17th International Conference
ENGINEERING MECHANICS 2011
Svratka, Czech Republic, 9 – 12 May 2011

INFLUENCE OF INCREASING TEMPERATURE ON THE MECHANICHAL PROPERTIES OF CEMENT PASTE MADE OF CEM I AND CEM II

O. Zobal[*], P. Padevět[*]

Abstract: *Cement is still one of the most important materials in the building industry. The experimental investigation addressing the influence of temperature on the mechanical properties of cement paste is presented. In particular, the mixtures of Portland cement CEM I and CEM II are examined. The manufactured test samples are gradually heated to the required temperature and then subjected to the destructive uniaxial compression and three point bending tests to determine the compressive strength, the static modulus of elasticity and the tensile strength in bending.*

Keywords: ***Cement paste, high temperature, compressive strength, tensile strength in bending, static modulus of elasticity.***

1. Introduction

Cement is the basic ingredient used in many mortars and concrete mixtures and is, obviously, one of the most important and widely used building materials. Despite the fact that cement is utilized in altered forms since middle ages, there are still the tendencies to examine and improve its properties. The various experimental tests are often supported by the numerical simulations for better understanding of material behavior, e.g. the numerical study of mechanical properties of cement - based composites was presented by (Kabele, 2010), (Sýkora et al., 2009) investigated transport processes in cement mortar, etc. On the other hand, the indispensable laboratory testing of cement based composites was introduced by many authors, e.g. (Padevět & Bittnar, 2009; Padevět & Zobal, 2009; Němeček et al., 2010) to cite a few. The main objective of this paper is to study the influence of increasing temperature on the mechanical properties of cement paste, particularly the compressive strength, the tensile strength in bending and the static modulus of elasticity.

2. Experimental test

In the exceptional conditions (e.g. in the fire conditions), the concrete structures are loaded by the high temperatures which can cause the destruction of mastic and consequently the decrease of concrete strength (Vystrašil et al., 2010). For the experiments described herein, the normative samples marked CEM I and CEM II, respectively, are manufactured out of a cement paste. Afterwards, the above mentioned experimental tests are carried out on these samples.

2.1. Manufacturing of test samples

Two different groups of samples for the experimental tests are fabricated.

- Cylinders with diameter 10 mm and length 100 mm are made in the mould, see Fig. 1, and later adjusted to the length 40 mm for the compression tests.
- Beams with the dimensions 20 x 20 x 100 mm are utilized for the three point bending tests.

The various coefficients of water – cement ratio w/c = 0.3; 0.4; 0.5 are assumed for both CEM I and CEM II. To ensure better workability the plasticizer is added to the mixtures with coefficients equal to 0.3 and 0.4. After 48 hours, the specimens are taken out of the mould and placed into the water for

[*] Ing. Ondřej Zobal and Ing. Pavel Padevět, Ph.D.: Faculty of Civil Engineering, CTU in Prague, Thákurova 7; 166 29, Prague; CZ, e-mails: ondrej.zobal@fsv.cvut.cz, pavel.padevet@fsv.cvut.cz

another 26 days. Note that the temperature of water is kept constant (20°C) during the whole period. Then the 28 days old samples are loaded by prescribed temperatures (Fig. 1) and the destructive tests are executed. Bear in mind that each examined group contains approximately five samples and all of them are measured and weighted to determine the volume weight (Zobal, 2009). All measurements are statistically evaluated and the resulting standard deviation does not exceed 5%.

Fig. 1: The samples in the mould after 48 hours (left), after loading by temperature of 450 ° C with visible cracks (right).

2.2. The methodology of the experiment

The experiment is designed in order to investigate the influence of temperature on mechanical properties and its relation with the value of w/c. The proposed experimental program involves the following temperatures: (i) 20°C – normal state; (ii) 200°C – water ejection; (iii) 450°C – clay decomposition; (iv) 600°C – portlantid decomposition; (v) 300°C – extra inter mediate measurement. The heating rate set to 100°C/10 min and the required temperature is hold for constant two hours. Then the samples are slowly cooled down and measured. For the temperature 450°C and 600°C, respectively, the samples are remarkably damaged, see Fig. 1, and the measurement is very complicated or sometimes impossible.

