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RIVER SEDIMENT AS ROAD MATERIAL

Miloš Šešlija[1] [0000-0002-8857-8952], Anka Starčev-Ćurčin[2] [0000-0002-1533-3874], Dragana Tomašević-Pilipović[3] [0000-0002-8275-3297]

Abstract

At the bottom of the canal, there are large deposits of silt. During the cleaning and scouring of the river bed, so-called by-product sediments are formed. Landfills are made along the river bed because it is a relatively close distance. During the preparation of this paper, the idea refers to the examination of sediment with additional binders to see its application in the road industry. The tests that will be presented in the paper are: the granulometric composition of the soil, determination of the maximum volumetric mass at optimal humidity (Proctor's test), determination of the soil's bearing capacity using the California Bearing Index, determination of uniaxial compressive strength after 7 and 28 days and indirect tensile strength after 28 days. The used binders are cement and lime with fly ash and other mineral additives. After the analysis, the cement binder showed slightly better results than the lime binder because the material has its natural humidity.

***Key words**: sediments, road materials, binders.*

1. Introduction

The cleaning of riverbeds and canals, as well as the disposal of by-products, produces sludge, that is, sediments from rivers. This kind of material is deposited a lot on parts of canals and riverbeds and creates large amounts of waste materials. In other surrounding countries in the Balkans, they conducted tests on river sediment after burning, where ash is obtained. They used such ash as a substitute for cement material as a binder. Based on the tests, it was found that ash from burnt sediment has good characteristics for hardened concrete after 7 and 28 days compared to pure cement (Nakić et al., 2018).

[1] Faculty of technical sciences, Department of Civil Engineering and Geodesy, University of Novi Sad, Serbia, sele@uns.ac.rs

[2] Faculty of technical sciences, Department of Civil Engineering and Geodesy, University of Novi Sad, Serbia, astarcev@uns.ac.rs

[3] Faculty of Sciences, Department of Chemistry, Biochemistry and Environmental Protection, Serbia, University of Novi Sad, dragana.tomasevic@dh.uns.ac.rs

In most EU countries, the problem of sludge management represents a continuous challenge and an economic burden for utility companies because the problem has not been completely solved, nor is it determined by regulations or guidelines. However, it should be pointed out that there are also positive experiences in solving that problem. Considering the various technological possibilities of wastewater treatment and treatment of the sludge itself, as well as its further management, as well as the possible sociological and environmental impact, it is necessary to reach a consensus among the scientific and professional communities on the impact of each country in order to find optimal solutions. EU Directive 91/271/EEC states that sustainable sludge management has to be sociologically and economically acceptable, and meets the conditions of efficient recycling and use of resources while simultaneously minimizing the impact of harmful and potentially dangerous substances and compounds on people and the environment. Thermal treatment of sludge facilitates further management, primarily by reducing the total mass and volume. At the same time, in the process of choosing a concrete solution, the calorific value of sludge should be considered (Fytili & Zabaniotou, 2008). The calorific value of sludge is close to that of brown coal, but it should be kept in mind that this refers to the calorific value of the organic component of the sludge, because the inorganic component has no caloric value. Therefore, it is most often necessary to bring the sludge to the level of ST around 28 – 33 % in order to ensure self-ignition without using significant sources of additional fuel in the process (Donatello & Cheeseman, 2013). Stabilization of sludge with lime contributes to reducing the spread of unpleasant odors and kills pathogenic things, but at the same time it also reduces the caloric value of stabilized and dehydrated sludge by approximately 10 - 20 MJ/kg. About 22 % of the sludge classified at the EU level is incinerated (Lynn et al., 2015), but these quantities are constantly increasing. This trend is due, among other things, to the growing concern over the use of stabilized sludge in agriculture and the increasingly strict conditions under which it is allowed, and in some cases means a complete ban on such practices. Incineration reduces the mass of sludge by approximately 70 % and the volume for 90% (Lynn et al., 2015), but also destroys dangerous organic components of sludge and minimizes problems related to the spread of unpleasant odors (Tantawy et al., 2012).

Authors Kamali et al. did a testing of the river sediment. They used cement as a binder with different moisture content of the material to obtain certain test results. In addition to the change in humidity, the use of different types of sediments from different river locations and different chemical compositions was additionally analyzed. Based on this, the analysis of the work concluded that the sediment with a binder amount of 6 % and humidity of 11 % has the best physical and mechanical properties, that is, the best uniaxial compressive strength (Siham et al., 2007). Also Yoobanpot et al. engaged in sediment testing where cement and fly ash were used as binders. They used optimal humidity to obtain maximum compaction of the material. The following tests were performed: uniaxial compressive strength, indirect tensile strength, USCS material classification, chemical analysis, etc. In this research, 25 working mixtures were made, and it was concluded that for the mixture containing ash, tests must be done after 28 days, in order to see the increase in compressive strength (Yoobanpot et al., 2020). In the paper (Zhang et al., 2021), a review of the literature on sediment remediation was made and certain conclusions were drawn based on testing.

