Internal curing of HPC with hydrogel

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Abstract. High performance concrete (HPC) is concrete with a very high cement content and very low cement/water ratio and this leads to better properties of concrete. These concretes have a problem with traditional methods of curing because of very dense cement matrix. Water from outside cannot reach the interior of the concrete to achieve hydration and it may not have enough curing water for cement hydration. In this paper is discussed effect of internal curing of HPC. The objective of internal curing is to create water storage inside concrete. This should be achieved with hydrogel which was selected to examine influence on internal curing. Hydrogel has a high water-absorption capacity about 300% so it should create a sufficient supply of water in internal reservoir. The prediction is that the hydrogel will release water after the concrete get hardened and provide water to another cement hydration. This should lead to the concretes with better properties.

1. Introduction

Internal curing is basic method how to provide sufficient amount of water for HPC curing during hydration. Especially in case of High Performance concretes, it is not easy to supply ordinary curing water through the very dense cement matrix. The deficiency of internal curing water is caused by cement hydration which consumes water. The un-hydrated cement grains serve only as a filler and do not participate in hydration [1-3]. The mechanical properties of HPC do not show an increase, oppositely, microcracks occurrence can reduce some properties - flexural strength, fracture properties and also durability. There are several options to supply concrete with internal curing water [4-6].

The aim of the internal curing is to create an internal “reservoir” that will release the water after the concrete get hardened and help cement to hydration. It will then serve as curing water and will not change the real water/binder ratio [7]. In accordance with [8], the water/cement ratio should be more than 0.38 to avoid microcracking and achieve good cement hydration. This means that the main goal of internal curing is to have really low water/binder ratio when mixing to create very dense cement matrix and have enough water in “reservoir” for later to get better hydration of cement.

Self-curing is not common in practice. There are only the traditional methods of curing concrete from "outside". This can be done by using wet geotextiles and moistening concrete surface with water. These methods are highly functional, but in the case of high performance concrete the cement matrix is very dense and traditional curing does not guarantee a sufficient amount of curing water in the concrete.

The objective of this study is to investigate the effect of hydrogel on the flexural and compressive strength. In this paper mechanical properties of fresh and hardened concrete was discussed.

2. Experimental details and materials

The objective of this paper is to test the effect of internal curing on properties of HPC. The composition of HPC mortars is shown in table 1. This concrete has a very high dosage of cement and...
very low water/binder ratio. Fraction 0-4 mm of sand was used as an aggregate and Portland CEM 42.5 R was used as a binder. Limestone was used as a micro filler and metakaolin was used like a substitute part of binder to enhance the properties of fresh and also hardened concrete.

We can divide types of concrete in two group. One group of concrete is “control” without internal curing agent. The other concrete has agent in composition. The percentage of agent dosage was 2.5 %; 5 %; 7.5 % and 10 % volume of fresh mortar. All mortars were mixed in laboratory mixer with a volume of 1 liter.

The composition of internal curing agent was made from hydrogel, water and chemical admixture PCA, so hydrogel was pre-soaked with PCA and water. Hydrogel is commercial product especially for soil treatment. According to the technical data sheet hydrogel has absorption 300 % by weight. That means that 1 gram of hydrogel can absorb 300 grams of water it prevents drying of soil. Hydrogel is dry and granulated. The dry grain size is about 1 mm as it can be seen in figure 1. Chemical admixture PCA was added to hydrogel to enhance internal curing. PCA is commercial product of Chryso chemie. According to the data sheet it should help stabilized water in concrete. PCA should help stabilized water in hydrogel, because PCA can bind water like starch and release this water supply gradually for a long time [9]. The composition of internal curing agent was (2 % - PCA, 4 % - hydrogel and 96 % - water). The precondition was that water “trapped” in hydrogel does not affect the amount of mixing water so the internal curing agent creates internal “reservoir” of water. According to this the total amount of water should be higher than calculated from water/binder ratio.