The experiments are performed by means of the MTS Aliance RT-30 machine (Fig. 2) with the maximal loading force equal to 30 kN in compression and tension as well. As mentioned above, the cylindrical samples are subjected to compression and the strain gauges are attached if possible to estimate static modulus of elasticity. Three-point bending tests are carried out on the beams with span of supports 80 mm and the load applied in the mid-span.

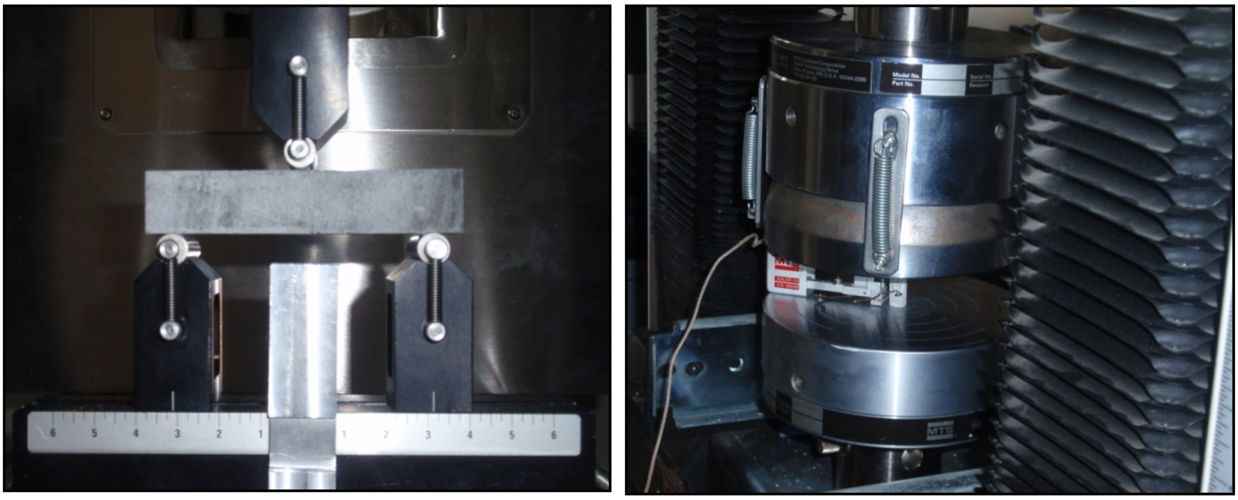

Fig. 2: MTS Aliance RT-30 - three point bending tests (left) a uniaxial compression (right).

2.3. Evaluation of the experiment

Fig. 3 shows the average values of compressive strength obtained from cylindrical samples after 28 days. The standard deviation for all results presented below did not exceed 5%. One can see that the compressive strength increased with the temperature up to 200 ° C for most of the samples and decreased at higher temperatures. The results demonstrate also the important role of the w/c. Its lower values induced higher compressive strength and vice versa. The highest value of compressive strength 147 MPa was obtained for samples manufactured out of cement CEM I with w/c = 0.3 at temperature 200 ° C and the lowest value (equal almost to zero) were measured for all samples with w/c equal to 0.4 and 0.5 at temperatures 450 ° C and 600 ° C.

