Determination of Volumetric Changes of the UHPC Matrix

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Abstract: Research in the UHPC applications field is very important. Current experiences shows that the structure design should be optimize due to relatively new Hi-Tech material with excellent mechanical and durability properties. It is not sure if the volumetric changes like creep or shrinkage has or has not an impact on an advantage for the construction. The effect of the shrinkage and creep of UHPC is mostly unknown because of the fact that some of experimental tests are long term and the development of the material is still in its basics.

Keywords: UHPC; Test Methods; Shrinkage; Creep.

1 Introduction

Volumetric changes of concrete are a very important factor that is necessary for the design of reliable construction. The UHPC (Ultra-High Performance Concrete) is still under the development it is necessary to experimentally verify (mostly individually) the material properties. The current paper describes some methods for testing shrinkage and creep on the UHPC matrix mixed in laboratories of the Klokner Institute. Previous research were mainly focused on the development of UHPC from local constituents and mechanical properties of the UHPC matrix [1], investigation of bond behavior [2] or layering of this fine-grained cement-based composite material to eliminate non-homogeneity of the steel fiber distribution [3], the fact was verified, that the excellent characteristics of UHPC have very good impact on general application, but also knowledge of the volumetric changes is very important.

Volumetric changes are described for ordinary concrete but they do not be described for high strength concretes and also for fine grained cement-based concretes like UHPC. The different UHPC mixture design is one of the differences between UHPC and normal strength concrete. Mixture design (dosage and type of cement, fineness, water/binder ratio and granularity), bulk density, air conditions, shape and dimmensions are the basic factors that affect the volumetric changes. The volumetric changes should be divided to shrinkage, thermal dilatation, stress included shrinkage, stress included thermal dilatation, basic creep and drying creep. Shrinkage should be define as a longtime irreversible deformation in time without load, creep should be define as a longtime deformation in time as a result of stess.

2 Test Methods

Main part of experiments was determined on two different mixtures of UHPC (one with short steel fibers - UHPFRC and second without short steel fibers - UHPC) and two types of tested specimens (small beams size $40 \times 40 \times 160$ mm and large beams size $100 \times 100 \times 400$ mm). The shape and the dimension of the specimen are important factors for subsequent evaluation of the overall shrinkage with respect to the real application of the matrix. Creep was tested on prism beam with dimensions $70 \times 70 \times 300$ mm that are inserted into special equipment that produces permanent stress (Fig. 1).

2.1 Shrinkage of UHPC

Shrinkage was measured using a dilatometer or in a special equipment with micron precision. Three UHPFRC (Ultra-High Performance Fiber Reinforced Concrete) large prism beams was stored in water and next

(a) equipment for creep testing

(b) equipment for shrinkage testing of small beams

(c) equipment for shrinkage testing of large beams

Fig. 1: Specimens in the testing equipment.

three UHPFRC large prism beams was stored at laboratory conditions (temperature around 20 °C, relative humidity around 50 %). The results and comparison of different storage conditions for large beams made from UHPFRC (reinforced by short steel fibers) are shown at Fig. 2. From the second mixture design of UHPC (without short steel fibers) were prepare three large prism beams that were stored at laboratory conditions and twelve small prism beams. The small prism beams were stored at different conditions, four of them were stored at laboratory conditions (air), next four at water and the last four prism beams were stored at climatic chamber with relative humidity around 95 % and temperature around 20 °C. The results and differences between storage conditions for small beams are shown at Fig. 4. Differences between small and large beams stored at laboratory conditions are also shown at Fig. 3. Material differences (UHPC matrix and UHPFRC matrix) are shown at Fig. 2 and Fig. 3. As you can see from Fig. 2 to Fig. 4 the shape, dimension, matrix design and different storage conditions have a main impact on the results of shrinkage measuring in time.

