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Study of Interaction between Fly Ash-cement and Bentonite Matrices

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Abstract. Among the important factors characterizing the quality of sealing mixtures is strength, durability, compatibility and permeability. Experimental work was therefore conducted to assess the use of cement, fly ash, gravel and bentonite in the form of artificial self-hardening sealing mixture. The results of the work show a good compatibility between the bentonite and cement during its fly ash replacement. Compactness of the structure was confirmed by studying of permeability and SEM microscopy, which in the system of ash-cement-bentonite matrix allowed assessing successive microstructure development of hydrating gel.

1 Introduction

Study of sealing and reclamation mixtures is very extensive. In recent years it has been directed mainly on the application of bentonite and cement for making sealing materials, such as in-situ effective reclamation technologies for redevelopment or reclamation work in contaminated areas. Interactions between cement and bentonite show that it is possible to consider about refund or reduction of cement with other binders in order to obtain better properties of the resulting mixtures.[1] Sealing compound based on soil and bentonite provides sufficient impermeability, in the order of 1x10-7 cm.s-1, with a characteristic low strength. However the determination of strength is a decisive factor in the application of this type of sealing mixtures, because of stability and durability. [2] For the remediation work is most frequently used sealing material on the bases of "cement-bentonite." These mixtures show a higher strength with sufficiently low permeability reaching values about 1x10-6 cm.s-1. Portland cement, used as a binder, is often replaced by other materials, which helps to improve the properties of sealing compounds as well as simultaneously improves financial aspects of remediation work by reducing the cost of the binder component. The typical replacement is blast furnace slag and fly ash from the combustion of solid fuels (by-products of coal combustion). Among the important factors which characterize the quality of the above mentioned sealing mixtures is undoubtedly strength, durability, compatibility of materials and especially permeability. It has also been studied the behavior of components during setting and hardening process of cementitious materials, together with a description of CSH gel formation. [3,4] From this work it is apparent that there has been the development of strength of mixtures with addition of additives of blast furnace slag or fly ash type. At the same time it is shown the connection between CSH gel phases and the newly formed structure of foil type. Change in morphology has a positive effect on the stability of cement-slag hydrated products. In the context with the properties of fly ash has also been confirmed that there is a higher materials resistance with fly ash and silica fume-cement compared to conventional mixtures. The content of CaO in ashes has participated in the improvement of initial strength development. Higher content of silica and CaO also contributed to higher mixtures resistance against sulphates. [5,6]

During mixing of cement with bentonite could be initialized process of ions exchange, since they are present in the solutions as for example calcium ions released during the hydration reaction of cement within the setting phase. As a result of exchange capacity of bentonite might be a situation where calcium ions are bonded into the interlayers of clay, with a corresponding modification to the Ca - bentonite. Ca-bentonite, then do not show such rheological properties as Na-bentonite (viscosity, swelling). [7] As indicated in work of Garvin and Hayles, water loss in interlayers, increasing the permeability and microstructure change of cement – bentonite mixtures, might be attributed to the concentration of calcium ions and to the high values of pH. Various approaches to prevent negative reactions between the cement and bentonite include application of colloid mixtures in form of additives to bentonite, and/or reduce the amount of cement. [8,9] On the structure of cement-bentonite mixtures and subsequent build barriers can also have an impact some organic substances that may contribute to the increased porosity of materials. [10]

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2 Material and methods

For the production of mixtures was used common type of Portland cement PC (CEM) - 42.5, ash from the combustion of solid fuels (fly ash from combustion of energy coal from local power plant Dětmarovice) and bentonite, which was represented by Na-bentonite type NK 80 from Minelco company.

The studied mixtures were subjected to the tests of resistance to compressive stress according to the standard for determining the strength of concrete (DIN EN 12390-3). For determining the compressive strength of the samples was used ELE AUTOTEST 2000. In accordance with the norm DIN EN 12390-3 Testing hardened concrete - Part 3: Compressive strength of test specimens, the laboratory samples were tested after 7 days, 28 days and 56 days. With the use of the electron microscopy SEM were finally analysed microstructural properties of both raw materials and setting matrix. For this purpose it was used an electron microscope FEI Quanta 650 FEG.

For the production of experimental samples of sealing mixtures were used the following group of materials: a) Portland cement (PC), b) fly ash from the combustion of solid fuels (P) c) clay component - Bentonite (B), d) the aggregate: natural aggregates (gravel) secondary aggregates (recycled concrete) e) water.

In the following table 1 is the sum of the chemical composition of fly ash and bentonite. As a cement was used commercially available Portland cement (CEM) – 42,5.

For testing purposes of physical and mechanical properties of self-hardening sealing materials was created a total of 12 different mixtures with different presence of raw materials (see Table 2).

Table 1. Chemical composition of fly ash and bentonite

Sample		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Fe_2O_3
		[mass %]									
Bentonite		< 1	0,39	32,84	47,58	0,06	0,059	1,69	0,33	0,66	2,17
Fly Ash		0,66	2,17	19,23	40,78	0,13	0,26	1,82	5,78	1,01	8,60

Table 2. Composition of self-hardening mixtures

Material	Mixtures											
	Quantity [weight %]											
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
PC	16,7	16,7	16,7	10,0	10,0	10,0	6,7	6,7	6,7	3,3	3,3	3,3
FA	0	0	0	6,7	6,7	6,7	10,0	10,0	10,0	13,4	13,4	13,4
SoB	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,7
W	8,4	8,4	8,4	8,4	8,4	8,4	8,4	8,4	8,4	8,4	8,4	8,4
B	0	2	4	0	2	4	0,5	1,0	1,5	0,5	1,0	1,5
A	83,3	81,3	79,3	83,3	81,3	79,3	82,8	82,3	81,8	82,8	82,3	81,8

PC: Portland Cement, FA: Fly Ash, SoB: Sum of Binder, W: Water, B: Bentonite, A: Aggregates

Representation of cement, fly ash, bentonite and gravel is summarily shown without the inclusion of water. Water was added to the remaining substances while was maintained the coefficient of water / cement (binder) equal to 0.5. Dimensions of the hydrated specimens for physical and mechanical test were 100 x 100 x 100 mm.