This paper gives a brief description of the sediment from the Begej River, where certain hydraulic binders (cement and lime with ash admixture) were used, with variable participation of binders, i.e. with 5 and 7 % of binders. The tests followed in this paper are the uniaxial compressive strength after 7 and 28 days, the indirect tensile strength after 28 days, the California Bearing Index (CBR), the content of the optimal amount of water at the maximum compaction of the material, as well as the granulometric composition of the material.

2. Testing methods

The test sample was taken from the Begej channel in Zrenjanin, not far from the oil mill. The Begej Canal flows from Timisoara in Romania to the confluence with the Tisa River near Titel in Vojvodina, in the northeastern part of the Republic of Serbia. The subject of this research is surface-deep sediment that was taken from a part of the landfill that was formed during canal cleaning. The tests that have been done include the following groups:

1. Identification - classification tests:
   - Determination of granulometric composition of aggregates (SRPS U.B1.018);
   - Determination of maximum compaction at optimal material humidity (SRPS EN 13286-2:2022)
   - 2. Soil compaction and bearing capacity tests:
   - Determination of the bearing capacity index (CBR) (SRPS U.B1.042);
   - Determination of uniaxial compressive strength after 7 and 28 days (SRPS EN ISO 13286-41:2022);
   - Determination of indirect tensile strength after 28 days (SRPS EN ISO 13286-42:2022).

In order to classify the sediment, an examination of the granulometric composition was carried out using the method of wet sowing with the use of distilled water. 800 g of material was used on a series of 4, 2, 1 mm and 500, 250, 125, 90, 63, 50, 40 and 38 μm sieves.

Proctor's test was performed in order to define the optimal amount of water that is needed to prepare test specimens for mechanical properties testing. To create uniaxial compressive strength according to the standard, a compaction energy of 600 kNm/m^3 should be used, but due to the equipment it was not possible to determine the force on the press, so it was decided to make it with a compaction force of 2750 kNm/m^3 for the California bearing capacity index.

The California Bearing Index (CBR) is a number that physically represents the indentation resistance of a standard piston in relation to standard values. When designing pavement constructions in the road sector, it is one of the basic parameters of material quality.

The parameters obtained by determining the strength under uniaxial pressure and free lateral expansion are used for a general overview of the characteristics of sediment as a building material and for calculating stability and load-bearing capacity. The diameter of the sample was 250 mm and the height was 200 mm. The sample was compacted in five layers with 25 blows each to obtain the best possible representative sample for testing. The prepared bodies were kept in plastic bags at a temperature of 20°C. The test was done after 7 and 28 days of age, and three samples were made for each mixture.

Indirect tensile strength (Brazilian experience) is used primarily for stabilized bearing layers. The development of this method enables the estimation of parameters, such as: tensile strength, tensile deformation, modulus of elasticity, Poisson's coefficient, at break, and other mechanical properties. Cylindrical bodies with a diameter of Ø = 102 mm and a length of 116 mm specially prepared in a standard mold according to Proctor's method in three layers were used for this experiment. The samples prepared in this way were kept in a humid chamber for 28 days.

3. Test results and discussion

The results of the granulometric composition of the aggregate are shown in Figure 1. It can be seen from the figure that it has a lot of clay particles over 20 % and dusty substances around 45 %, while the sandy component is represented by 30 %. The particles belonging to the gravel material are less than 3.5 %, measured on a 4 mm sieve. Based on this curve, it can be concluded that it is a plastic, a clay-dusty material.

The optimal moisture content of the material is used to make samples that are later tested for the California bearing index, for uniaxial compressive strength and indirect tensile strength. Four tests were performed with different moisture content and with an increase of 4 %. The initial value was 8 % of moisture content for the samples that were made of cement material, and for the lime binder the initial amount of moisture was from 9 to 10 %. After obtaining the four points, the optimal humidity value was obtained, which gives the maximum compaction of the material. The test results are shown in Figure 2. It can be seen, as the amount of binder increases, the amount of optimal material moisture also increases.

