Measuring the Creep and Material Properties of Cement Paste Specimens

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Abstract: The paper describes creep tests of the small specimen, and analyses the material properties of cement pastes. Material properties were tested in compression tests. Creep of cement pastes was tested on the cylindrical specimens with diameter 10mm. Tests were focused for the pastes made from Portland cement CEM I and CEM II and water, whose water-cement ratio was 0.3; 0.4 and 0.5. Tested specimens for measurement of creep were waterlogged and dried. Shrinkage of cement specimens was measured too. After finalization of the measuring were specimens used for compression tests and Modulus of elasticity was measured. History of creep, material properties, history of specimens are inputs for simulation by finite element method.

Key-Words: Cement paste, shrinkage, creep of cement paste, concrete specimen, compression test, lever mechanism.

1 Introduction

Design of building structures depend at material properties of the constructions. The properties of building materials are influenced by many parameters like a material properties, structural strength, environmental conditions atc. The building constructions from concrete are influenced its material parameters, but for design of the large concrete constructions is indispensable creep influence. Engineering construction, like a containment of the nuclear of the power plant, basement slab can fail to the rise of shrinkage cracks.

Understanding of the reason the cracks origin first step for a prevent inception of that effect. That means, is important don't underestimate of the rise cracks factors like a physical and chemist reasons. Physical reason of the origin of the cracks incurred by the creep is shrinkage of concrete. Shrinkage of the concrete is influenced by loss of the physical bounded water, by change of the porous pressure. Chemical reason of concrete creep is the origin the shrinkage incurred by chemical volume changes [6] and by self desiccation [5].

Second step for prevent of the rise of the creep cracks is knowledge how can be measurement of the concrete creep. If is possible measure the creep, then is possible adapt procedure in the design of the concrete structures. Design of concrete structure is primarily influenced by suitable choice of the reinforcement of structure. Quantity, placing and orientation of the reinforcement can restrict or stop of the creep of concrete. Reinforcement in concrete structure may be chosen like a classic reinforcement [8] in the reinforced concrete structure, secondary reinforcement like a steel fibrous concrete and finally by plastic or carbon fibrous concrete. Steel fibrous concrete is mostly applicable in floor concrete structure or basement structures. In these constructions is inaccessible inception of the creep cracks, frequently.

Within used reinforced concrete is possible creep of the concrete influence namely by suitable selection of the component part of concrete mixture and by its suitable design. Concrete is mixture by cement, water, aggregate and admixtures. Aggregate is stabilizing part in concrete mixture. In the most cases is not aggregate absorptive and its volume changes are a negligible. Our focus can be fixed for the cement – water mixture.

Cracks incurred by creep in the construction can be reason for inapplicableness. Cement paste, aggregates and water are basic components of the concrete. Cement and water create component part – cement paste that is bonding agent for aggregates. Cement paste is product of the mixture cement and water, eventually admixtures. By suitable selection of the quantity of cement and water is possible creep of concrete decidedly decrease.

For the mathematical simulations [1] of the concrete creep are important material properties of cement paste. Strength of cement paste and Modulus of elasticity are basic material properties for simulations. Strengths of cement pastes are tested in compression tests in the MTS Alliance RT 30 equipment. Modulus of Elasticity is tested in MTS equipment too.

Other properties for simulations of the concrete creep are: mass, specific humidity of specimens and curves of the creep of cement paste, strength of cement paste, cement content, water/cement ratio, aggregate/cement ratio, geometry of specimen, Poisson's ratio, history of the loading. Mass is calculated from specimen's volume and its weight. Specific humidity is calculated from volume of specimen and a change of weight the specimen.

Curves of creep and shrinkage are measured by lever mechanisms. Strength of cement paste is determined from compression tests of the cement paste specimens.

2 Specimens

For the creep tests and compression tests was used one type of specimens. Cylindrical specimens were made into the plastic moulds. Their length was 10cm [2]. Lengths of specimens for creep tests were 70mm. After the process hardening cement paste were specimens cut from length 10cm to 7cm. Diameter of all specimens was 10mm.

In this paper are presented results of testing of specimens that was made from Portland cement. First series of specimens was made from Portland cement CEM I 42,5R with water cement ratio 0.5. Water cement ratio (w/c) is the weight proportion of the water and cement. Second series of specimens was made from Portland cement with w/c = 0.4, see Fig 1. Third series was made from Portland cement and water too, but with w/c ratio 0.3. Cement mixture was sufficiently liquid (w/c = 0.5) and was it possible pour to moulds.

Other series were made from Portland cement CEM II, 32,5R. Three series were used, too, with water-cement ratio 0.5, 0.4 and 0.3.

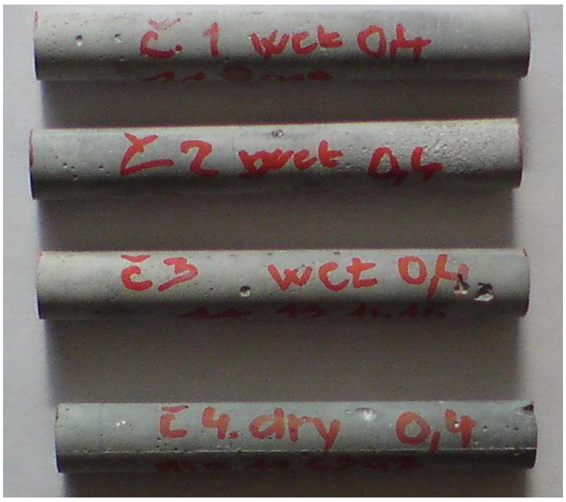


Fig.1. Specimens for creep tests (w/c = 0.4)

3 Testing equipment

Measuring of the material properties was realized in the MTS Alliance RT 30 testing machine. By MTS Alliance were tested: strength (Fig.2) and Modulus of elasticity. By continuous loading were measured parameters of material and was possible acquire the stress-strain diagram of the cement paste specimen.

