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Karolina KNAPIK[1], Joanna BZÓWKA[2]

PERMEABILITY OF THE MIXTURE OF FINE GRAINED SOIL AND FLY ASH FROM FLUIDIZED BED COMBUSTION

Abstract

Based on known correlations permeability was calculated for the mixtures containing various proportions of selected FBC fly ash, Speswhite kaolin and lime. The influence of initial water content of the mixtures was also considered. The study was limited to the first four weeks of curing time. Results of calculations were discussed on the background of previously obtained observations for mixtures of tested materials.

Keywords

Fly ash, Fluidized Bed Combustion, permeability, oedometer tests.

1 INTRODUCTION

Fly ash from coal combustion in fluidized bed can show pozzolanic–hydraulic activity, as confirmed in previous study [2]. With curing time appearance of newly formed phases was evidenced by X–Ray diffraction and Thermogravimetric Analysis. Creation of hydrates causes that the properties of the mixtures are not stable with the time. Based on performed tests presented in [2], it was confirmed that bonding between solid particles influences the grain size distribution and the porosity of the mixtures is changing, as well. It leads to improvement of mechanical behaviour of tested mixtures – higher cohesion, increased yielding stress and reduced volumetric strains upon loading. Moreover, the water content of the mixture plays relevant role in this process. First of all water is a substance necessary for reactions which leads to hydrates formation. On the other hand, it is widely known that significantly increased water content contributes deterioration of mechanical properties of soil. Following discussion on the mixtures permeability and changes of this property depending on the curing time and components proportions in the mixture is the next step in expanding knowledge in the application of FBC fly ash for soil treatment.

2 METHODS AND PROCEDURES

Fine grained soil selected for the study was Speswhite kaolin. This highly rafined soil is mostly composed of kaolinite with minor amounts of illite/muscovite and quartz. Its almost one-component mineral composition and physical and chemical stability from one batch to another allowed to avoid problems related to the diversity typical for natural soil taken from the site.

Sample of fly ash selected for the study was obtained from the power plant using Fluidized Bed Combustion (FBC) technology, placed at the Upper Silesia region of Poland.

Lime used in experimental research was mostly portlandite (72%) and quicklime (20%).

[1] Karolina Knapik, PhD Eng., Department of Geotechnics and Roads, Faculty of Civil Engineering, The Silesian University of Technology, Akademicka 5, Gliwice, Poland, e-mail karolina.knapik@polsl.pl.

[2] Assoc. Prof. Joanna Bzówka, DSc.,Ph.D., CEng., Department of Geotechnics and Roads, Faculty of Civil Engineering, The Silesian University of Technology, Akademicka 5, Gliwice, Poland, e-mail joanna.bzowka@polsl.pl.

For the purpose of oedometer tests, mixtures were put into the oedometer ring (diameter 5 cm, height 2 cm) just after preparation and cured in dry conditions and reduced contact with atmospheric air. The curing time was selected to be: not more than 21 hours (0 day), 7 and 28 days. After specific curing time, the test was started. During the oedometer test, settlements caused by applied vertical stress σ were measured every one second with an accuracy of 0.001 mm. Mixtures were prepared from components added in proportions presented in the Table 1.

Tab. 1: Names of materials and proportions of components used during preparation

Symbol of material	Speswhite Kaolin	Fly ash		Lime		Distilled water	
	g	g	% of dry soil weight	g	% of dry soil weight	g	% of all dry components weight
Kaolinw50	100.0	0.0	0.0	0.0	0.0	50.0	50.0
FA20w50	100.0	20.0	20.0	0.0	0.0	60.0	50.0
FA40w50	100.0	40.0	40.0	0.0	0.0	70.0	50.0
FA20CaO2w50	100.0	20.0	20.0	2.0	2.0	61.0	50.0
Kaolinw100	100.0	0.0	0.0	0.0	0.0	100.0	100.0
FA20w100	100.0	20.0	20.0	0.0	0.0	120.0	100.0
FA40w100	100.0	40.0	40.0	0.0	0.0	140.0	100.0
FA20CaO2w100	100.0	20.0	20.0	2.0	2.0	122.0	100.0

