EAN 2013
51th conference on experimental stress analysis

The Evolution of the Cement Paste Creep with Addition of Fly Ash in Time and Ratio of Parts 60/40

Pavel Padevět[1, a], Petr Bittnar[2,b]

[1]Czech Technical University, Faculty of Civil Engineering, Department of Mechanics, Thákurova 7, Prague 6, Czech Republic

[2]Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics, Thákurova 7, Prague 6, Czech Republic

[a]pavel.padevet@fsv.cvut.cz, [b]petr.bittnar@fsv.cvut.cz

Keywords: Cement paste; Shrinkage; Basic Creep; Strength in Compression; Saturated Cement Paste.

Abstract. The article is focused on comparing the resize of creep of cement pastes with addition of fly ash in time. Creep was observed in the one monthly measurement for more than one year. The cement paste was prepared with fly ash in the ratio of the components 60/40 in favor of the cement components. Development of basic creep and creep was observed in water-saturated material. The measurement results are used as input data for the simulation of creep by the model B3 and determine the values of coefficients of q to determine the thermal of creep of cement paste.

Introduction

Knowledge of the properties of cement pastes with addition of fly ash is an important piece of knowledge for the design of structures, in which the ash is used. The amount of fly ash [1] in cement affects the rate of hydration of the cement components. The changing the amount of fly ash in cement also causes positives like a lower production the cement in achieving similar final properties, a lower rate of rice the strength and lower heat of hydration.

The compression strength, tension strength in bending, modulus of elasticity, creep coefficient, volume weight is material properties important for design of the building constructions [2]. This work presents results of measurements and mathematical modeling of the creep evolution.

Material for testing

The cement paste is fine grain and homogeneous material [3]. The homogeneity of material is suitable for measurement the creep on the small specimens. The material that retains their hydration properties can occur by adding of the fly ash in the Portland cement.

Portland cement CEM I 42.5R was used for the preparation of the cement paste in this work. The classical fly ash was used as an additive to the cement paste. Usual amount of the fly ash added to the cement paste is between 20 – 30 % of the cement weight. In this case the ratio c/fa (cement/fly ash) was higher, namely 60/40. The 40 % of the cement weight was used to the replacing by classical fly ash. Water cement ratio 0.4was used, for its tried and suitable consistency.

The specimens were prepared in the plastic moulds. The specimens were placed in the water for one month and then were left on air.

Testing equipment

The most important change of compressive strength is in the first three months after production. At the age of 10 months, the material is stable from the viewpoint of strength [4], [5]. Fast hydration processes are terminated after 3 months. The second selected time period test of cement paste were four months after production. The testing equipment allowed the using specimens with length maximally 70 mm [6]. The diameter of tested specimens was 10mm.

Fig. 1. Instrumentation of testing.

These dimensions of the specimens allow testing in the lever mechanism, as shown in Fig. 1. The specimens tested for creep are loaded with weight that is placed on the lever apparatus. The specimens tested on shrinkage are not contrary loaded with weights. Creep was measured at the 4 specimens and shrinkage at the 2 specimens. Two specimens were dried before start of testing and two specimens were saturated in the water for measurement of the creep. Similarly, for the shrinkage, one specimen was dried and second specimen was saturated in the water.

The deformations of the specimens were measured during the whole time of testing. The specimens were loaded with weights at the beginning of the test. Specimens were unloaded after 30 days of measurement, as it sees in Fig. 4 and 5. The temperature was constant during the test [2]. Also, the moisture conditions of specimens were maintained in the steady state.

Results

The results of measurement are displayed in Fig. 2 to 5. Firstly, in Fig. 2 and 3 are displayed curve of the basic creep in 30 days measurement. Basic creep is calculated like the difference between creep of dried specimen and shrinkage of the dried specimen, too. Similarly, results of the creep of water saturated specimen are displayed in Fig. 4 and 5. In both cases is significant rapid increase of the creep in the first 5, respectively 12 days, due to the load.

