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Comparison of the Humidity Influence on the Material Properties of Cement Paste with Fly Ash

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Abstract. The different properties of building materials are often caused by their varying humidity respectively water saturation levels. The cement paste is a porous material. The cement paste mixed with fly ash is highly porous material whose properties depend on the amount of pores in the material and the state of saturation. The article compares the basic material properties of cement paste with fly ash for two states, saturated and dried materials. The ratio of cement and bulk ash was 1:1.

Introduction

The compressive strength and the tensile strength, elastic modulus and fracture energy are important and interesting material properties. Changes in the properties of cement paste [1] with fly ash to pure cement paste can be documented on those parameters.

The density of fly ash is significantly lower than the density of cement. It moves around 900 kg/m^3.

Compressive strength is a property determined from uniaxial compressive tests, the specimen is loaded by centric force. The proportion of maximum pressure achieved strength and load-bearing surface element determines the size of the compressive strength [2].

Tensile strength in bending is determined from another type of material test. The most commonly used three-point bending test. The specimen of the section is handled in the middle of the defined range increasing force until to failure. Tensile bending strength is calculated from the dimensions of specimen, distance support and achieved load.

The modulus of elasticity is significant characteristic determined from the compressive stress and the deformation during loading. Most often is determined from pressure tests, as secant value 1/3 strength and the corresponding strain.

Fracture energy is the properties of a given size of the energy required to breach the specimen. It is determined from the three-point bending test. Several methods exists for determination its value. All methods are based on measurement of deformation and vertical forces on the specimen, that has created under an applied force notch defined thickness. These properties are important for the design of structures in terms of capacity [3].

Its outstanding features are the water absorption and porosity. Fly ash is a porous material of high hardness. Article is comparing the above-mentioned material properties of dried and saturated specimens.

The volume density is important properties too. Its size depends on the content of the water. Due these two types is possible divide on the volume density in dry and saturated condition. First one is determined from the sizes of specimens and weight of water dried specimens. Second one is calculated from the water saturated specimens.

Preparation of material tests

The cement paste containing the fly ash is a homogeneous material. Homogeneity of the material allows the use of small specimens for testing. Specimens with size 20 x 20 x 100 mm were determined for experiments. The cement paste made from water and Portland cement CEM I 42.5 R was initially chosen for production. Water-cement ratio for the preparation of cement pastes was selected 0.4 [1]. The consistency of cement paste is liquid, well-workable and does not need a plasticizer used for preparation.

The same water-cement ratio was used for the production of cement paste with fly ash. The ratio between the amount of cement and fly ash was 1:1 [4]. Specimens were produced in steel moulds with precise dimensions.

All specimens were stored in to water bath after the concreting. Testing was performed at the age of one and three months. The article presents the results of the test after 28 days. The specimens were removed from the water bath and divided into the two groups before testing. First one is the dried and second one concludes specimen saturated with water. All specimens were loaded at high temperatures. For testing were selected at 20, 150, 200, 250 and 300 °C. After removing specimens from the water basin followed by thermal loading, the specimens were heated to a specific temperature at 100 °C / hour. Subsequently, the temperature was defined by specimen is heated for 24 hours and then the temperature was decreased by naturally cooling to 20 °C.

Saturated specimens were brought back into the water bath and left there two days. The compression strength was tested by using the six specimens. The specimens were prepared from the three original specimens so that it was cut into two equal parts the height of 50 mm.

Specimens for the test in tension in bending were used in the original size and their numbers was 5.
The Modulus of elasticity [5] was measured together with the test compressive strength was realized [6]. Each specimen was loaded into 3 times to 1/3 the expected strength and then it was carried out compression test. The extensometer was used for measurement of strain in compression test, as is possible see in Figure 1.

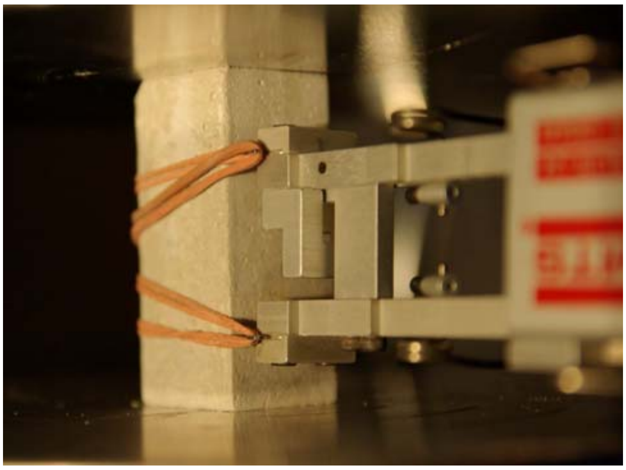

Fig.1 The specimen from cement paste in compression test. On the specimen is clipped extensometer.

In the experiments were carried out tests on the fracture energy [7]. Four specimens in each group were provided with the notch to half the height of section.

