



EMC REFERENCE PROJECTS

Cement has been produced according to the EMC method since 1995 using a small pilot plant of 1 ton per hour capacity. In total some 2,500 tons cement has been produced.

Reference projects have been chosen to gain a broad experience with the performance characteristics of EMC cement in industrial projects. This includes not only a wide variety of applications, but also the exposure of EMC concrete to the harsh climates of northern Sweden.

Casting with EMC cement can be done in very cold temperatures of about minus 20 °C (minus 4 Fahrenheit).

These projects confirm the competitive and in cases superior performance of EMC cement over ordinary Portland cement (OPC).

The projects selected for this document are not a complete list of all projects undertaken but give a good picture of the diversity of challenges to which the EMC cement has been exposed.

Bridge over river Matojoki, Karungi in northern Sweden in 1998

Cement type : EMC-50 with 50% ordinary Portland cement and 50% fine quartz sand of size 0-2mm.

Customer : Swedish Road Administration (Vägverket).

Constructor : Skanska AB (major international construction group and until recently majority owner of Scancem, Europe's 6th largest cement producer).

Concrete : Volume about 250 m³; designed 28-day strength of the concrete 45 MPa.

Mix design :

- EMC cement content 480 – 530 kg/ m³,
- water to cement ratio, w/c = 0.37 – 0.40,
- amount of entrained air ca 5.6%,
- amount of superplasticizer ca. 0.5% by cement weight.

Note: These are the recommendations of Swedish Road Administration also for concretes using ordinary Portland cement

Experience

Workability : concrete mix had a slump during casting about 120 mm and showed very high sensitivity to vibration (with only slight vibration the concrete performed almost as self-compacting concrete).

Strength : the 28-day compressive strength was 60 – 62 MPa,

Frost resistance: Was tested according to Swedish National Standard (with 3% of chloride solution) and showed mass loss after 56 cycles 0.15 kg/ m³ (upper limit 1.0 kg/ m³).

Surface and Appearance : The surface of the concrete is very smooth, without any cracks and defects. The concrete had a light grey colour similar to concrete structures produced with white cement.

Benefits (examples)

- High level of strength development with 50% reduction in Portland cement content.
- Relatively low heat liberation and low thermo cracking propensity.
- Reduced volume of Portland cement offering a more environmentally friendly product.
- High level of workability.
- Increased sulphur resistance.
- High level of frost resistance.
- Attractive surface appearance compared to Portland cement

After 7 years of exploitation Karungi bridge according to Swedish Road Administration is in excellent condition. For further information please contact: Mr. Gunnar Zweifel Swedish Road Administration (Region Norr), phone: +46 920 23 6200, e-mail address: gunnar.zweifel@vv.se

Shotcreting (wet mix process) (Sweden 1997-1998)

Cement type : EMC-50 cement containing 50% ordinary Portland cement and 50% fine quartz sand of size 0-2mm

Customer : LKAB, Sweden (Leading iron ore producer)

Constructor : KGS AB

Project : Shotcreting (wet mix process) with EMC cement for tunnel linings in iron ore mines at Kiruna and Malmberget in Northern Sweden.

Shotcrete : Volume of EMC cement about 100 tonnes covering a shotcreting area of about 4000 m².

Mix design :

- EMC cement content 450 kg/ m³,

- water to cement ratio 0.45,
- silica fume content 35 kg/ m³,
- plasticizer content 0.3% by cement weight,
- designed 3 day compressive strength at curing temperature 8 degrees Celsius > 20 MPa.

Experience

Workability & placement properties

: Shotcrete with EMC-50 showed excellent rheological performance without any gluing effects. The shotcrete also showed practically no rebound in comparison with 10 – 15% of rebound when ordinary Portland cement was used.

Strength : 28-day strength and adhesion to the rock surface are in line with the one produced with ordinary Portland cement..

Benefits

Due to excellent workability and no rebound effect for shotcreting with EMC-50 cement, it is possible to reduce by up to 30 % the silica fume content and up to 20% the plasticizer content in the concrete mixture. EMC shotcrete showed no scaling during blasting.

Concreting foundation for ready mix concrete factory (1996-1997)

Cement type : EMC-50 cement containing 50% ordinary Portland cement and 50% fine quartz sand of size 0-2mm.

Customer : Betongindustri AB, a wholly owned subsidiary of Scancem Group, Europe's sixth largest cement producer.

Constructor : Betongindusrti AB

Project : Concreting the foundation of the new RMC factory in Stockholm, Sweden.

Concrete : Total volume of concrete about 100 m³ with design 28-days compressive strength 50 MPa.

Mix design :

- cement content 370 to 570 kg/m³,
- water to cement ratios from 0.45 to 0.35.

Workability : Slump of concrete mixture was about 120 mm, which is in line with workability of the concrete of the same mix design produced with ordinary Portland cement.