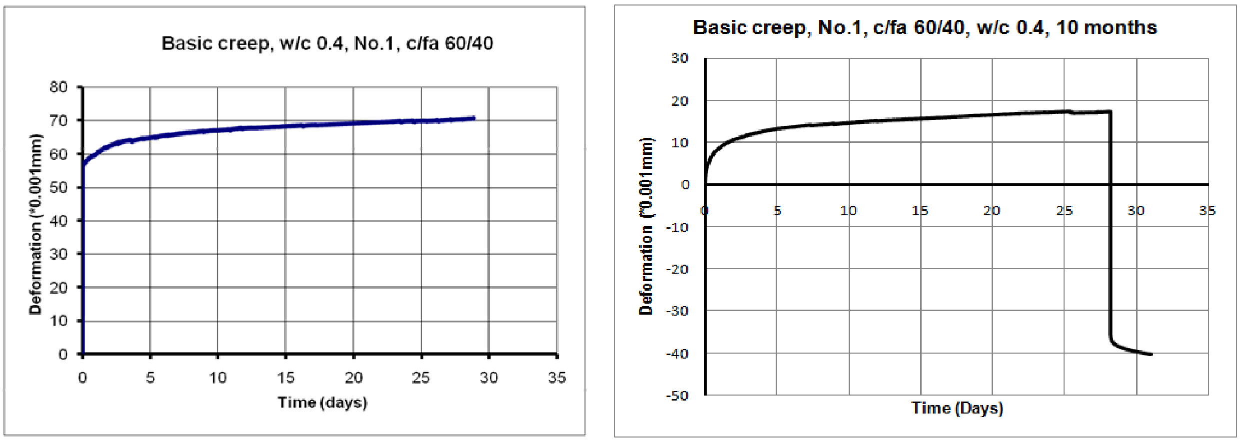

Fig. 2. Basic creep of cement paste with fly ash in 4 months (left) and in 10 months (right) for specimen No. 1.

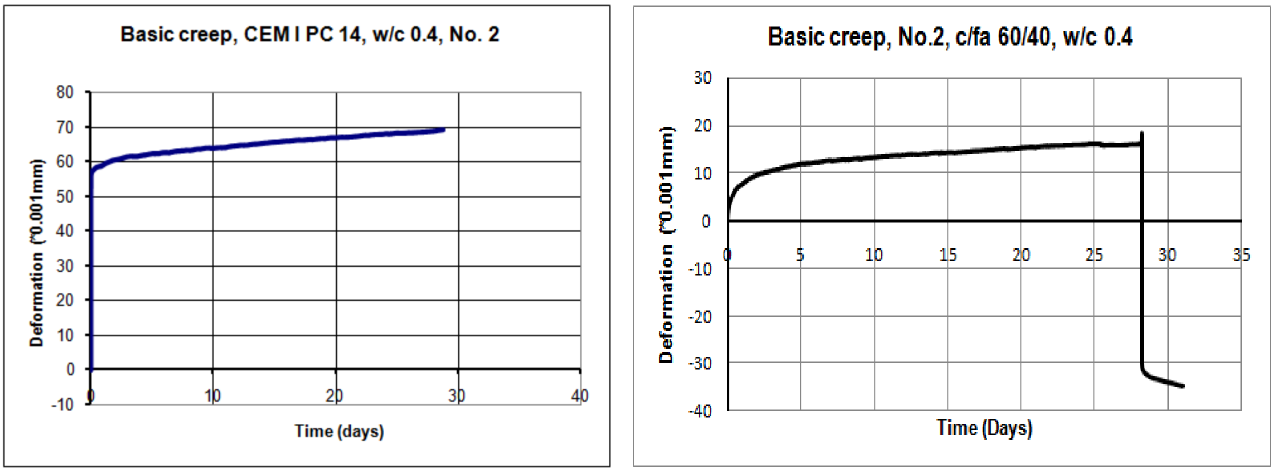

Fig. 3. Basic creep of cement paste with fly ash in 4 months (left) and in 10 months (right) for specimen No.2.

The difference between basic creep of 4 months and 10 months old paste is obvious from figure 2 and 3 Younger paste has already after 3 days of fairly steady increase from the basic creep deformation. Steady increase in creep comes later in the older paste. Nevertheless the decrease of the size of creep is apparent with the passage of 6 months between measurements.