Comparison of material properties

First of all volume density is possible compare. Dried specimens containing fly ash have the same density, although the temperature was raised to 600 °C.

Table 1 Volume density of the cement paste with fly ash.

Temperature (°C)	Dried (kg/m^3)	Saturated(kg/m^3)
20	1322	1752
150	1340	1713
200	1303	1736
300	1325	1745
450	1305	1727
600	1301	1729

Third column shows the change of volume weight of the pastes, which were heated to the specified temperature and then refunded for 2 days in the water. Volume weight of saturated solids mixed with fly ash was near to 1700 kg/m^3, see Table 1.

A comparison of the volume densities can be seen in a significant reduction in the manufacture of mixtures containing fly ash. A very significant difference is obtained by comparing the values for pure cement paste and the paste mixed with fly ash in the dry state. The difference reaches almost 700 kg/m^3. Pure cement paste had volume density between 1600 and 2050 kg/m^3.

Table 2 Compression strength of the cement paste with fly ash.

Temperature (°C)	Dried (MPa)	Saturated(MPa)
20	34.33	24.68
150	28.39	22.42
200	29.19	22.01
300	29.49	30.69
450	13.88	23.21
600	8.79	20.13

The compressive strength of specimen is divided with the content of fly ash into two groups. In Table 2, we can see a comparison between the saturated cement paste with fly ash and dried cement paste with fly ash.

Third column shows the compressive strength of saturated specimens. In comparison with the desiccated specimens in Table 2, is initially lower strength of 10 MPa. At the temperature of 250 °C, the strength of dried and saturated specimens has already mutually corresponding. For the saturated material the increasing of strength was compared to the values at 200 °C. Conversely dried specimen show sustained slight decrease of strength from the outset. Tensile specimens saturated to 200 °C holding the value of strength 22 MPa. Exceptional strength value 30.6 MPa belongs to temperature of 300 °C. An increase in temperature means a return the strength to again close 20 MPa.

The decreasing trend of strength at the temperatures higher than 200 °C is evident. Rate of decline in strength is formed. The strength of dried specimens reaches only 8.79 MPa at 600 °C.

Water saturated cement paste with fly ash behaves quite differently. At higher temperatures is also a significant the decrease in compressive strength. But this decline is slower. The strength of saturated specimens is at 450 °C nearly 2 times higher than for the dried specimens.

The comparison of the development of the compressive strength of cement paste containing fly ash is shown in Figure 2.

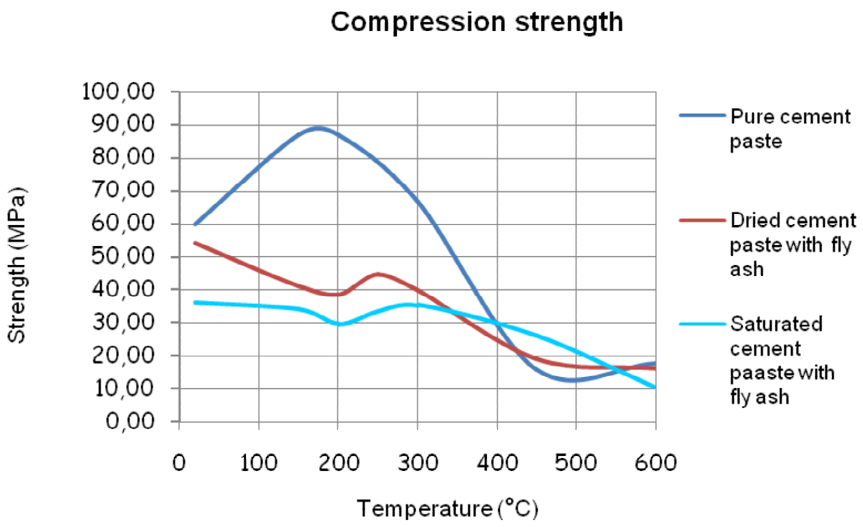

Fig. 2 Compression strengths compared with pure cement paste.

The results of tensile strength in bending are shown in Table 3. The table is again compared strength of dry cement paste tested at high temperature and dry cement paste mixed with fly ash.

Table 3 Tensile strength in bending of the cement paste with fly ash.

Temperature (°C)	Dried (MPa)	Saturated(MPa)
20	7.48	5.70
150	6.36	4.19
200	5.52	3.79
300	5.56	3.14
450	0.84	2.48
600	0.42	2.33

The dried cement paste with fly ash has consistently decreasing character development of the tensile strength. Initially, the strength value for pastes with fly ash is higher than in case of the pure cement paste.

Tensile strength in bending dried cement paste decreases with increasing the temperature, as shown in Table 3. The significant decrease occurs after the temperature reaches 300 °C. This behavior corresponds to the compressive strength of dried cement paste.

The saturated specimens by water show a steady decrease in tensile strength in bending since the temperature of 20 °C. At temperature of 450 °C the strength is only 2.48 MPa. However, this value is considerably higher than in the case of pure cement paste and dry cement paste with fly ash.