Lever mechanism (Fig.3) is equipment for measuring of creep of cement paste [3].

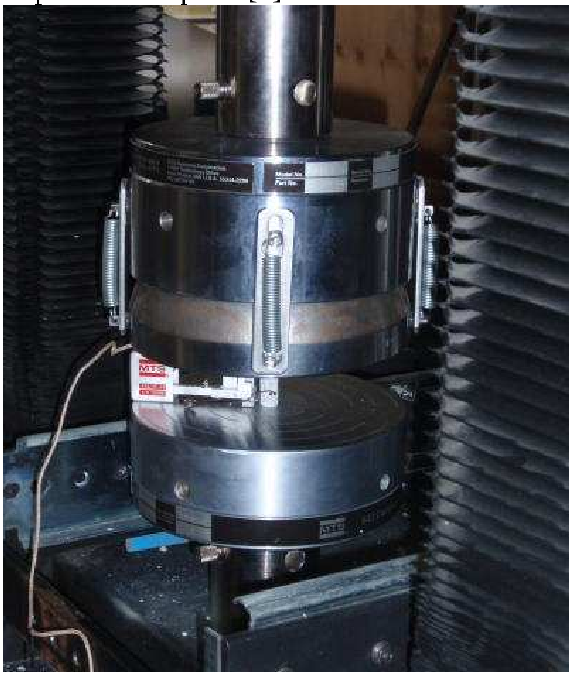


Fig.2: Specimens in compression test equipment.

Fig.3: Lever mechanism

Specimens were loaded by constant loads. Sizes of the load depend on the weight of plumb and location of plumb at the lever. For used specimens with diameter 10mm were applied loads approximately from 740N to 760N. In the case measurement of shrinkage at the specimens, load 76N was applied. Applied load on each specimen was constant for whole period of the loading.

Specimens were firstly placed into the lever mechanism, and after then was system loaded by plumb. Measuring the deformation was start when specimen was placed into the lever mechanism. Period of measure was from 25 to 28 day.

4 Results from compression tests

Cylindrical specimens were tested in compression tests, after creep tests finishing.

Specimen No.	w/c 0.3	w/c 0.4	w/c 0.5
1	114.325	79.959	67.233
2	104.875	142.559	43.1
3	70.172	142.686	70.233
4	104.141	130.757	58.666

Table 1. Compression strength of specimens of cement paste from CEM I (MPa).

Three sets of specimens from Portland cement CEM I were tested (Table 1). First set was prepared with water-cement ratio (w/c) 0.3 and included 4 specimens. Average strength of specimens was 107.78MPa. Third specimen was cut out because its strength was much lower of the other specimens, its loading parts wasn't plane-parallel.

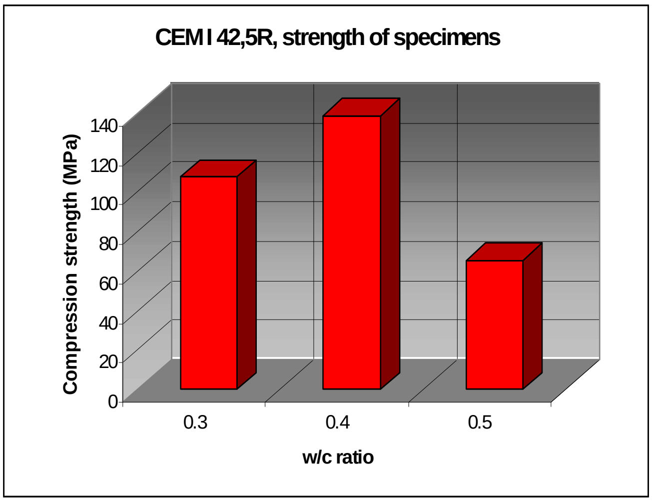


Fig.4: Graph of average compression strengths of the specimens from CEM I.

Second set of the specimen was prepared with w/c = 0.4. Average strength of specimens was 138.66MPa. 1st specimen was cut out because its strength was lower of the other specimens.

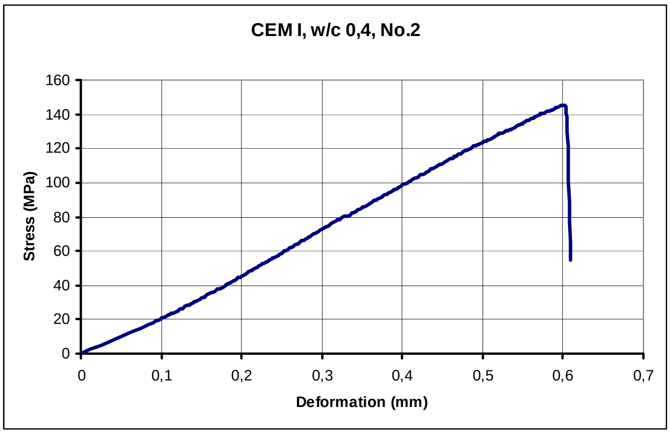


Fig.5: Stress – deformation diagram.

Third set included 4 specimens and their average strength was 65.37MPa. Specimen no. 2 had strength much lower to other specimen of the set. Therefore to average strength this specimen wasn't calculated.

Specimen No.	w/c 0.3	w/c 0.4	w/c 0.5
1	90.658	102.585	29.538
2	119.185	100.674	48.705
3	60.009	91.180	73.893
4	125.930	28.092	51.166

Table 2. Compression strength of specimens of cement paste from CEM II (MPa).