Calculations of permeability based on the results obtained during the compressibility test performed in oedometer apparatus were carried out additionally. It was assumed that the end of primary consolidation occurs when the settlements are relatively stable and consolidation curve takes a linear shape. The permeability coefficient can be calculated with the use of Formula 1 [5]:

$$k = \frac{c_v \cdot \gamma_w}{M_0} \tag{1}$$

where:

k – permeability coefficient [m/s]

c_v - consolidation coefficient [m^2/s]

γ_w – specific gravity of water [kN/m^3]

M_0 – modulus of primary compressibility [kPa]

The consolidation coefficient was calculated based on the shape of consolidation curve with the use of Casagrande method, as described in [4].

3 RESULTS AND DISCUSSION

Results of calculations performed for the mixtures prepared with various fly ash content are presented in the Figure 1. They are evidencing that increased amount of fly ash in the mixture results in higher permeability and the differences are more evident for the mixtures with higher initial water content (Figure 1b).

The influence of initial water content on the permeability is presented in the Figure 2. It can be observed that at very high level of vertical stress the permeability of the mixtures prepared at different initial water content tends to reach the same values.

The results of calculations presented in the Figure 3 show, that the addition of small amount of lime into the soil-fly ash mixture does not affect the permeability in the short term (0 day).

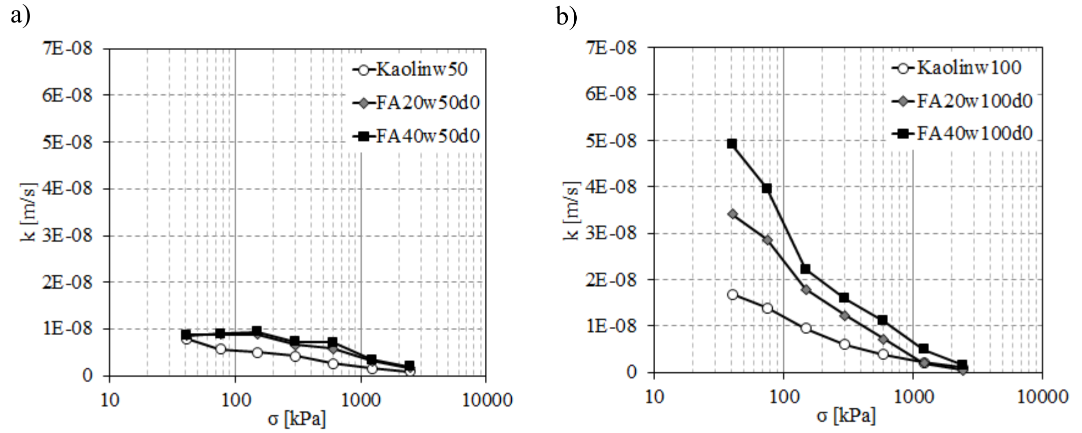

Fig. 1: Permeability calculated for the materials characterized by different proportions of components prepared at: a) initial water content 50%, b) initial water content 100%