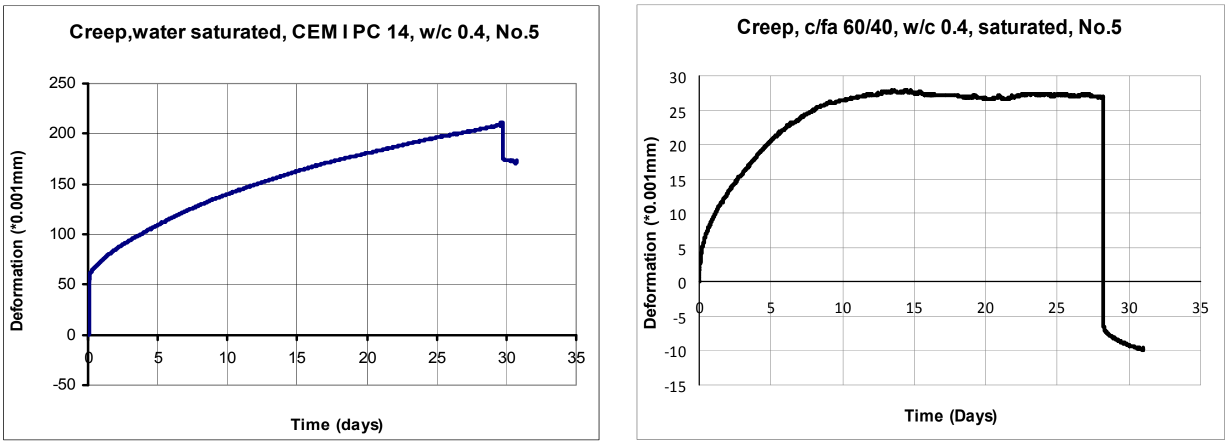

Fig. 4. Creep of cement paste with fly ash in 4 months (left) and in 10 months (right) for specimen No.5.

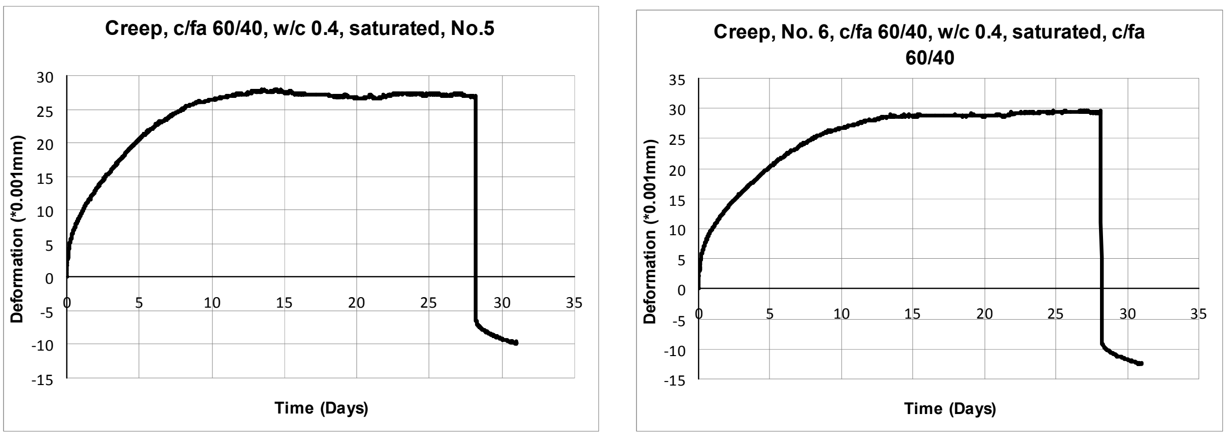

Fig. 5. Creep of cement paste with fly ash in 4 months (left) and in 10 months (right) for specimen No.6.

The basic creep of paste has a size of 13 microns for a period of 25 days, and in old age 4 months. 10 microns is the size of the creep cement of paste with fly ash in old age 10 months over the same period.

A much more significant difference is observed for cement paste with fly ash, which is saturated with water. Waveform creep is fixed to a linear course after 10 days, in both cases, the age of the paste. A much more significant difference is observed for cement paste with fly ash, which is saturated with water. Waveform creep is fixed to a linear course after 10 days, in both cases, the age of the paste. Size of creep is greater than 120 microns for the cement paste in old age of 25 days. By contrast, the creep has a size of only 20 microns in old age of 10 months. The creep of saturated cement paste with fly ash is almost double than of the creep dried cement paste in old age 10 months. At younger ages, this difference is almost eightfold.

Creep was mathematically simulated by B3 model, which is compounded in environment OOFEM [7]. Results of model depending on the material properties of the cement paste, the age of material and humidity conditions.

The results are the creep coefficients q_1 to q_4, with which it works B3 [8] model of creep of concrete. In the Table 1 are displayed coefficients, which affect shape of curves of the creep and basic creep.

