water/Binder** | 0.43 | 0.41 | 0.45 | 0.40 | 0.48 | 0.44 | 0.45 | 0.45 | 0.44 |
| The plasticiser used was a standard lignosulphonate - added to aid the dispersion of the microsilica. | | | | | | | | | |

*Table 2. Mix design*

into separate blocks approximately one metre square by half a metre deep. The blocks were hand-compacted and float-finished and left exposed after 24 hour curing with a plastic sheet. The blocks were cored at six months for further testing and also used to measure the abrasion resistance.

All test specimens were stripped the day after casting and transferred to the test facility in a sealed damp condition.

Table 3 sets out those tests performed on the specimens and the exposed blocks.

## Results

Due to the size of the trial programme and the number of tests, it would be impossible to display all of the data from this report. Table 4 presents an overview of the data. Generally speaking, the performance of the microsilica mixes outperform the other mixes as seen from figures 2, 3, 4, 5, 6 and 7.

**The overall best mix in terms of durability is the triple blend of OPC/GGBS/microsilica.**

| Test | Standard | Remarks |
|---|---|---|
| **Workability** | BS 1881:102:1983 & 105:1984 | Concretes were tested for both slump and flow. |
| **Bleeding** | ASTM C232-90 | The bleed water was collected from the surface of a known weight of concrete and the result is expressed as a percentage. |
| **Compressive Strength and Density** | BS 1881:108, 114 & 116:1983 | Measured at a series of ages up to 6 months. |
| **Flexural Strength** | BS 1881:109 & 118:1983 | Measured at 28 days. |
| **Cylinder Strength** | BS 1881:110:1983 | Measured at 7 and 28 days and on some mixes at 6 months. |
| **Modulus of Elasticity** | BS 1881:121:1983 | Measured at 7 and 28 days and at 6 months. |
| **Abrasion Resistance** | C&CA rolling wheel apparatus (Concrete Society Technical Report 34) | Tested at 6 months on the in-situ cast blocks. Three hardened wheels under a load of 65 kg, run for 15 minutes on the concrete and the penetration depth is noted. |
| **Drying Shrinkage & Wetting Expansion** | BS 1881:5:1970 | |
| **Thermal Expansion** | Sandberg procedure TP F/4 | |
| **Water Absorption** | BS 1881:122:1983 | |
| **Porosity** | Belgian Standard NBN B15-217 | Test performed on mixes A, B, E, F and G only |
| **Water Permeability** | DIN 1048 | Test performed on mixes A, B, E, F and G only |
| **Chloride Diffusion** | Taywood Engineering procedures | Taywood has developed recognised techniques for measuring the diffusion of chlorides in concretes. The tests here were carried out on water cured cylinder specimens and on cores from weathered blocks of the test concrete. Test performed on mixes A, B, E, F and G only |
| **Electrical Resistance** | Taywood Engineering procedures | Using both a standard resistance meter and the Taywood resistivity meter. |
| **pH** | Sandberg - in house test | The pH is measured on a 1:1 extract of ground concrete in water. Test was not performed on mixes H and I. |
| **Sulfate Resistance** (flat prisms) | ACI SP91, Sandberg TP F/2 | |

*Table 3. Test programme*

The full report contains complete results and has analyses of different relationships such as strength to ‘E-modulus’, cube to cylinder strength, etc. There is also a discussion of the relative durability characteristics and the improvements gained through the use of microsilica.

## Reference


Sandberg report number X/602/45;
Microsilica Concretes - Trial Mix and Test Data - Final Three Year Report. Compiled by John P.H. Frearson.