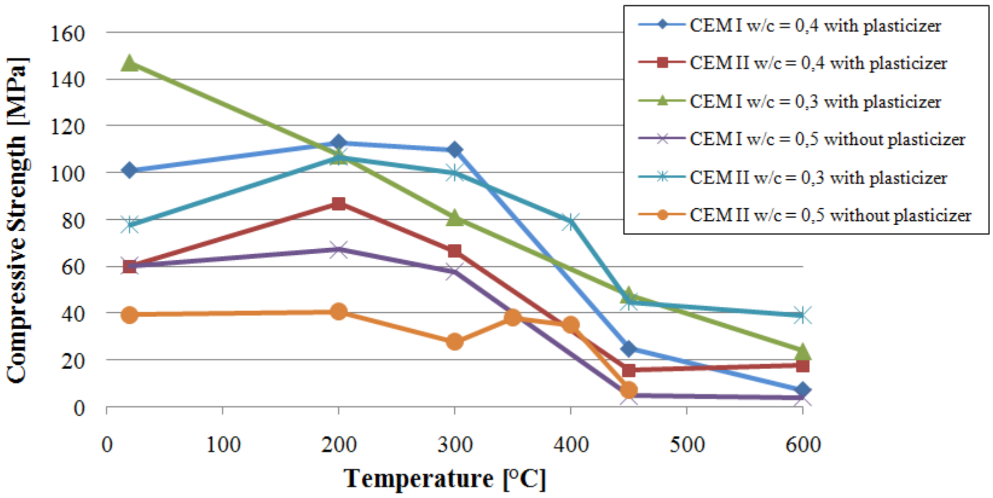

Fig. 3: Average compressive strength of cement paste after 28 days.

The average values of tensile strength in bending measured on beams are depicted in Fig. 4. The results show similar relation of tensile strength and the temperature as for the compressive strength. The highest value 9.5 MPa was obtained here for samples manufactured out of cement CEM II with w/c = 0.3 at temperature 200 ° C and the lowest value approached to zero at temperature 600 ° C for most of the samples.

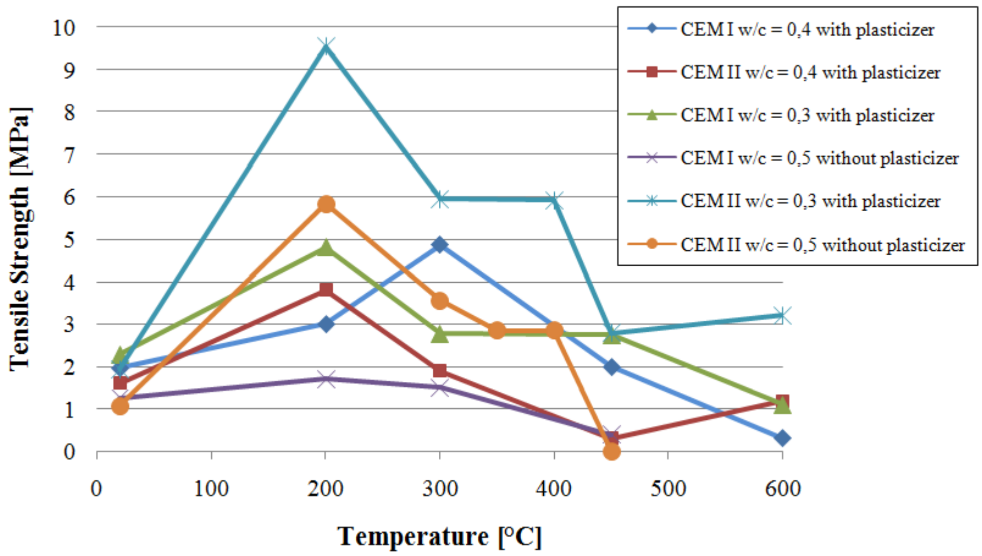

Fig. 4: Average tensile strength in bending of cement pastes after 28 days.

Using strain gauges, we measured the deformation of cylinders and we used it for computation of the static modulus of elasticity. The resulting average values decreases along with the increasing temperature for most of the samples, see Fig. 5. The only exception is the sample made of cement CEM I with w/c = 0.3. In contrast to quantities investigated above, the values of the elastic modulus decrease much more rapidly. The highest value 33.2 GPa was again obtained for samples with w/c = 0.3 at temperature 200 ° C.