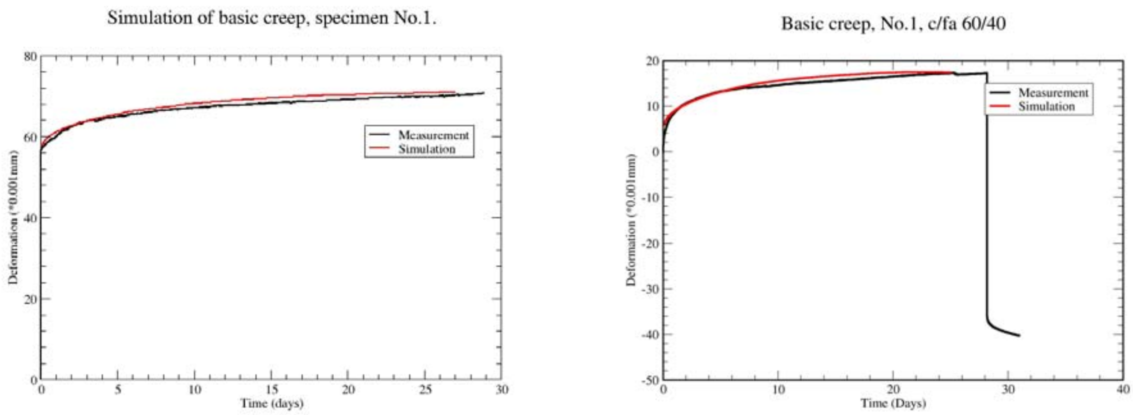

Fig. 6. Simulation of basic creep of the specimen No.1. Left picture is for 4 month old material and right picture is for 10 month.

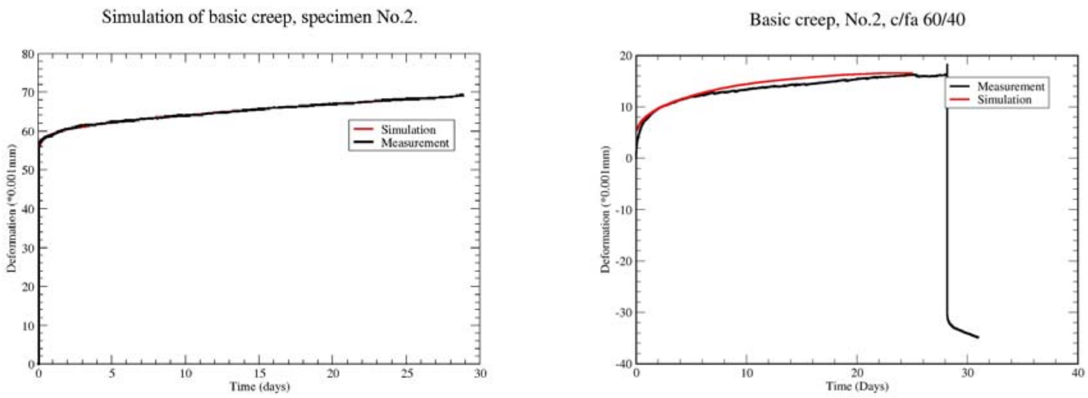

Fig. 7. Simulation of basic creep of the specimen No.2. Left picture is for 4 month old material and right picture is for 10 month.

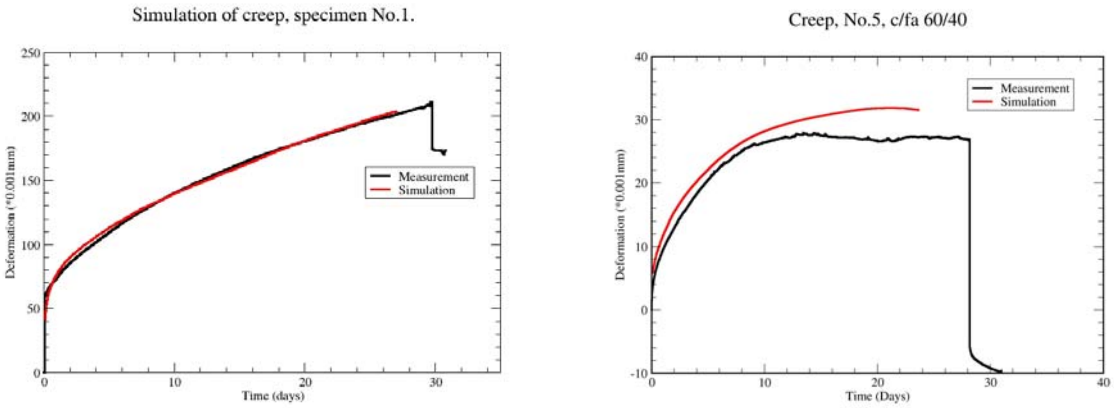

Fig. 8 Simulation of creep of the specimen No.5. Left picture is for 4 month old material and right picture is for 10 month.

