EFFECT OF CEMENT ON THE K-VALUE OF POWER PLANT FLY ASH

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Abstract

This paper deals with the determination of the k-value and activity index for power plant fly ash with CEM I 42.5 R cement and CEM II/A-M (S-V) 42.5 R cement. The objective is to determine the activity index of this active admixture for different cement replacements to determine the k-value based on the relationship between water coefficient and compressive strength for fly ash and to assess the effect of different cement types on the k-value. Based on the results obtained, the effect of blended cement, which has a higher amount of active admixture than Portland cement, on the compressive strength, the activity index and the k-value of fly ash was assessed.

Keywords

Concrete, k-value, active admixture, fly ash, activity index

1 INTRODUCTION

Concrete, being one of the most extensively used construction materials, significantly influences construction costs and environmental considerations. The cornerstone material for concrete production is cement, known for being the costliest and the most environmentally burdensome due to its high CO_2 emissions [1]. Consequently, there is a current imperative to diminish the reliance on Portland cement in concrete. This reduction can be achieved through the utilization of active admixtures, specifically secondary raw materials like fly ash, ground granulated blast furnace slag, and metakaolin, among others. These substances serve as active admixtures in concrete, categorized as either pozzolans or latent hydraulic substances [2].

For the reasons described above, the number of types of Type II blended cement used in the Czech Republic and the European Union is beginning to increase. These are types of cement in which part of the cement is already replaced by an active admixture, such as finely ground slag or inert admixture as finely ground limestone. When using these types of cement, no concept of value or other consideration of the replacement of the Portland clinker part by an admixture is used, but these types of cement must meet the requirements of EN 197-1 ed. 2 for the properties of these types of blended cement [3]. Due to the increased use of the types of Portland blended cement, there is a need to investigate their effect on the continued use of active admixtures in concrete and their effect on the k-value concept used in the design of concrete in which part of the cement is replaced by an active admixture [4].

The Czech Republic addresses the potential use of active admixtures as a cement substitute in concrete through the k-value concept. In Europe, similar considerations are covered by the equivalent performance of combinations and the equivalent concrete performance concept, outlined in the European standard EN 206+A2 [4]. However, it's noteworthy that this standard does not provide a specific methodology for determining these k-values, and the concept itself is presented in a rather broad manner. The principle of the k-value concept is based on a comparison between reference concrete and concrete with active admixture based on compressive strength or durability. The k- value concept allows the use of active admixtures if [5]:

- the water/cement ratio is replaced by water/(cement + k × admixture),
- quantity of cement + k × admixture is greater than the minimum amount of cement for a given exposure.

The effect of active admixtures on concrete properties depends on various concrete parameters. For example, the nature of the individual materials, the age of the concrete, the external conditions, etc. To take all these influences into account when designing concrete, the k-value concept uses the relationship between the water coefficient and the compressive strength. If the condition of equal compressive strength is met, the relationship applies (1) [6]:

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$$w_0 = \frac{v}{c + k \cdot p} \quad (1)$$

where w_0 is the water coefficient of concrete without admixture, v is the water content of concrete with admixture in kg/m^3, c is the cement content of concrete with admixture in kg/m^3, p is the content of admixtures in kg/m^3 and k is k-value.

2 METHODOLOGY

In this work, 2 types of reference mortar were mixed with CEM I 42,5 R from Mokrá cement plant and CEM II/A-M (S-V) 42,5 R from Prachovice cement plant. For both of these cements, 10, 20 and 30% of the cement was replaced by Opatovice cement plant fly ash. Recipes of the mortar are shown in Tab. 1. The fresh consistency of the cement mortar was determined according to EN 1015-3 [7]. The compressive strengths in the hardened state were determined at 7, 28 and 60 days according to EN 196-1[8]. 3 specimens of each mortar were prepared for each testing age. The activity index was determined according to formula (2) based on the obtained compressive strengths and the k-value for power plant fly ash in combination with CEM I 42.5 R and CEM II/A-M (S-V) 42.5 R was determined according to the relation (3) [9].

$$I_u = \frac{f_{c,p}}{f_{c,ref}} \cdot 100 \quad (2)$$

where I_u is the acitvity index in %, $f_{c,p}$ is the compressive strength of cement mortar with admixture in MPa, $f_{c,ref}$ is the compressive strength of the reference mortar in MPa.

$$f_c = K \cdot \left(\frac{1}{v/c} - a\right) \quad (3)$$

where f_c is compressive strength in MPa, K is the coefficient dependent on the reference cement in MPa, c is the amount of cement in the concrete in kg/m^3, v is the amount of water in the concrete in kg/m^3 and a is the coefficient depending on the age of the concrete.