Second group of material were specimens made from Portland cement CEM II. CEM II is not pure Portland cement, but cement wit additives like (slag, siliceous ash) [4], [7]. In the group were three sets of specimens tested (Table 2). First set was prepared from cement and water with w/c = 0.3 and included 4 specimens. Average strength of specimens was 111,92MPa. Third specimen was cut out because its strength was much lower of the other specimens.

Second set of the specimen was prepared with w/c = 0.4. Average strength of specimens was 98,14MPa (Fig.6). 4th specimen was cut out because its strength was lower of the other specimens.

Third set included 4 specimens and their average strength was 50,82MPa. Specimen no. 1 and 3 had strength much lower and higher to other specimen of the set.

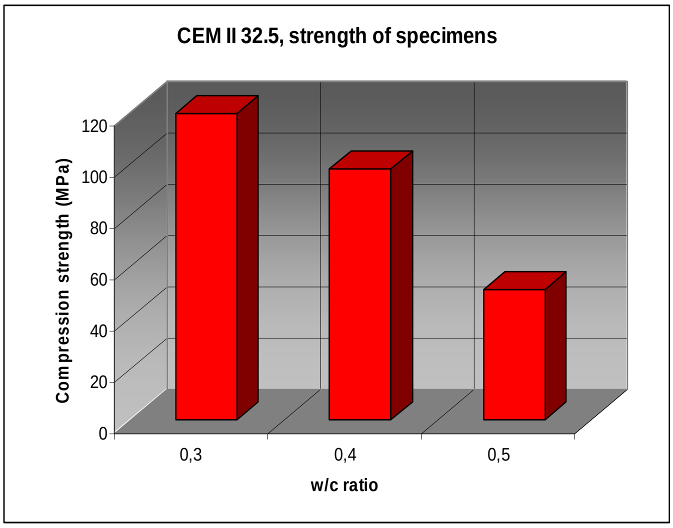


Fig.6: Graph of average compression strengths of the specimens from CEM II.

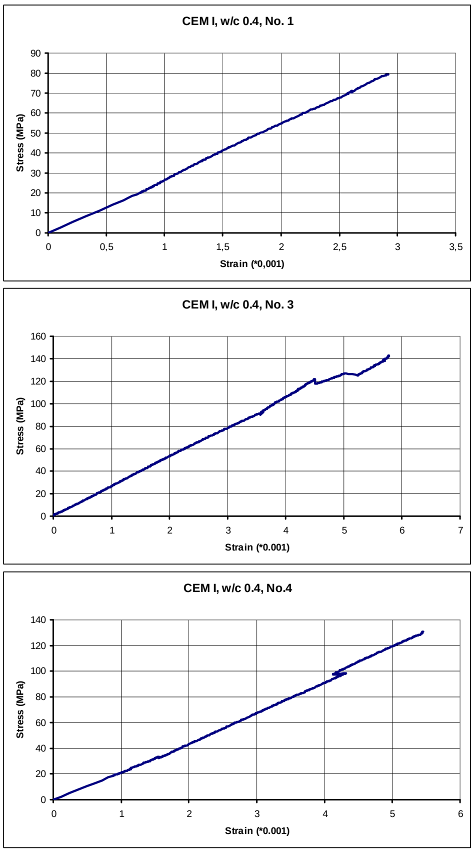


Fig.7: Stress-strain diagrams CEM I, water-cement ratio 0.4.

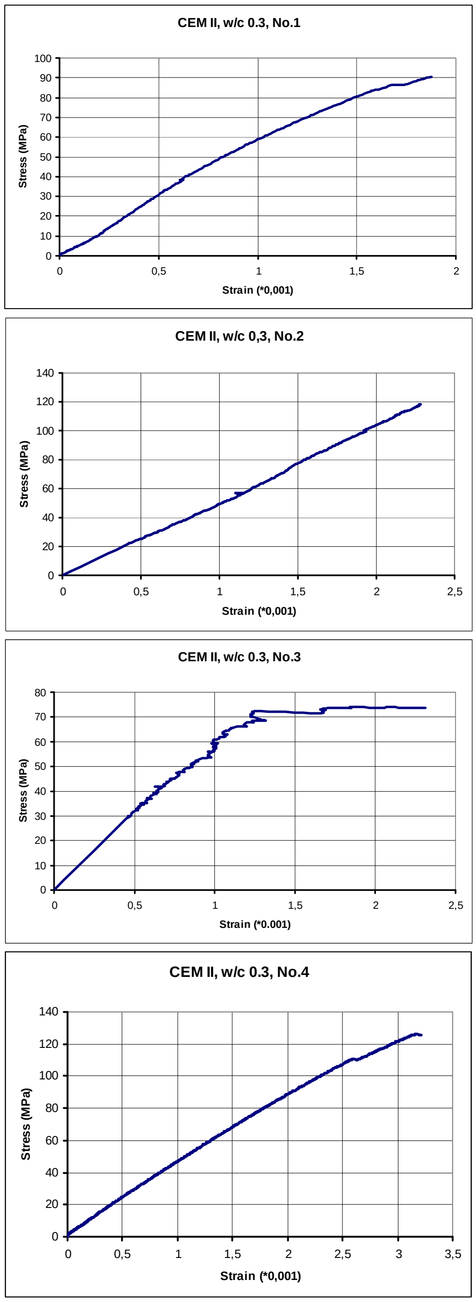
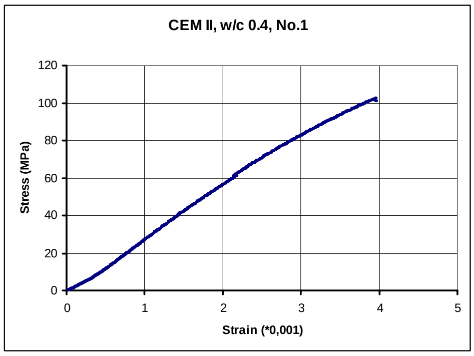


Fig.8: Stress-strain diagrams CEM II, water-cement ratio 0.3.



