Technical performance of **ConcreCem**

Freeze-Thaw
with ConcreCem

Freeze-Thaw damage
without ConcreCem

exterra
concrete technology

PowerCem Technologies
Innovations for better solutions!

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1 Introduction

ConcreCem for a superior quality of concrete

1.1 Company information

PowerCem Technologies is a privately held company and was established in 1996. It specializes in the research and development of a range of products contributing to a more sustainable industrial activity in general and to cement-based construction activities in particular. The developed products have a unique composition and have patent coverage on a worldwide basis. The PowerCem products provide a significant difference to all applications where cement and regular binders are used, even in the most difficult situations.

PowerCem Technologies provides their product-range to almost every continent. We have a policy of selecting our partners on the basis of reputation, reliability and expertise with the particular field of operation. PowerCem based products have already been used by both governmental bodies and by industries that are associated with the road- and construction industry

This document only covers the aspects of ConcreCem.
Documents for the other PowerCem-products: RoadCem, ImmoCem and NucliCem can be requested via our website: (www.powercem.com).

1.2 ConcreCem

ConcreCem is specifically designed as a concrete and mortar improver.
ConcreCem is a fine grain sized powder based on alkali earth metals and synthetic zeolites complemented with a complex activator.

ConcreCem is manufactured in The Netherlands according to ISO 9001 and ISO 14002 standards and complies with the REACH regulations. PowerCem Technologies obtained the CE-label for ConcreCem.
A certified body has ascertained that PowerCem Technology fulfils all provisions concerning the attestation of factory production control (FPC) described in Annex ZA of the standard EN 934-2. The EC-FPC certificate is available on request.

The addition of ConcreCem to concrete and mortar, increases the strength and flexibility. ConcreCem provides for strongly improved impermeability against water, salts and acids and delivers significantly enhanced heat resistance and overall performance of the finished products. Its unique characteristics increase and extend the properties of concrete and allows for tailor made concrete and mortar mix designs to meet the requirements of specific concrete and cement applications.

ConcreCem is able to effectively treat toxic Chromium VI and reduce it to a harmless Chromium III. ConcreCem is generally used in combination with cement and reduces the amount of cement needed. When ConcreCem is used in the concrete or mortar mixture it also allows the use of lower quality aggregates.

ConcreCem modifies the dynamics and chemistry of the cement hydration process and enhances the crystallization processes by forming long needle crystalline structures. By varying the addition of ConcreCem and maintaining the water cement ratio, the viscosity of the mixture can be influenced to create faster or slower settings.

2 Added values with ConcreCem

ConcreCem produces a crystalline structure which is able to partially block the capillary pores. Because of its fiber-like structure it also prevents cracking and micro-cracking to occur.
This will considerably lower the speed by which harmful materials are transported into the concrete. As a result the service life will be prolonged and the maintenance costs of concrete constructions which contain ConcreCem will be strongly reduced compared to concrete constructions which have been made without the use of ConcreCem.

Environment friendly

ConcreCem is friendly to the environment!
This is confirmed and reported by certified laboratories after testing the leaching behavior of composite materials for a simulated period of 100 years.

CO2 reduction

ConcreCem helps to reduce the emission of CO_2 as it enables a reduced consumption of binders like cement.
The production of 1000 kg's of Cement requires the consumption of 5.1 Giga Joule of Energy and corresponds to the emission of 1200 kg of CO_2.
Hence, the use of ConcreCem in cement type C35/C45 enables a reduction of Cement in the preparation of concrete by up to 20%, this enables the reduction of CO_2 emission equivalent to about 300 kg per m^3 compared to an emission of 400 kg CO_2 per m^3 of concrete without ConcreCem .. a net saving of 100 kg CO2 per cubic meter of concrete,

Technical aspects that count and are adding value!

ConcreCem makes the construction of large area slabs possible with fewer or no expansion joints at all. It also reduces the need for steel reinforcement. The extent of the possible reduction of steel reinforcement needs to be evaluated through detailed laboratory studies specific to the actual application.

ConcreCem improves the workability and reduces heat generation during the hydration of the Cement. It reduces the need for additional additives to an absolute minimum and allows full control of the hydration dynamics and early strength development.

Added value of ConcreCem

ConcreCem is used as an additive to cement with the effect of improving the desirable characteristics of Cement bound materials: mortars, concrete, stabilized soil, concrete prefabricated products etc.
When used in prescribed quantities it improves among others the workability, strength, acid resistance and fire resistance.
For each application a particular mix has to be designed. The materials available at the location determine the required dosage of ConcreCem as a function of the desired characteristics of **the end product** (compressive strength, flexural strength, water resistance, freeze and thaw resistance, acid resistance, high thermal shock resistance as well linear rising temperatures ($\geq$2000°Celsius) etc.).

As a general guideline we recommend the following dosage:

- Mortars: 0,1% - 3% by mass of cement
- Unreinforced Concrete: 0,1% - 2,4% by mass of cement
- Reinforced Concrete: 0,1% - 0,7% by mass of cement
- Pre-tensioned concrete: 0,1% - 0,2% by mass of cement

3 ConcreCem and strength-improvement

Concrete mixtures have been tested in the laboratory. The composition of the reference concrete mixture is in accordance with EN 480-1 (Reference Concrete I).

Three different sizes of aggregate (figure 3.1) have been used to establish a particle size distribution which is within the requirements mentioned in the EN 480-1.
Table 3.1 shows the particle size distribution of the aggregate used in concrete mixtures.

Figure 3.1: Three different sizes of aggregate to establish the particle size distribution

Table 3.2 show the mix specifications. Also the results of testing the wet concrete and the strength improvement after 24 hours when different amounts of ConcreCem is used.

Table 3.1: Particle size distribution of aggregate used (sand and gravel)

Aperture size	Passing
31,5	100%
16	90%
8	56%
4	43%
2	40%
1	33%
0,500	18%
0,250	5%
0,125	2%
0,063	0%

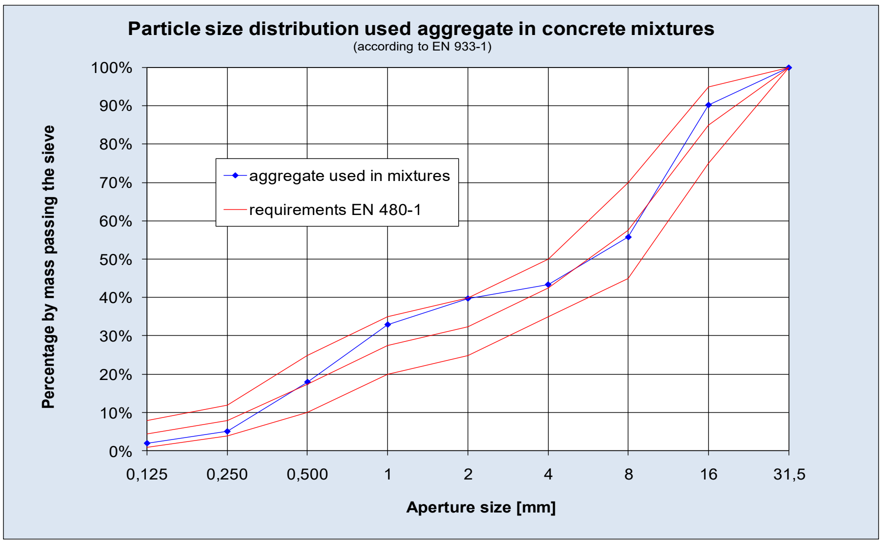


Table 3.2: Mix Specifications

Material	Amount (kgs) of material in 1m³ of concrete			
	Reference Mix: **0,0% C**oncreCem	Mix I: **0,3%** ConcreCem	Mix II: **0,6%** ConcreCem	Mix III: **0,9%** ConcreCem
CEM I 42.5 N	350	350	350	350
Water	180	180	180	180
Sand 0/4	793	793	793	793
Gravel 4/16	517	517	517	517
Gravel 4/32	517	517	517	517
ConcreCem	**0,00**	**1,05**	**2,10**	**3,15**
Water / cement ratio	0,51	0,51	0,51	0,51
Density wet concrete (EN 12350-6)	2380 kg/m^3	2360 kg/m^3	2370 kg/m^3	2350 kg/m^3
Air content wet concrete (EN 12350-7)	1,8%	1,5%	1,9%	2,1%
Slump (EN 12350-2)	70 mm	80 mm	60 mm	60 mm
Compressive Strength improvement after 24 hours as to reference mix	-	36%	34%	28%

Figure 3.2 shows compressive strength improvement after 24 hours when ConcreCem is used. Although there is still a large improvement, it is slightly lower at early stage when more ConcreCem is used. However, the strength improvement after 28 days will end higher in case of using a larger amount of ConcreCem. It is important to know what kind of properties the concrete should have (for example: a higher early strength or a higher 28-days strength) to develop a concrete mixture with the right amount of ConcreCem.
The three tested mixtures with ConcreCem comply with the requirements mentioned in the European standard EN 934-2, table 7 ("Specific requirements for hardening accelerating admixtures.")

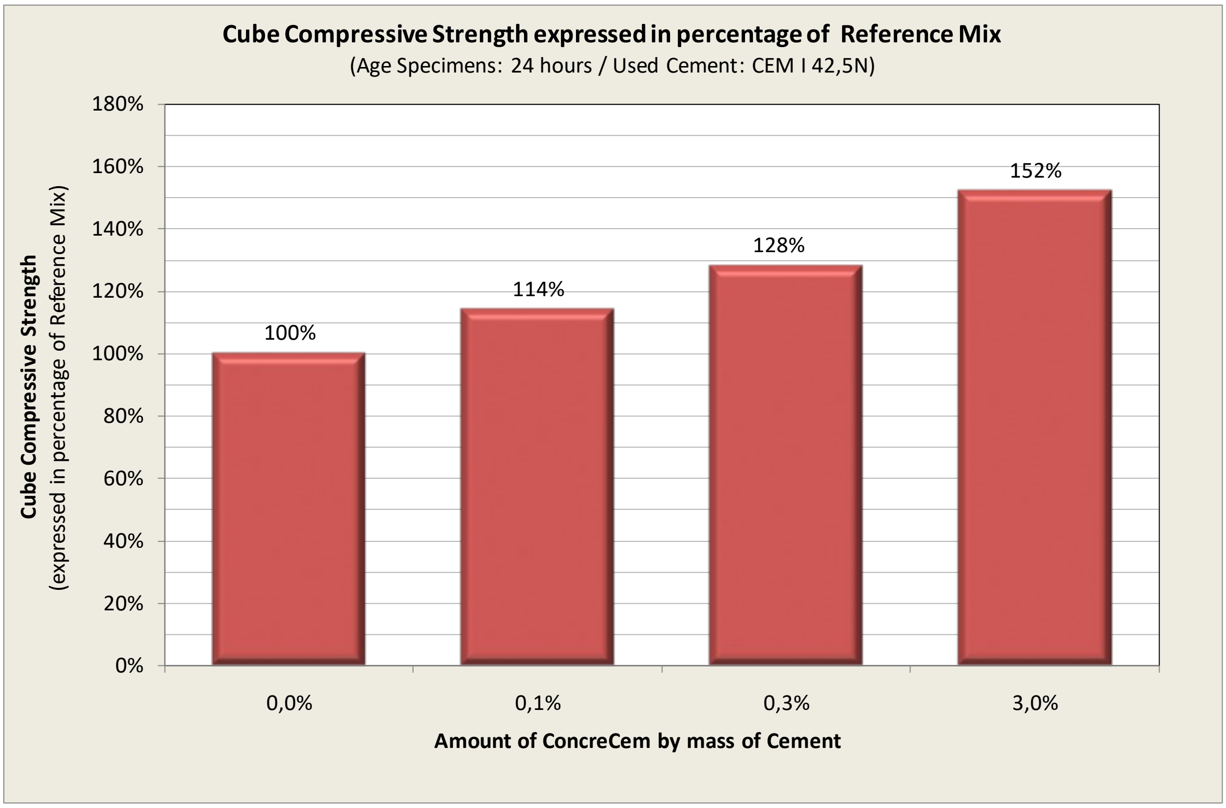


*Figure 3.2: Improvement of Compressive strength after **24 hours** when using ConcreCem*

Figure 3.3 to 3.5 shows the mixing and testing of wet concrete; the casting and monitoring of different kinds of samples and destructive testing on different kinds of samples after 28 days.

Figure 3.3: Mixing and testing (slump, air content and temperature) wet concrete

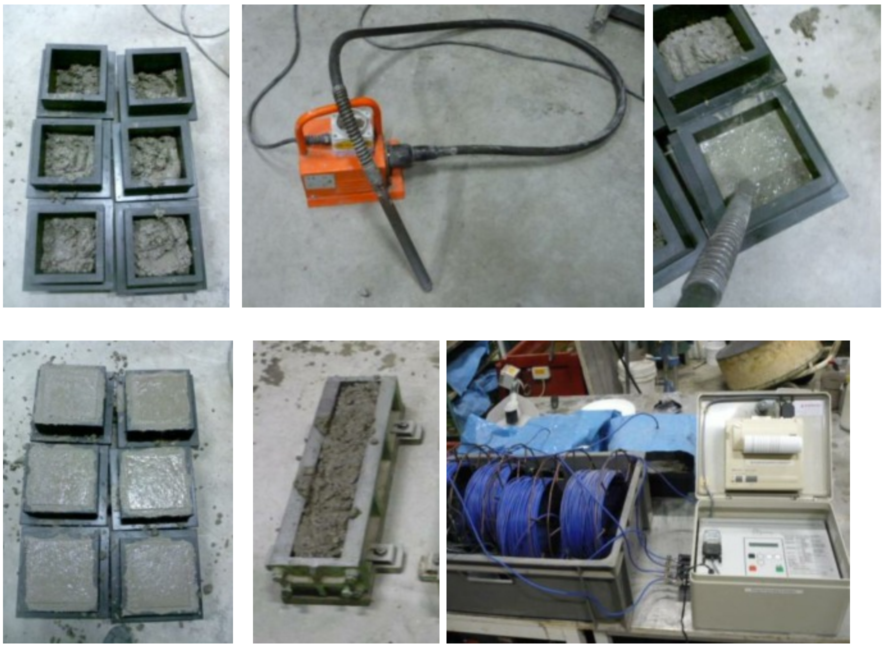


Figure 3.4: Casting and monitoring samples

Figure 3.5: Testing compressive strength, tensile strength and tensile splitting strength.

