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Structural Alterations of Ultra High Performance Concrete at High Temperatures

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ABSTRACT

Ultra High Strength Concrete, also called Ultra High Performance Concrete (UHPC), is a very dense material with compressive strength between 150 N/mm² and 250 N/mm². Pilot tests with UHPC have been already conducted during the 1970ies in the USA and Scandinavia. First applications in building technology followed in 1997 by the erection of a pedestrian bridge in Canada and a repair of a cooling tower in Cattenom in France.

Concerning alterations, water liberation and other transport phenomena of UHPC up to now only a few data are at hand. The aim of the study was to fill some of the present gaps of knowledge.

To obtain information concerning thermally induced changes of the transport properties and the material behaviour thermal analyses, weight loss measurements and dilatometric studies were performed during heating of the materials. The resulting structural changes were analysed by mercury porosimetry.

Four different materials were investigated. The proportions of the mixes are indicated in the following table 1, in which the mass of the different components related to the cement content are listed.

The binder contains of Finnish Super Rapid Cement and 25% silica fume. Series 1 and 2 were made with coarse crushed Diabase aggregates (3 – 6 mm grain size). Series 3 and 4 contain only fine quartz sand (0.125 … 0.6 mm grain size) and series 4 was made without PP-fibres. “H” indicates heat treatment at 95°C and saturated water vapour. The materials were cast in plastic pipes to produce cylindrical specimens (diameter=70 mm, length=200 mm) for mechanical high temperature tests.

The thermal stability and the water vapour liberation of the materials have been investigated by simultaneous thermal analysis. Measured and determined resp., were the weight loss, the differentiated weight loss and the DTA-curves, which give the temperature difference between an inert sample and the sample under investigation.

Table 1- Mix proportions of the specimens

Materials	FIR/LA/PF/H Series 1	FIR/LA/PF Series 2	FIR/022/PF/H Series 3	FIR/022/H Series 4
SR cement	1	1	1	1
Silica fume	0.2500	0.2500	0.2500	0.2500
PP fibres	0.0004	0.0004	0.0004	0
Sand (0.125mm-0.6mm)	0.8000	0.8000	0.8000	0.8000
Diabase	1.8000	1.8000		
Quartz	0.2000	0.2000	0.2000	0.2000
Super plasticiser	0.0500	0.0500	0.0400	0.0400
Water	0.2190	0.2190	0.2000	0.2000
W/B ratio	0.2600	0.2600	0.2200	0.2200
W/C ratio	0.2000	0.2000	0.1760	0.1760

The series 1 sample showed a series of peaks indicating the following endothermal and exothermal reactions:

- 20°C – 120°C evaporation of the physically bound water (about 3% weight loss)
- 175°C – 210°C exothermal reaction due to the deterioration and oxidation of PP-fibres
- 120°C – 650°C continuous liberation of physically stronger bound water (about 3% weight loss)
- 650 – 700°C step in the weight loss curve, which indicates the dehydra tion of the CSH-phases, connected with the formation of ß-C_2S (about 0.3% weight loss)
- 573°C DTA-peak due to quartz transformation $\alpha \rightarrow$ ß-quartz
- 700°C–1000°C further continuous liberation of CSH-water (again 1% weight loss)

The structural changes due to heating were investigated by aid of mercury porosimetry. For these tasks 10 mm thick slices were cut out of the cylindrical specimens and heated to 150°C, 250°C, 350°C, 450°C, 550°C, 650°C, 750°C and 850°C, resp., and analysed after cooling to ambient temperature. – The 20°C specimens were vacuum dried at room temperature.

The results indicate that the thermally unstressed material inheres nearly no porosity in the pore region between 30 µm and 0.4 µm. The capillary porosity in pore region 0.4...0.03 µm (≈3 mm²/g, =0.8 Vol.-%) is also neglegibly low. The penetrateable gel pore volume (0.03...0.00375 µm) has a rather low volume (≈4 mm³/g:=0.9 Vol.-%).