3 Results and discussion

Strength values have provided insight into the growth of strength from 7 on up to the final test carried out in 56 days. Strength development of laboratory samples of each mixture is shown in Figure 1.

From the time point of view is obvious that in setting and hardening is increasing trend of compressive strength. The measured strength values of the samples ranged from 0.3 MPa to 48.4 MPa. On the resulting strength values had a great impact the proportion of fly ash in each mixture. With decreasing weight of cement compounds, respectively, an increasing proportion of fly ash the compressive strength of laboratory samples decreased.

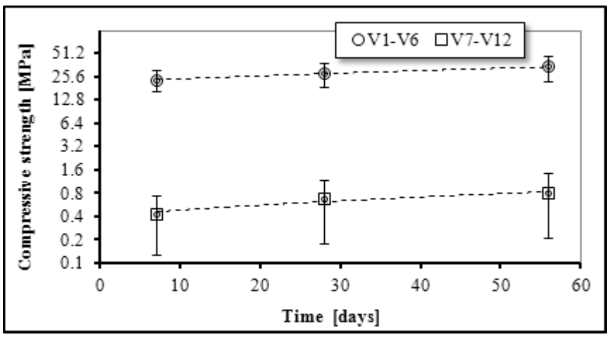

Figure 1. Compressive strength of V1-V12 mixtures

The achieved results of prepared materials could be divided into two groups. The first group consists of materials with 0% and 40% of fly ash quantity in binding compounds. Into the second group were included mixtures with 60% and 80% of fly ash. The results of the first group after 7 days of testing were in the order of tens, while their continued in gaining of the strength also in testing after 28 and 56 days. The results of strength of those mixtures in which the fly ash was presented by 60% and 80% reached values after 7 days and after 28 and 56 days in the order of one tenth of MPa.

After 56 days the highest strength has reached a mixture consisting of 100% of the cement content as a binding component with 2% of the proportion of bentonite. In the second group of materials is from the results evident, that within the same amount of ash content of 60% or 80% were achieved similar strength regardless of the mass proportion of bentonite. As well, in the second group of mixtures is obvious that there is greater volatility of strength results. This is seen in Figure 1, where are included the total deviation calculated on the basis of previous measurements of the strength. From the perspective of bentonite and its effect on the strength is therefore necessary to take into account also the amount of fly ash in the tested materials.

4 The structure of materials and materials compatibility

In Figure 2 can be seen binding of bentonite to the basic matrices of CSH gel. In contact phases of aggregate components and binding compounds is occurred filled space by plates of bentonites, which can be observed in relation to CSH gel and separately as well.

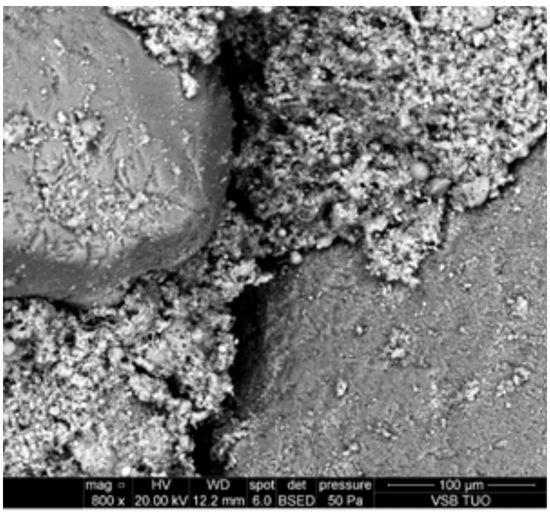

Figure 2. SEM image of the cement-bentonite matrices

Already 2% amount of bentonites in the formed matrices could result in their involvement in the hydration reaction. With the increasing proportion of ash in the formed tested matrices, although there is a reduction of the total strength of samples, but there is also a reduction in porosity. CSH gel of the basic matrices with a share of fly ash more than 60% and with the subsequent addition of bentonite are positively involved in hydration which leads to the formation of compact, low permeable structure.

Based on the experimental results related to the complement tests of permeability can also be noted that, as a mixtures with low cement content and mixtures with fly ashes above 60% and bentonite aroud 2% have very low permeability, which is in the order of the values below 10-8 cm.s-1 and can therefore serve as a good insulating material.

5 Conclusions

An important additive that was applied during laboratory testing was clay compound bentonite. Within the laboratory testing of produced sealing materials therefore attention was concentrated on these two aforementioned elements whose in various combinations contribute to the development of the final state of materials. In terms of overall summary can be viewed on the experimental data as follows:

- Influence of fly ash on compressive strength of prepared samples was significant. Within the strength testing was stated that between 40% and 60% of fly ash content in binding there is the biggest drop in strength. At higher proportions of 60% fly ash and 80% content the differences in final compressive strength were very small, in the order of one tenth of MPa.
- Durability of materials that were produced based on fly ash-cement-bentonite system was assessed as good. During testing of durability of materials against aggressive agents such Na_2SO_4 solution was observed higher resistance in samples where the fly ash content was above 60%.
- SEM structural images refer to the gradual formation of the basic matrices, leading to a compact structure resistant to aggressive environments.

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