A very interesting property of ConcreCem is the ability to improve the early strength of concrete when mixing the concrete at a low temperature. All the materials were kept at 5°C prior to mixing in a climate chamber (figure 5.6).

The temperature of the wet reference concrete mix was 11,5 °C and the temperature of the wet concrete mix with 0,3% ConcreCem was 11,2 °C.

These tests show that concrete with 0,3% ConcreCem improves compressive strength after 48 hours with 35% compared to the reference mix.
This complies with the requirement mentioned in the European Standard EN 934-2, table 7 (“Specific requirements for hardening accelerating admixtures”).

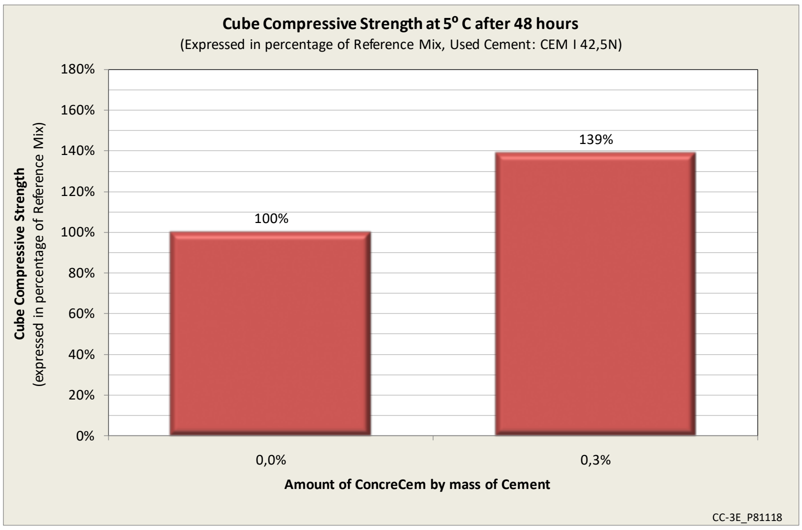


Figure 3.6: Keeping materials at 5°C prior to mixing and results compressive strength after 48 hours at 5°C

4 ConcreCem and latent-hydraulic materials

Tests have been performed with a combination of ConcreCem and latent hydraulic materials, like calcareous fly ash and blast-furnace slag. To understand how latent-hydraulic materials react, it is necessary to understand the chemical reaction of cement and water.

Cement is made by heating limestone (figure 4.1-A) and shale in a clinker-oven at a temperature of about 1450 ^oC. After cooling down the clinker (figure 4.1-B) is grinded to produce Ordinary Portland Cement. It is also possible to grind the clinker together with blast-furnace slag (figure 4.1-C) to produce Blast–furnace slag cement.

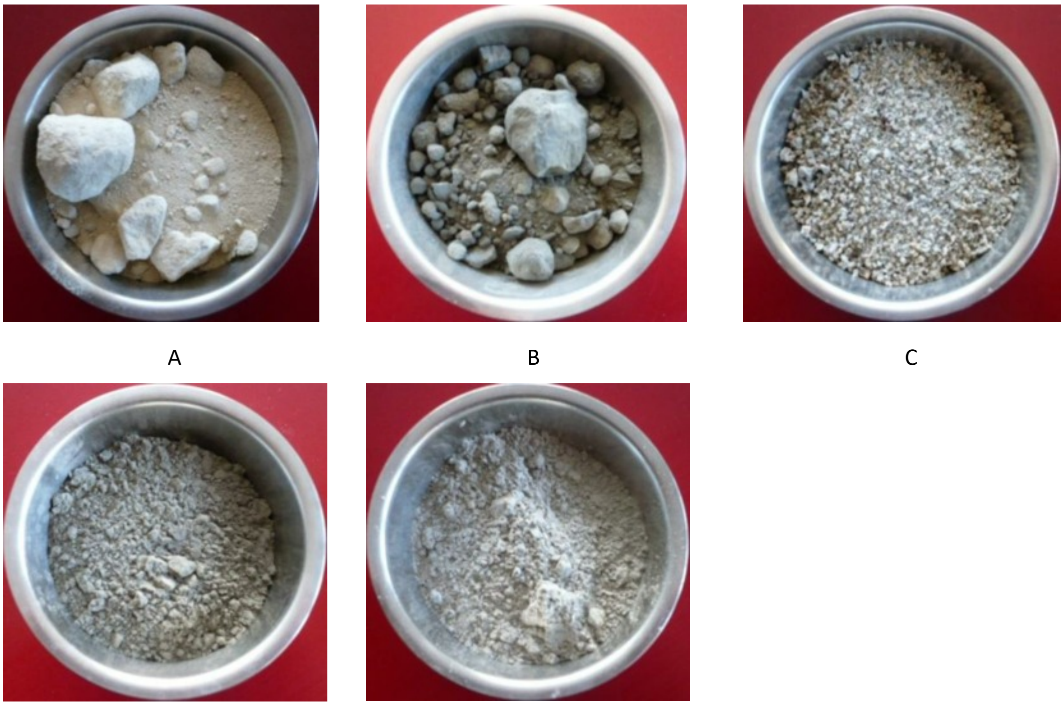


Figure 4.1: Limestone (A), Clinker (B), Slag (C), Ordinary Portland Cement (D), Blast-furnace Slag Cement (E)

Basically the cement reaction with water is a chemical reaction between:
A. calcium oxide (CaO)
B. reactive silicon dioxide (SiO_2)
C. aluminium oxide (Al_2O_3)
D. iron oxide (Fe_2O_3) and
E. water.

The calcium oxide is normally provided with the cement and the cement also contains some of the other components (added to the clinker oven as sand and/or clay). In a later stage water is added to the mix.
With a normal Portland cement there is always too much calcium oxide present. This excess amount of calcium oxide (can) react with SiO_2, Al_2O_3 and Fe_2O_3 which are present in other materials that are added to the mix. Very often fly ash or silica-fume are added. These materials are called **pozzolana's** (from the Italian place of origin on the Vesuvius) and are siliceous in nature: they contain over 70% of $SiO_2 + Fe_2O_3 + Al_2O_3$.

Another type of materials are called **latent-hydraulic** and contain, like cement: CaO and SiO_2. Examples of latent-hydraulic materials are blast-furnace slag and calcareous fly-ash. These materials react with water in the same way as cement, but they react very slowly. Portland cement is normally used as an activator. However, the addition of ConcreCem to the blend, makes the chemical reaction much faster.

The three different chemical reactions of cement, pozzolan and latent hydraulic with water are mentioned below.

Cement reaction:	$C_3S + H_2O \rightarrow CSH + Ca(OH)_2$
Pozzolan reaction (slow):	$Ca(OH)_2 + SiO_2 \rightarrow CSH$
Latent hydraulic reaction (moderate):	$CaO + SiO_2 + H_2O \rightarrow CSH$

In the following paragraphs mix designs with calcareous fly ash and ground granulated blast furnace slag are presented.

4.1 ConcreCem with calcareous fly ash

Tests with a blend of 65% CEM I 42,5 N and 35% calcareous fly ash and different amounts of ConcreCem demonstrate a very large influence on the early strength compared to the blend without ConcreCem.
To determine this improvement mortars according to EN 196-1 were prepared and prisms were casted. Table 4.1 shows the results and figure 4.2 gives these results in a graph.

Table 4.1: Compressive strength of a Blend (65% CEM I 42,5 N + 35% calcareous fly ash) with 0,0% - 0,3% and 0,6% ConcreCem

Age samples	Compressive strength [N/mm^2]					
	Blend I: Blend + **0,0%** ConcreCem		Blend II: Blend + **0,3%** ConcreCem		Blend III: Blend + **0,6%** ConcreCem	
0	0	-	0,0	-	0	-
1	3,2	100%	4,0	125%	3,6	113%
2	7,2	100%	8,7	121%	10,9	151%
7	17,0	100%	21,1	124%	18,6	109%
28	33,0	100%	35,5	108%	34,8	105%
56	44,0	100%	45,8	104%	-	-
91	47,1	100%	51,5	109%	55,3	117%
"Source: 316.002_901-5"						

Compared to the reference (Blend I) adding ConcreCem can improve the compressive strength in the early stage up to 25%. This is a very significant improvement!
Even after 56 days using 0,3% ConcreCem has a 4% higher compressive strength than the reference mixture. Although the results of 0,6% ConcreCem after 56 days were a bit behind the reference, after 91 days there is an improvement of 17% compared to the reference.

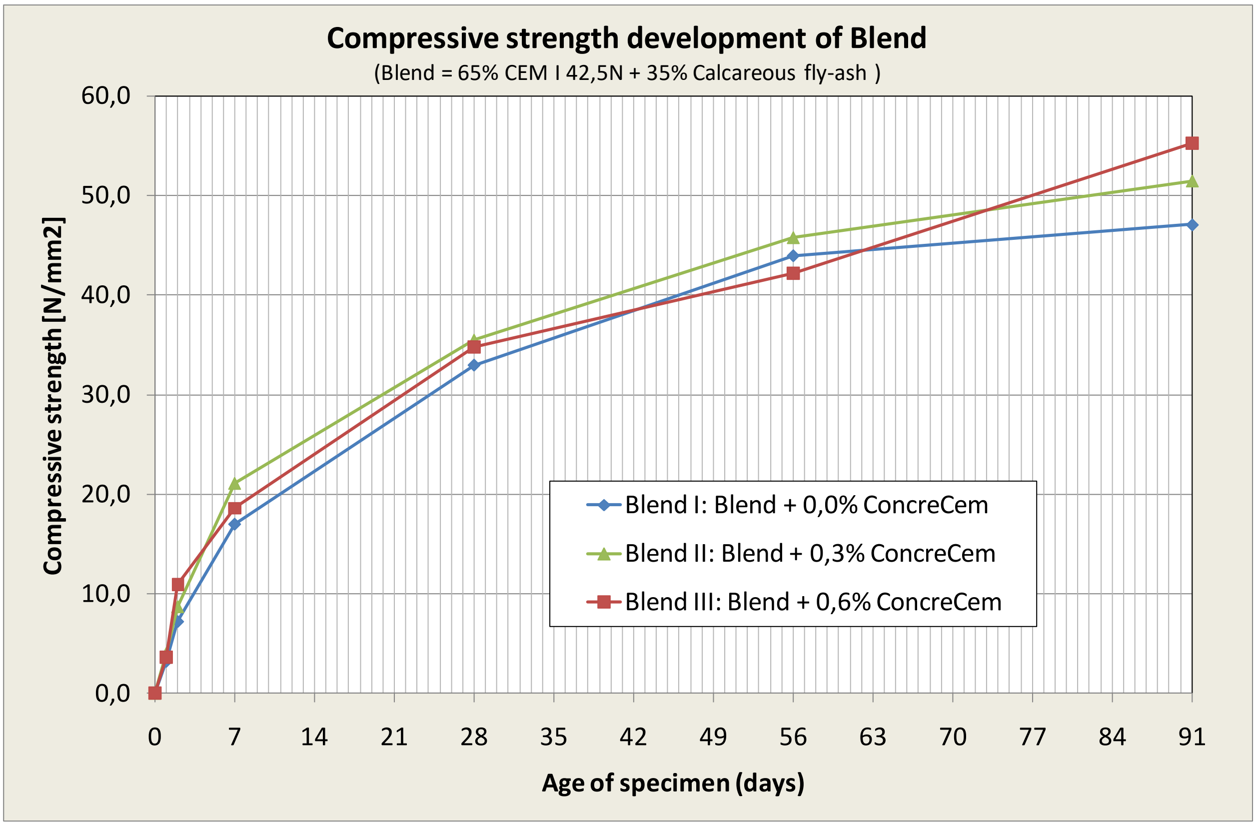


Figure 4.2: Results compressive strength of Blends (CEM I 42,5N + Fly-ash) + ConcreCem

Figure 4.3: Steps in preparation samples

4.2 ConcreCem with ground granulated blastfurnace slag

Designs with a blend of Ordinary Portland Cement, ground granulated blast furnace slag and ConcreCem were prepared. Table 4.2 shows the results known so far and figure 4.4 gives these results in a graph.

Table 4.2: Compressive strength of a Blend I CEM I 52,5 R VS. (70% CEM I 52,5 R + 30% ground granulated blast furnace slag) and ConcreCem

Age samples [days]	Compressive strength [N/mm^2]					
	Blend I: Blend + 0,0% ConcreCem		Blend II: Blend + 0,3% ConcreCem		Blend III: Blend + 0,6% ConcreCem	
1	3,1	100%	4,0	129%	3,6	116%
2	10,5	100%	11,3	108%	11,7	111%
7	31,6	100%	35,5	112%	-	-
28	48,6	100%	55,0	113%	55,3	114%
56	54,9	100%	57,5	105%	58,0	106%
"Source: 316.002_811-13"						

Compared to the reference (Blend I) adding ConcreCem can improve the compressive strength after 1 day with **29%**. This is a stunning result, keeping in mind that the reference mixture is prepared with the best cement type within this application field available. Also **after 28 days** the compressive strength of the **blends with ConcreCem** is approximately **14% higher** in compressive strength compared to the reference mixture.