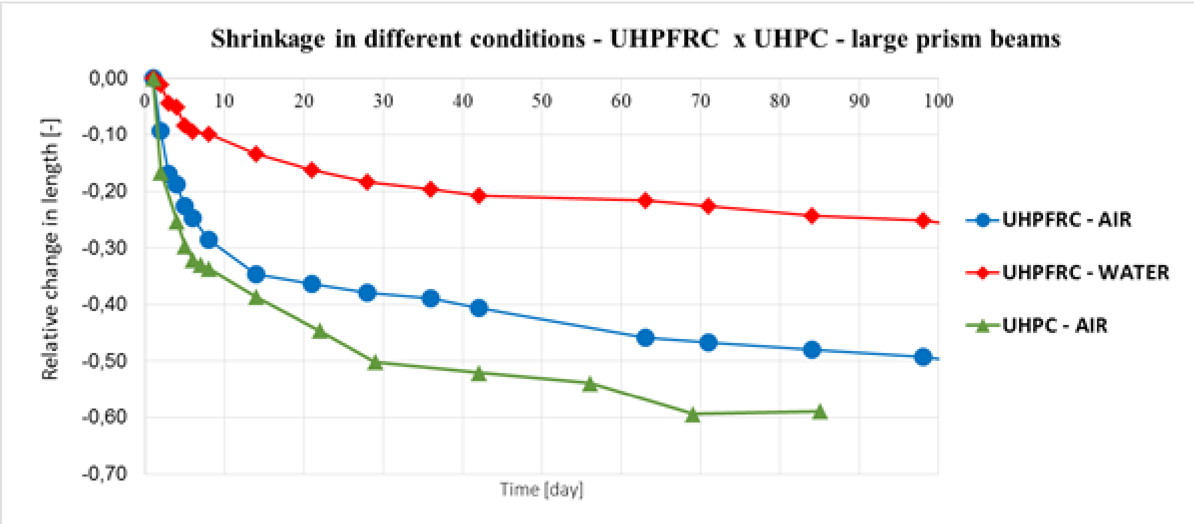

Fig. 2: Comparison of shrinkage of large prism beams stored in water and laboratory conditions (air).

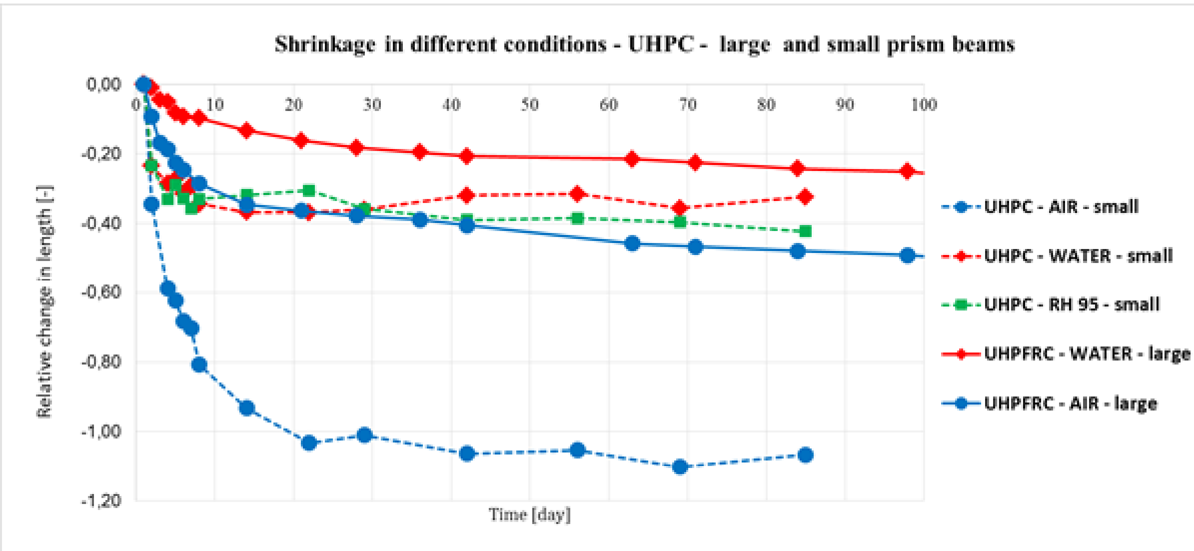

Fig. 3: Comparison of shrinkage of small prism beams stored different storage conditions (water, air, RH = 95 %) and large prism beams stored in laboratory conditions.