Strength : 28-day compressive strength 45 – 60 MPa.

Frost resistance: Tested according to Swedish National Standard (with 3% chloride solution) the concrete showed mass loss about 0.15 kg/ m² after 56 cycles.

Appearance : Concrete had light grey colour.

Road stabilisation projects in the Northern Sweden, 1998

Cement type : EMC-50 cement containing 50% ordinary Portland cement and 50% fine quartz sand of size 0-2mm.

Customer : Swedish Road Administration (Vägverket)

Constructor : Vägverket Produktion AB

Project : The stabilisation project included i) mixing EMC-50 cement with fine fractions of local soil material, and ii) compacting the mixture with rollers. Thickness of the stabilised layers was 0.5 to 2.0 m.

Mix Design :

cement contents 70 to 120 kg per m³,
moisture contents 7 to 10%.

Strength : 28-day compressive strength of the "stabilised" material 10 – 15 MPa.

Performance : After one winter, the part of the road using the EMC method of stabilisation was significantly better than the part where it was not used.

Benefits

The EMC method of stabilisation offers significant environmental and economic benefits.

In traditional road stabilisation operations, up to 3 meters of the roadbed needs to be replaced with new stabilisation materials such as concrete. The existing material needs to be removed and transported to a storage area where it is handled according to environmental requirements.

The EMC method combines EMC-cement with a new method of stabilisation which makes it possible to reuse the existing road bed material by mixing it with EMC cement and compacting with rollers.

The EMC method of road stabilisation has been tested in the harsh climate of northern Sweden, where the temperature difference between winter and summer can range between minus 40 degrees centigrade (or Fahrenheit) and plus 30 degrees centigrade (90 degrees Fahrenheit).

After 7 years of exploitation roads stabilized with EMC cements according to Swedish Road Administration are in excellent condition. For further information please contact: Mr. Gunnar Zweifel Swedish Road Administration (Region Norr), phone: +46 920 23 6200, e-mail address: gunnar.zweifel@vv.se

Bridge on highway E4, Stockholm – Haparanda, span ca 25 m, 1997

Cement type : EMC500 (95% ordinary Portland cement and 5% of silica fume)

Customer : Swedish Road Administration (Vägverket)

Constructor : Vägverket Produktion AB, Sweden

Concrete : Volume of concrete about 520m³ (total volume of cement delivered about 180 tons).

Mix design :

- Cement content 320-370 kg/ m³,
- w/c = 0.53,

Strength : 28-days compressive strength ca 60 MPa.

Benefits

EMC500 cement permits the reduction of binder content in the concrete up to 30% without reduction of strength

After 8 years of exploitation bridge according to Swedish Road Administration is in excellent condition. For further information please contact: Mr. Gunnar Zweifel Swedish Road Administration (Region Norr), phone: +46 920 23 6200, e-mail address: gunnar.zweifel@vv.se

Pumping station for drinking water, Sweden, 1995

Cement type : EMC500 (95% ordinary Portland cement and 5% silica fume)

Customer : Luleaa Municipality, northern Sweden

Constructor : Nåiden Bygg AB

Cement : Volume of cement delivered about 150 tonnes

Mix design :

- Cement content: 270 kg/ m³,
- silica fume content 15 kg/ m³,
- superplasticizer content 0.6 % per cement weight,
- water to cement ratio 0.60

Workability : Slump 120 – 150 mm

Strength : 28-day strength 48 – 50 MPa, 3-years strength ca 60 MPa
(samples were drilled out of the structure).

Permeability : The concrete had very low early age water permeability (test at 8atm pressure during 24 hours), e.g. after 5 days of curing the depth of water penetration was less than 30 mm and after 14 days less than 20 mm.

Benefits

This pumping station is one of three identical units built for the Luleaa Municipality at the time. The two others were built by the same company but using ordinary Portland cement.

The unit built with EMC cement using only about 270 kg cement per m³ concrete has shown excellent performance during 4 years of use with no leakage, no cracking, etc.

The two other units containing about 350 kg of ordinary Portland cement per m³ concrete (about 30% more) have had to undergo cracking repair.

Foundation for Silver Museum Arjeplog, Sweden, 1995

Cement type : EMC500 (95% ordinary Portland cemen and 5% silica fume)

Customer : Arjeplog Municipality, northern Sweden

Constructor : Nåiden Bygg AB

Cement : Volume of cement delivered about 160 tonnes

Concrete characterisations are the same as for the bridge on highway E4 between Stockholm and Haparanda detailed above.

Containment pool for low concentrated sulphuric acid, Sweden 1995

Cement type : EMC500 (95% ordinary Portland cement and 5% silica fume).