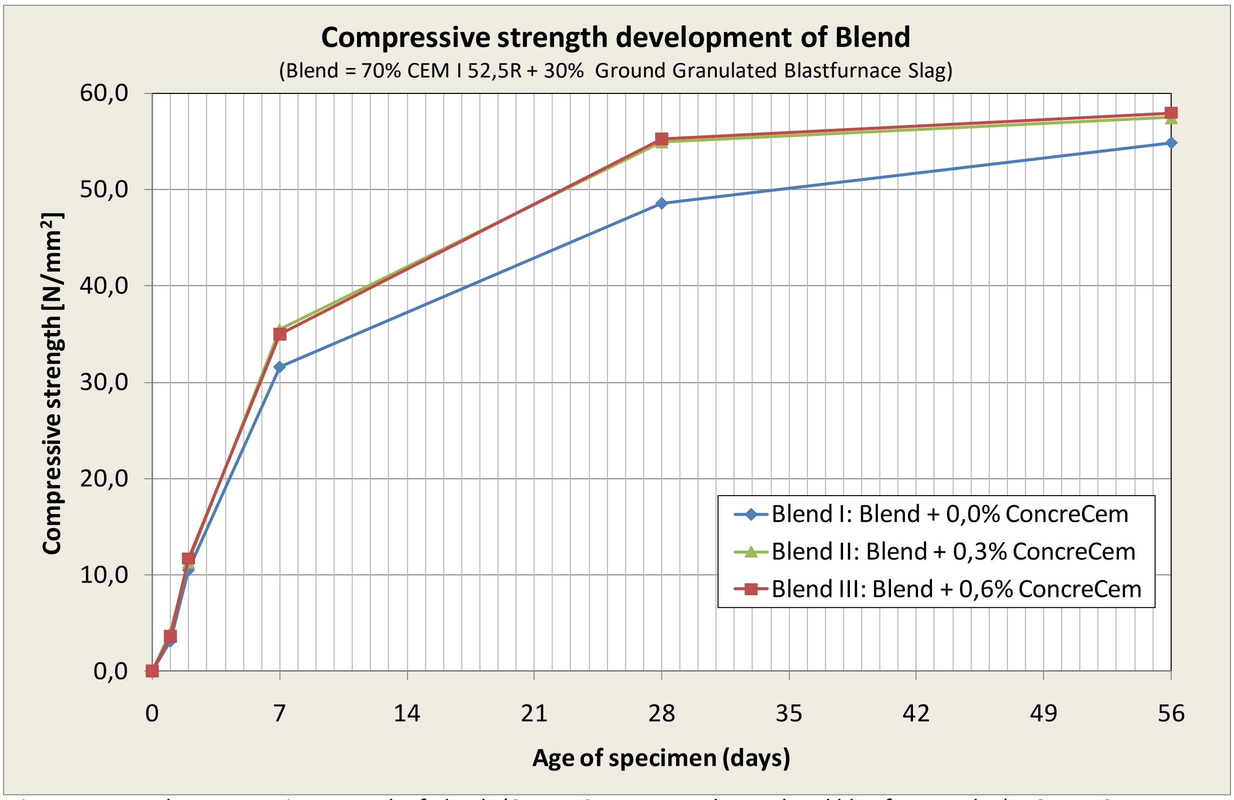


Figure 4.4: Results compressive strength of Blends (CEM I 52,5R + ground granulated blastfurnace slag) + ConcreCem

Figure 4.5 shows the steps in preparation samples.

Figure 4.5: Steps in preparation samples

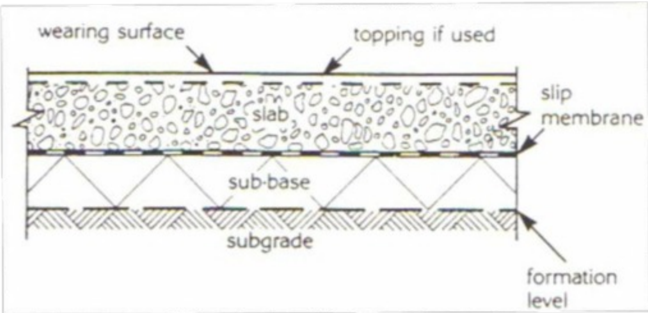
4.3 Conclusion

Based on the test results it can be concluded that ConcreCem increases the early compressive strength in blends with calcareous fly ash with 51% and in blends with ground granulated blast furnace slag with 29%. Also after 56 days and 91 days ConcreCem improves compressive strength.

Further Research is still going on.

5 ConcreCem in Rapid Powder Concrete for wearing surface

A special application of ConcreCem which has been tested in laboratory is a mixture for the wearing surface of a concrete floor. Figure 5.1 shows the elements of a floor.



Source: “Concrete Ground Floors, their design, construction and finish” R. Colin Deacon

Wearing surface:	upper surface of the slap, suitably finished or applied topping
Slab:	main structural concrete element forming the floor.
Slip membrane:	used to reduce friction and to prevent loss of cement fines from the wet concrete into the material base
Sub-base:	selected material imported to form a level smooth working platform on which to construct the slab
Subgrade:	naturally occurring ground excavated down to formation level or imported fill material

Figure 5.1: Elements of a floor

This mix is very special because of the following characteristics:

- Compressive strength > 100 N/mm^2.
- Very high workability.
- Maximum particle size of 1 mm.
- Very high ductility because fibers and ConcreCem are used to provide excellent resistance against mechanical impact.
- Very dense cement matrix because blast-furnace slag cement, silica-fume and ConcreCem are used, providing excellent resistance to both chemical and physical impact.

The mixtures shown in table 5.1 have been prepared in the laboratory. Compressive strength tests have been performed after 24 hours, 7 days and 28 days.

Table 5.1: Mix Specifications Rapid Powder Concrete

Material	Amount per 1 m^3 of concrete [kg]		
	Reference Mix: **0,0%** ConcreCem	Mix I: **0,3%** ConcreCem	Mix II: **0,3%** ConcreCem
CEM I 52,5 R	358	358	358
CEM III/A 52,5 N	554	554	554
Silica Fume	60	60	60
Water	229	229	229
Glenium 51 (superplasticiser)	44	44	44
Sand 0/1	1012	1012	1012
ConcreCem	**0,00**	**2,7**	**2,7**
Steel fibres (figure 5.7)	0	0	63
Water / cement ratio	0,24	0,24	0,24
Density	2300 kg/m^3	2290 kg/m^3	2400 kg/m^3
Compressive strength - after 24 hours - after 7 days - after 28 days	 43,0 N/mm^2 94,3 N/mm^2 94,3 N/mm^2	 50,8 N/mm^2 96,9 N/mm^2 107,4 N/mm^2	 57,4 N/mm^2 101,0 N/mm^2 118,1 N/mm^2
Slump-Flow (Haegermann)	350 mm	345 mm	353 mm

Figure 5.2: Mixing and testing Rapid Powder Concrete and used steel fibers

Rapid powder concrete can also be used to produce large concrete elements. Examples of successful use in Europe are large beams in nuclear power stations and sheet pilings. Examples of successful use in the United States are large thin roof tiles.

In these cases the aggregates, the type of fibers and the amount of strength contributing, ConcreCem have to be properly adjusted to meet the application requirements and design criteria.

6 ConcreCem against deterioration by Hydrochloric and Sulphuric acid

ConcreCem increases the durability of concrete, because of the chemical reaction between water and cement particles inside the concrete. To validate this statement tests with immersion of specimen in **hydrochloric** and **sulphuric acid** were executed.

6.1 Hydrochloric acid (36% M - 1,19 g/ml)

Two regular mortar samples of a 28-days-days-old mixture (prepared with saltwater and salt Sahara sand) have been immersed in a solution of **hydrochloric acid**. One sample was a mixture with 0,3% ConcreCem and the other was the same mixture but then without any ConcreCem added. The **hydrochloric acid** had a pH-value of 0,45.
Immediately after being immersed the samples were getting damaged. Figure 6.16 shows several pictures of the immersion in **hydrochloric acid** and the deterioration of the samples.

Figure 6.1: Immersion in 36% M hydrochloric acid (pH = 0,45) and deterioration of the prisms

The loss of weight was measured after a couple of minutes. Table 6.1 shows the results and figure 6.2 shows these results in a graph.

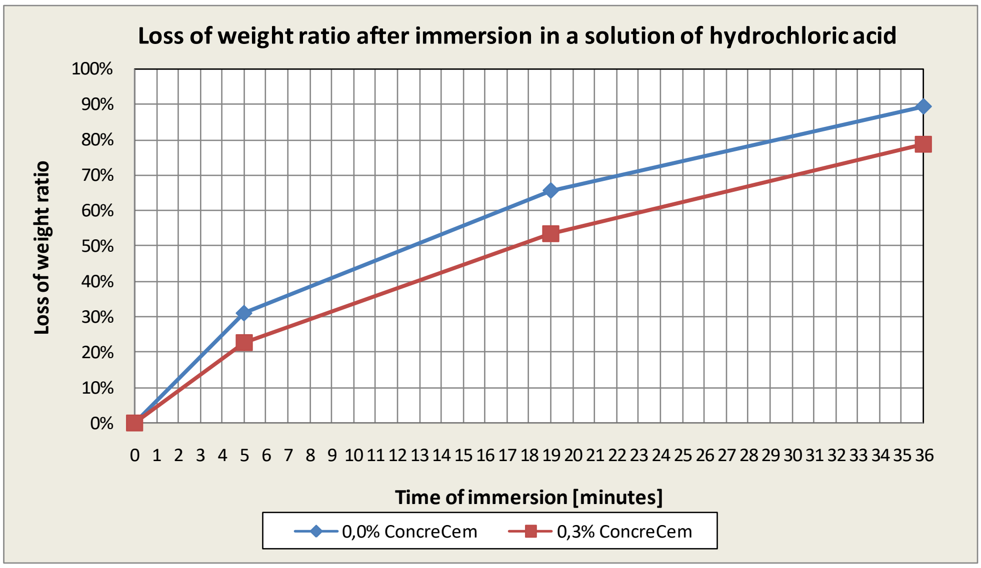
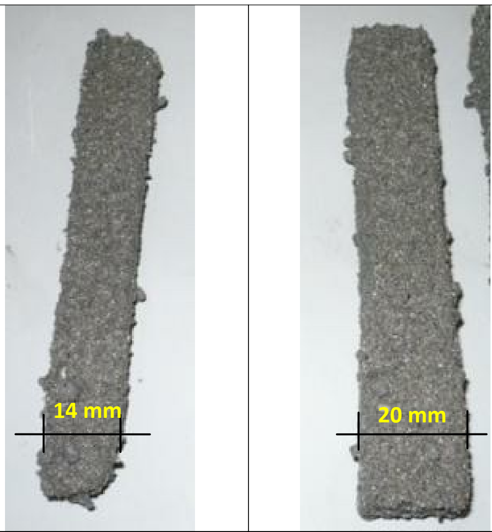


Figure 6.2: Loss of weight ratio after immersion in a solution of hydrochloric acid (pH = 0,45)

Table 6.1: Results loss of weight (ratio) after immersion in hydrochloric acid

Time of immersion [minutes]	Loss of weight of prisms [g]			
	Mix 1 **0,0% ConcreCem**		Mix 2 **0,3% ConcreCem**	
0	537,1	0%	550,9	0%
5	370,2	31%	425,8	23%
19	184,1	66%	256,4	53%
36	56,6	**89%**	117,4	**79%**

The mixture with 0,3% ConcreCem (mix 2) has a lower weight loss ratio than the mixture without ConcreCem. Figure 6.3 shows the difference in weight loss after 36 minutes. We can clearly see that there is more left of the samples with ConcreCem than the samples without ConcreCem. Normally a sample is 40 mm in width. After 36 minutes immersion in hydrochloric acid the width of the sample without ConcreCem decreases to 14 mm and the width of the sample with 0,3% ConcreCem decreases to 20 mm. There is a difference in width of 6 mm (as can be seen in figure 6.3). As calculated to the width of a sample this difference is 15%.
In this test the samples were exposed to the worst possible scenario of an acid-attack with a pH-value of 0,45. In reality this process will be much slower. However, the mortar mix with ConcreCem is more resistant to these attacks than the mixture without ConcreCem.



Mix 1: 0,0% ConcreCem sample in hydrochloric acid	**Mix 2: 0,3% ConcreCem** sample in hydrochloric acid

Figure 6.3: samples after 36 minutes of immersion in hydrochloric acid

6.2 Sulphuric acid (37% - 1,28 g/ml)

Tests with 273 days old normal weight concrete (water-cement-ratio = 0,51) without ConcreCem and with 0,3% ConcreCem in **sulphuric acid** (37% M) are executed. Figure 6.4 shows the dried specimen immersed in water and in **sulphuric acid** for 16 days.

273 days old concrete **without ConcreCem**

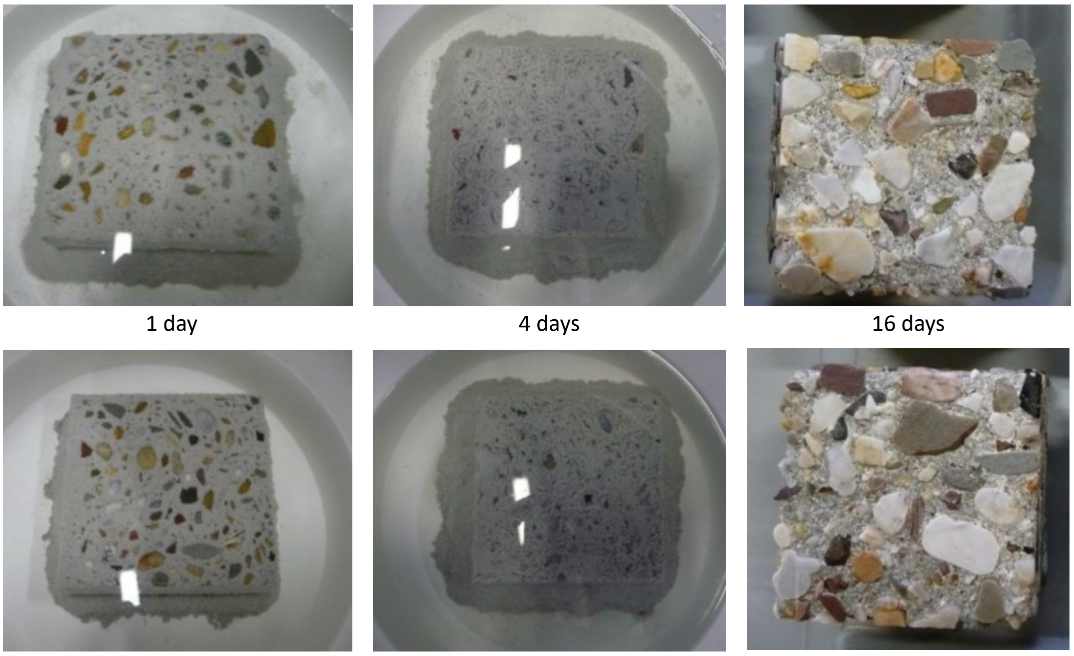
Immersed in water — immersed in sulphuric acid

273 days old concrete with **0,3% ConcreCem**

Immersed in water — Immersed in sulphuric acid

Figure 6.4: Specimen immersed in water and in Sulphuric acid

Figure 6.5 shows the steps of deterioration after immersion in sulphuric acid of concrete specimen without and with 0,3% ConcreCem.