2.2 Creep of UHPC

The strain of the sample from UHPFRC under constant load over time was examined in these tests. The value of the load is critical for creep. Permanent load (1/3 compressive strength) was applied to the specimens. Both types of specimens (one mixture of UHPFRC and one of C50/60) were loaded at 4(3) days after the

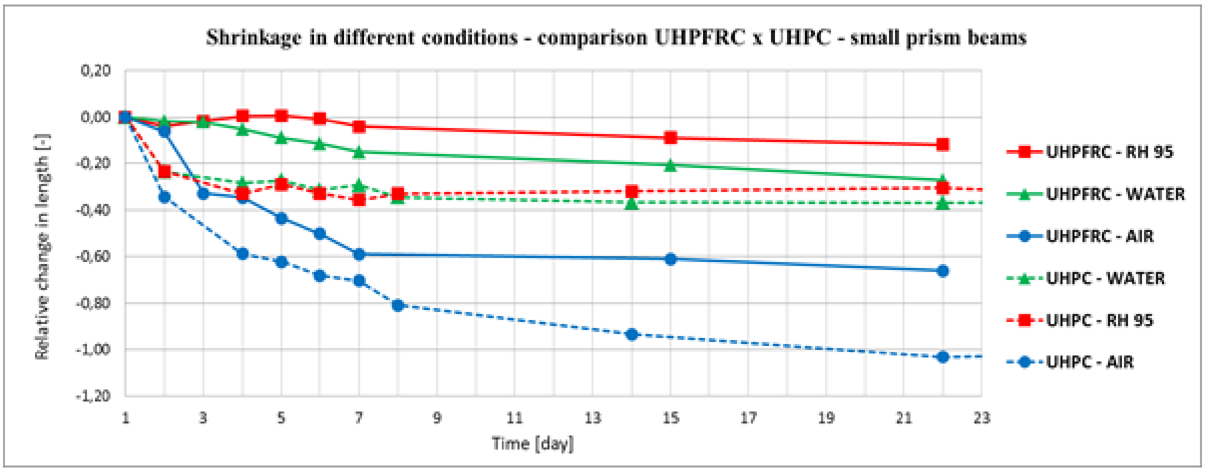

Fig. 4: Comparison of shrinkage of small prism beams made from two different mixtures stored in laboratory conditions.

casting. The test simulates the real behavior of the material and it is therefore important to choose the load time with regard to real application. The development of the deformations due to constant permanent load in time is shown at Fig. 5–7. $\varphi(t, t_0 = 4 \text{ days})$.