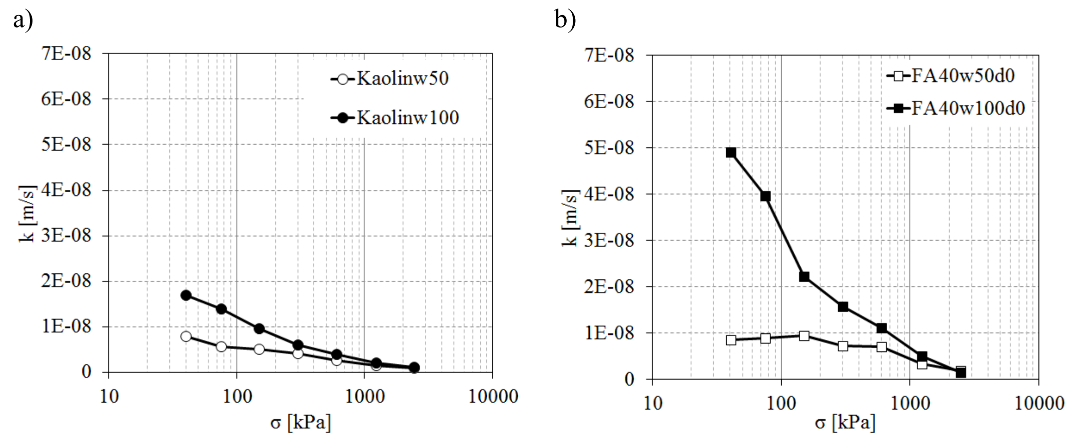

Fig. 2: Permeability calculated for the materials prepared at initial water content 50% and 100% obtained for: a) Speswhite kaolinite, b) the mixture FA40

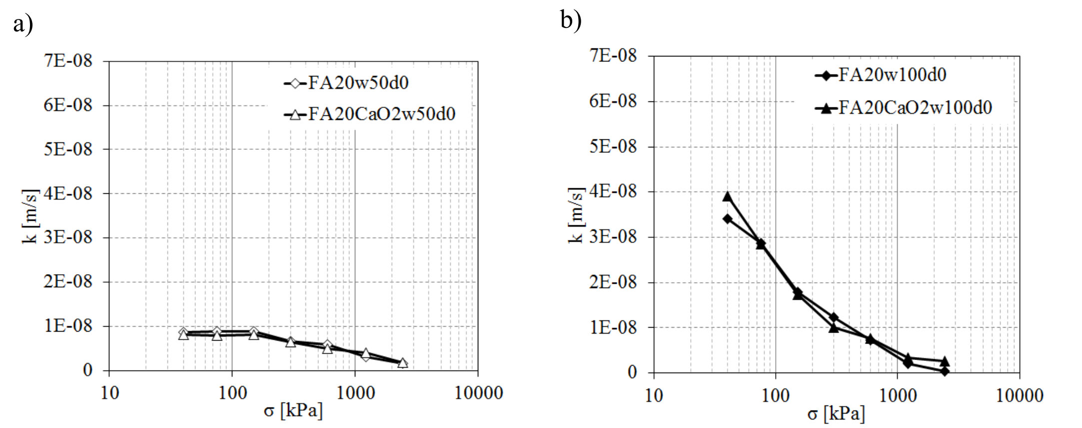

Fig. 3: Permeability calculated for the mixtures with and without lime addition prepared at: a) initial water content 50%, b) initial water content 100%

Results of calculations presented in the Figures 4 and 5 indicate that the permeability of the mixtures is changing with the curing time. During the first 7 days, it is slightly decreased in all samples. It should be mentioned that for the mixtures prepared at the initial water content equal to 50% tested after 28 days, the values of yielding stresses were very high. Considering that the samples were prepared in not fully saturated state ($S_r \geq 0.89$), it was not possible to obtain reliable results of calculations.