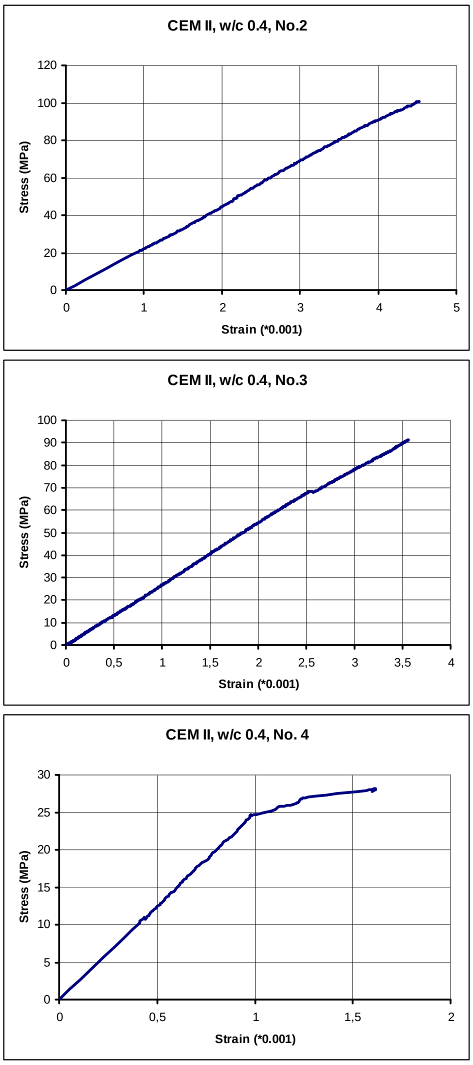
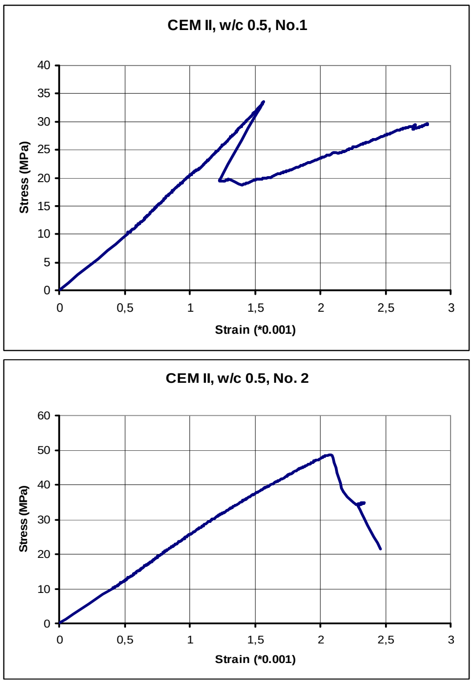


Fig.9: Stress-strain diagrams CEM II, water-cement ratio 0.4.



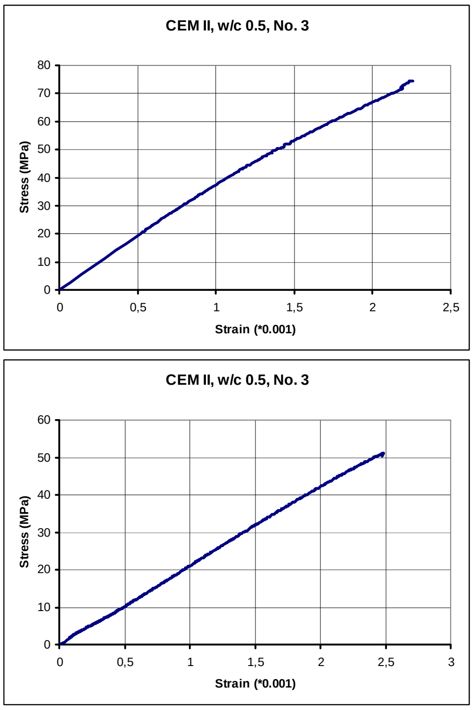


Fig.10: Stress-strain diagrams CEM II, water-cement ratio 0.5.

5 Modulus of elasticity

Modulus of elasticity is one of important parameters for the simulation of creep tests. Its value is defined like a relation between stress and strain. Value of stress is at 30% of the strength of specimens. Line between start and value of stress at 30% of stress define Modulus of elasticity [5]. Higher value of the Modulus is corresponding with more brittle material. Measurement is realized on the small specimens by one extensometer with measuring length 25mm (see Fig. 2).

Paper present Modulus of elasticity measured at the all specimens made from CEM II (Fig 8, 9 and 10) and three value of specimens made from CEM I and w/c 0.4 (Fig. 7).

Specimen No.	w/c 0.3	w/c 0.4	w/c 0.5
1	49.215	27.802	19.317
2	61.663	21.846	25.058
3	64.071	26.663	38.810
4	47.196	24.941	20.820

Table 3. Modulus of elasticity of specimens of cement paste from CEM II (GPa).

In the table 3 are noted value of Modulus of elasticity for specimens made by use cement CEM II. Average value for w/c ratio 0.3 was 55.536GPa. For the cement paste made with w/c ratio 0.4 was average value of the Modulus of elasticity 25.313GPa. Last group of specimens made with w/c ratio 0.5 achieve the value of Modulus of elasticity 26.000GPa. W/c ratio 0.5 was highest value for 3rd specimen. The same specimen had highest value of strength for w/c 0.5. If is specimen No.3 shift off, then average level of Modulus of elasticity is 21.731GPa. After this is possible observe decreasing of Modulus of elasticity with increasing content water in cement paste (Fig. 11).