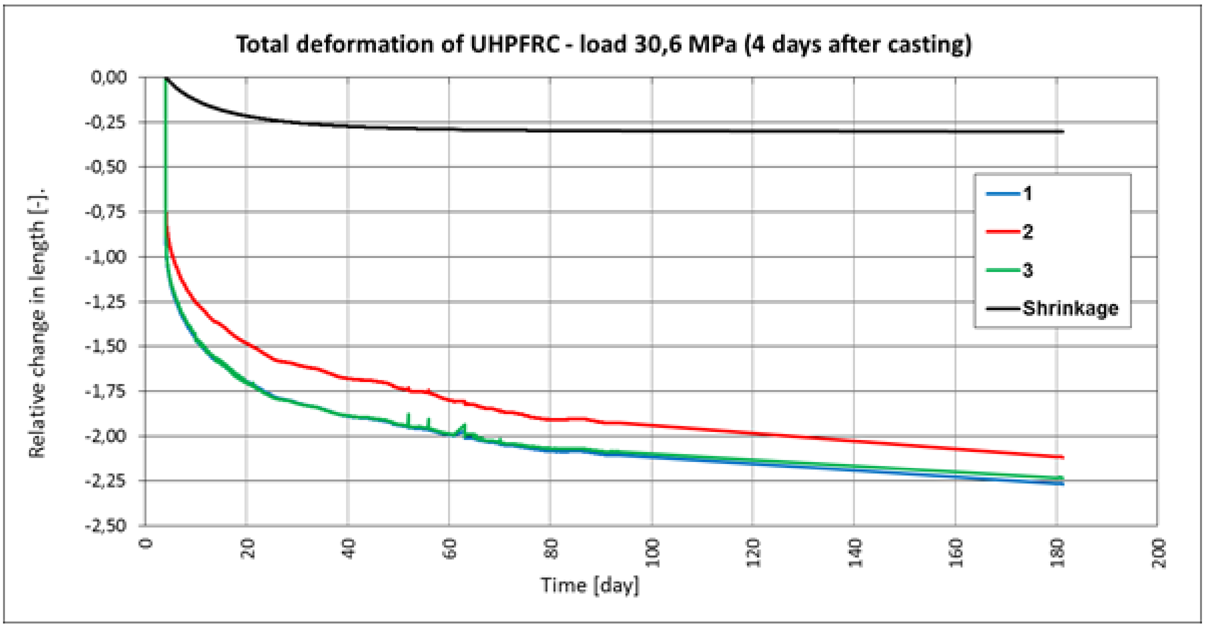

Fig. 5: Creep deformations at time for UHPFRC beams size 70 × 70 × 300 mm.

Main result of these test is creep coefficient $\varphi(t, t_0)$, which is calculated from deformation (including stress, creep and shrinkage in time – Fig. 7). For C50/60 is creep coefficient $\varphi(t, t_0 = 3 \text{ days})$: 1.06 (28 days), 2.2 (170 days) and for UHPFRC is $\varphi(t, t_0 = 4 \text{ days})$: 0.86 (28 days), 1.4 (170 days).

3 Conclusion

The volumetric changes for normal strength concretes are well known and information and computing models are described in several publications and design standards but the volumetric changes of UHPC matrix are not described because the development of the UHPC is still on basic in the Czech Republic. Some recommendations are shown at AFGC/Setra documentations. Previous project of UHPC were focused on a basic material properties. Volumetric changes are very important for reliable design of UHPC structure. The results of the creep and the shrinkage and comparison between different mixture designs are presented in this paper. The shrinkage was measured at small prism beams 40 × 40 × 160 mm and at large prism beams