![Figure 1. Photo of dry (left) and soaked (right) grains.](image)

**Table 1.** Composition of concrete to 1m$^3$.

| TYPE | Cement [kg/m$^3$] | Metakaolin [kg/m$^3$] | Limestone [kg/m$^3$] | Plasticizer [l/m$^3$] | Water [l/m$^3$] | Sand [kg/m$^3$] | hydrogel [kg/m$^3$] |
|------|------------------|------------------------|-----------------------|------------------------|-----------------|----------------|------------------|
| C    | 650              | 90                     | 227.5                 | 10                     | 206             | 1200           | 0                |
| H 2.5% | 650              | 90                     | 227.5                 | 10                     | 206             | 1200           | 25               |
| H 5.0% | 650              | 90                     | 227.5                 | 10                     | 206             | 1200           | 50               |
| H 7.5% | 650              | 90                     | 227.5                 | 10                     | 206             | 1200           | 75               |
| H 10% | 650              | 90                     | 227.5                 | 10                     | 206             | 1200           | 100              |

C – Control  
H - with hydrogel
3. Experimental procedures
All mortars were mixed in laboratory mixer in accordance to EN 196-1 [10] with a volume of 1 liter. The workability of mortars was measured by a truncated cone flow (low diameter 100 mm, upper diameter 70 mm, height 60 mm). The flow was measured on a jolting table immediately after remove from cone and after 15 jolts in two perpendicular directions.

After mixing the mortars were put into molds and compacted in accordance to EN 196-1 [10]. The prims were demolded at the age of 1 day and they were immediately wrapped in plastic foil and stored under laboratory conditions (temperature 23 °C and 52 % humidity), except prims for 24 hours strength. Prims were stored in plastic foil because the effect of the internal curing is more noticeable especially witch such a low water/binder ratio. Flexural and compressive strengths were measured on the prisms (40x40x160 mm) at the curing age of 1, 7 and 28 days (2 prisms at each age).

4. Results and discussion

4.1. Bulk density development
One of the evidence that internal curing agent really creates a reservoir with internal water is bulk density. Because if concrete has a pore filled by internal curing agent, with density lower than concrete, it has to be lighter than control concrete sample which has lower porosity. As shown in figure 2 shows that concrete with high dosage of internal curing agent has a lower bulk density than control concrete sample.

![Figure 2. Density of different types concrete.](image)

4.2. Workability of mortar
As it can be seen in figure 3 the workability of fresh mortar has changed with higher dosage of internal curing agent. Apparently, the hydrogel did not “lock” all water in itself, so some water was released while mixing. This has a negative influence on fresh concrete and hardened concrete too. The target workability was 250 mm. This test was mainly performed to determine if the water was released or not while fresh concrete was mixed. Maximum value (300 mm) of flow cannot be measured due to the device size. In further research it will be necessary to focus on how to better “lock” water in hydrogel.
4.3. Strengths development
When internal curing agent is used, the flexural strength is lower than strength of control sample as it can be seen in figure 4. The interesting is difference between 7 and 28 days flexural strength. Controls sample has 28 days strength higher than 7 days. But the strength of sample with internal curing agent were similar in 7 days and 28 days. Hydrogel probably during hydration produce aggressive substances that react with the cement components. Aggressive substances produce either soluble compounds or insoluble compounds which do not have binding properties. Because of this in next research will be important to focus on chemical analysis of hydrogel and synergy of hydrogel with cement.

Figure 3. Workability of fresh mortar.

Figure 4. Flexural strength of concrete.
Figure 5 shows that agent is likely to have a negative effect on the water/binder ratio. The higher internal curing agent dosage, the lower the flexural strength as in case of flexural strength and also by changed water/binder ratio. It could be seen on ratio between compressive strength. The ratio between 1 day and 28 days compressive strength is around 50 percent higher for sample with 10 % dosage of internal curing agent than ration between strength of control sample and this is probably due to the changed water/binder ratio. This will be examined in further research.

![Figure 5. Compressive strength of concrete.](image)

5. Summary
Internal curing was provided by internal curing agent which was in this case composition of hydrogel, PCA and water. The precondition was that hydrogel would not release water immediately after mixing the mixture, but after some time. This should suppress the negative effects (change of water/binder ratio, change of workability etc.) by adding water. This internal curing agent do not seem very effective. But hydrogel itself seem to be very promising internal curing agent because of its cost and absorption ability. Because precondition was not fully fulfilled. Water in hydrogel were partly release during mixing especially in high dosage of hydrogel. In this case both flexural and compressive strength of sample with agent was lower than strength of control sample. Flexural strength of control sample was about 11 MPa. But the higher internal curing agent dosage was, the lower the flexural strength was. This happens probably due to chemical reaction between hydrogel and cement and changed water/binder ratio while mixing. Necessary will be chemical analysis of hydrogel and synergy with cement.

Released water while mixing change the workability of fresh mortar. When dosage of internal curing agent was higher than 5 % of volume the mortar was self-compacted. Concrete with higher dosage of internal curing agent has lower density due to higher porosity of concrete.

In next research would be interesting combine with another way of internal curing. However, it is necessary to improve the methodology of the comparison of individual result and the effect of internal curing on other factor influencing mechanical and physical properties of concrete.

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