Tab. 1 Recipes of cement mortar.

Recipe	I	I-10	I-20	I-30	II	II-10	II-20	II-30
CEM I	511	460	409	358	-	-	-	-
CEM II	-	-	-	-	511	460	409	358
Water	254	254	254	254	254	254	254	254
Fly ash	-	51	102	153	-	51	102	153
Sand 0.1-0.6	443	443	443	443	443	443	443	443
Sand 0.6-1.2	517	517	517	517	517	517	517	517
Sand 1-4	572	572	572	572	572	572	572	572

3 RESULTS

This section presents the results of the experimental part. Results of consistency, compressive strength, activity index and k-value of types of cement mortar with fly ash are presented in Fig. 1, Fig. 2, Fig. 3, Fig. 4 and Fig. 5.

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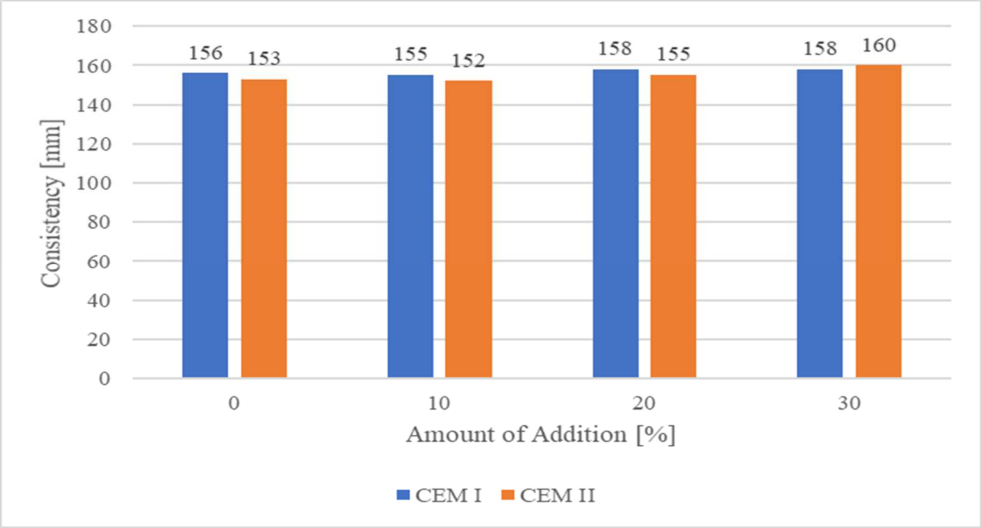

Fig. 1 Consistency of fresh mortar.

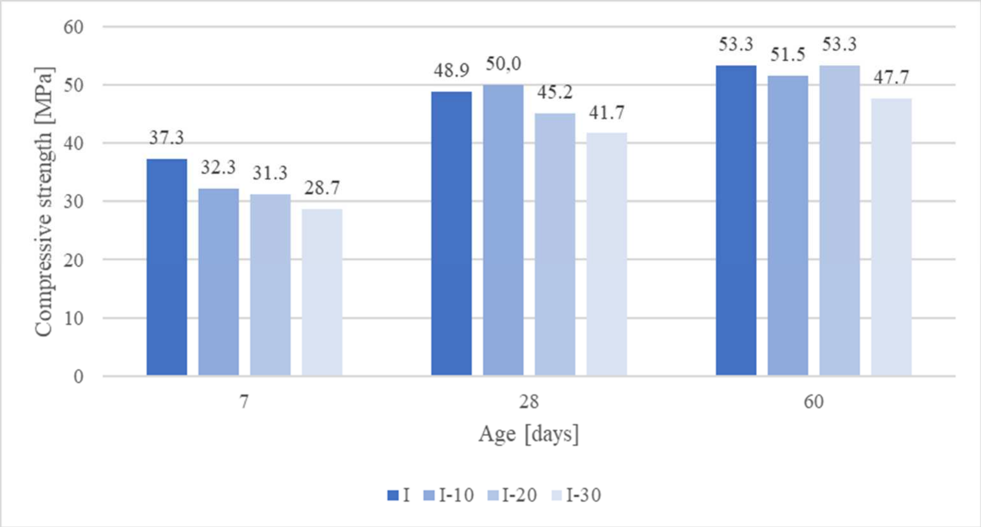

Fig. 2 Compressive strength of cement mortar with cement CEM I 42,5 R.