1 day | 4 days | 16 days

273 days old normal weight of concrete **without ConcreCem** after immersion in Sulphuric acid (37% M)

1 day | 4 days | 16 days

273 days old normal weight of concrete **with 0,3% ConcreCem** after immersion in Sulphuric acid (37% M)

Figure 6.5: Steps of deterioration after immersion in sulfuric acid of concrete samples without and with 0,3% ConcreCem

After a safe curing period of 273 days the first class concrete samples are placed for 16 days in a sulphuric acid bath. After such a long period of perfect conditioning the samples are exposed for a period in an aggressive environment with a 37% M Sulfuric concentration, visually no engraving differences so far. However checking the physically/mechanically behavior and reduction in compressive strength we see an impressive difference in advance of just this minor quantity of ConcreCem. Safety and security especially within the framework of sensitive applications is possible if the end product can be marked as durable or long lasting!!!

After immersion in sulphuric acid the specimen were dried in a ventilated oven and tested on compressive strength. Table 6.2 shows the results.

Table 6.2: Compressive strength before and after immersion in sulphuric acid

Compressive strength [N/mm^2]			
Mix (water-cement-ratio = 0,51)	28 days old specimen stored in water	289 days old specimen stored in water	273 days old specimen stored in water + 16 days stored in Sulphuric acid
0,0% ConcreCem	42,7	59,2	**34,7** (41% strength loss)
0,3% ConcreCem	47,3	59,8	**42,3** (29% strength loss)

First of all there is an increase in compressive strength after 289 days compared to the compressive strength after 28 days. But immersion in **sulphuric acid for 16 days** decreases compressive strength of concrete **without ConcreCem** with **41%. Adding a minor quantity of 0,3% ConcreCem will lower this deterioration in this mix design with just 12%!**

I t can be concluded that ConcreCem indeed increases durability! An higher percentage of CC gives a higher resistant against all types of chemicals like Sulphuric acids, Hydrochloric based acids, Ammoniac based substances etc.

7 ConcreCem against chloride induced Corrosion of reinforcement

Most concrete structures show good performance over a long period of time, partly as a result of the passive environment provided by the concrete to the reinforcing steel. However, changes to the concrete environment itself (for example using salt water or salt aggregate) can make it possible to change the corrosiveness leading to the initiation of corrosion beneath apparently solid concrete.

Very often the first indication of the problem is the appearance of a crack following the line of the reinforcement, or the development of rust stains in porous concrete. The corrosion of steel produces products which have a 2 to 3 times the volume of the original metal. This causes tensile stress which results in cracking and spalling of the concrete cover. Figure 7.1 shows examples of chloride induced corrosion of reinforcement.

Figure 7.1: Examples of chloride induced corrosion

To see if an admixture causes corrosion of steel, the European standard EN 480-14 ("Admixtures for concrete, mortar and grout – Test methods – Part 14: Determination of the effect on corrosion susceptibility of reinforcing steel by potentiostatic electrochemical test") describes a test method. The test cell layout is shown in figure 7.2 and 7.3. The maximum current between 1 hour and 24 hours is measured and the maximum current density is calculated as $\mu A/cm^2$ using the calculated area of the rebar in contact with mortar.

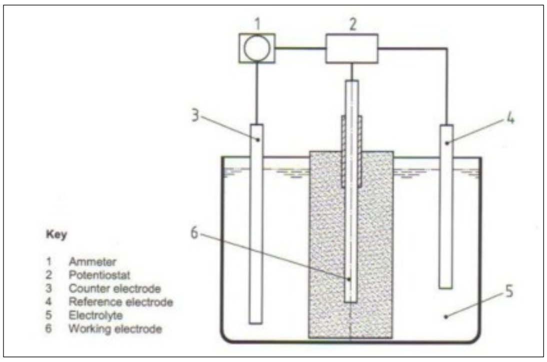


Figure 7.2: Test cell layout according to EN 480-14

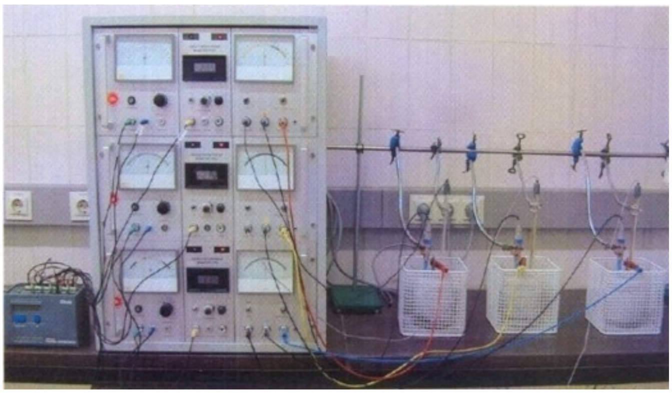
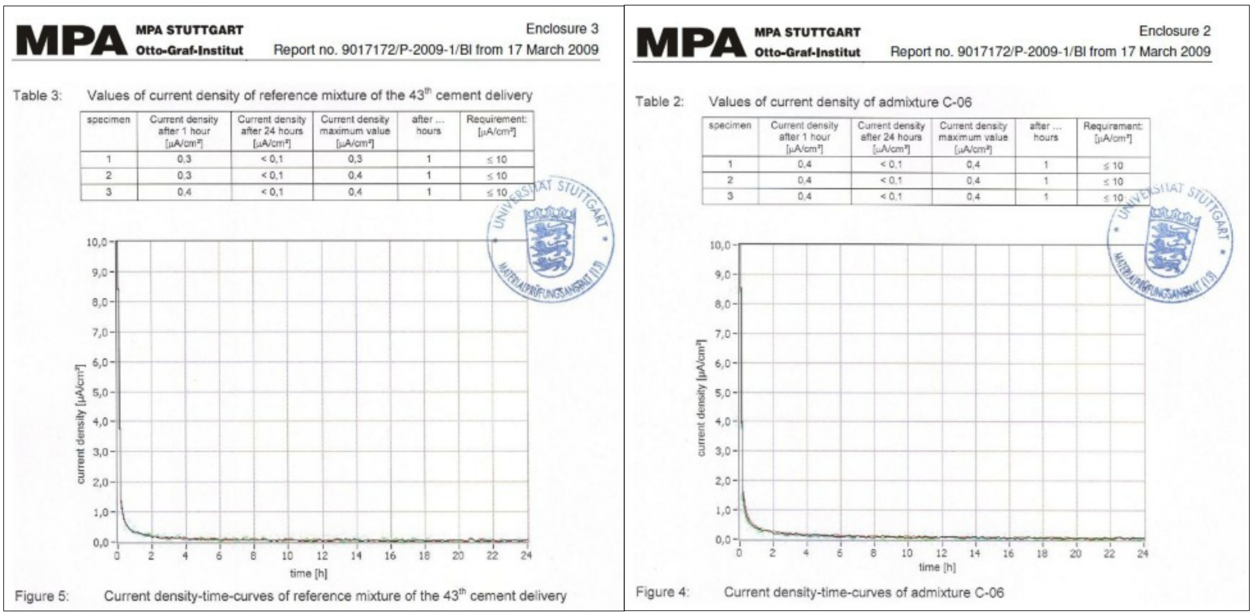


Figure 7.3: Test cell lay-out lined up in MPA Stuttgart

Tests have been performed in accordance with the mentioned method to see what happens if the maximum dosage of chlorides is added in the reference mortar mix according to EN 196-1. After testing the samples were split. The samples on the left of figure 5.21 was already split during testing. In this samples 10% Chlorides, by mass of cement were added. This is an extremely large amount of chlorides and the influence on the reinforcement steel can clearly be seen in figure 7.4.

Figure 7.4: Samples after testing according to EN 480-14

EN 934-1 prescribes requirements for the current density. The current density shall not exceed 10 µA/cm². At MPA in Stuttgart ConcreCem was tested according to EN 480-14. The reference mix (without ConcreCem) had a mean (n = 3) current density of 0,4 µA/cm². The mix with 0,8% ConcreCem by mass of cement had a current density of 0,4 µA/cm². This is in the same range as the reference mixture and considerably below the limit mentioned in the EN 934-1. Figure 7.5 shows the test results of MPA Stuttgart of the reference mortar and the mortar with 0,8% ConcreCem.



MPA STUTTGART Otto-Graf-Institut — Enclosure 3 — Report no. 9017172/P-2009-1/BI from 17 March 2009

Table 3: Values of current density of reference mixture of the 43th cement delivery

specimen	Current density after 1 hour [µA/cm²]	Current density after 24 hours [µA/cm²]	Current density maximum value [µA/cm²]	after ... hours	Requirement: [µA/cm²]
1	0,3	< 0,1	0,3	1	≤ 10
2	0,3	< 0,1	0,4	1	≤ 10
3	0,4	< 0,1	0,4	1	≤ 10

Figure 5: Current density-time-curves of reference mixture of the 43th cement delivery

MPA STUTTGART Otto-Graf-Institut — Enclosure 2 — Report no. 9017172/P-2009-1/BI from 17 March 2009

Table 2: Values of current density of admixture C-06

specimen	Current density after 1 hour [µA/cm²]	Current density after 24 hours [µA/cm²]	Current density maximum value [µA/cm²]	after ... hours	Requirement: [µA/cm²]
1	0,4	< 0,1	0,4	1	≤ 10
2	0,4	< 0,1	0,4	1	≤ 10
3	0,4	< 0,1	0,4	1	≤ 10

Figure 4: Current density-time-curves of admixture C-06

Reference mortar *Mortar with ConcreCem*

Figure 7.5: Test results of the reference mortar and mortar with 0,8% ConcreCem

Although ConcreCem is characterized for CE-label as a hardening accelerator, it is far from the same as an admixture based on Calcium-Chlorides. This type of admixture was used in a reference mortar in an amount of 1,2% and 2,4% by mass of cement. The admixture was a liquid with a solid content of 33%. The amount of liquid CaCl of 2,4% is similar to the amount of ConcreCem used in the tests performed by MPA Stuttgart.
The two mixes with CaCl were tested according to EN 934-1 and the current density measured in the samples with 0,8% CaCl was beyond the range of the test-equipment (more than 54 µA/cm²). ***The mix with 0,4% CaCl didn't meet the requirements of 10 µA/cm².*** The maximum measured current density was 52 µA/cm². More than 5 times higher than the allowed limit. Figure 7.5 shows test equipment and test results of this mix.

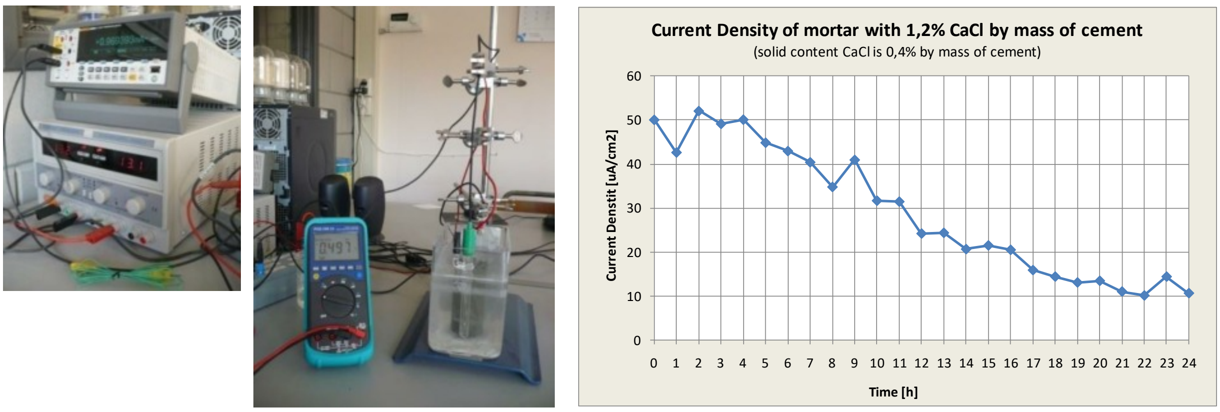


Figure 7.6: Pictures of testing equipment and test results of the mortar with 1,2% CaCl by mass of cement (solid content is 0,4% by mass of cement)

8 ConcreCem and Freeze-thawing resistance: scaling

Concrete with the addition of ConcreCem is also tested on freeze-thaw behavior. A 50 mm thick samples was sawn from a cube 150 mm x 150 mm x 150 mm. A 3 mm thick rubber sheet was glued to all surfaces except the test surface. When the concrete was 28 days old, a layer of about 3 mm deep de-ionised water was poured on the top surface. This saturation was kept for 3 days. After 3 days (dated 18-5-2009) the de-ionised water was replaced by a solution of 97% by mass of de-ionised water and 3% by mass of NaCl and all surfaces of the samples (except the top surface) were thermally insulated with 20 mm thick polystyrene cellular plastic. The insulated samples was stored in a climate chamber which subjects the samples to repeated freezing and thawing during 56 cycles according to the time - temperature cycle mentioned in figure 8.1. After 56 cycles scaling of the samples was measured.

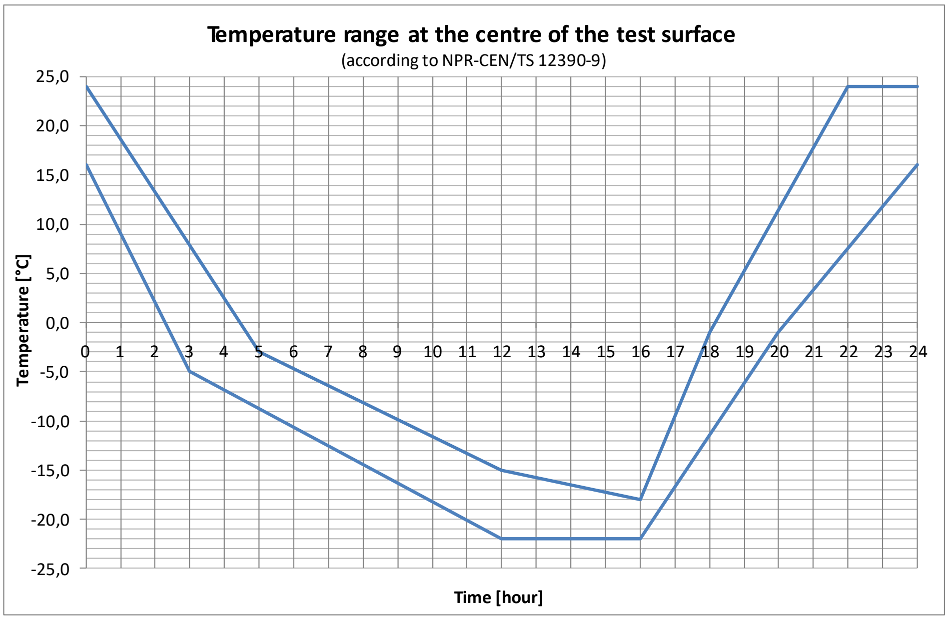


Figure 8.1: Time- Temperature cycle in the freezing medium at the centre of the surface (according to NPR CEN TS 12390-9)

Figure 8.2 shows several impressions of the testing procedure.