Very interesting is the ratio between compressive strength and tensile strength in bending. For example, at 200 °C, the compressive strength of pure cement paste is 14 times greater than the tensile strength in bending. For the dried cement paste with fly ash, this ratio is significantly lower, namely 4x.

It follows that the properties of compressive and flexural strength is balanced for the dried specimens. On the other hand, the decrease in strength is greater for the dried cement paste than for the saturated cement paste above 300 °C. As shown in Table 3 and Figure 3, is declining trend in tensile strength in bending observable also in saturated specimens with fly ash. In this case, the ratio of the compressive strength and flexural strength slightly higher than for the dried specimens, specifically 5 times.

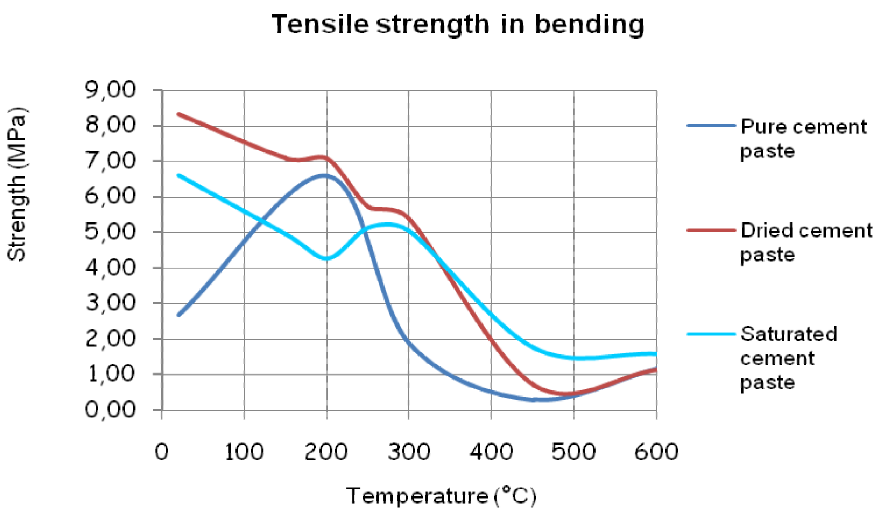

Fig. 3 Tensile strength in bending for saturated and dried cement paste with fly ash.

The modulus of elasticity shows a downward trend as well. Downward trend of temperatures higher than 150 °C is steady in the case of the dried paste. When the temperature reaches 450 °C modulus is only 1.59 GPa. The steady value of the modulus of elasticity is evident for the saturated specimens. From temperature 150 °C the strength value is between 8-10 GPa.

At the temperature of 450 °C the saturated specimens reached about 6.67 MPa higher modulus of elasticity than the specimens dried how is possible see in Table 4.

Saturated cement paste with fly ash is in terms of deformation at higher temperatures better then the dried paste. Saturated material retains deformation properties almost the same as at 20 °C.

Table 4 Modulus of elasticity for cement paste with fly ash.

Temperature (°C)	Dried (GPa)	Saturated(GPa)
20	8.3	14.36
150	11.38	7.86
200	8.82	9.65
300	7.36	8.92
450	1.59	8.26
600	-	9.80

Saturated cement paste with fly ash is in terms of deformation at higher temperatures better then the dried paste, as is displayed in Figure 4. Saturated material retains deformation properties almost the same as at 20 °C.

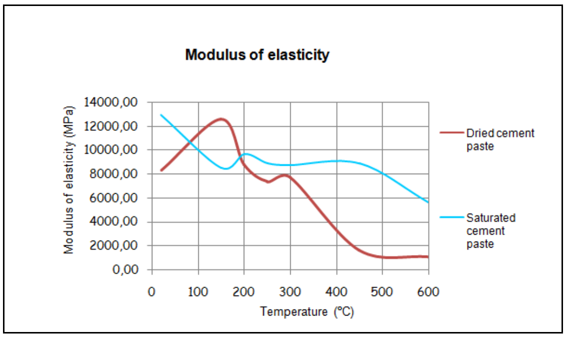

Fig.4 Modulus of elasticity for cement paste with content of fly ash compared to pure cement paste.

Summary

As it was shown in the article the material made from fly ash reaches comparable parameters such as cement paste made from Portland cement.

The cement paste mixed with fly ash reaching interesting properties at higher temperatures [8]. The material properties of paste depends on the temperature of which was loaded. The behavior of saturated cement paste with fly ash at high temperatures achieved better performance than that of dried paste [9].

The tests proved the dependence of the dried material and reached the compressive strength and the independence of the parameters for the case of water-saturated material.

A significant effect of energy saving is in the use, and therefore the need of only half the amount of cement. It is processed material, which was stored in landfills. The positive trend is reflected in the long term, when the properties cement paste with addition of fly ash is improving.

Very interesting is the perspective of the use of fly ash in the structures of fire protection when at elevated temperature reaches the same and better properties than pure cement paste.

Acknowledgements

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