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MICROSILICA CONCRETE: OPTIMISING DURABILITY.

Durability

- **x** So what do we mean here?
 - The ability of a construction to achieve the required characteristics - to be able to do the 'work' it is built for and to last for as long as possible.

• Do we get this?

Well.... Most of the time we get pretty close.

Is that good enough?

99% right is 100% wrong - and it usually costs us money!

x So how can we get even closer to that 100%?

Less than 99%



Otterburn base – needs 110%!



The Pantheon: Pozzolanic concrete



The Roman Pantheon is the largest (43.4m dia.) un-reinforced solid concrete dome in the world. It was built by the emperor Hadrian almost 2,000 years ago. It is probably the most sustainable concrete structure in the world.

History of Microsilica in Concrete

- × First collected 1947
- First tests in concrete in 1950-1952
- Industrial recovery developed early 1970's
- Increasing use and availability of standards for microsilica and its use in concrete.

 More than 10 million m³ of microsilica concrete are produced annually.



SiO₂-støv som cementtilsetning.

Det har lenge vært kjent at tilstrekkelig finkornet SiO, ved vanlig trykk og temperatur kan reagere med kalk og danne faste, cementliknende forbindelser som viser stor trykkstyrke. Dette forhold er unyttet ved at f. eks. kiselgur og vulkansk åske (pussolan og trass) er blitt anvendt til støpearbeider i forbindelse med vanlig Portland cement. Enkelte industrielle avfallsprodukter som slagg og flyaske gir tilsvarende virkning.

I den senere tid har det vært gjort store framstot spesielt i amerikansk forskning for å klarlegge fullt ut virkningen av disse stoffer (1). Ved A'S. Piskaa Verk, Kristiansand, fåes som biprodukt et stoff soni kan hetegnes som en flyaske, Kjemiske analyser viser et innhold av SiO₂ på 80–90 %. Äv andre bestanddeler kan nevnes ca. 5 % Fe.O₂ og ca. 7 % C. Det finnes ikke Ca og ikke S i stoffet. Stoffet er uhyre finkornet. Ved betraktning i mikroskop viser det seg at hovedmengden av stoffet består av kuleformede partikler av storrelsesorden 0,3 µ. Disse kuler klumper seg sammen i løse baller av storrelsesorden 10–12 µ. For å gi et inntrykk av storrelsesforholdet mellom SiO₂ støvet, cementpartiklene og de fineste partikler av vanlig støpesand er vist mikrofotos av de tre stoffer. Samtlige stoffer er siktet gjennom sikt med maskevidde 88 µ (4000 masker pr. cm²). Mikroskopets forstørrelse var 1000 x,

IUN

Microsilica Production

Quartz, coke and wood as raw materials

2000 degrees electric arc furnace

Smelting plant with furnaces, coolers and baghouse

Silicon or ferro-silicon

Microsilica



Microsilica for durability

- Microsilica in dual and triple blends is specified in virtually all of the major concrete structures worldwide.
- **×** Normal placing, Shotcrete, Self Compacting, Underwater...
- **×** Greater Strength
- × Virtually Watertight
- **×** Greater Sulfate Resistance
- Greater Chloride Resistance
- Increased Strength: Faster Construction, Less Volume = <u>Better Economics.</u>
- Increased Durability: Increased Lifetime, Fewer Repairs = <u>Better Economics.</u>

Strength Compressive strength Cubes - MPa ---OPC OPC+MS $\mathbf{20}$ ---OPC/GGBS OPC/GGBS+MS $\mathbf{20}$ Days curing

Water permeability

Permeability DIN1048 - Water penetration - mm



Sulfate attack



Singapore MRT

Somerset to Newton Circus Concrete lining cast in 1986

Pictures taken after 15 years in service







DTSS, Singapore

Precast Concrete Segments for Deep Tunnel Sewage System (DTSS) in Singapore

Main quality requirement: High Early Strength - Demoulding after 6–10 hrs

Design life: 120 years



Concrete placed in mould and mechanically vibrated



Segment Storage Yard



Segment hoisted into TBM for erection into place

Chloride attack



Corrosion potential

Electrical Resistivity

9 months wet curing



Troll platform



Troll A - 472 metres high - the largest moveable structure ever built. At tow-out it weighed 1.2 millionT. It took 2,000 workers 4 years to cast 245,000 m³ concrete and 100,000T of reinforcement (about 15 Eiffel towers) into this impressive structure. The rig operates in water over 300 m deep.