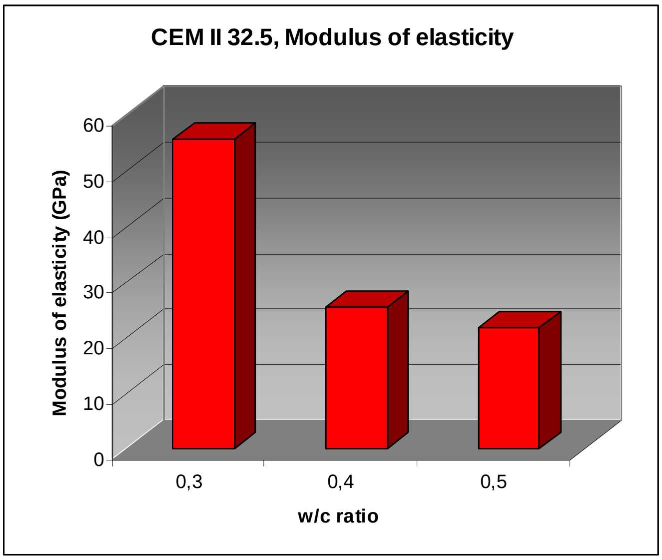
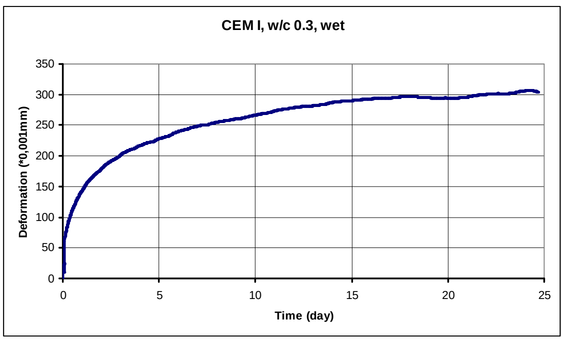


Fig.11: Graph of average values of Modulus of elasticity of the specimens from CEM II.

6 Results from creep tests

Before testing material properties in compression tests were specimens tested into the lever mechanisms for achieve results of creep. In the any series were tested 2 specimens loaded by load 740N with condition – water saturated specimen. Specimen – water dried was tested in each series, too. At least cement paste shrinkage was measured, too. Durations of the measure were from 27 to 30 day.

Next pictures (Fig.12) include graphs evolution of deformation in time. In the all sets the first 2 graphs include data of the water saturated specimen, one graph of water dried specimen and one graph of the shrinkage.



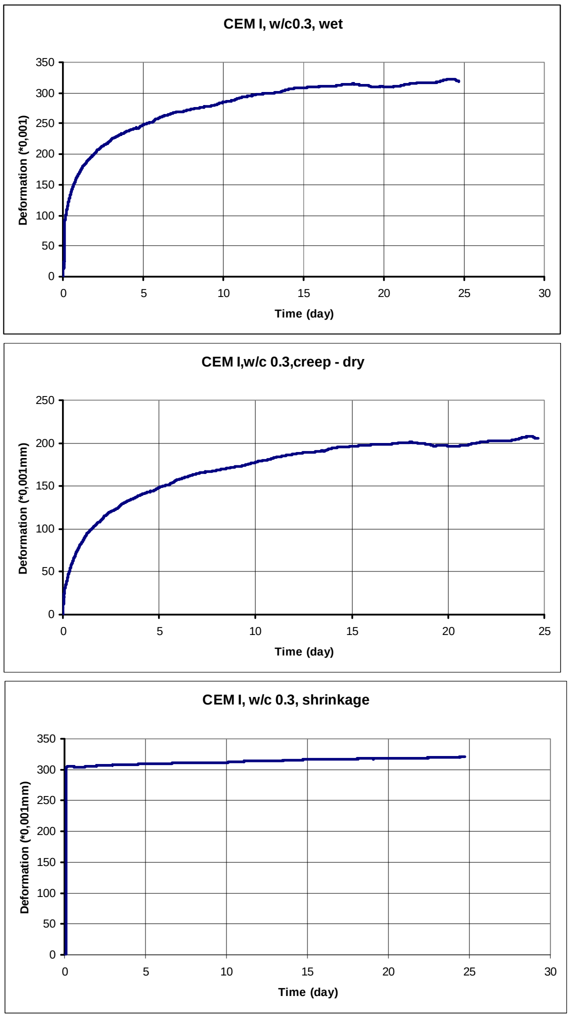
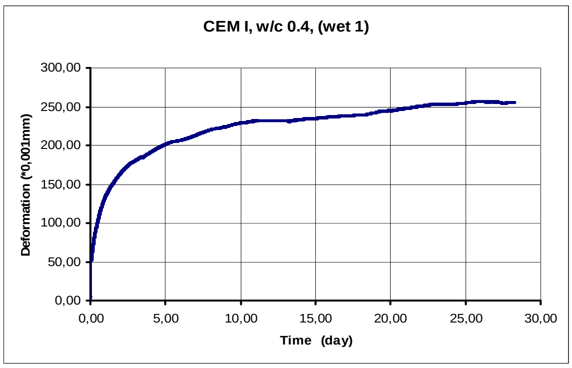


Fig. 12: Creep of specimens w/c 0.3 (CEM I).

Graphs viewed in Fig. 13 included results of measure the creep and shrinkage cement paste with w/c 0.4.