Customer : Swedish Steel AB (SSAB), Luleå, Sweden, 1995

Constructor : Nåiden Bygg AB

Cement : Volume cement delivered, about 80 tonnes

Mix design :

- cement content 400 kg/ m³,
- silica fume content 40 kg/ m³,
- w/c= 0,40

Workability : Slump ca 80 mm

Strength : 28-day compressive strength 120 MPa.

Performance

The pool contains sulphuric acid solution with concentration of about 3.5% and temperature of about 130 °C

Normally, pools such as this would be built in concrete using ordinary Portland cement and a cover of stainless steel or acid-resistant ceramic material for protection of the concrete.

Due to the high strength and density and correspondingly very low permeability SSAB chose to use EMC concrete only, there being considered to be no need for protective measures.

Tests on the concrete after storage for 45 days in these high aggressive conditions gave about 100 MPa and the depth of penetration of the aggressive solution in the concrete was about 20 mm.

After 4 years of exploitation the pool is in very good condition, no leakage has been registered and SSAB gives very high performance rating.

Repair of floors of the pulp/paper plant in northern Sweden, 1996

Cement type : EMC500 (95% ordinary Portland cement and 5% silica fume)

Customer : SCA AB, Piteå, Sweden (one of the largest paper producers in Europe).

Constructor : Skanska and NCC, Sweden (two of Scandinavia's largest construction groups).

Cement : Volume of cement delivered, about 80 tonnes.

Project : Repair of floors of about 300 m² and thickness of 20 – 60 mm.

Mix design :

- cement content 330 kg/ m³,
- w/c = 0.56,

Workability : Slump about 100 mm.

Strength : 28-day compressive strength about 60 MPa.

Performance:

The concrete is attacked by low concentrated solutions of acids and alkalis and aerosols of acids and alkalis. Concrete produced with the ordinary Portland cement in these conditions deteriorates during 2 – 3 years to a depth 20 to 40 mm.

After 3.5 years of exploitation in these very harmful conditions EMC concrete showed excellent performance without and scaling or cracking. The EMC concrete was also characterised by very high adhesion to the old concrete.

Repair of airport runway, northern Sweden, 1996.

Cement type : EMC500 (95% ordinary Portland cement and 5% silica fume)

Customer : Swedish Air Force

Constructor : EMC Production AB

Cement : Volume of cement delivered about 50 tonnes.

Project : Repair of runway of the military air base F 21, Luleå, Sweden; thickness of the new concrete was about 80 mm.

Mix design :
cement content 350 kg/ m³,
w/c = 0.55,

Workability : slump ca 100 mm,

Strength : 28-days compressive strength 55 – 60 MPa.

Benefits: approximately 3 hours after casting the EMC concrete was subjected to a very intensive rain for about 2 hours without any damage of the concrete surface. The EMC concrete also had very good adhesion with old concrete.

High performance floors, northern Sweden, 1995

Cement type : EMC500

Customer : SSAB (Swedish Steel AB), Luleå, Sweden,

Constructor : SIAB.

Cement : Volume of cement delivered, about 50 tons

Project : Construction of floors exposed to very high mechanical abrasion in combination with high temperature 100 – 150 C (220-300 F)..
Total area ca 1500 m².

Mix design :

- cement content 380 kg/ m³,
- w/c = 0.42,
- fibre reinforcement,

Strength : 28-day compressive strength 80 MPa.

Benefits: While concrete produced with ordinary Portland cement usually needs to be replaced after about 1 – 1.5 year after exploitation in such conditions, the floors produced with EMC cement are still in very good condition after 4 years.

Appendix 5. Experience with EMC-50 at Bridge casting.

MEMORANDUM

Date: 15.01.2000

Prepared by: HANS HEDLUND

Experiences of EMC-50 at Bridge casting

Background

In a joint task within the Centre of High Performance Cement (CHPC) and the Swedish National Road Administration, Region North, a bridge with a span equal 16m was to be cast with approximately 200m³ concrete using Energetically Modified Cement (EMC). The EMC binder contained 50% of fine quartz sand and 50% of Swedish Standard Slite cement (CEM I 42.5 R from Cementa AB, a subsidiary of Heidelberger Zement).

The bridge was built by Skanska AB; one of the leading construction group's in the world.

The bridge was located some 50 km south of the Polar Circle where the temperature often drops below -30°C during winter and rises above +20°C in the summer period. The transportation time from the ready mix factory was approximately 50 - 60 minutes.

Performance requirements for the concrete was as follows:

- * Suitable for the use of pumping equipment
- * Good workability - slump at app. 100mm on site
- * Air content of 4.0 - 4.5% at site
- * Frost resistance (Borås-method)
- * Strength class of K55 - K60
- * Topping of steel fibre reinforced concrete (SFRC)

A key performance element for casting a concrete bridge in such severe climate is frost resistance which requires the use of a well-distributed air void system. From an architectural as well as an economic point of view a high strength and slender structure was desired. Another key element to achieving a long lasting bridge is to have excellent performance during casting. This requires a good composition of the fresh concrete.