The Øresund Bridge



JJ Hospital Flyover, Mumbai



First 75 MPa precast project in India

- 1 932 m long, 7.9m high,
 16.2m wide, 34.5m spans
- 20,000m³ of HPC
- 500 kg OPC + 50 kg microsilica, w/b = 0.27
- 28d = 80 MPa, 90d = 87 MPa,
 1 year = 95 MPa
- Drying Shrinkage = 0.00142%
- Rapid Chloride (ASTM 1202)
 < 240 coulombs

Heading out from Bandra

CALL IN THE P

29 12:15

The full length view



Tarapur Nuclear Power Plant, India



Tsing Ma Bridge - built to last !



Hong Kong Marine Specification

RECOMMENDED SPECIFICATION FOR REINFORCED CONCRETE IN MARINE ENVIRONMENT

The main features of the recommended specification are summarized as follows :

- The minimum characteristic strength of the concrete mix shall be 45 MPa.
- The maximum water/cementitious ratio shall not exceed 0.38.
- Condensed silica fume is to be added to reduce the permeability of the concrete.
- The cementitious content shall be within 380-450 kg/m³, including 5-10% CSF and PFA at 25 40% or GGBS at 60 75%.
- The cover to all reinforcement in all exposure zones shall be 75 mm.
- For flexural crack width design and control purpose, the allowable crack width, taken to be 0.1 mm for marine structures, may be increased by a factor of 1.25.

Quoted from:

PORT WORKS DESIGN MANUAL, PART 1;

General Design Considerations for Marine Works

Civil Engineering Office, Civil Engineering Department The Government of the Hong Kong Special Administrative Region (first published May 2002)

Typical clauses: 100 year design

- Concrete shall contain a combination of PC (Portland cement), GGBS (granulated blast furnace slag) or PFA (pulverised fly ash), and MS (microsilica) in accordance with the latest EN Standards.
- The concrete, when tested at 28 days, shall have the following performance:
 - + ASTM C1202: Mean coulomb value less than 800, with no individual test result above 1,000.
 - + Chloride diffusion coefficient to be less than 1x10⁻¹²m²/sec when tested to international standards acceptable to the engineer.
 - Permeability, when tested to DIN 1048 shall be less than 5 or 10mm.

Shanghai East-sea Bridge



Design life: 100 years Quad blend (PC/GGBS/FA/MS) Total length: 32.5 km

311 South Wacker Drive, Chicago.



- 70 Floors, 293 m high
- 121,000 m² office tower completed in 1990
- 83 MPa concrete specified for columns of the first 14 floors.
- MS for pumpability in 69 to 52 MPa concrete from 15th floor.

Benefits:

- Saving rebar & concrete
- Same forms for each floors
- Less equipment
- Rapid construction
- More rentable space

Think about those numbers...

× Cement

3,000 tonnes

× Coarse Aggregate

× Fine Aggregate

7,650 tonnes

5,250 tonnes



1,071,000 litres

Another Trump Tower

Trump Palace/Embassy Suites New York City, NY 1989

Cement (I/II) Silica fume (11%)		799 lbs/yd ³ 88 lbs/yd ³	474 kg/m ³ 52 kg/m ³
H.R.W.R.		30 - 35 ozs/cwt	7 - 9 l/m ³
W/C + SF			0.32
Slump		9-11 inches	230 - 280 mm
Compressive strength	3 day	7,900 psi	54 mpa
	7 day	10,400 psi	72 mpa
	28 day	12,600 psi	87 mpa
	56 day	13,600 psi	94 mpa
Modulus of elasticity	56 day	7.4 X 10 ⁶ psi	51gpa





One Island East, H.K.

Grade 100 columns & core walls Mean Strength at 28 days:113.5 MPa (max: 129.5, min: 105.0 / SD: 3.4) <150 coulombs RCP

Results by kind permission of Gammon Construction Ltd



The Baynunah Tower.