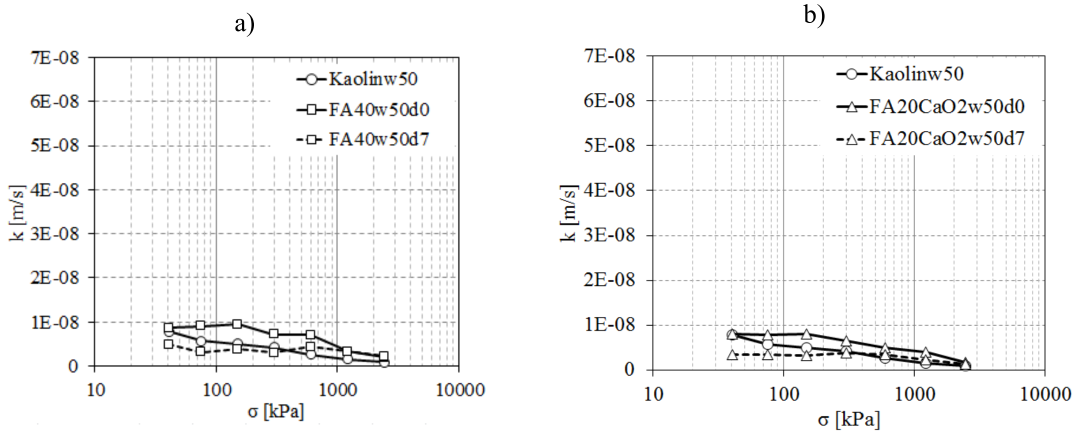

Fig. 4.: Permeability calculated for the sample of Kaolinw50 and the mixture tested after 0 and 7 days of curing time: a) FA40w50, b) FA20CaO2w50

The results of calculations obtained for the mixtures prepared at 100% of water content tested after 28 days of curing time are presented in the Figure 5.

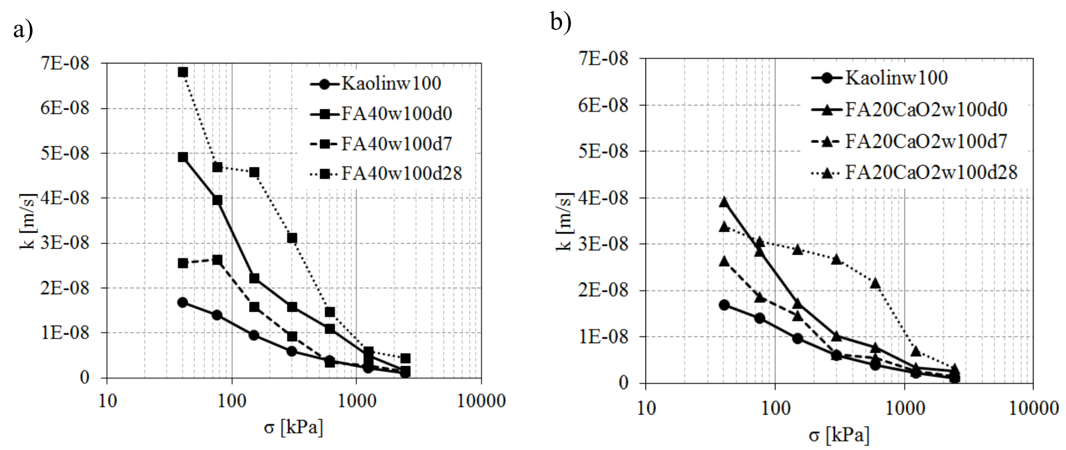

Fig. 5: Permeability calculated for the sample of Kaolinw100 and the mixture tested after 0, 7 and days of curing time: a) FA40w100, b) FA20CaO2w100

It can be observed that the permeability is initially decreasing (first 7 days of curing time), however in longer terms (after 28 days) it tends to increase. Thus, it is possible that newly created hydrates cause not only filling the voids in the mixture but also their appearance is connected with swelling effect.

4 SUMMARY

Obtained results presented in this paper can be in general separated into two groups – permeability calculated for the mixtures tested in short term and in long term (7 and 28 days).

In short term addition of fly ash into the fine grained soil such as the Speswhite kaolin causes that the water filtration inside the uncompacted material goes faster. As described in [2], addition of FBC fly ash into the Speswhite kaolin results in immediate changes in grain size distribution due to the fact that the fly ash sample is mostly composed of silt and sand while the Speswhite kaolin consist mainly silt and clay fractions. It is important to note that initial conditions of the sample have a major influence on the materials permeability due to the fact, that increased water content of the mixture was connected with higher initial porosity index (see Figure 3). Moreover, it is clear that the permeability is affected also by the value of vertical stress acting on the sample. As the load increases, the permeability curves of the materials prepared at different water content tend to converge. Similar observation was made based on the compressibility curves presented in the Figure 6.