The tested samples is a steel-fibred concrete with 0,3% ConcreCem. After 7 cycles no scaling was determined. After 14 cycles only the fibres are corroded as can be seen in figure 5.4 but still no scaling appears.

Figure 8.3: Surface of steel-fibred concrete with 0,3% ConcreCem at 7 cycles of freeze-thaw testing and after 14 cycles.

Figure 8.2: Impressions of testing freeze-thaw behavior,(Nummering volgorde klopt niet)

Freeze-thawing tests are also performed to concrete of 205 days old, with and without the addition of ConcreCem. Except for the amount of ConcreCem both mixes have an identical mix design.
As can be seen in the following pictures, the concrete with 0,3% ConcreCem has clearly fewer scaling than the concrete without ConcreCem.

The concrete without ConcreCem had a weight loss of 3,6 kg/m^2 , whereas the concrete with 0,3% ConcreCem had a weight loss of a marginal 0,7 kg/m^2 only.

*Figure 8.3: Surface of 205 days old concrete **without ConcreCem** after 14 cycles of Freeze-thawing*

*Figure 8.4: Surface of 205 days old concrete **with** after 14 **0,3% ConcreCem** after 14 cycles of Freeze-thawing*

After 28 cycles the mass of scaling is also measured and figure 8.5 shows the amount of scaling of the concrete with and without the addition of 0,3% ConcreCem. The difference in the amount of scaling is really huge!

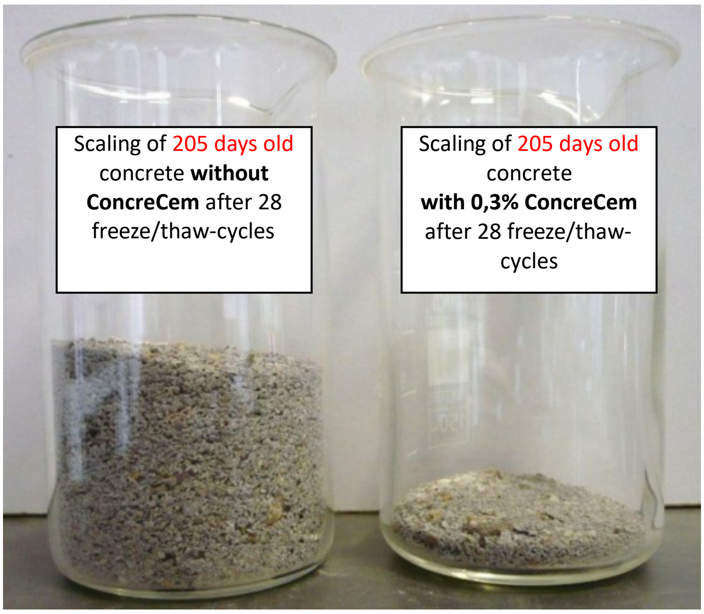


*Figure 8.5: A*mount of scaling of the concrete with and without the addition of 0,3% ConcreCem

The addition of ConcreCem provides enhanced durability. This cannot easily be calculated and expressed in hard currency. It remains very difficult to calculate the costs of repairing concrete in which no ConcreCem was used. For instance the damage caused by freeze-thawing as shown in this chapter. **The use of only 0,3% ConcreCem will reduce freezing-thawing damages fivefold!**

For us the question remains how can we calculate these benefits, however the customer or authority faced with the annual repair bill can quickly make this calculation!

9 ConcreCem and mix design of Normal Strength Concrete

To design a concrete mixture, specification of the concrete and properties of the materials has to be known (in Europe according to EN 206-1). Table 9.1 shows examples of (useful) properties that need to be known.

Table 9.1: Properties needed for mix design according to EN 206-1

Specification concrete	Properties materials				
	Cement	Additives	Water	Admixtures	Aggregates
strength class early strength environmental classes consistency class density special requirements reinforcement	type strength class early strength chloride content	density chloride content	density chloride content	density liquid or powder solid content chloride content	type particle size distribution water absorption particle shape chloride content

ConcreCem improves the early strength (24 hours) by about 70% depending on the dosage compared to the same concrete without the addition of ConcreCem. The equivalent improvement at 28 days can be up to 25%, again depending on the dosage.

In some countries a maximum of the chloride and alkali content in the concrete is prescribed. For this reason it is important to know the chloride and alkali content of the different materials which are used in a mixture. It is also important to know and understand the local regulations. Together with these data and information calculations can be made to determine the maximum allowable dosage of ConcreCem for each specific country.

For example in Europe, EN 206-1 limits the chloride content in concrete and local regulations limit the alkali content in concrete. As a result, with common Dutch materials the maximum allowable dosage of ConcreCem in reinforced concrete in The Netherlands is 0,8% by mass of cement.

Taking this limitation into consideration example mixes with typical Dutch materials are given on the next pages. The mixtures have been designed by means of strength class and workability (slump). In Europe a water/cement ratio of 0,65 is not usual. Furthermore the use of a plasticizer is recommended in case a slump of more than 150 mm is required to prevent segregation of the mix.

The estimated strength class of Mix C16/20 in paragraph 9.1 can be a C30/37 when ConcreCem is added. However to validate this assumption, mixtures with local available materials should be made in the laboratory in consultation with PowerCem Technologies.

9.1 Mix C16/20, slump = 180 mm

Materials	**Density [kg/m^3]**	**Amount of material in 1 m^3 concrete [kg]**
CEM I 42,5N	3150	331
ConcreCem (0,3% by mass of cement)	2180	1,01
Water	1000	214
Sand 0/4 mm	2650	702
Gravel 4/16 mm	2650	1050
Air content (EN 12350-7)		2%
Water / cement ratio		0,65
Estimated slump (EN 12350-2)		180 mm
Estimated compressive strength after 24 hours		10 N/mm^2
Estimated compressive strength after 28 days		46 N/mm^2

9.2 Mix C20/25, slump = 140 mm

Materials	Density [kg/m^3]	Amount of material in 1 m^3 concrete [kg]
CEM I 42,5N	3150	310
ConcreCem (0,3% by mass of cement)	2180	0,95
Water	1000	202
Sand 0/4 mm	2650	720
Gravel 4/16 mm	2650	1080
Air content		2%
Water / cement ratio		0,65
Estimated slump		140 mm
Estimated compressive strength after 24 hours		8 N/mm^2
Estimated compressive strength after 28 days		38 N/mm^2

9.3 Mix C30/37, slump = 100 mm

Materials	Density [kg/m^3]	Amount of material in 1 m^3 concrete [kg]
CEM I 42,5N	3150	345
ConcreCem (0,3% by mass of cement)	2180	1,06
Water	1000	191
Sand 0/4 mm	2650	720
Gravel 4/16 mm	2650	1080
Air content		2%
Water / cement ratio		0,55
Estimated slump		100 mm
Estimated compressive strength after 24 hours		18 N/mm^2
Estimated compressive strength after 28 days		46 N/mm^2

10 ConcreCem and mix design of High Strength Concrete

In case of high strength concrete a lot of cement is used which contributes to easily cracking of the concrete due to the high temperature which will occur in the mix.
Adding ConcreCem will reduce this cracking.
In the paragraphs below mix designs with ConcreCem of a C120, C150 and C180 are given.

10.1 Mix C120

Material	Amount of material in 1 m^3 concrete [kg]
CEM I 52,5R	358
CEM III/A 52,5 N	554
ConcreCem (0,3% by mass of cement)	2,74
Silica Fume	60
Water	229
Super plasticiser, Glenium 51	44
Round Sand 0/1	1012
Steel fibres (OL13/.16)	125
Water / binder ratio	0,25
Density	2380 kg/m^3
Compressive strength (after 28 days)	120,0 MPa

Figure 10.1: Preparing, mixing and testing mix C120

In figure 10.2 the samples after testing for the compressive strength is shown and figure 10.3 after tensile splitting strength. On the left picture of figure 10.3, the impression of the timber board is visible. Because of the fibres and ConcreCem the cube isn't split in two halves.

Figure 10.2: compressive strength

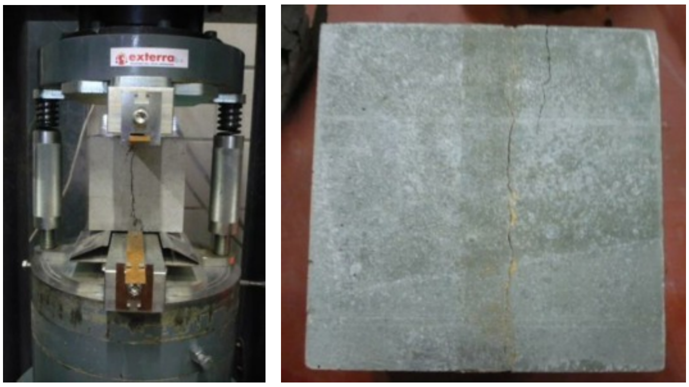


Figure 10.3: Tensile splitting strength

Table 10.1 describes the results of the compressive strength and the tensile splitting strength.

Table 10.1: Density, compressive strength and tensile splitting strength cubes (EN 12390-3 / EN 12390-6)

samples	date			D	A_c	F_c	$\mathbf{f_c}$	F	$\mathbf{F_{ct}}$
	prepared	tested		[kg/m^3]	[mm^2]	[kN]	**[N/mm^2]**	[kN]	**[N/mm^2]**
1	19-12-08	22 hr	20-12-09	2440	9993	777,9	**78,0**	-	**-**
2	19-12-08	28 d	16-01-09	2360	9850	1181,3	**120,0**	-	**-**
3	19-12-08	28 d	16-01-09	2380	-	-	**-**	258,0	**16,35**

Remarks:

Rate of load tensile splitting strength: 0,04 – 0,06 MPa/s

Rate of load compressive strength: 0,2 – 1,0 MPa/s

D: Density samples [kg/m3]

A_c: Cross-sectional area samples

F: Maximum tensile splitting load at failure [kN]

F_c: Maximum compressive load at failure [kN]

F_{ct}: Flexural strength [N/mm^2]

f_c: Compressive strength [N/mm^2]

10.2 Mix C150

Material	**Amount of material in 1 m^3 concrete [kg]**
CEM I 52,5R	981
ConcreCem (0,3% by mass of cement)	2,94
Silica Fume	216
Quartsfiller	325
Water	178
Super plasticiser, ACE 30, con. 30%	92
Crushed sand 0/1	472
Steel fibres (OL13/.16)	196
Water / binder ratio	0,21
Density	2470
Estimated compressive strength (after 28 days)	150 MPa

The way of mixing the different materials is very critical. The following procedure was used:
- Sand + Cement + ConcreCem
- Mixing for 1 minute
- Adding water + super plasticizer
- Mixing for 1 minute
- Adding Silica Fume
- Mixing for 2 minutes
- Adding Quarts filler

- Mixing for 2 minutes
- Adding steel fibres
- Mixing for 4 minutes

Remark:

- The working period of this specific mixture was determined at approx. 30 minutes.

Figure 10.4 show the steps in mixing and preparing samples.

Figure 10.4: Mixing and preparing samples Mix C150

Samples were tested for flexural- and compressive strength according to EN 196-1 and are exposed in Table 10.2
Unfortunately the available flexural strength testing equipment reached its limits on measurement after 3 days. Our own laboratory has no possibility to monitor the flexural strength up to 28 days. Consequently these tests will now be performed in a different laboratory. The conclusions and findings will be added to this document.
Figure 10.5 shows the sample after flexural strength testing. The micro steel fibres, which keep the two parts of the sample together, are clearly visible.

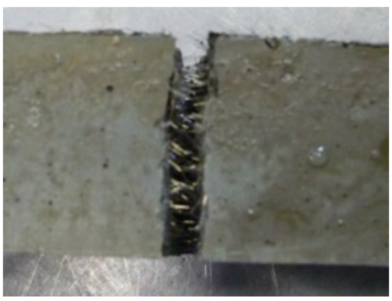


Figure 10.5:sample after testing flexural strength

Table 10.2: density, flexural and compressive strength prisms according to EN 196-1

samples	date			D	F_f	R_f	F_c	R_c
	prepared	tested		[kg/m³]	[kN]	**[N/mm²]**	[kN]	**[N/mm²]**
90417-M1	17-04-09	21 hours	18-04-09	2380	6,15	**14,5**	108,1	**67,6**
		3	20-04-09	2390	> 10	**> 22**	158,9	**99,3**
		5	22-04-09	2410	-	-	179,2	**112,0**
		7	24-04-09	2410	-	-	188,3	**117,7**
		14	01-05-09	2350	-	-	201,2	**129,8**
		28	15-05-09	2360	-	-	238,5	**149,0**

Remarks:

Rate of load flexural strength: 50 ± 10 N/sec

Rate of load compressive strength: 2400 ± 200 N/sec

D: Density samples [kg/m3]

F_f: Maximum flexural load at failure [kN]

F_c: Maximum compressive load at failure [kN]

R_f: Flexural strength [N/mm²]

R_c: Compressive strength [N/mm²]

Figure 10.6 shows the results up to 28 days.