- **×** First 'real' Skyscraper in the Gulf
- × Built in 1993-4
- × 157 metres tall
- × 10% MS dosage on 400 kg opc,
- × 0.38 w/c ratio mix
- × 28 day Strength 80+ MPa
 × Water permeability ZERO (DIN 1048)
 × Chloride permeability 480 Cmb (ASTM C1202)

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And then they started this...

Specifications.

- **×** Compressive Strengths:
- **×** Minimum Cement:
- × W/C ratio:
- **×** Flow (at site):
- ***** Water Penetration
- **×** Water Absorption
- × RCPT
- **× Water Permeability**

45 to 80MPa 252 + 168 + 30 kg/m³ (MSRPC + PFA + MS) 0.34 > 600mm

<10mm	(BS EN 12390-8)
<1.5%	(BS 1881:122)
<1200	(ASTM C1202)
<5mm	(DIN 1048)

Results - Mechanical.

Compressive Strengths (150mm cubes - averages)

+ 7 days	40.5 MPa
+ 14 days	51.5 MPa
+ 21 days	60.5 MPa
+ 28 days	64.5 MPa
+ 56 days	75.5 MPa

x Tensile Strength (300 x 150mm cylinders - averages)

- + 14 days 3.75 MPa
- + 28 days 4.35 MPa

Results - Durability.

×	RCP Test	(1200)	590
×	Water Absorption	(1.5%)	0.7%
×	Water Penetration	(10mm)	Zero

Water Permeability (5mm) Zero

The Future?

The Burj Khalifa topped out at 828m, but already there are plans for taller buildings:

×	Tokyo Sky City	1000m
×	Kingdom Tower, Jeddah	1050m
×	India's Dream Solar Tower	1200m
×	China's Bionic Tower	1228m
×	Frank Lloyd Wright Tower	1600m
×	The Mile High Tower (Nakheel)	1600m
×	Tokyo Dream Tower	2001m

Solid Waste Authority - Florida

Mix Specification

SOLID WASTE AUTHORITY FLOOR "ULTRA-DURABLE" CONCRETE

MIX DESIGN (1 cubic yard S.S.D.):

Type I Cement	705 lbs
Silica Fume, dry-compacted	141 lbs
Pearock	1689 lbs
Natural Sand	926 lbs
Water	288 lbs
A.E.A.	7 ozs
Retarder, Type B	20 ozs
H.R.W.R., Type F	288 ozs

W/C = 0.34, Slump \approx 9-10", Set time \approx 3 hours, NBS Abrasion @ 1 hour = 0.23", 8,200 psi @ 2 days

B&Q Pontypridd – after 21 years...

Kinzua Dam, USA

Parameters for durability?

- × Lifetimes from 75 years to 150 years are now asked for.
- Triple blends used frequently to achieve durability characteristics:
 - + opc + ms
 - + opc + pfa + ms /opc + ggbs + ms / msrpc + pfa + ms,
 - + opc + ggbs + pfa + ms...
- **×** Strengths:
- **×** Water penetration:
- Chloride Penetration:
- **×** Sulfates:

60 to 120 MPa (150) <5mm (Zero) <500 coulombs (<250) All the above >src.

And the longer they last...

- × The less we have to repair.
- × The less we need to rebuild.
- **×** And both of these can cost far more than the original construction!
- And if we don't have to do these, we save even more of our natural resources, as well as the cost.

But that costs money now!

- **×** Does it actually cost more to build?
- Analysis of actual construction costs on a number of projects using HPMSC have shown that it actually costs less...
- **x** Don't believe me? Let's take a look...

'Green' Microsilica Concrete:

- 311 South Wacker concrete was 50% extra per m³. Saved 7,650m³ – including 1 million litres of water. The actual building was finished ahead of time, for less cost than the original design, and the owner got more rentable space.
- Mumbai Pune Expressway Tunnels the microsilica shotcrete cost 21% extra per m³. The finished, 'on the wall', cost was 11% less than using standard shotcrete...
- Indianapolis Airport Parking 7,100 spaces. Normal cost -\$15,000 per space. Using microsilica concrete, saving volume and time, the actual cost was only \$12,000 per space....That's a saving of...

16 months, 5 floors, 46,500m²/floor...

Thank you!

Any Questions?