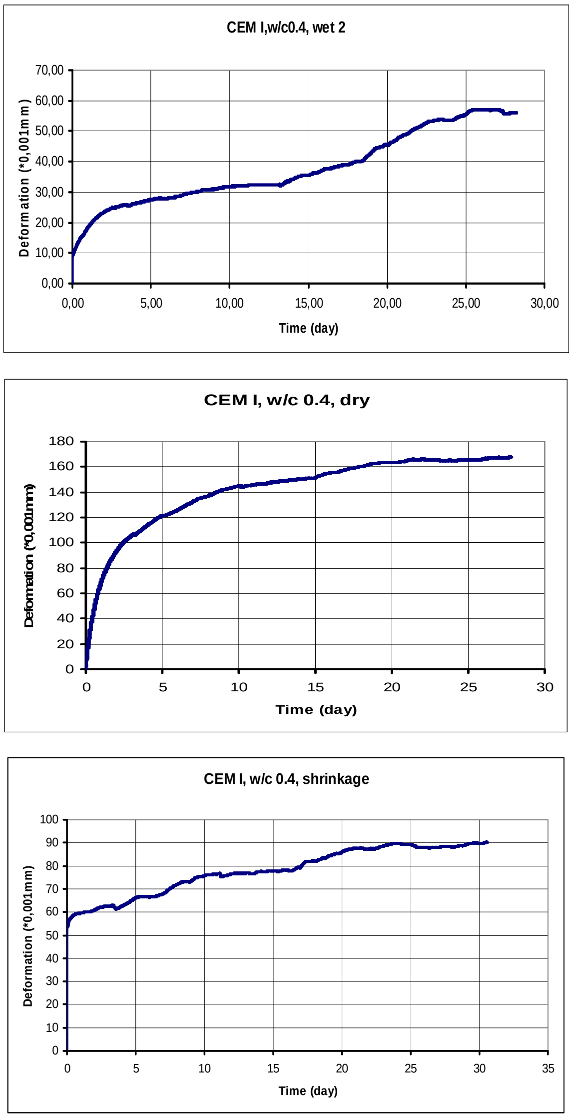
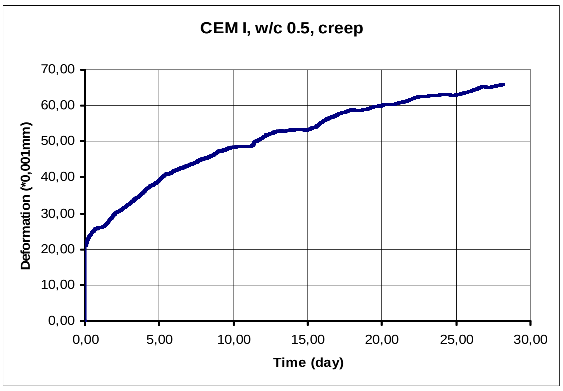


Fig. 13: Creep of specimens w/c 0.4 (CEM I).

Third set of pictures (Fig.14) are diagrams of evolution of creep in the time for cement paste with w/c 0.5.



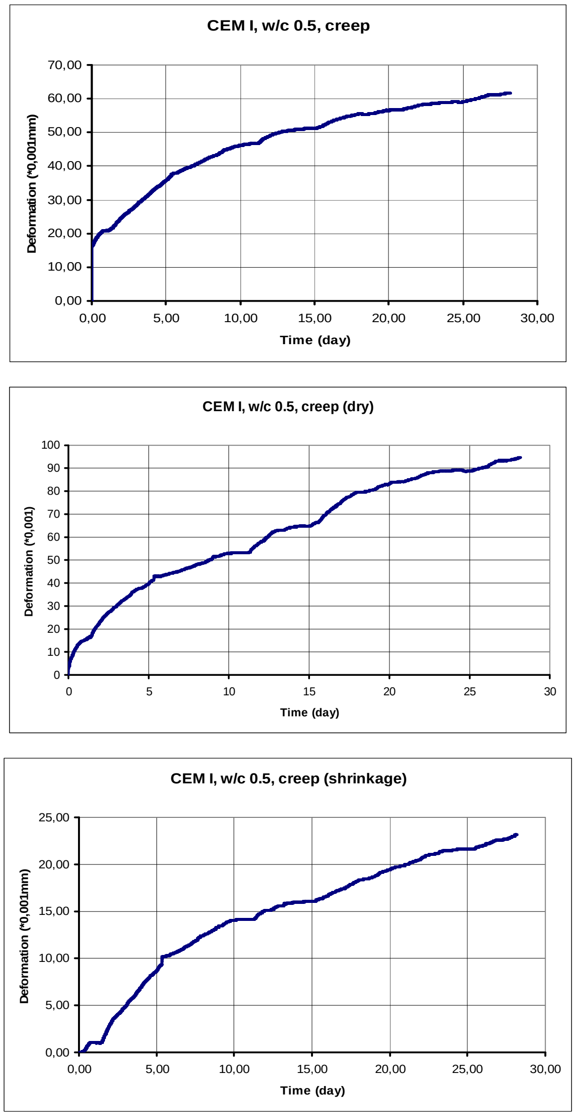
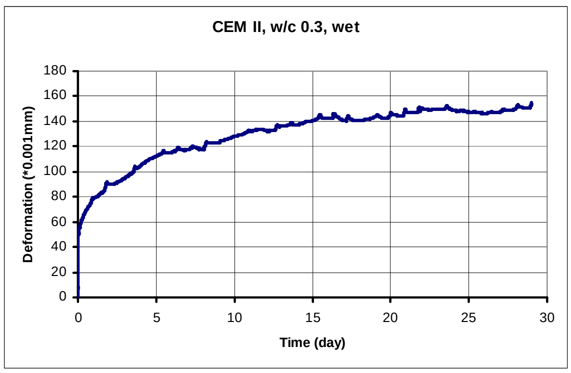


Fig. 14: Creep of specimens w/c 0.5 (CEM I).