Conclusions

A comparison between laboratory tests and tests of on site casting shows that bridge concrete made of EMC-50 cement has equal performance to concrete using 100% OPC. (See table attached.)

Preliminary Laboratory testing

In co-operation with the ready-mix factory, Kallax Betong och Grus, in Kalix and Luleå University of Technology (LTU) the EMC concrete mix was designed and tested to follow the desired requirements.

Testing was done at the concrete laboratory of the Structural Engineering Division at LTU. Strength development and maturity, temperature development (generated heat), frost resistance, shrinkage, free deformation together with workability aspects were tested (see Norberg 1998).

Workability of the fresh EMC-50 concrete was designed to fit the production procedure chosen by the contractor.

Nearly 50 different fresh concrete mixes were tested to evaluate slump loss, loss of air content due to transportation, early age strength development, etc.

The optimal sieve curve of aggregate consisted of 52% gravel and 48% coarse aggregate in combination with a relatively low cement/binder content.

Tests were done using EMC-50 binder content ranging between 530 - 600 kg/m³. Best results over all were obtained using 530 kg of EMC-50 per cubic meter concrete.

Initial slump after casting was about 180 – 200mm. Investigations showed 70 - 80mm slump loss one hour after mixing in a simulated transportation.

In the same way the air content decreased about 1.0 -1.5%.

These results are all in line with those normally achieved with 100% OPC. (See table attached.)

Bridge casting experience

During bridge casting the ambient temperature was in average -5°C and windy.

The production of the main bridge was cast using a concrete pump and vibrating sticks and the topping was cast directly on the wet main deck using a bucket and a vibrating beam. The creating personal was pleased with the remarkable good workability after such a long transportation and it was no problem to place it. The concrete had the same consistency as ordinary concrete, but behaved more like self-compacting concrete.

The site manager from Skanska remarked that the surface appearance was significantly better than for ordinary concrete. It was also appreciated that the concrete surface had a much lighter colour compared with ordinary bridge concrete.

The strength development of the chosen concrete mix reached 75% of its 28-day compressive strength within ten days of maturity. The slight retardation in early strength development was caused by slightly higher dosages of superplasticizer used to achieve the good workability (lignosulfonate based) (0.5% in comparison with average value 0.3-0.4% by cement weight for OPC). The strength development started about 10 - 12 maturity hours after casting. The heat evolution started earlier – before the strength development - preventing the concrete from freezing thus confirming the winter concreting potential of the EMC binder.

Analysis of the heat liberation of the bridge concrete has been performed in parallel with both semi-adiabatic and adiabatic equipment. The measurements performed by Skanska at the bridge were in line with the temperature development calculated in the laboratory. The EMC-

50 mix has significantly lower final value of generated heat compared with heat liberation of the base cement (Slite Std P). No thermal cracks occurred during construction work.

The frost resistance was tested according the Borås method up to 56 freeze and thaw cycles. The Borås method is periodical cycles with 3% sodium-chloride solution as the temperature changes from +20°C - -20°C and back to +20°C within a 24-hour period. The EMC-50 concrete mix had an air content of 5.3% giving good frost resistance of the bridge mix.

Measurements of the autogenous deformation indicate shrinkage of the same magnitude as high performance concrete (HPC) with the same level of water-binder ratio. This effect may be due to the amount of superplasticizer used. Thermal dilatation is of the same magnitude as for ordinary concrete mixes containing ordinary Portland cement.

About one week before casting of the main bridge and deck it was decided to use a steel fibre reinforced concrete (SFRC) topping cast on the bridge. The same requirements were set as for the main bridge. Using 60 kg/m³ of steel fiber the slump measured 120mm after casting and 80mm one hour later.

The SFRC topping showed the same experiences as mentioned above.

References

Norberg, J, (1998), "Concrete of the future - a comparison of some mechanical properties for energetically modified cement and Portland cement", Luleå University of Technology, Division of Structural engineering, 1998:256 CIV, pp 60. (in Swedish)

Hans Hedlund, Average test results (laboratory tests, casting tests and reference OPC concrete tests, see table A5-1.

Luleå, January 15, 2000

Hans Hedlund

Table A5-1. Average test results of EMC and OPC concretes (laboratory tests and data from bridge casting)

Mix type	Binder type	Binder content, kg/ m ³	w/B	Slump, mm	Density, kg/m ³	Compressive strength, MPa			
						1 d	3 d	7 d	28 d
Laboratory	EMC-50	530	0.38	175 - 180	2400	15-18	32	41	66
In-situ casting	EMC-50	530	0.38	180 - 200	2400	17	31	40	63
Reference (lab)	OPC	530	0.38	175 - 190	2400	18-20	30	40-45	60-65