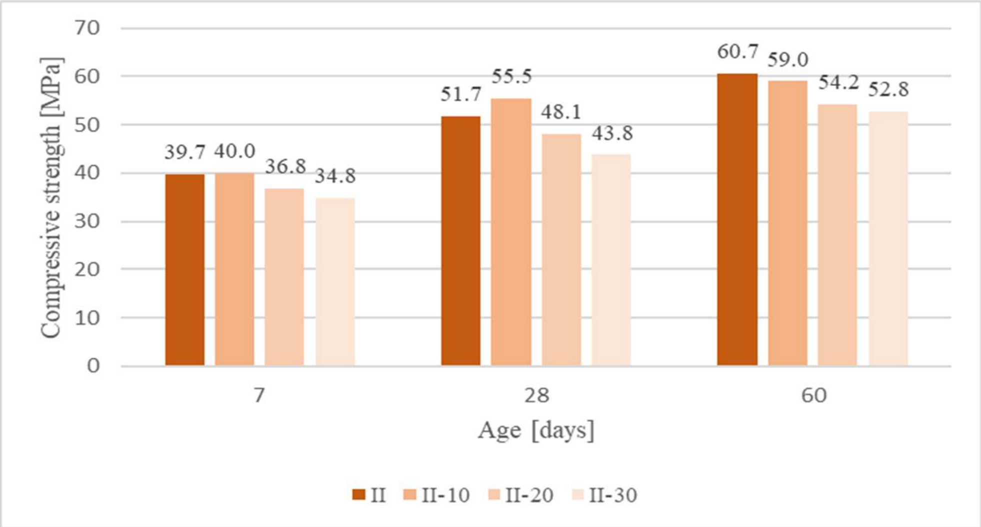

Fig. 3 Compressive strength of cement mortar with cement CEM II/A-M(S-V) 42,5 R.

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Fig. 4 shows activity indices. The activity indices of the types of mortar with CEM II are higher at the age of seven days, but lower at the age of sixty days than the activity indices of the types of mortar with CEM I.

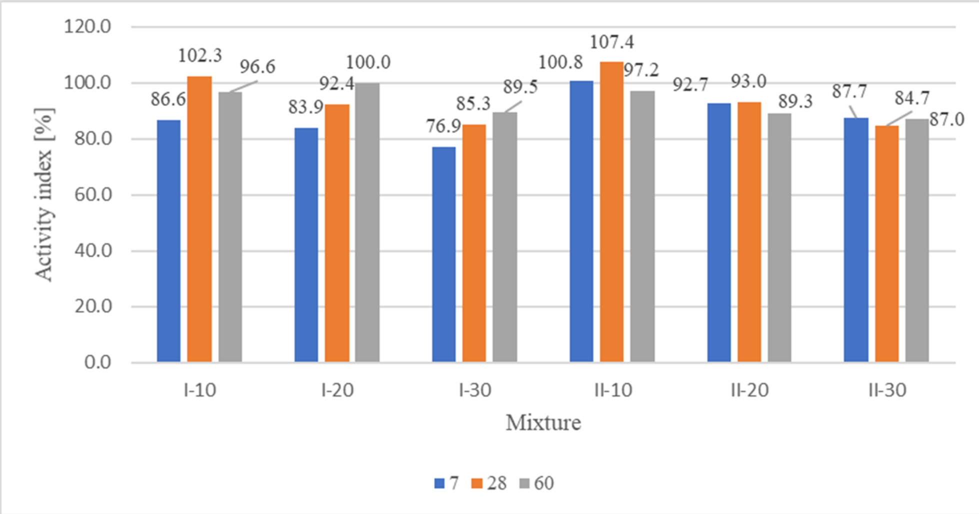

Fig. 4 Activity index of fly ash with cement CEM I and CEM II.