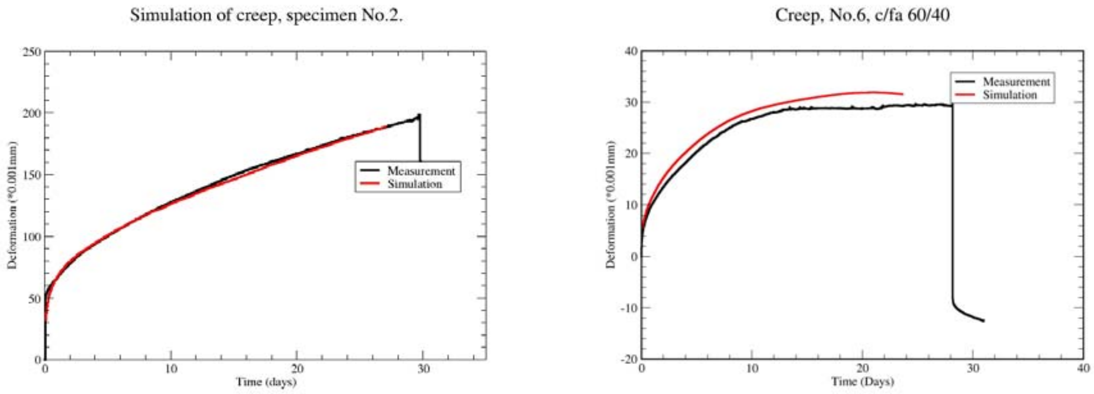

Fig. 9 Simulation of creep of the specimen No.6. Left picture is for 4 month old material and right picture is for 10 month.

Summary

Age of cement pastes containing fly ash significantly affects the size and growth the creep. Almost one year old cement paste has a significantly slower growth of the creep deformation, the material than 4 months old. Very significant difference is in the creep of cement paste, depending on the water content in the pores.

Table 1. Values of q coefficients.

Specimen number	Age of material	q_1	q_2	q_3	q_4
1	4	0.081262	-100.54	9.1978	-0.34482
2	4	0.070090	-1.116827	0.139287	0.038830
5	4	-0.13502	-100.48496	9.53563	0.31785
6	4	-0.170419	3.404279	0.087555	0.662869
1	10	-0.001294	-300.624	20.094	-0.97565
2	10	-0.0011861	-300.1244	18.055	-0.82269
5	10	-0.00093783	-1121.3	64.75	-3.0668
6	10	-0.00017342	-1148.3	66.307	-3.1427

The results of experiments correspond with simulation very good, see Fig. 6 to 9. The model B3 is suitable for simulation of the cement paste creep. The values of parameters q are presented in Table 1, depending on the age and the water content. The results are very consistent for the pastes 10 months old. The cement paste with fly ash shows significant differences in the parameters q_1 to q_3 in old age 4 months and for the different states of water saturation.

Nevertheless B3 model more accurately captures the behavior of younger cement paste. The simulation is problematic for older saturated cement paste as it possible sees in Figure 8 and 9.

Acknowledgements

This work has been supported by project GACR under No. P104/11/2285.

References

[1] http://www.cez.cz/cs/odpovedna-firma/zivotni-prostredi/programy-snizovani-zateze-zp/vyuziti-vedlejsich-produktu-uhelnych-elektraren.html, Information about secondary energy products.

[2] T. Plachý, M. Polák, P. Tesárek: Evolution of Dynamic Young's Modulus of Grey Gypsum in Time, Proceedings of the 50th Annual Conference on Experimental Stress Analysis, pp. 333-336, Tábor, Czech Republic, 2012.

[3] A. M. Neville: Properties of Concrete, John Wiley & Sons, (1997), ISBN 0-470-23527-6.

[4] O. Zobal, P. Padevět: Mechanical Properties of Cement Paste with Various Content of Fly Ash after 6 Months, Engineering Mechanics 2012, Svratka, Czech Repulic, pp 396 / 397, ISBN 978-80-86246-39-0.

[5] P. Padevět, O. Zobal: Change of Material Properties of the Cement Paste CEM I, in Proceedings of the 48th International Scientific Conference on Experimental Stress Analysis, Velké Losiny, May – June 2010, pp. 307-310, ISBN 978-80-244-2533-7.

[6] P. Padevět, P. Bittnar: Measuring of Creep of Cement Paste Specimen, Proceedings of the 2nd WSEAS International Conference on Applied Mathematics, Simulation, Modeling (ASM'09), Athens, Greece, 2009, pp. 33-39.

[7] B. Patzák: OOFEM project home page, http://www.oofem.org, 2000.

[8] Z. P. Bažant, S. Baweja: Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structure – Model B3, *Materials and Structures,* Vol. 28, pp. 357-365, 1995.