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EFFECT OF MICROSTRUCTURE ON MECHANICAL PROPERTIES OF FLY ASH-BASED STABILIZER

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ABSTRACT

The presented article deals with fly ash-based stabilizer used in railway trackbed and investigation of a development of its properties. Initially the compression strength, static deformation modulus, permeability, thermal conductivity, moisture and bulk density of the stabilizer were observed. The increase of the compression strength and static deformation modulus was detected on extracted samples during long-term observation in years 2005 to 2015. In particular the article is focused on principles and reasons, why the mechanical strength and stiffness of the stabilizer increased. An electron microscopy was employed to analyze the microstructure. Its results provide explanation of the long-term improvement of the stabilizer.

Keywords: Compressive Strength, Electron Microscopy, Fly Ash-Based Stabilizer, Microstructural Analysis, Railway Trackbed

I. INTRODUCTION

At the Department of Railway Structures, Faculty of Civil Engineering, Czech Technical University in Prague several projects with the focus on the use secondary materials were realized between 2002 and 2011. In particular, the projects were focused on fly ash-based stabilizer produced by Chvaletice plant (CHCE). In 2005 there was established a 330 m long trial section (Fig. 1) in the railway station Smiřice (the railway track between cities Pardubice – Liberec) for the long-term monitoring of the fly ash-based stabilizer. In the trial section the layer with thickness 250 mm was laid on the subgrade surface made from argillaceous limestone which is sensitive to an effect of rainwater. The experimental layer made of stabilizer was covered with crushed stone mixture with thickness 150 mm [1, 2]. The goal of the long-term monitoring was to determine whether the properties of the stabilizer change due to environment and railway traffic [3].

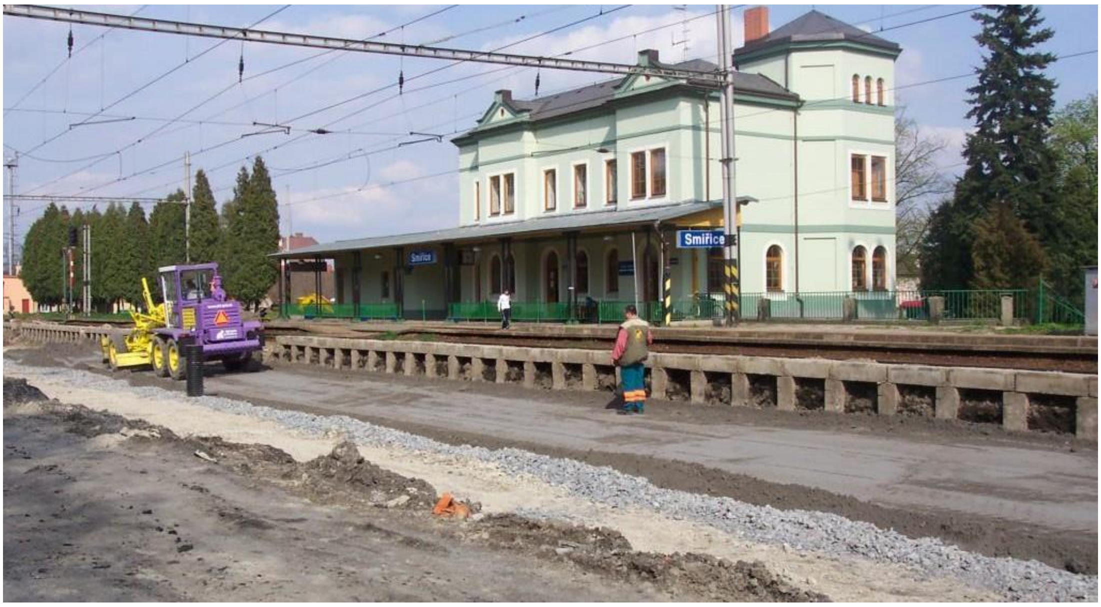


Figure 1: Placing of fly ash-based stabilizer layer in railway station Smiřice in 2005

II. TESTED MATERIALS AND SPECIMENS

The composition of the fly ash-based stabilizer used for the layer in railway trackbed is in the Table 1. Based on [4] there was no assumption regarding the formation of ettringite, which negatively affects the size of swelling [4, 5]. Parameters of the stabilizer used in railway station Smiřice are summarized in Table 2.

