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Changing the Properties of Cement Paste with Addition of Fly Ash in Time

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Abstract: Cement paste with addition of fly ash is one of the possible variations of processing waste material, including fly ash which they belong. The article presents results of material properties of cement paste. Between the mentioned properties are: compressive strength, tensile strength, bending strength, modulus of elasticity and fracture energy. Cement paste was made with different proportions of cement and fly ash. In all cases, the mixture was used with water - cement ratio of 0.4.

Keywords: Fly Ash, Cement Paste, Strength, Fracture Energy.

1. Introduction

The mechanical behavior is influenced by the materials used. Most of engineering materials is possible categorized into brittle, ductile, or quasi-brittle materials [1][5]. The fracture energy is one of properties of the material, which is possible measuring by relatively simple method. This property described capability of the material resist to loading.

The cement paste is material based only on two parts; water and cement. Properties of cement pastes are relatively well known. Particular, the compressive strength depends on the water/cement ratio w/c. Equally, an important factor for compressive strength, the water content in the material. Increasing the amount of water in cement paste allows the maturation of the paste. The water content in the long term has a positive effect on the strength of cement paste. Experiments described in the article investigated the influence of humidity of cement paste to the size of the fracture energy [6].

Nowadays, much attention is focused on processing of waste materials. Very good usable waste material can be fly ash. This material is generated by burning coal to produce electricity in coal-fired power plants. Particulate solid phase has a granulometry 0 - 1000 microns. Bulk density is 750-950 kg/m3. Chemically it is the inert material, composed mainly of SiO_2 and Al_2O_3. The power plants in the Czech

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Republic produce annually 8 million tons of fly ash. The burning of brown coal arises 10-30 ash as a waste material.

Some experiments described below were carried out using traditional fly-ash. Conventional fly-ash contains up to 80% glass phase, as the main component. Sulfur content (expressed as SO_3) usually does not exceed 1 %. In the high-temperature combustion of coal is not necessary to add ground limestone into burnt mixture. The resulting ash typically does not contain calcium compounds such as $CaSO_4$, and also higher amount of sulfur in the form of SO_3.

This study aims to evaluate the changing properties of cement paste if is into the paste added component of waste – fly-ash, typically.

2. Specimens

The advantage of the cement paste is the homogeneity. Homogeneous fine-grained materials are suitable for testing in smaller testing equipments. Therefore, the preparation of specimens was selected type of form 20 x 20 x 100 mm.

Portland cement CEM I 42,5 R was used for production of specimens. Because the intention was not to use a plasticizer, were selected water-cement ratio 0.35, 0.4 and 0.45. Grout with a water/cement ratio beyond the specified limit has high fluidity, which may cause segregation of cement and water. On the other hand, the grout may be too rigid and treated by practically no plasticizer. Consistency of 0.4 was chosen as a tougher type of cement paste. Conversely, thinner type of cement paste was defined by w/c ratio of 0.45. Specimens of cement paste were stored in the water basin for about 30 days.

The specimens were removed from the water two days before testing. Subsequently, specimens were dried for 48 hours at 60 °C. During the drying was to reduce weight to saturated samples from 11 to 12 %, see Table 1.

Table 1. Change of specimens' weight (in grams).

w/c ratio	Weight – saturated (grams)	Weight – dried (grams)	Lost of weight (grams)	Lost of weight (%)
0.35	82.59	73.54	9.05	10.9
0.4	78.04	68.54	9.5	12.2
0.45	76.23	66.74	9.49	12.4

Before the start of testing, at each specimen was cut notch about 7 mm deep. The width of the notch specimens was 1 mm. Synoptic information is the mass density of cement paste for the water/cement ratios. Increasing the value of the water/cement ratio causes a reduction in the value of mass density, see Table 2.

Specimens prepared from fly ash and cement paste had w/c factor of 0.4. Water/cement coefficient of 0.4 has a good consistency, in which there is no separation of water and cement. Adding fly ash, which is in principle the not wetted surface, is not impaired by the mixture. On the other hand, the mixture is more liquid, but the individual components do not segregate.

Table 2. Caption of table one caption of table one.

w/c ratio	C/A ratio	Mass density (kg/m3). Saturated	Mass density (kg/m3). Dried
0.35		2072	1862
0.4		1965	1737
0.45		1948	1635
0.4	0.5/0.5	1739	
0.4	0.4/0.6	1716	

In this case, the degree of fluidity of the mixture depends on the quantity fly ash in cement paste. Quantity fly ash is defined by the C/A ratio. It expresses the ratio of weight of cement and fly ash. In the first case in the tests performed using the same quantity of cement and fly ash. In the second case, in the cement paste was used 40 % cement and 60 % ash.

Feature testing was performed on 6 specimens in each group. The group formed a designated water/cement ratio. Sets of dried specimens contained only 5 specimens. A total of 45 specimens were tested.