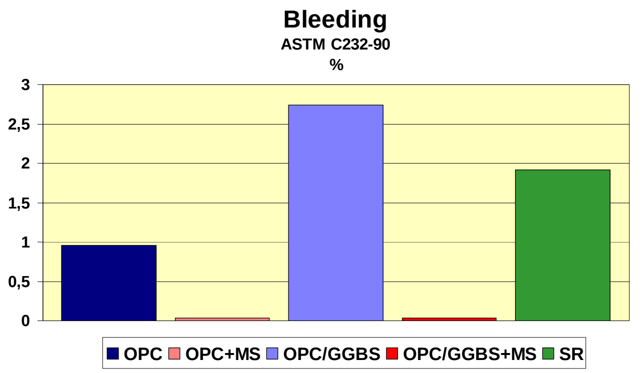


*Figure 2. Bleeding test results*

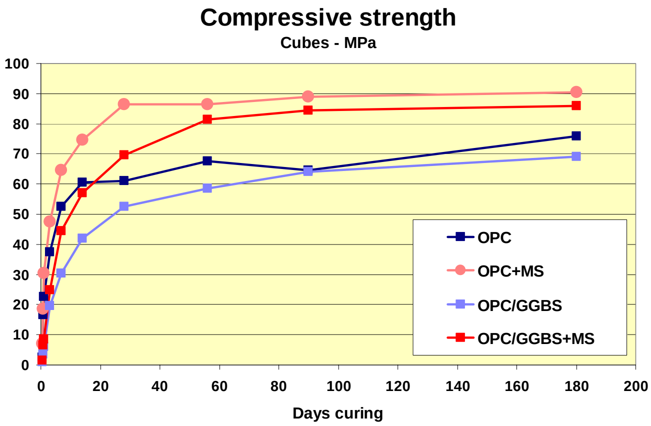


*Figure 3. Cube strength results*

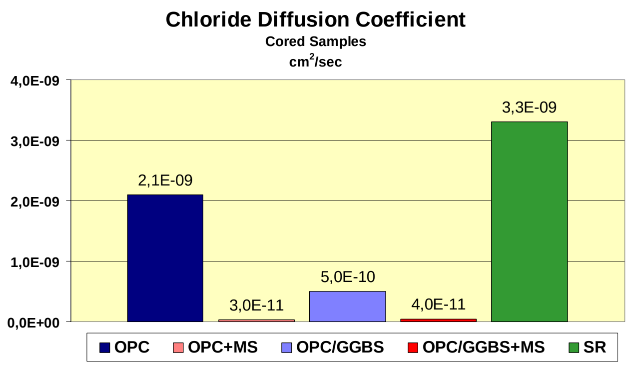


*Figure 4. Chloride permeability test results*

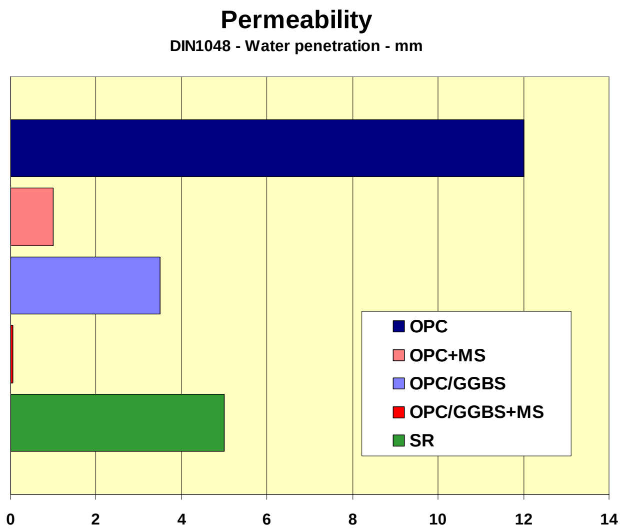


*Figure 5. Permeability test results*

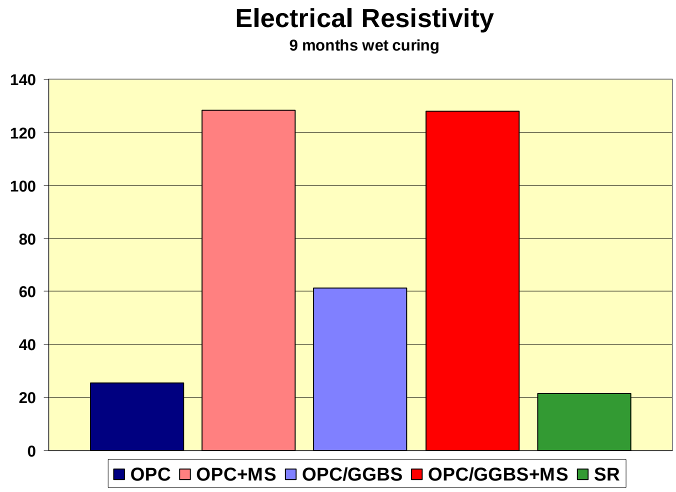


*Figure 6. Electrical resistivity test results*

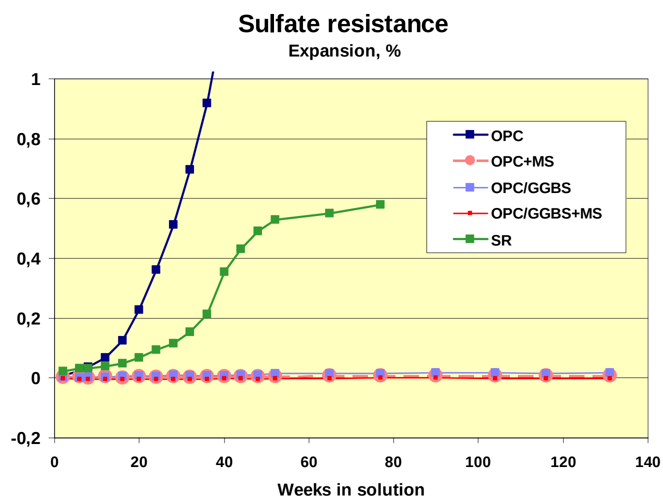


*Figure 7. Sulfate resistance test results*

| Test | Unit | | Mixes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H | I |
| Workability | mm | slump | 60 | 40 | 55 | 50 | 90 | 80 | 65 | 70 | 40 |
| | | flow | 410 | 340 | 380 | 400 | 430 | 400 | 390 | 410 | 370 |
| Bleeding | % | | 0.96 | 0 | 0.76 | 0 | 2.74 | 0 | 1.92 | 0.36 | 0 |
| Compressive Strength | MPa | 1 day | 22.5 | 30.5 | 24.5 | 29.0 | 6.0 | 8.5 | 11.0 | 21.5 | 25.0 |
| | | 3 days | 37.5 | 47.5 | 47.0 | 51.0 | 19.5 | 25.0 | 29.5 | 31.5 | 50.0 |
| | | 7 days | 52.5 | 64.5 | 63.5 | 66.5 | 30.5 | 44.5 | 43.0 | 47.0 | 63.5 |
| | | 28 days | 61.0 | 86.5 | 74.5 | 88.0 | 52.5 | 69.5 | 62.0 | 58.0 | 78.5 |
| | | 56 days | 67.5 | 86.5 | 81.5 | 96.0 | 58.5 | 81.5 | 63.5 | 61.5 | 84.0 |
| | | 91 days | 64.5 | 89.0 | 83.5 | 96.5 | 64.0 | 84.5 | 71.5 | 66.0 | 85.5 |
| | | 6 months | 76.0 | 90.5 | 92.0 | 100 | 69.0 | 86.0 | 73.0 | 70.0 | 91.0 |
| Density | $kg/m^3$ | average | 2400 | 2395 | 2465 | 2465 | 2400 | 2390 | 2405 | 2405 | 2420 |
| Flexural Strength | MPa | 28 days | 6.3 | 8.1 | 8.4 | 9.6 | 6.3 | 5.9 | 7.0 | 5.9 | 6.5 |
| Cylinder Compressive Strength | MPa | 7 days | 41.5 | 57.0 | 52.5 | 62.0 | 25.5 | 40.5 | 35.5 | 40.0 | 53.5 |
| | | 28 days | 52.0 | 75.0 | 61.0 | 83.0 | 49.0 | 66.5 | 54.5 | 46.0 | 75.0 |