Table. 1: Fly Ash-Based Stabilizer Composition – Mixture R4 [2]

Description of ingredients	Weight proportion [%]
Fly ash – lignite from ECH	52.0
Calcium oxide – lime CL 90 (origin: Kotouč Štramberk)	3.0
Gypsum – product of fume gas desulphurization of ECH	28.4
Water – process water	16.6

Table 2: Properties of fly ash-based stabilizer layer [2]

Property	Value
Bulk density [kg m^{-3}]	1236
Compressive strength (non-saturated specimens, 201 days after placing) [MPa]	3.5
Coefficient of thermal conductivity [W m^{-1}K^{-1}] (at r.h. = 45.5 %)	0.8
Permeability [m s^{-1}]	1.3×10^{-7}

The mechanical properties were determined based on a set of laboratory tests performed on extracted specimens. The extraction of specimens was carried out using boreholes with diameter of 100 mm. For drilling the stabilizer layer the rig based on the diamond coring tool Hilti DD130 was chosen. The coring tool contained the diamond core bit, the water supply unit and the power generator. Using hand-guided drilling the hole was able to sample the stabilizer within the whole thickness of the layer (up to 280 mm) [3].

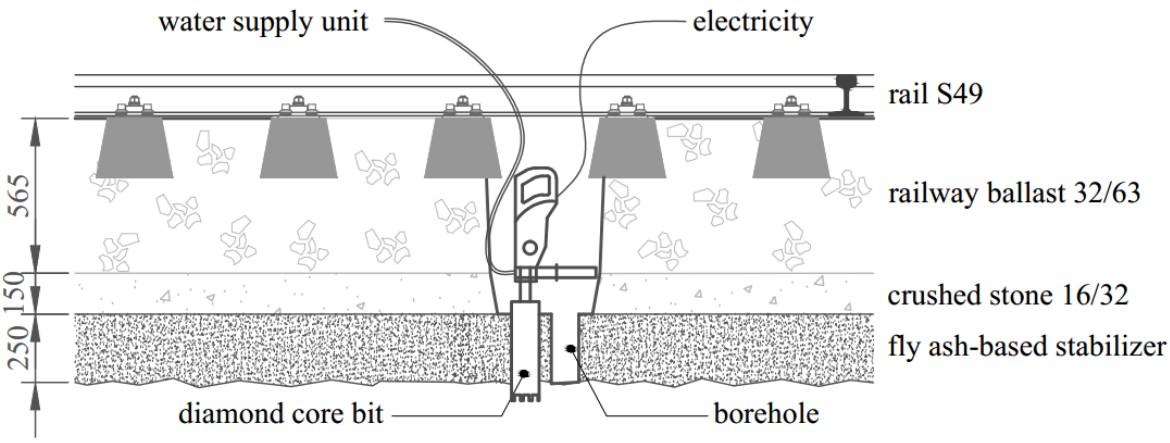


Figure 2: Method of specimen extraction using core drilling in railway station Smiřice [3]

There was extracted a total of 111 specimens for determination as follows laboratory tests: compressive strength, bulk density (non-saturated), permeability and thermal conductivity. There are mean values of properties in 2005 and in 2014 complemented with static deformation modulus of whole stabilizer layer in Table 3. Measurement of the static deformation modulus was conducted in the trial section in Smiřice with static plate load test.