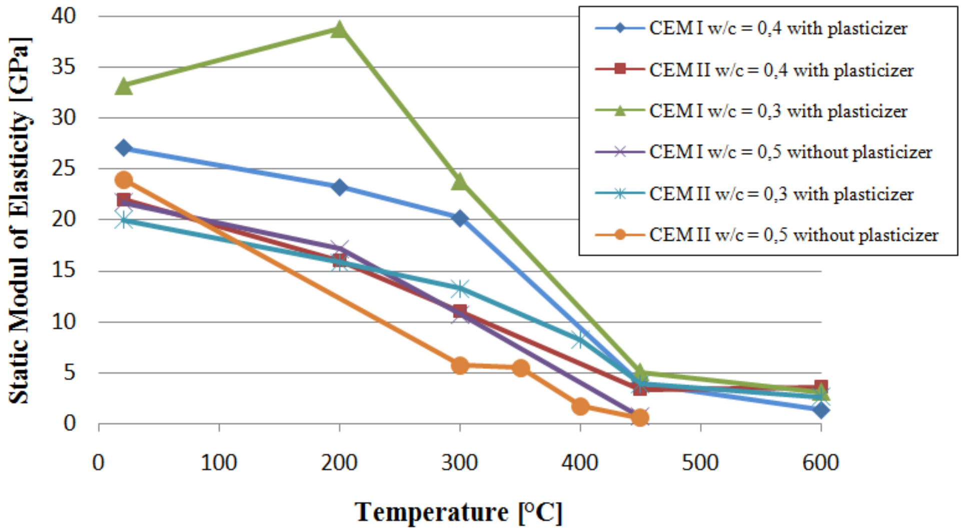

Fig. 5: Average static modulus of elasticity of cement pastes after 28 days.

3. Conclusions

The influence of high temperatures on mechanical parameters is significant for samples made of cement paste, and thus also for the concrete. It was shown that the w/c ratio has also an important impact to the results, while the increasing amount of water in cement paste reduces the values of investigated mechanical properties. Regarding the cement types, the variant CEM I attained higher values than the variant CEM II. The most important observation was the phenomenon of increasing values of studied properties along with the temperature up to 200 ° C. For higher temperatures, nevertheless, their values started to decrease according to our presumptions. Therefore, we will study this phenomenon in our future experiments in more details.

Acknowledgement

The financial support of this experiment by the Faculty of Civil Engineering, Czech Technical University in Prague (SGS project No. 10/136/OHK1/2W/11 „Advanced experimental methods“) is gratefully acknowledged.

References

Kabele, P. (2010) Stochastic finite element modeling of multiple cracking in fiber reinforced cementitious composites. in: Fracture and Damage of Advanced Fibre-reinforced Cement-based Materials. Freiburg: Aedificatio Publisher, pp. 155-163.

Sýkora, J., Vorel, J., Krejčí, T., Šejnoha, M. & Šejnoha, J. (2009) Analysis of coupled heat and moisture transfer. in masonry structures. Materials and Structures. 42, 8, pp. 1153-1167.

Padevět, P. & Bittnar, P. (2009) Creep of cement paste with w/c ratio 0,5. in: Experimental Stress Analysis 2009. Liberec: Technical University, 2009, pp. 183-187.

Padevět, P. & Zobal, O. (2009) Material Properties of Cement Paste at High Temperatures. in Selected topics on Applied Mathematics, Circuits, Systems, and Signals. Athens: WSEAS Press, 2009, pp. 39-42.

Němeček, J., Pečová, P. & Němečková, J. (2010) Effect of Surface Treatment on the Microstructure of Cement Paste Assessed by AFM. in Experimentální Analýza Napětí 2010. Olomouc: Palacky University, 2010, pp. 269-276.

Vyšvařil, M., Bayer, P., Rovníková, P. (2010) Properties of rehydrated cement paste under high temperatures (Vlastnosti rehydratovaných cementových past po expozici vysokými teplotami). in Proc.: 17. Betonářské dny 2010, pp. 479 – 483, Hradec Králové

Zobal, O. (2009) Influence of temperature on the material properties of cement paste. Master Thesis, CTU in Prague, Prague.