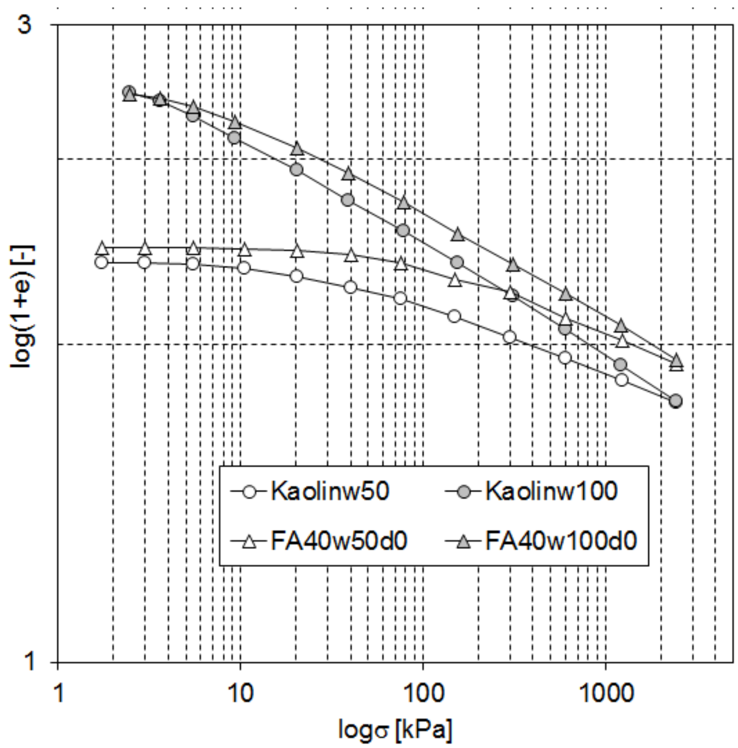

Fig. 6: Consolidation curves obtained for Speswhite kaolin and the mix FA40 prepared at initial water content 50% and 100%, tested at 0 day of curing time [3]

As the vertical stress acting on the sample increases, the permeability as well the porosity of all of the mixtures is similar.

In longer term the permeability of the mixtures is affected by the appearance of newly created hydrates. Initially, during the first week of curing time, the permeability is slightly lowered as the voids are filled by new phases. The Mercury Intrusion Porosimetry test results presented in [2] evidenced that diameter of predominant pores in the mixtures prepared at initial water content 50% tends to decrease during first week of curing time. Those results are consistent with the results of calculations presented in the Figure 4, which indicate decreasing permeability of the mixtures during first 7 days of curing time. However, the results of calculations performed for the mixtures prepared at higher water content tested after 28 days indicate that the permeability increases. It should be highlighted that the samples during curing were not loaded and the swelling was free for occuring. Swelling behaviour of tested samples prepared at initial water content 50% observed during curing in contact with water was discussed in [2]. It was evidenced that increased amount of used fly ash cause the increase of volume of tested samples with the time. Due to the consistency of the samples prepared at initial water content 100% similar tests were not possible to perform, as even negligible load caused by cap and the displacement sensor applied on the upper surface of samples resulted in immediate settlements. It should be mentioned that the value of linear swelling is important for practical use of FBC fly ash used for example in roads constructions. However this material is promising for other geotechnical works, such as drilling slurries. The presence of calcium sulphate and calcium oxide in FBC fly ash can potentially be used to obtain controlled expansion, needed in some cases to ensure proper adhesion [6].

In order to verify the accuracy of calculations discussed in this paper they should be compared with the results of the tests performed in accordance with the standard [1].

LITERATURE

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