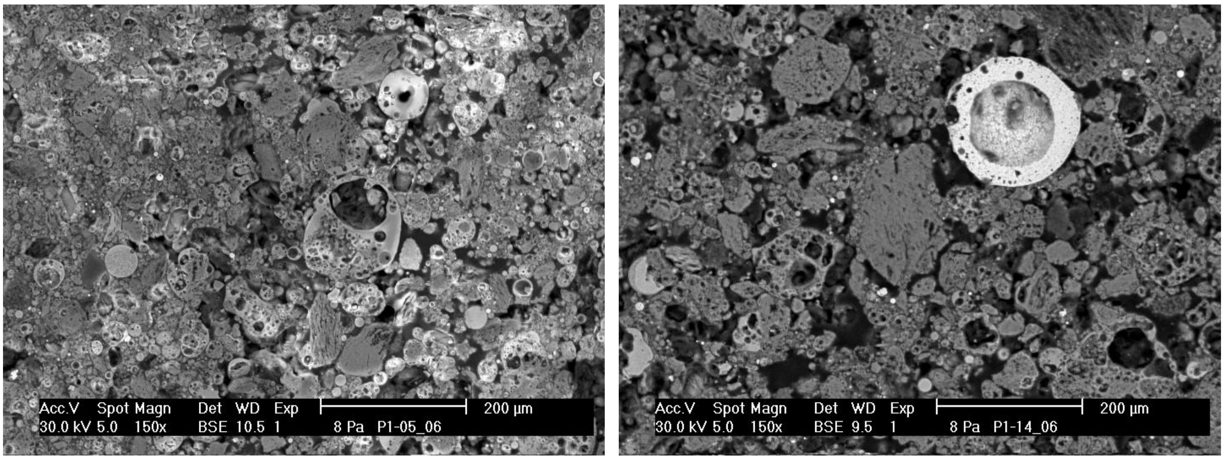
Table 3: Comparison of fly ash-based stabilizer properties in 2005 and in 2014 [2]

Parameter	Mean value	
	Autumn 2005	Autumn 2014
Bulk density [kg.m^{-3}]	1233	1307
Compressive strength [MPa]	3.5	5.8
Static deformation modulus of the layer [MPa]	363	900

In general the behavior of the layer in the first three years may be characterized by the increase of compressive strength, which significantly increased together with the static deformation modulus. The improvement of the properties slowed after three years. Such behavior of the fly ash-based stabilizer is presumably caused with changes on the structural level of this material. For this reason the microscopic analysis of stabilizer specimens extracted between 2007 and 2014 was carried in the framework of project CESTI in 2015.

III. EXPERIMENTAL METHODS AND RESULTS

In order to obtain detailed information about individual phases 4 extracted samples were investigated using electron (BSE) and optical microscopy. However, for since the BSE images provide more detailed description, only these are presented here. The samples extracted in 2005 and 2014 are presented here, the rest can be found in [2]. The investigated samples of the fly-ash stabilizer were polished, and microscope HR FEG MERLIN (by Zeiss) located at UCEEB institute in Buštěhrad, was employed for the study.



a) sample extracted in 2005 **b) sample extracted in 2014**

Figure 3: Electron microscopy image of samples extracted in 2005 and 2014; magnification 150×

The results demonstrate that the extraction methodology of the fly ash-based stabilizer layer by hand-guided core drilling was well chosen and allows to obtain a sufficient amount of specimens for following laboratory test. The main reason causing the increase of the stabilizer compressive strength depending on time is synthesis of the new binder co called C-A-S-H gel made of slug-ash particles in alkaline environment of CaO respectively $Ca(OH)_2$. C-A-S-H gel synthesis in track-bed given by specific environment is slow and the synthesis intensity is caused:

- directly with the “activator”, i.e. CaO, resp. $Ca(OH)_2$,
- together with low temperature of the stabilizer in the railway track-bed,
- and in addition with low water saturation, resp. oscillating water content, which depends on atmospheric precipitation.

The metamorphic process, the recrystallization of the flue gass desulphurization gypsum (FGD gypsum) particles is as follows: from originally fine-grained aggregates varied in the shape gradually grow larger gypsum crystals of flake-shape to create an interconnected net of microcenters [3], yielding a compact structure. Such crystallization results in strengthening behavior of the stabilizer.

IV. CONCLUSIONS

The studied track-bed stabilizing material exhibited the strength and stiffness increase over the period of a decade, however, to generalize the findings further studies must be carried out. The presented results are related only to the studied material based on fly-ash when deposited in specific conditions. Without a proper study it is not possible to apply the results on any fly-ash based material. The same applies for instance on recycled concrete based on micro-ground activated cement [6-8].

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