Specimens were covered by plastic wrap during the testing. Before covering were specimens placed into the water basin. Specimens tested on drying creep were removed from water and 2 day dried out. All specimens were 1 year old.



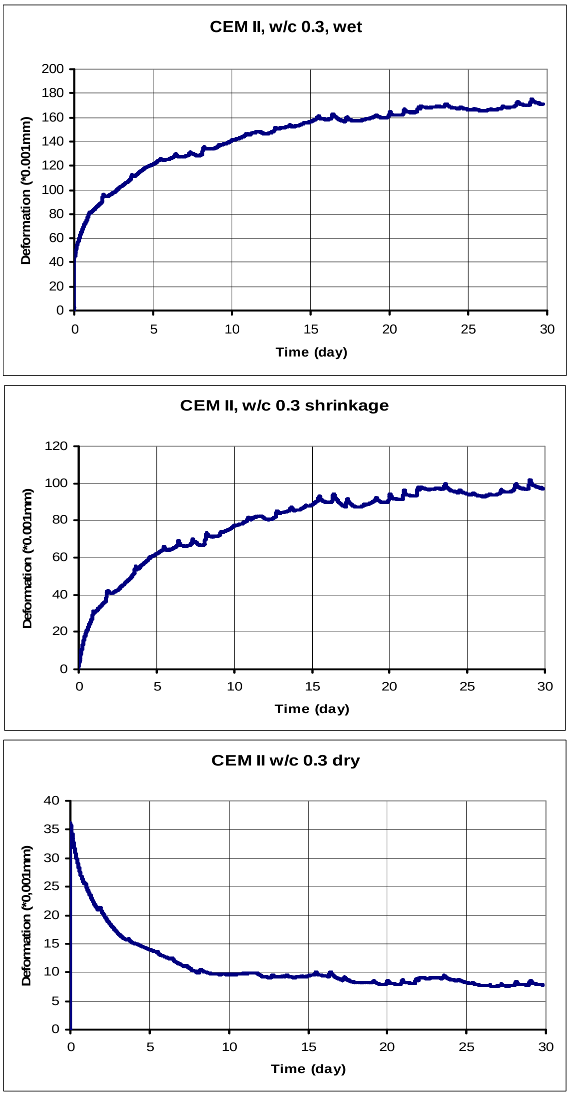


Fig. 15: Creep of specimens w/c 0.3 (CEM II).

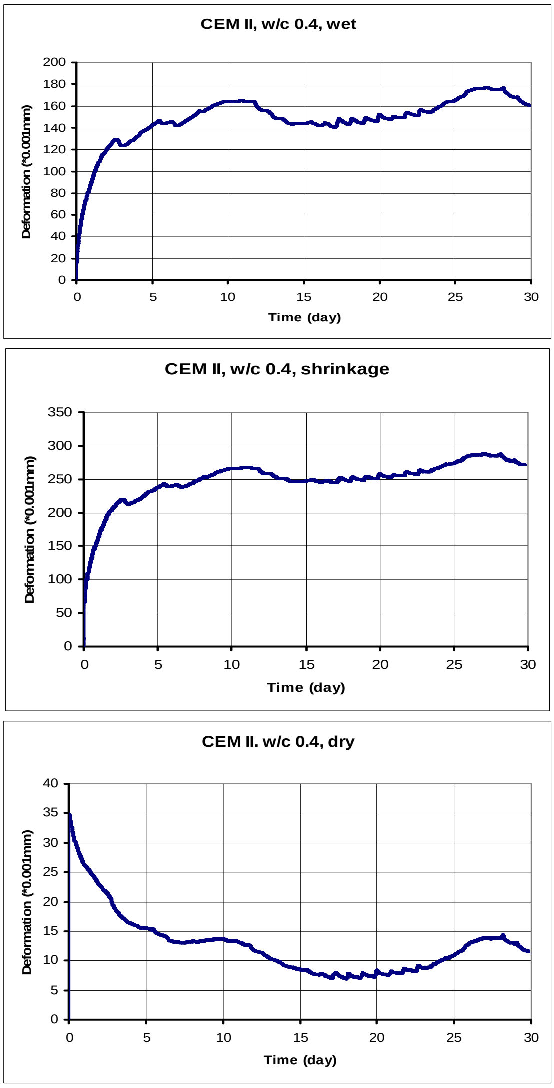
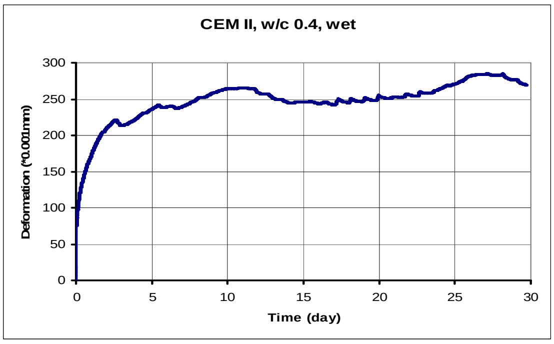
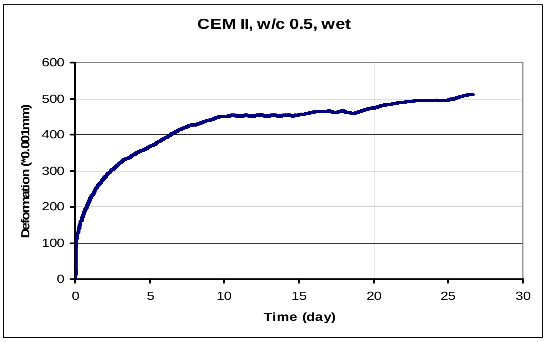
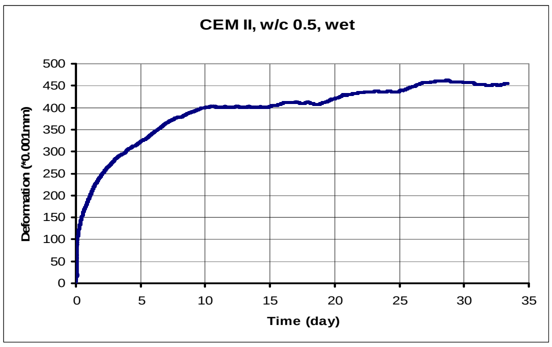