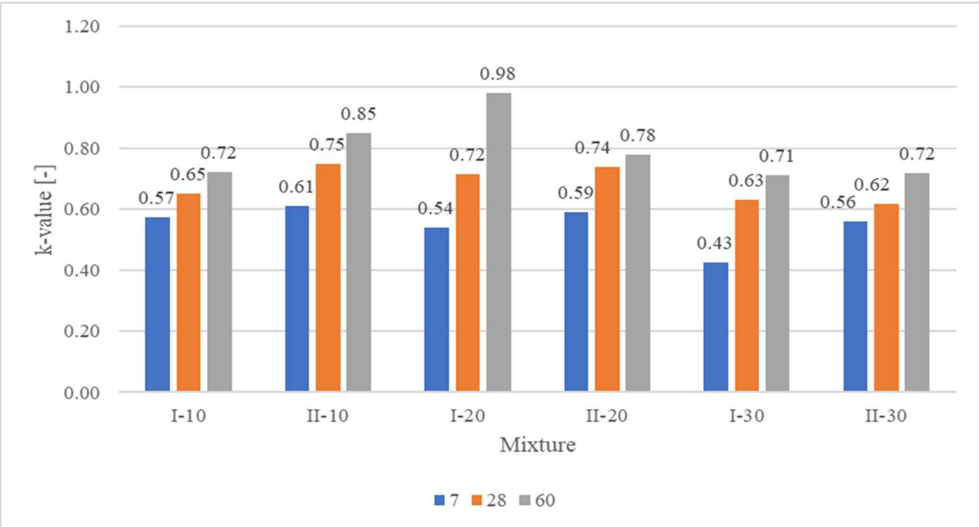

Fig. 5 K-value of power plant fly ash.

4 DISCUSSION

In the experimental part, types of cement mortar were mixed with CEM I 42.5 R and CEM II/A-M(S-V) 42.5 cement. The consistency of the cement mortar was tested fresh on a shaking table according to EN 1015 - 3.

The consistency of the reference mortar was almost the same in both cases, namely 156 mm for CEM I cement and 153 mm for CEM II cement. When replacing cement with fly ash, the most significant change in consistency was observed for the replacement of 30% CEM II cement, by 7 mm (5%). In this case, it can be said that the use of CEM II cement does not have a significant effect on the consistency of cement mortars with fly ash.

In the case of both types of cement, the mortar with fly ash had lower strengths at 7 days of age and the cement mortar with 30% replacement of cement with fly ash had the lowest strengths. However, in the case of cement mortar with CEM II cement, an average increase of 5% in compressive strengths was achieved. At the age of 28 days, in both cases, the cement mortar with 10% of fly ash achieved higher strengths than the reference mortar. This match with activity indices that are higher than 100%. With the increasing replacement of cement by fly ash, the compressive strengths and activity indices continued to decrease. For the CEM II cement, the same progression of strengths occured at 60 days of age as at 7 days of age, but for the CEM I cement, the mortar with 20% of fly

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ash has the same strength as the reference mortar (activity index of 100%) and the 10% and 30% replacements achieve lower strengths. For 30%, this phenomenon was expected.

The k-values were determined based on the water coefficient relationship using formula (3). At the age of 7 days, it can be seen that the k-values for power plant fly ash with CEM II cement were higher than those for fly ash combined with CEM I cement. This was a weighting of 8% on average. As the age of the cement mortar increased, the k-values for the combination of fly ash with CEM II cement decreased compared to the combination of fly ash and CEM I cement. This is probably due to the fact that the blended cement contains finely ground granulated blast-furnace slag, which has a slower increase in compressive strengths and achieves higher compressive strengths at higher ages than mortar with CEM I cement. Therefore, a higher difference in these strengths enters into the calculation of the k-values and the resulting k-values are lower.

5 CONCLUSIONS

The work aimed to assess the effect of the type of cement on the k-value of the power plant fly ash. Using experimental work, it was found that the effect of the type of cement is noticeable both at the initial age of 7 days and at further ages of 28 and 60 days. Based on the experimental results obtained, it can be said that:

- the use of different types of cement has no significant effect on the consistency of cement mortar with different fly ash replacements;
- at the age of 7 days, lower compressive strengths occured with higher cement replacement by fly ash, solid increases of compressive strength only appeared at the age of 28 and more days;
- CEM II cement mortar achieved higher strengths than CEM I cement mortar;
- the k-values were higher at the age of 7 days for power plant fly ash combined with CEM II cement, but lower for higher ages than for the combination of power plant fly ash and CEM I cement.

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