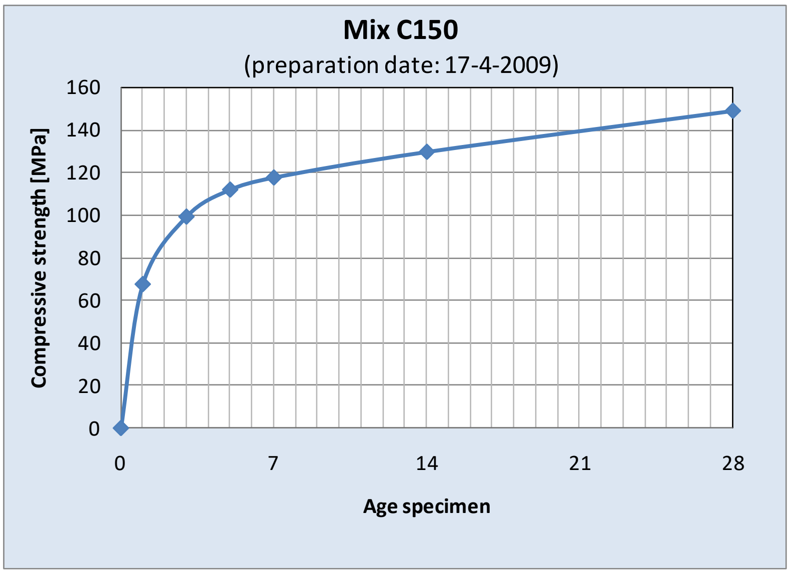


Figure 10.2: Compressive strength prisms Mix C150

10.3 Mix C180

Material	**Amount of material in 1 m³ concrete [kg]**
CEM I 52,5R	864
ConcreCem (0,3% by mass of cement)	2,6
Silica Fume, powder	198
Quartsfiller	335
Water	196
Super plasticizer, Glenium 51	105
Crushed sand 0/1	432
Steel fibers (OL13/.16)	542
Water / binder ratio	0,25
Density	2680
Estimated compressive strength (after 28 days)	180 MPa

Remark:

- This mixture contains an surplus of fibres and therefore the workability slows down.
- The workability can be improved by using a retarder. Findings and results will be added to this report.

Samples were tested for flexural - and compressive strength according to EN 196-1 and are shown in Table 5.1 Unfortunately the available flexural strength testing equipment reached its limits on measurement after 3 days. Our own laboratory has no possibility to monitor the flexural strength up to 28 days. Consequently these tests will therefore be performed in a different laboratory. The conclusions and findings will be added to this report.

Figure 4.1 shows the prism after flexural strength testing. The micro steel fibres, which keep the two parts of the prism together, are clearly visible.

Table 10.3: density, flexural and compressive strength prisms according to EN 196-1

samples	date			D	F_f	**R_f**	F_c	**R_c**
	preparing	testing		[kg/m^3]	[kN]	**[N/mm^2]**	[kN]	**[N/mm^2]**
90415-M3	15-04-09	1	16-04-09	2440	1,56	**3,5**	12,0	**7,5**
		2	17-04-09	2460	> 10	**> 22**	166,0	**103,8**
		8	23-04-09	2460	-	-	231,8	**144,9**
		28	13-05-09	2490	-	-	290,2	**181,4**

Remarks:

Rate of load flexural strength: 50 ± 10 N/sec — Rate of load compressive strength: 2400 ± 200 N/sec

D: Density samples [kg/m3]

F_f: Maximum flexural load at failure [kN] — F_c: Maximum compressive load at failure [kN]

R_f: Flexural strength [N/mm^2] — R_c: Compressive strength [N/mm^2]

Because of the very poor workability, only 3 prisms were prepared. This mixture will be monitored during 28 days.

Figure 10.3 shows the compressive strength build up during 28 days.

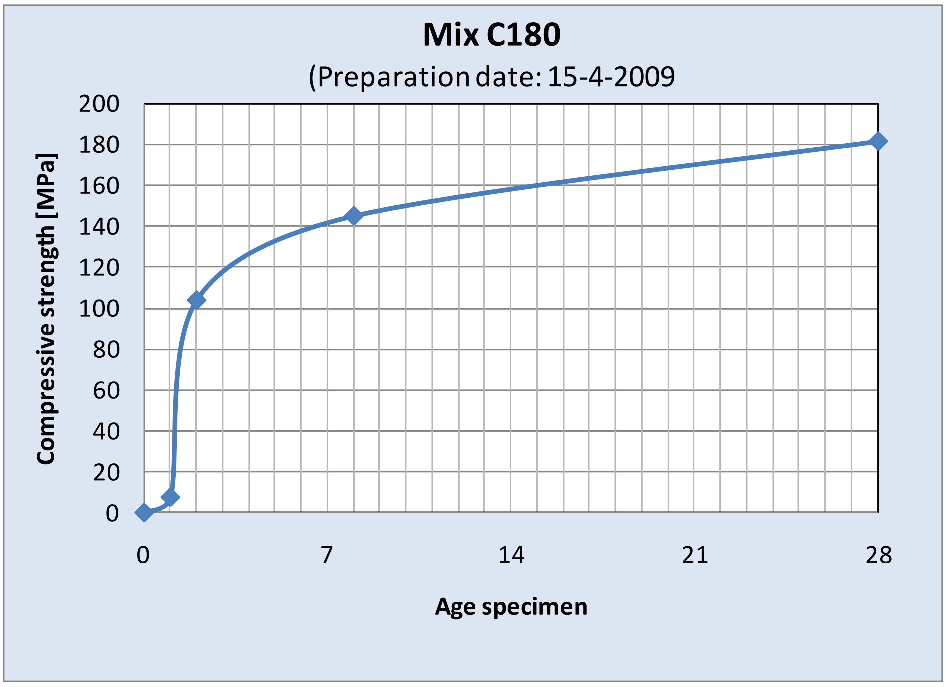


Figure 10.3: Compressive strength prisms Mix C180

11 Field applications

ConcreCem has successfully been applied in different kinds of field applications where details and durability are critical. Some project examples are given below.

11.1 Landing strip repair Air Force Pretoria South Africa

Landing strip repair (electronically devices)??? for **Air Force Pretoria South Africa**




11.2 Taxi trip repair Airport Weeze Germany

Repair Taxi strip Airport Weeze (former NATO base) at Germany



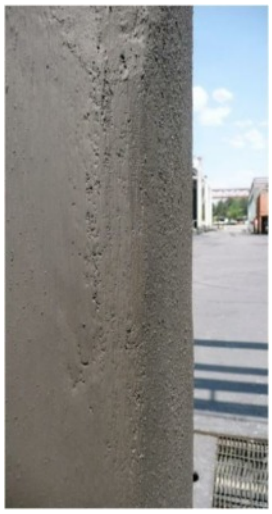


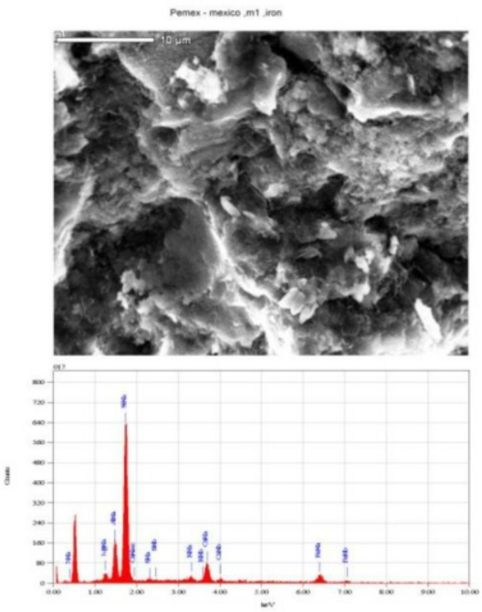
11.3 Concrete repair at Chemical Factory Mexico

Repair concrete columns and beams at **Chemical Factory in Mexico**

An investigation and repair of concrete corrosion caused by air pollution (SO_x and NO_x impact).
ConcreCem prevents future corrosion of the reinforcement.




Parts of concrete fallen from the damaged concrete columns and concrete beams

Air pollution and sulphur emissions are causes of acid rain and humidity which are working abrasively and could be responsible for concrete corrosion. ConcreCem is not only a superior solution for repairing older and damaged concrete structures it is also a superior product to protect new concrete structures under various types of chemically aggressive environments whilst withstanding heavy physical and mechanical challenges.

11.4 Concrete slab South Africa

A company in South Africa requested PowerCem Southern Africa a solution for a concrete floor, without joints, and applied on a average bearing layer. A concrete slab of 375 m^2 was applied with traditional concrete modified with ConcreCem. ConcreCem is used to significantly enhance the physical and mechanical properties of the monolith structure. ConcreCem also contributes to more flexibility and a faster binding process.

The Slab with a thickness of 200 mm was applied on a granular foundation that was directly applied on the black cotton clay soil. The slab has **no** reinforcement and **no** expansion joints. After 4 months of intensive mechanical use the flexible concrete layer is in great shape! In the mixture 300 kg Cement and 2,1 kg ConcreCem were used per 1 cubic meter of concrete with a water/cement ratio of 0,55.






11.5 Wadeville concrete slab South Africa

In cooperation with a large cement producer, PowerCem Southern Africa has established a concrete slab of 100 mm thickness, without joints and monitored this during 28 days. Neither cracks nor curling has been observed.

11.6 Pumpable Self-leveling Floor Screed in Ireland

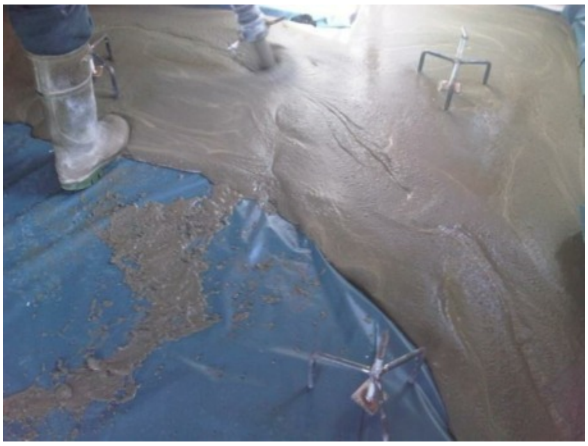
In Ireland and the UK, sand-cement floor screed emplacement has historically been a very labor intensive process, with a four man crew capable of laying 15m3 per day of screed, at thicknesses of between 75-100mm.

CEM Ltd studied this process and decided to initiate lab trials on the design of a pumpable, self-leveling sand/cement screed, which, would not crack, suffer shrinkage nor suffer edge curl-up, and give sufficient integrity to perform as the traditional dry screed.

It was decided to **include ConcreCem** in the pumpable screed to negate the perceived problems above. ConcreCem was introduced in the trials at **0,3% of the cement content** (330 kg/m^3) and a high water/cement ratio of 0,85 was decided on to give the desired slump/flow of 260-280mm. Compressive strength results at 28 days of between 12-18 Mpa, dictated the need for field trials.

Two small floors of circa 20m2 have been poured. The process time for these from pumping, to leveling, to vacating the site has been in the order of 20 minutes for 1.5m3 of screed. This would give us typical single pumpable day rates of 120 m^3. Pumping was carried out in 6 minutes.

a. Screed being pumped



b. Screed being primed for levelling

c. Transfer from mixer

d. Finished floor

Further field trials and testing is ongoing, including the determination of flexural strength and BRE Impact testing. To date the screeds have exhibited no cracks, shrinkage or edge curling and have taken foot traffic at 1 day.

12 Cost Analysis ConcreCem

This document describes the benefits of using ConcreCem, before we say something about the cost benefits, we first highlight the main benefits to concrete construction qualities contributed by the addition of ConcreCem:

- **A greater flexural strength.**
- **A significant increase of compressive strength in the early stage.**
- **A significantly lower shrinkage.**
- **A very low water impermeability and absorption.**
- **High resistance to thermal shock and thermal linear rising temperatures.**
- **High resistance to freezing and thawing.**
- **High resistance to acids and base chemicals.**
- **More durable construction.**

The above mentioned benefits can normally only be achieved by the addition of a range of different additives. ConcreCem delivers all these benefits in one additive !

Compared to the chloride-free accelerators the use of ConcreCem contributes a saving of more than € 3,00 per 1 m^3 of concrete (based on amount of 360 kg cement per 1 m^3 of concrete).

The addition of ConcreCem provides enhanced durability. This cannot easily be calculated and expressed in hard currency. It remains very difficult to calculate the costs of repairing concrete in which no ConcreCem was used. For instance the damage caused by freeze-thawing. The use of only 0,3% ConcreCem will reduce freezing-thawing damages five fold!
For us the question remains how can we calculate these benefits, however the customer or authority faced with the annual repair bill can quickly make this calculation!

In the next table two mixes are compared in costs (basis average Dutch pricing Mid 2009). Both mixes are freeze-thaw resistant.

Materials	Costs per 1000 kg	Costs per kg	Mix 1		Mix 2	
			Amount per 1m^3 concrete	Costs	Amount per 1m^3 concrete	Costs
CEM I 42,5N	€ 100,00	€ 0,10	352	€ 35,20	-	-
CEM I 52,5N	€ 100,00	€ 0,10	-	-	466	€ 46,60
Silicafume	€ 800,00	€ 0,80	-	-	69	€ 55,20
GGBS	€ 50,00	€ 0,05	-	-	188	€ 9,40
Water	€ 2,00	€ 0,00	185	€ 0,37	144	€ 0,29
Superplasticizer	-	€ 2,00	-	-	13	€ 26,00
Sand 0/4	€ 20,00	€ 0,02	786	€ 15,72	625	€ 12,50
Gravel 4/16	€ 45,00	€ 0,00	-	-	951	-
Gravel 4/32	€ 40,00	€ 0,04	1026	€ 41,04	1026	€ 41,04
ConcreCem	-	€19,80	1,06	€ 20,99	-	-
Total costs of mix			**€ 113,32**		**€ 191,03**	

The difference between the two mixes is € 77,71 per 1 m^3 of concrete.

13 CE-Label and quality control

The CE registration for ConcreCem is a pre-requisite for large scale sales and marketing in the European market.
The CE label is a European proof of conformity that allows manufacturers and exporters to circulate products freely within European Union (EU) members. The abbreviation "CE" indicate that the manufacturer has satisfactorily fulfilled all assessment procedures specified by law for its product to be sold in the European market.

ConcreCem essentially is a cement improver. Unfortunately there is no standard for the CE marking for cement improvers. An admixture seems to be the most suitable label to fill the gap within this segment. The general European standards for admixtures are:.