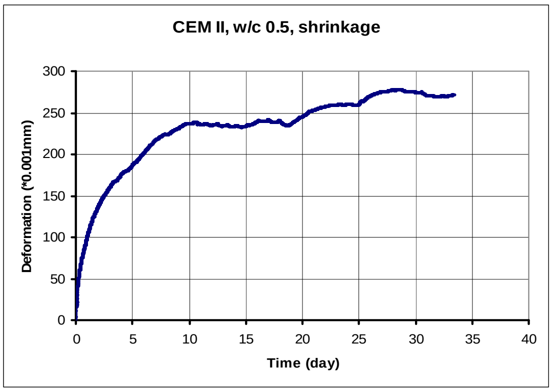
Fig. 16: Creep of specimens w/c 0.4 (CEM II).

Graphs viewed in Fig. 16 included results of measure the creep and shrinkage cement paste with w/c 0.4 made from CEM II.









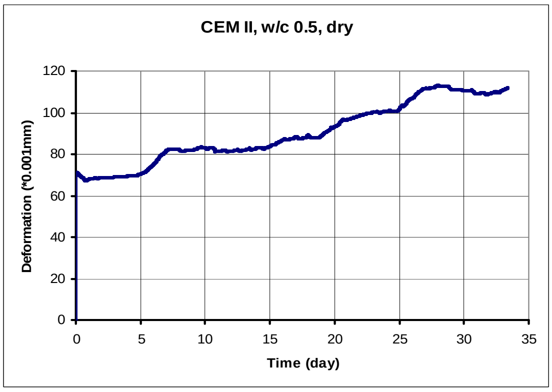


Fig. 17: Creep of specimens w/c 0.5 (CEM II).

6. Achieved results and their analysis

The goal of experimental work was in the getting dates from tests and its application in the simulation of the creep cement pastes and concrete. In the table 3 are summarized results from creep tests of the cement pastes specimens.

Specimen	1	2	3	4
w/c 0.3 Cem I	237	223	171	18.5
w/c 0.4 Cem I	190	47	142	32.6
w/c 0.5 Cem I	40	44	83	23
w/c 0.3 Cem II	100	100	26	84
w/c 0.4 Cem II	193	132	28	189
w/c 0,5 Cem II	386	335	30	223

Table 4. Values of creep and shrinkage after 25day.

Values in the table are deformation of cylindrical specimens (length 70mm) in μm (*0,001mm). Values in rows pertains to series 0.3; 0.4 and 0.5 of the CEM I and CEM II. Data in the first and second columns are deformations of water saturated specimens, third column is characterized by deformation of the water dried specimens. Data in the fourth column appertain to the shrinkage of cement paste. In the third column are strengths of dried. For the first series achieved creep after 25 day values between 223 and 237 μm. Deformation of the dried specimen is lower to deformation water saturated specimens. Shrinkage of cement paste specimen with w/c 0.3 is only 18.5μm.

In the second series (w/c 0.4) were result of measure "wet" creep (creep of the water saturated specimen) different. Values of the wet creep were from 47 to 190 μm. Value of the creep of the water dried specimen was 142 μm. Shrinkage of cement paste was little bit higher 32 μm.

Third series (w/c 0.5) is characterized by next results:

Deformation of the wet specimens was between 40 and 44 μm. Deformation of the dried specimen was 83 μm. Finally, shrinkage of specimen was 23 μm. The above described results pertain to the cement paste from CEM I. Following results are related with cement CEM II.

In this first series was achieved creep after 25 day values 100μm. Deformation of the dried specimen was lower to deformation water saturated specimens. Shrinkage of cement paste specimen with w/c 0.3 is 84μm. In the second series (w/c 0.4) were result of measure "wet" creep (creep of the water saturated specimen) little bit different. Values of the wet creep were from 132 to 193 μm. Value of the creep of the water dried specimen was 189 μm. Shrinkage of cement paste was 28μm. Third series (w/c 0.5) is characterized by next results: Deformation of the wet specimens was between 335 and 386 μm. Deformation of the dried specimen was 30 μm. Finally, shrinkage of specimen was 223 μm.

4 Conclusion

The paper compares results material properties from compression tests and from measuring of creep. In compression tests was the strongest 2nd series (CEM I). Third series CEM II was compression strength the lowest (50.82MPa). From achieved values result that optimal mixture is for w/c ratio 0.3 (for CEM I and CEM II near results). In the making cement paste with w/c ratio 0.5 is some content of water separated from cement gel. Whereas, in the making cement paste with w/c 0.3 is possible observe insufficient content of the water for treatment.

According with results of the compression tests are lowest (best) deformations from creep tests for w/c 0.3. If content of water in cement gel is increasing, deformation water saturated specimens in creep test is increased, too. The effect is reversed for CEM I. Shrinkage of the all kinds of cement paste was between 18.5 and 223 μm). Values of the creep of cement paste have increasing trend, too. The biggest difference is between drying creep and wet creep for specimens with w/c ratio 0.5 (CEMI).

For cement paste made by CEM II is possible observe decreasing trend for compression strength and Modulus of elasticity.

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