From Table 2, the visible decrease in volume weight, as mentioned above. Addition of fly ash into the cement paste experienced the following reduction in volume weight. Reducing specimens weight is with water saturated nearly 12%.

3. Testing of specimens

Execution of experiments was carried out in the test machine MTS Alliance RT 30kN [8]. It is an electromechanical testing machine with a very subtle shift in the crosshead. By using relatively small specimens can achieve the desired results the test method. The size of test specimens and stiffness are two important parameters for achieving good results. If the stiffness of the testing machine is too small and the large size of specimen on the contrary there is a snapback or only achieve the maximum load, without softening the material is measured [2].

Fig. 1. Specimens with notch is prepared for three point bend test.

Fracture energy was measured in the tests performed using the three-point bending test (Fig.1). Distance support the specimen was 80 mm. The notch was located in the middle of the range below the point where the applied load. To assessment the test were required two parameters, strength and vertical deflection of the specimen. For those of parameters it is possible to calculate the fracture energy of the test specimen. Before the tests were measured dimensions of each specimen.

The RILEM Technical Committee 50-FMC on Fracture Mechanics of Concrete – Test Method proposed a draft recommendation to measure the material fracture energy Gf using a three-point bend beam. Fracture energy is calculated on the basis of relation Eq. (1) [3].

$$G_f = \frac{W}{b \cdot (d - a)} \qquad (1)$$

Where:

G_f is fracture energy;

W is total fracture energy;

b is width of the specimen;

d is height of the specimen and

a is notch size.

The energy absorbed by the beam is represented by the area under the load – displacement curve P – δ curve, where δ is the load point displacement [4]. The total area under P – δ curve is referred to as W, which may be divided into three parts, W_0, W_1, and W_2 Eq. (2).

$$W = W_0 + 2P_W \delta_0 = W_0 + W_1 + W_2 \qquad (2)$$

Where:

W_0 is area below the measured P - δ curve.

W_1 is $P_W * \delta_0$. Both values W_1 and W_2 can be determined from measured P – δ curve. Peterson, Swartz and Yap demonstrated that value W_1 is approximately equal to the value of W_2.

P_W - additional equivalent force is value which may be represented by influence of self-weight.

4. Results

The data obtained from tests carried out are summarized in graphs. The descending branch of the diagram is captured 95% decrease in strength to the maximum achieved value.

In the loading phase the specimen, there is a linear increase deformation of and strength. After reaching almost 90% strength is accelerate our growth deformation of the specimen. After reaching the ultimate strength is increasing with little deformation of to steep reduction strength of material. In addition to reducing the rate of decrease in strength, but rather deformation of the specimen is accelerating.

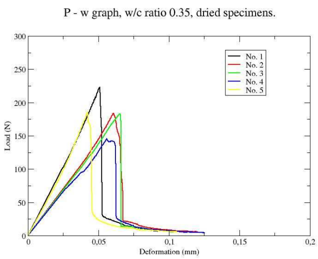
The test specimens, whose properties have been experimentally verified at first view, do not show signs of failure. If we had the opportunity to focus in detail on the area of the notch, we have seen a typical crack front based on the notch and directed into the place the specimen loading, see Fig. 2.

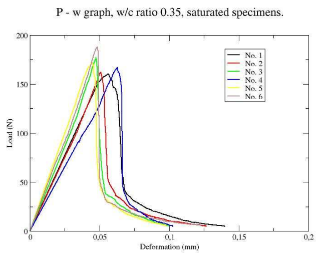
Fig. 2. Specimens after tests. Crack arises in the middle part of specimen.

The shape of the curve is very important for determining the resulting fracture energy of the material. If there were a snap back, it would be possible to clearly determine the value. The result of testing is to a great extent dependent on the appropriate ratio of stiffness of the test equipment and tested stiffness of the specimen.

The shape of the descending branch of the stress-strain diagram is dependent on ductility of material. In the case of cement paste and cement paste mixed with fly ash is a rapid decrease in strength against the deformation of increment. Quite a different result would be achieved by using the reinforcement of cement paste, such as a dispersed reinforcement.

The resulting graphs are shown in Fig. 3 to 10. Pictures are sorted by categories of water/cement ratio and by water saturation of specimens.