- EN 934-1: "Admixtures for concrete, mortar and grout. Part 1: Common requirements"
- EN 934-2: "Admixtures for concrete, mortar and grout. Part 2: Concrete admixtures. Definitions, requirements, conformity, marking and labeling.

In the EN 934-2 a definition for an admixture for concrete is given:
"Material added during the mixing process of concrete in a quantity not more than 5% by mass of the cement content of the concrete, to modify the properties of the mix in the fresh and / or hardened concrete."

Furthermore the standard gives 13 different types of admixtures with for each category specific requirements.

To obtain the CE-label, ConcreCem needs to meet the requirements mentioned in one or more of these categories. Tests are continuously going on and ConcreCem meets all the requirements of the following category: "Hardening accelerating admixtures" (EN 934-2, table 7).

PowerCem Technologies aims to produce a high quality product (multilateral applicable) and therefore each and every batch of ConcreCem is produced under the strictest quality control which is described in a quality control manual.

Table 1.1 shows the tests which are performed continuously on a sample ConcreCem of every produced batch.

Table 1.1: Tests performed on each batch of ConcreCem

no.	Property	test method
1	homogeneity	visual
2	color	visual
3	effective component	EN 480-6
4	absolute density [g/cm^3]	ISO 758
5	conventional dry material content	EN 480-8
6	pH value	ISO 4316
7	total chlorine	EN ISO 1158
8	water soluble chloride (m/m)	EN 480-10
9	alkali content (Na_2O equivalent)	EN 480-12
10	corrosion behavior	EN 480-14

The in this table exposed test scheme used for ConcreCem is also applicable for norm concrete. These tests and the requirements or norms are mentioned in table 1.2.

Table 1.2: Tests procedure for and regulations on concrete with and without ConcreCem

no.	Property	test method	requirement
1	slump [mm]	EN 12350-2	70 ± 10 mm
2	density wet concrete [kg/m3]	EN 12350-6	-
	temperature wet concrete	thermometer	-
3	Air content wet concrete	EN 12350-7	test mix ≤ 2% by volume above control mix
4	compressive strength after 24 hours at 20 ºC	EN 12390-3	test mix ≥ 120% of control mix
	compressive strength after 28 days at 20 ºC	EN 12390-3	test mix ≥ 90% of control mix
5	compressive strength after 48 hours at 5 ºC	EN 12390-3	test mix ≥ 130% of control mix

On 15 May 2009 PowerCem Technologies achieved CE-label registration for ConcreCem. The certified test institute Kiwa N.V. has determined that PowerCem Technologies satisfies all the provisions concerning the attestation of factory production control (FPC) described in Annex ZA of the standards EN 934-2. Figure 1.1 shows page 1 and page 2 of the EC-FPC Certifcate.


kiwa
Partner for progress

Number 0620-CPD-49855/01 Replaces
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Certificate

EC-FPC CERTIFICATE
AoC-level 2+

Notified Body 0620, Kiwa N.V. has determined that

PowerCem Technologies

fulfils all provisions concerning the attestation of factory production control (FPC) described in Annex ZA of the standards EN 934-2.

Product:
Hardening accelerating admixture ConcreCem

Task PowerCem Technologies
Factory Production Contol
Initial Type Testing
Further Type Testing

Task Kiwa N.V.
Initial inspection of FPC
Certification of FPC
Surveillance of FPC

Bouke Meekma
Director Kiwa N.V.

This certificate consists of 2 pages .
Publication of the certificate is allowed.

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kiwa
FPC


EC- FPC CERTIFICATE
AoC-level 2+

0620-CPD-49855/01

In compliance with the Directive 89/106/EEC of the Council of European Communities of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to the construction products (Construction Products Directive - CPD), amended by the Directive 93/68/EEC of the Council of European Communities of 22 July 1993, it has been stated that the construction product

ADMIXTURES FOR CONCRETE, MORTAR AND GROUT

characterised by:

EN 934 Part 2 Concrete admixtures
Definitions, requirements, conformity, marking and labelling

placed on the market by

PowerCem Technologies

and produced in the factory

Bavel

is submitted by the manufacturer to a factory production control and that the approved body

\- 0620 Kiwa N.V. -

has performed the initial inspection of the factory and of the factory production control and performs the continuous surveillance, assessment and approval of the factory production control.
This certificate attests that all provisions concerning the attestation of factory production control described in Annex ZA of the standard mentioned above are applied.

This certificate remains valid as long as the conditions laid down in the harmonised technical specification in reference or the manufacturing conditions in the factory or the FPC itself are not modified significantly.

CE

kiwa
FPC

Figure 1.1: EC-FPC Certificate, AoC-level 2+

A1 Aspects of ConcreCem

Table 1.1: Aspects of ConcreCem

Parameter	Value	Method
Color	Grey	visual
Composition	Alkalimetal(s): 60-80% Zeolites: 5-10% Alkali metal silicates: 5-10% Calcium Carbonite: 10-20%	-
Effective component	Infra red spectra (figure 4.1)	EN 480-6
Bulk density	900 – 1500 kg/m^3	-
Absolute density	2150 – 2210 kg/m^3	ISO 758
Conventional dry material content	84 – 93%	ISO 480-8
pH value	9,55	ISO 4316
Total chlorine	< 31,0 %	ISO 1158
Water soluble chloride (Cl^-, m/m)	< 34,0 %	EN 480-10, method 1
Alkali content (Na_2O-equivalent)	18,1%	EN 480-12
Particle size distribution (mean value)	Sieve size: Passing 63µm: 100% 45µm: 99% 31 µm: 97% 16 µm: 87% 8 µm: 64% 4 µm: 37% 2 µm: 18% 1 µm: 7% 0 µm: 0%	CILAS 920-L (figure 4.2)

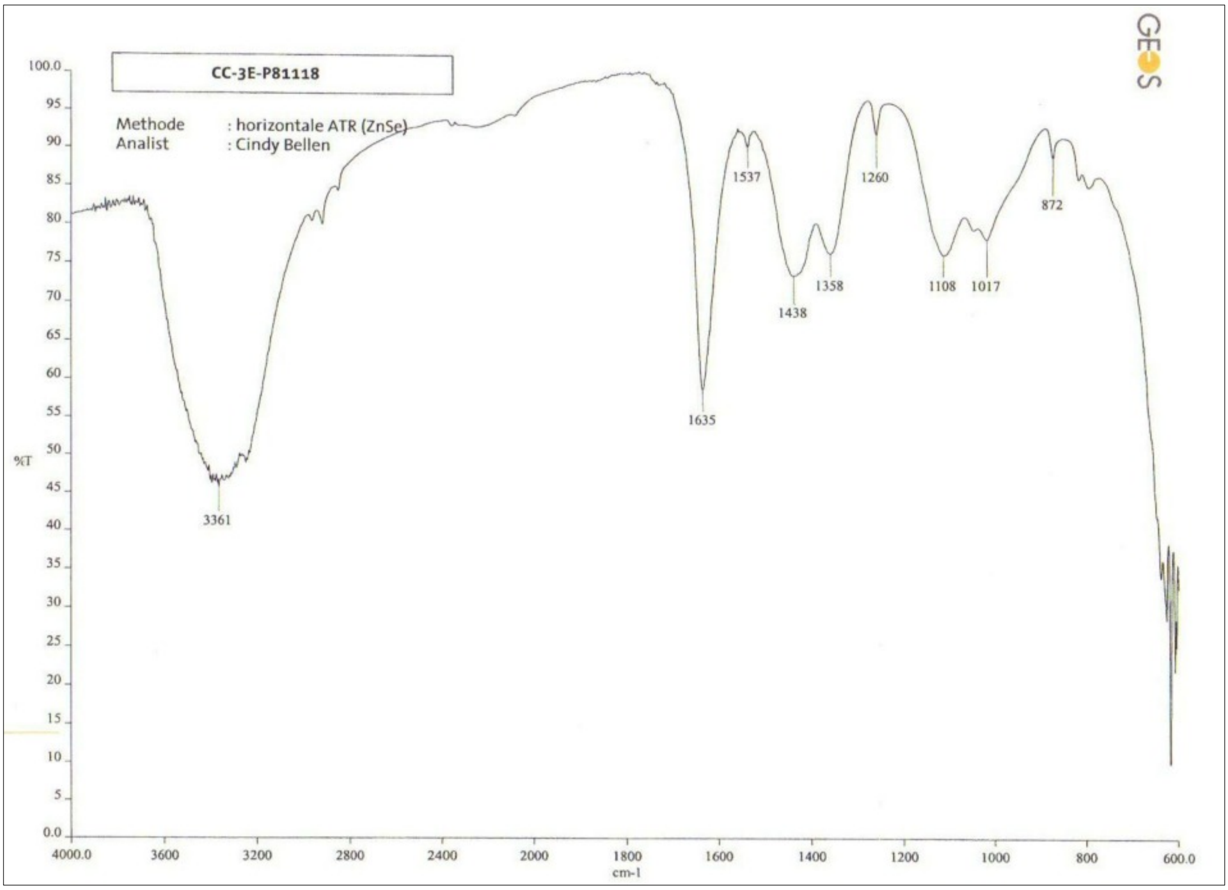

Figure 1.1: Infra red spectra ConcreCem (report: 450591)

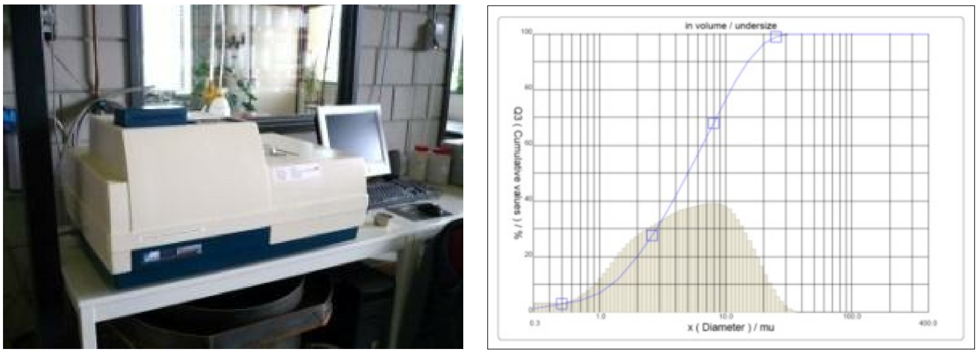

Figure 1.2: Device (Cilas 920-L) to determine Particle size distribution

A2 ConcreCem and Durability

To understand how ConcreCem can enhance durability, it is important to know what “durability” means. Put in a simple way: durability is performance related to time. But two questions arise:

1. what is the period of time: where does it begin and where does it end;
2. when is something durable and when is it not.

To answer these questions we have to relate durability to a specific object. For concrete the following objects should be considered:

- a construction
- concrete
- a concrete construction

2.1 Durability of a construction

When talking about the durability of a construction or part of a construction in relation to time, we normally mean the design life or economic life. The construction has a good durability when in this period of time it reaches a certain performance level. Graphically this is shown in figure 2.1.

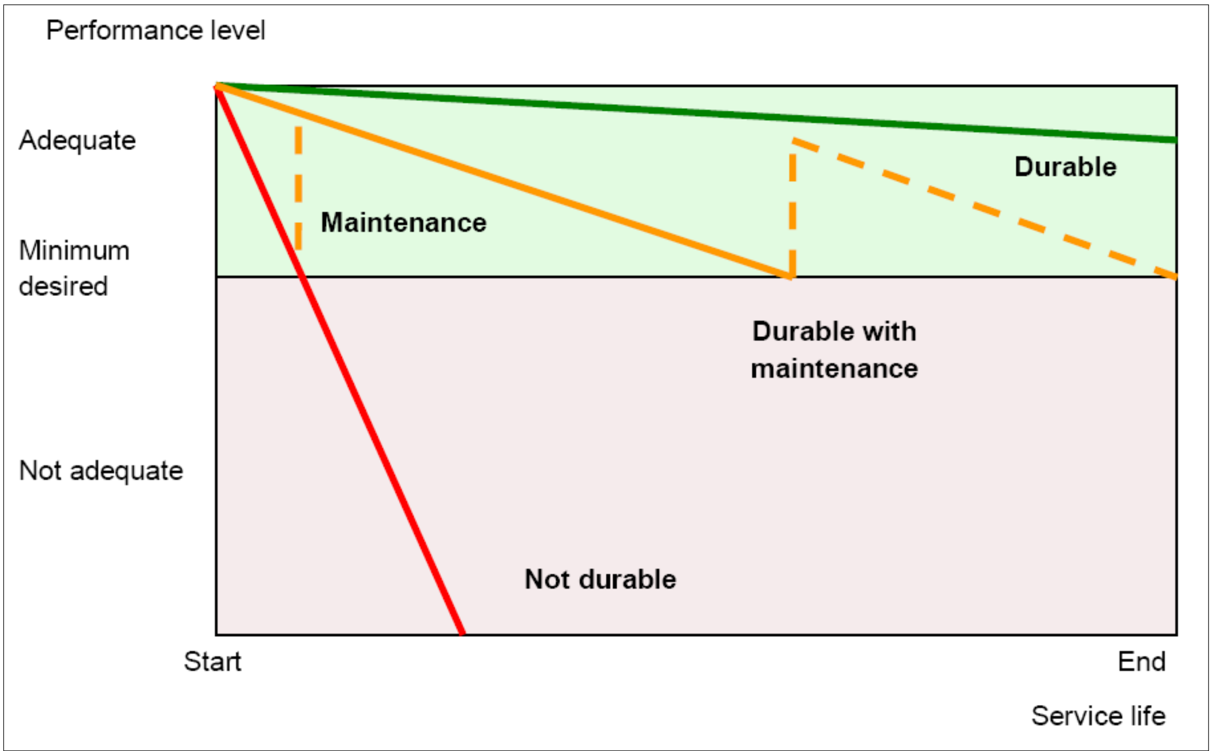

Figure 2.1: durability related to performance level in time

As shown in figure 2.1 in order to be durable, a construction has to meet its minimum desired performance level during its service life. When for some reason the performance level is not adequate anymore maintenance can restore it to an adequate level. This maintenance can be planned in advance or be unforeseen. In both cases it will involve costs, not only the actual costs but also additional costs when the construction can’t be maintain in operative service.