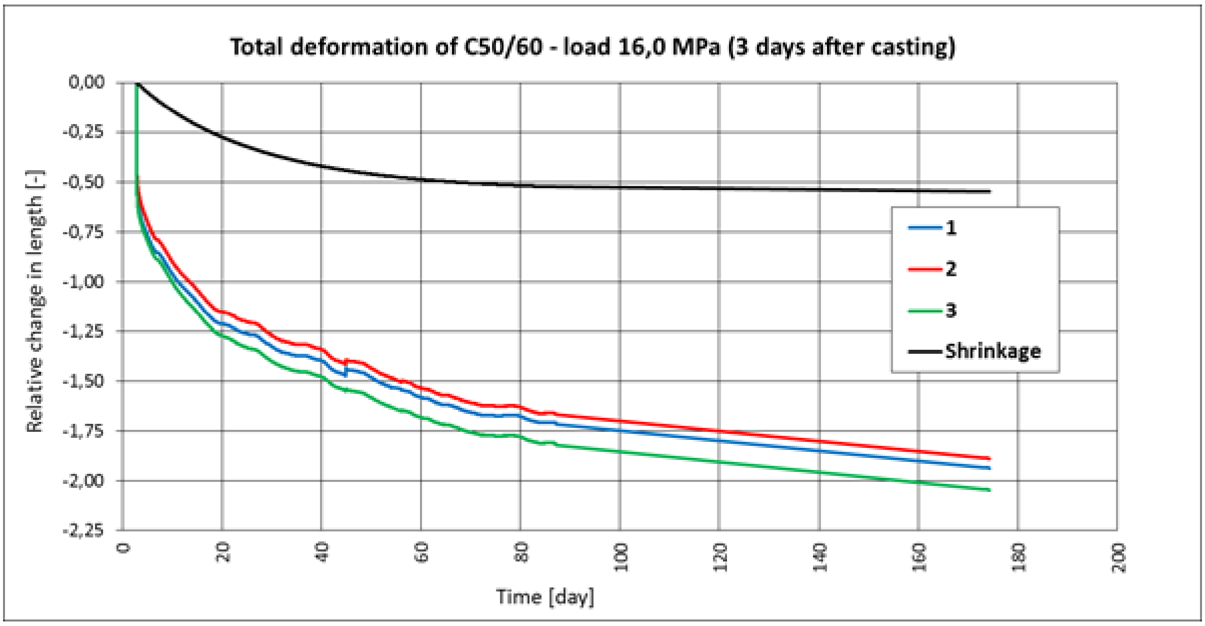

Fig. 6: Creep deformations at time for C50/60 beams size 70 $\times$ 70 $\times$ 300 mm.

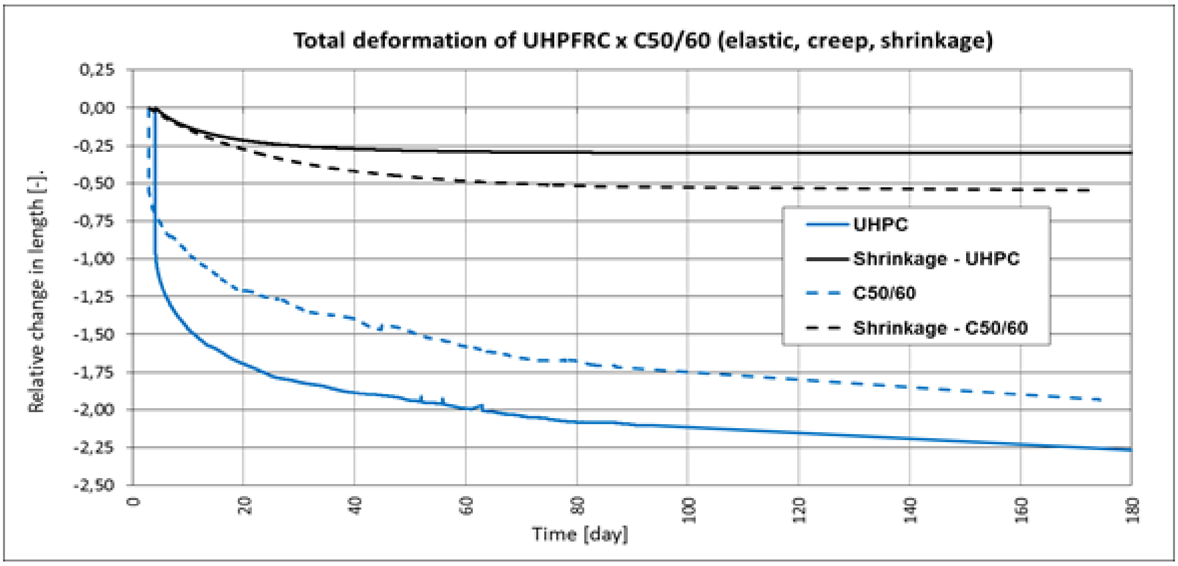

Fig. 7: Comparison of total deformation at time – UHPFRC $\times$ C50/60.

100 $\times$ 100 $\times$ 400 mm stored at different conditions (air, water, climatic chamber). Large beams was made from both type of mixture, small beams were made only from plain UHPC mixture. The results presented in this paper shown, that the shrinkage of large and small UHPC beams is smaller than shrinkage of large and small UHPFRC beams stored at the same air conditions. Creep was measured at laboratory conditions at prism beams size 70 $\times$ 70 $\times$ 300 mm made from two different mixtures - UHPFRC and ordinary concrete C50/60. The permanent static load was applied at the age of 4 days for UHPFRC and at the age of 4 days for C50/60. Results shown, that UHPFRC has significantly lower creep coefficient than ordinary concrete.

Acknowledgement

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