| | | 6 months | 61.5 | 69.5 | 74.0 | - | 55.5 | 70.5 | 61.0 | 58.0 | - |
| Modulus of Elasticity | $x\ 10^3$ MPa | 7 days | 35.0 | 34.5 | 44.0 | 42.5 | 29.5 | 33.0 | 34.0 | 31.5 | 35.5 |
| | | 28 days | 36.0 | 40.0 | 46.5 | 48.5 | 37.5 | 36.5 | 36.0 | 34.5 | 40.5 |
| | | 6 months | 36.8 | 40.0 | 46.8 | - | 39.8 | 43.3 | 38.0 | 36.5 | 43.5 |
| Abrasion | mm | 6 months | 0.65 | 0.42 | 0.49 | 0.48 | 1.10 | 0.66 | 0.49 | 0.56 | 0.42 |
| Drying Shrinkage | % | | 0.040 | 0.025 | 0.035 | 0.020 | 0.040 | 0.035 | 0.045 | 0.040 | 0.025 |
| Wetting Expansion | % | | 0.020 | 0.010 | 0.030 | 0.015 | 0.010 | 0.015 | 0.030 | 0.020 | 0.010 |
| Thermal Expansion | ms/c | | 11.6 | 11.2 | 9.4 | 9.9 | 11.0 | 11.9 | 11.4 | 10.9 | 11.3 |
| Water Absorption | % | | 2.4 | 1.6 | 2.1 | 1.3 | 2.4 | 2.0 | 2.6 | 2.7 | 2.0 |
| Capillary Absorption | $g/cm^2$ | 72 hours | 0.34 | 0.22 | - | - | 0.35 | 0.24 | 0.33 | - | - |
| Capillary Rise | mm | 72 hours | 45 | 40 | - | - | 45 | 25 | 30 | - | - |
| Permeability | mm | | 12 | <1 | - | - | 3.5 | 0 | 5 | - | - |
| Chloride Permeability | $x\ 10^{-9}$ $cm^2/s$ | Water cured | 4.1 | 0.3 | - | - | 0.8 | 0.1 | 15 | - | - |
| | | Cores | 2.1 | 0.03 | - | - | 0.5 | 0.04 | 3.3 | - | - |
| Electrical Resistivity | k.o.c | 9 months | 25.4 | 128.2 | 45.1 | 128.0 | 61.3 | 128.0 | 21.5 | 15.5 | 110.5 |
| pH | | | 12.0 | 12.0 | 12.1 | 12.0 | 12.0 | 11.8 | 12.0 | - | - |
| Sulfate Expansion | % | 6 months | 0.361 | 0.003 | - | - | 0.006 | -0.005 | 0.031 | - | - |
| | | 12 months | >2.0 | 0.005 | - | - | 0.014 | -0.002 | 0.213 | - | - |
| | | 24 months | - | 0.008 | - | - | 0.017 | -0.001 | 0.528 | - | - |
| | | 36 months | - | 0.009 | - | - | 0.022 | -0.005 | 0.602 | - | - |

*Table 4. Test results*

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