Typically for modern economies infrastructure requires a long service life with no, or only as little as possible maintenance in order to keep the overall economic costs within control. A high performance level at the start and only a slow deterioration over time is a critical consideration.

2.2 Durability of concrete

When the durability of concrete is considered there is normally no reference to time. The only thing mentioned in literature is that concrete has to withstand chemical, physical or mechanical impact from the environment.

For design purposes a period of 50 years is considered as normal. But especially for infrastructure a design life of 100 or even 200 years is sometimes more appropriate.

2.3 Durability of a concrete construction

When we combine durability of a construction with durability of concrete the following definition of durability of a construction made of concrete can be formulated.

> A durable construction made of concrete, is able to perform during its service life at a minimum required service level with or without foreseen maintenance. To meet this requirement the concrete has to withstand chemical, physical or mechanical impact from the environment.

From this definition new questions arise which have to be answered:

1. Which performance is required from concrete?
2. What exactly are those impacts from the environment?
3. What influences the rate of deterioration?

2.3.1 Performance of concrete

Concrete has to fulfill the following requirements during its service life:

- take on all (compressive) tensions without exceptional deformation;
- to protect the reinforcement against high temperatures and corrosion;
- (when needed) a visually attractive surface

2.3.2 Service life influencing factors

All of the service life influencing factors on concrete and on reinforcement are mentioned in figure 2.2 and figure 2.3 respectively.

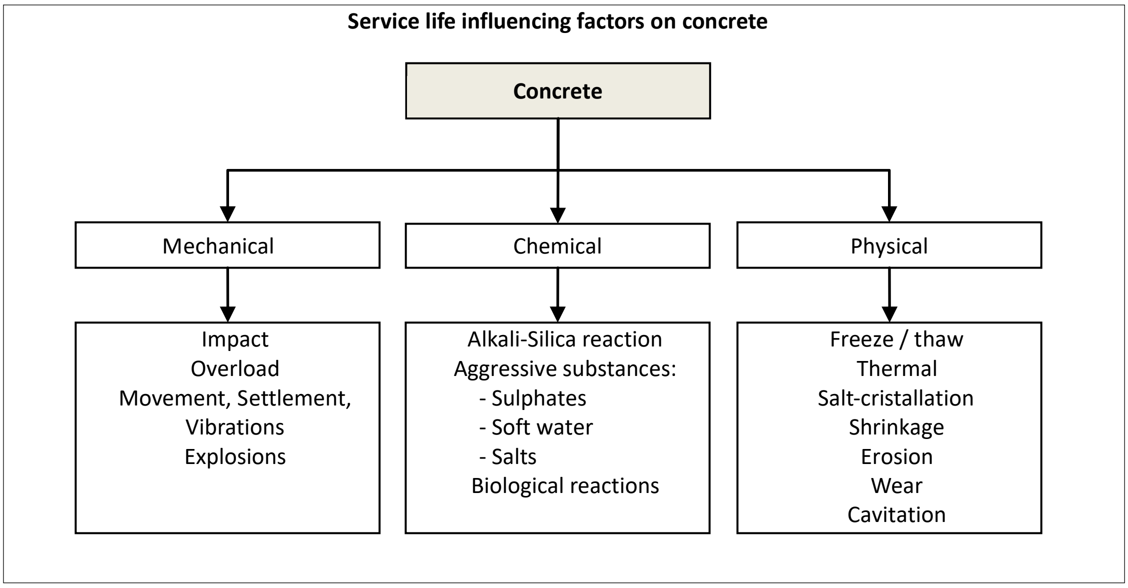

Figure 2.2: direct and indirect influencing factors on concrete according to EN 1504-9

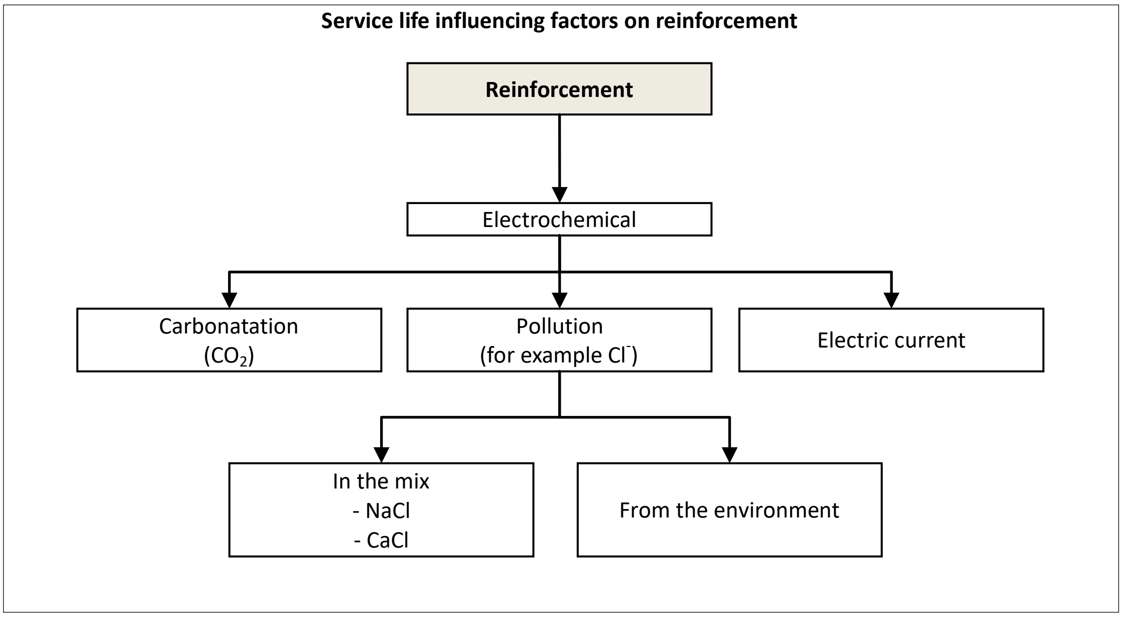

Figure 2.3: direct and indirect influencing factors on reinforcement according to EN 1504-9

2.3.3 Rate of deterioration

In order for concrete to deteriorate in most cases liquids or gases are needed, like for example carbon dioxide, oxygen, water, sulphates, alkalis, etcetera, which have to be transported from somewhere outside the concrete into the inner structure. Transportation processes and the available pores play a very important role.

The following pores and voids are present in the (micro-)structure of concrete:

Gel-pores
Gel-pores are formed within the CSH-gel during the hydration process. These pores are relatively small (< 2 nanometer) and are considered not to be available for transportation processes. No harm can be expected from this kind of pores.

Capillary pores
Capillary are also formed during the hydration process.(In these pores) The size of these pores are in the range of 10 to 1000 nanometer (1 micrometer). They can be interconnected and are filled with water which has not been used in the hydration process. All kinds of salts are dissolved in this water. The transport of gases and salts is possible and relatively easy in these pores.

Micro-cracks
Micro-cracks will occur locally when the tension exceeds tensile strength during hydration. The size of these cracks is in the range of 1 to 100 micrometer. Such micro-cracks could facilitate the transportation of dissolved contaminants.

Air-voids
Air voids could be entrained by using an air entrainer or could be formed during the mixing process. The average size is about 0,1 mm (100 micrometer). Entrained air voids will be in the range of 10 to 60 micrometer. Air voids normally will slow down transportation because these voids will interrupt the capillary pores.

Voids
Voids are the result of bad compaction or could be formed below coarse aggregate particles or reinforcement. The size is about 1 mm. Voids could facilitate the transportation when they are interconnected, but they could also function as a storage for harmful material.

Cracks
Cracks will form as a result of mechanical forces, physical processes or chemical reactions. The size will vary between 100 micrometer and several millimeters or even bigger. Also cracks can easily facilitate the transportation, but can also function as a storage for harmful material.

A3 Instructions for use

ConcreCem is used in a normal way as a cement. However there are some specific requirements to maximize its effects. These requirements are explained in the next subsections.

3.1 Use in wet mix and dry premix

The required dosage is determined as a function of the specified requirements and other materials to be used. Once the required dosage is specified the mixing can be initiated. The mix should be prepared in accordance with steps in figure 3.1.

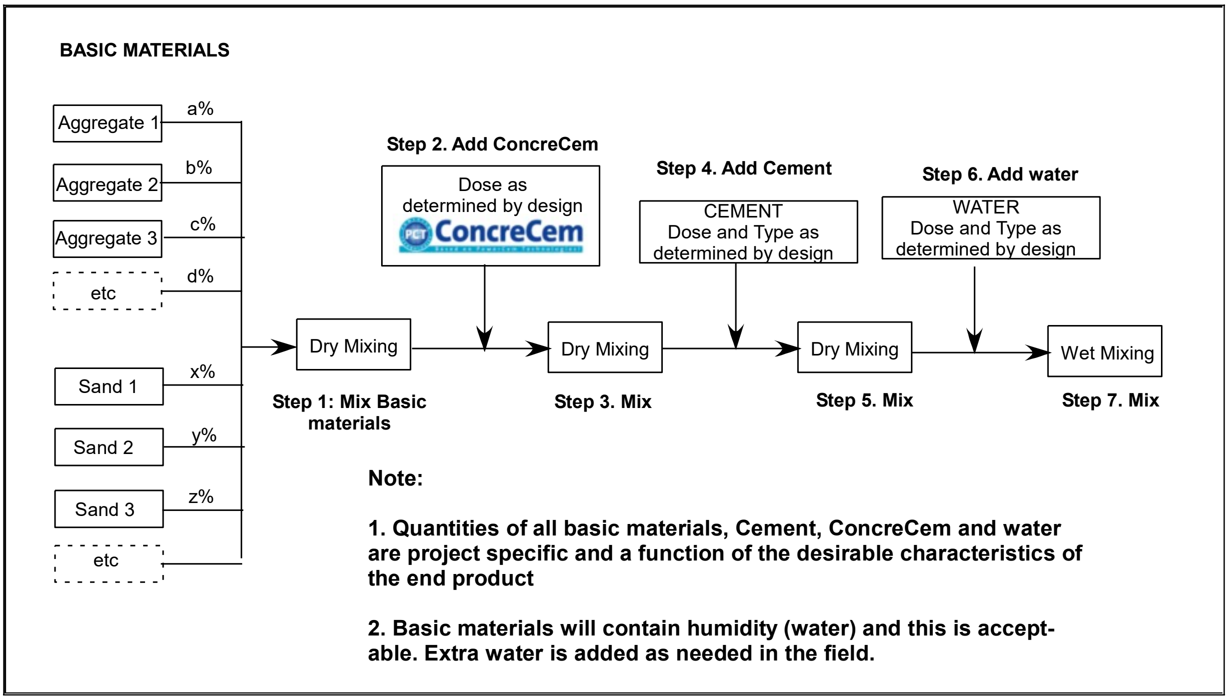

Figure 3.1: Use in wet mix

ConcreCem can be premixed with Cement and or other pozzolanic materials (e.g. fly ash) and used as a cementitious binder in its own right. For such applications the use in the field is proceeded by premixing steps in figure 3.2.

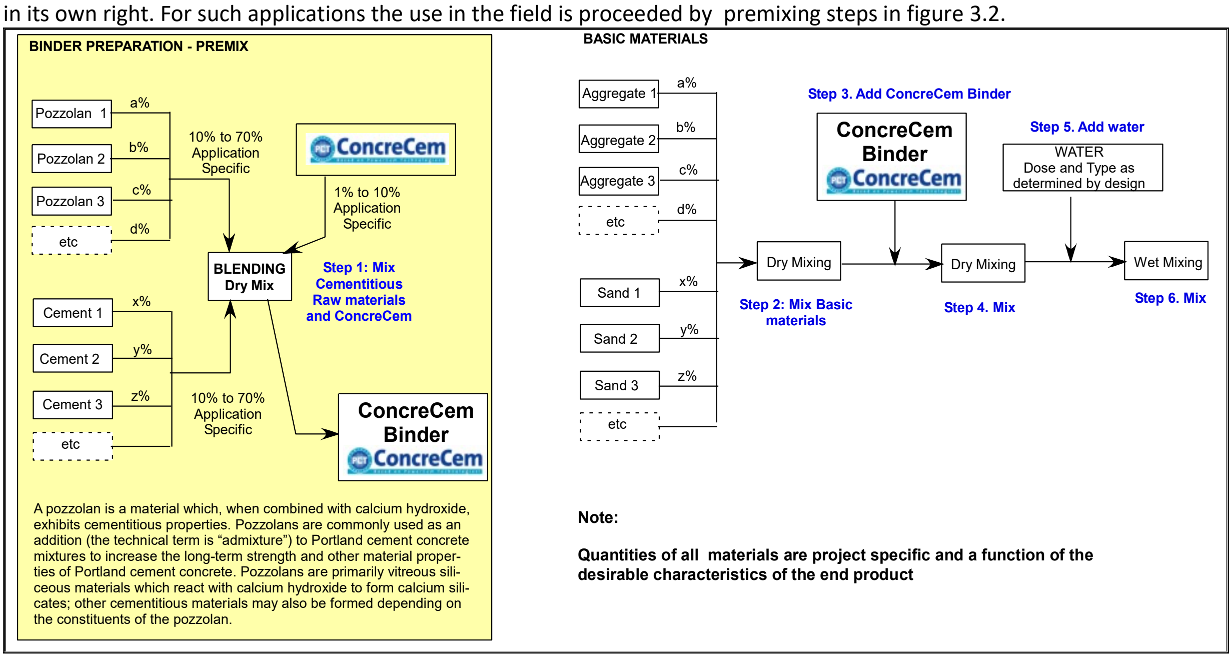

Figure 3.2: Use in dry-premix preparation

3.2 Use in Laboratory

ConcreCem contains some ingredients in rather small quantities. As a dosage of ConcreCem rarely exceeds 1% by mass of cement, the amount of ConcreCem actually used in a mix is very small.

As a result of this when working with ConcreCem in the laboratory, and in order to have representative results from the laboratory tests, the minimum sample size (batch mix size) needs to be adjusted so that a minimum amount of ConcreCem that is used in the preparation of the batch mix in the laboratory is equal to or exceeds a minimum quantity of 40 gram/batch.

Figure 3.3 shows the laboratory preparation of samples and their eventual destructive testing.

Figure 3.3: Mixing mortar, casting and curing samples and testing

COLOFON

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