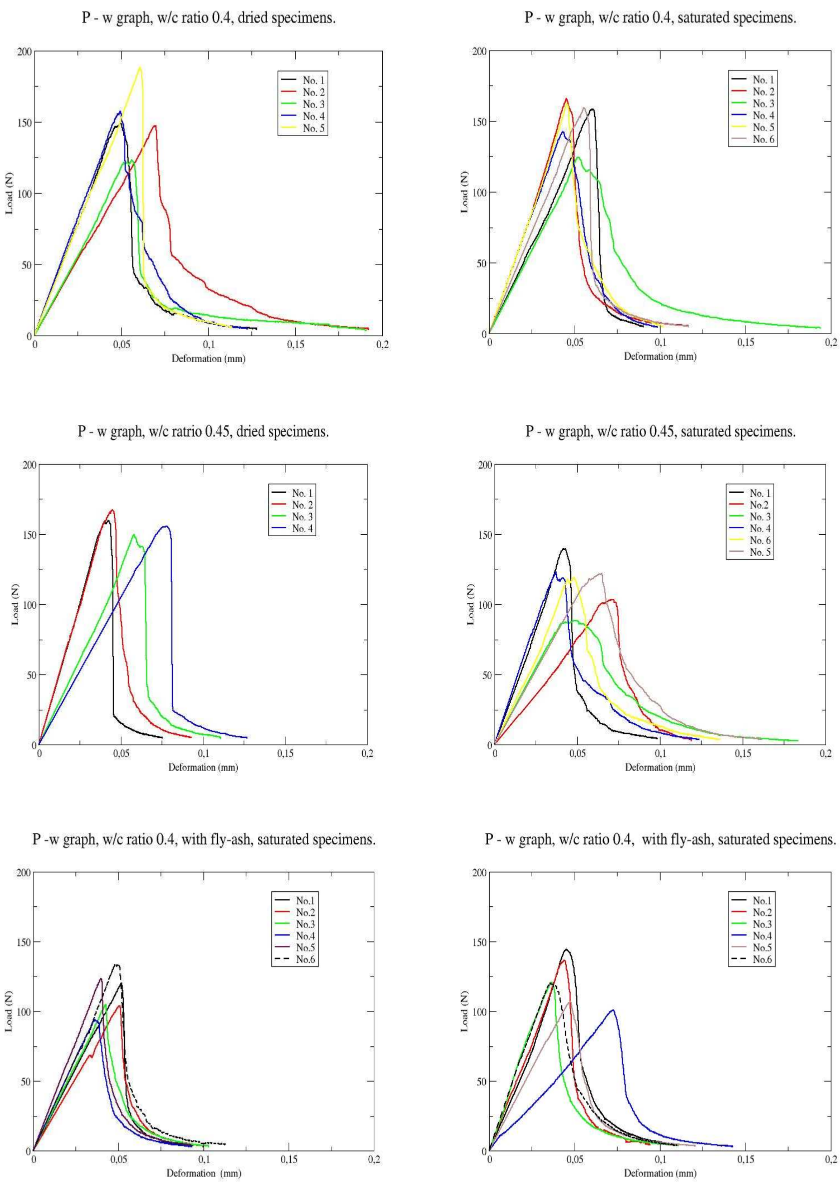


Fig. 4 – 10. Graphs of P – δ diagrams.

Table 3 and Table 4 show the changes of fracture energy for changing the water/cement ratio. Increasing water/cement ratio causes a decrease in fracture energy.

Table 3. Fracture energy of specimens.

w/c ratio	C/A ratio	Fracture energy (N/mm). Saturated	Fracture energy (N/mm). Dried
0.35		26.74	23.67
0.4		24.13	25.81
0.45		22.02	22.41
0.4	0.5/0.5	16.66	
0.4	0.4/0.6	18.73	

Table 4. Tensile strength from bending test of cement paste.

w/c ratio	C/A ratio	Fracture energy (N/mm). Saturated	Fracture energy (N/mm). Dried
0.35		5.92	6.04
0.4		5.19	4.98
0.45		4.04	5.00
0.4	0.5/0.5	4.71	
0.4	0.4/0.6	4.03	

There are also in Table 4 presented the values of tensile strength in bending of cement paste, depending on the moisture of specimens. Tensile strength in bending decreases with increasing w/c ratio. For water saturated specimens is decreasing of values 1 MPa. Similarly, tensile strength, in bending decreases with dried specimens of 1 MPa [7].

5. Conclusion

Fracture energy for water-saturated specimens decreased by 18%, depending on the water/cement ratio increased from 0.35 to 0.45. Fracture energy for water-saturated specimens decreased by 18 %, depending on the water/cement ratio increased from 0.35 to 0.45. Change of fracture energy for the dried specimens was only 5%. But the value of fracture energy for the w/c factor of 0.4 is higher than for the w/c 0.35 and 0.45.

Very interesting is the decrease of fracture energy of cement paste containing fly ash. Decline in value is up 30% towards the value for the corresponding w/c ratio. Very interesting fact is the increasing value of fracture energy of cement paste, which contained a lower amount of cement and higher amount of ash.

In conclusion, the value of fracture energy of cement paste varies from 22 to 26 N/mm. The direct effect of humidity on the size of the fracture energy of cement pastes was not proved.

By contrast, significant changes in the fracture energy of cement paste in tensile strength, bending strength were no major changes. Comparison with values for w/c ratio we record a decrease of, but it is also depending on the amount of fly ash in the cement paste.

Reducing the strength of cement paste containing fly ash corresponds to the reduction volume weight. A very significant factor that has a definite influence on the mechanical properties of cement paste is the amount of fly ash in the mixture. Quantity ash is influencing factor in the case of fracture energy.

Acknowledgements

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