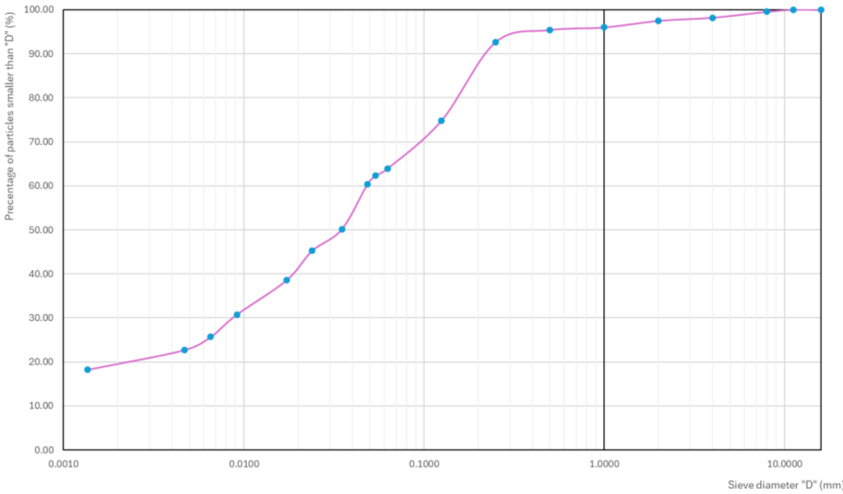

Figure 1: Granulometric composition

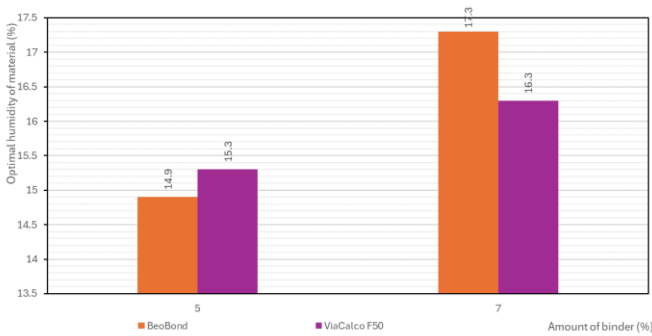

Figure 2: Optimal humidity of material

The California bearing index represents the resistance of the piston to be pressed into the sample. Pressing was done in three samples, with different binder content, 5 and 7 %. The values of the test results are shown in Figure 3. It is noticeable that with the increase in the share of binders, there is an increase in the bearing capacity, i.e. the value of the California bearing index. Considerable growth is achieved by the cement binder, and it has proved much better for sediment than the lime binder. Cement binder contains certain percentages of ash and lime.

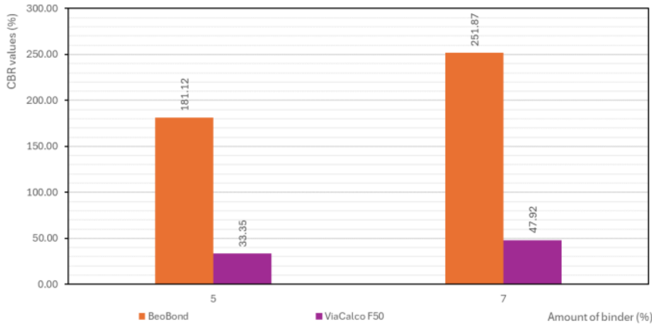

Figure 3: California Bearing Index (CBR)

The uniaxial compressive strength shows the results in N/mm^2, where it is observed that with the increase in the binder content, there is an increase in strength after 7 and 28 days. A sudden difference can be observed with the use of cement binder from 5 to 7 %, while this is not the case with the lime binder, a rise in results is seen, but not as prominent as with the previous binder. The test results after 7 days are shown in Figure 4, while Figure 5 shows the results of the uniaxial compressive strength after 28 days.

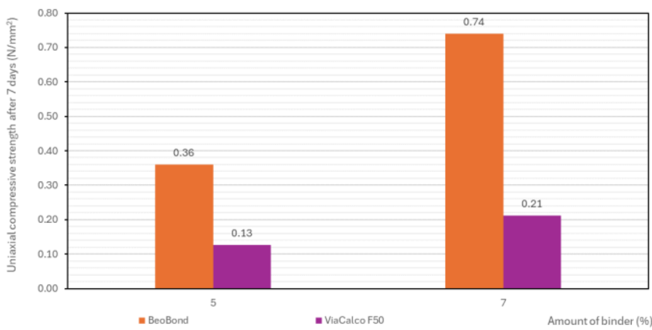

Figure 4: Uniaxial compressive strength after 7 days

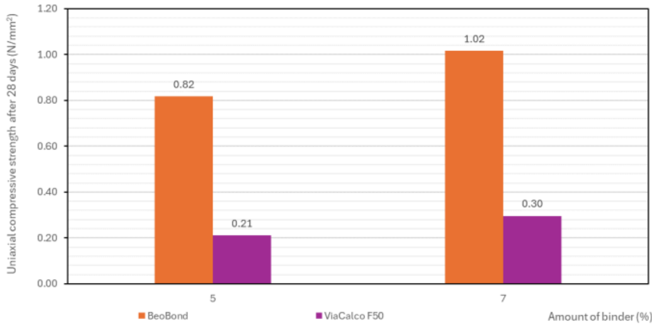

Figure 5: Uniaxial compressive strength after 28 days

The indirect tensile strength shows the results in N/mm^2, where it is observed that with the increase in the binder content there is an increase in strength after 28 days. A sudden difference was observed with the use of cement binder from 5 to 7 %, while this was not the case with lime binder. It was observed that with 5 % binder content no force reading could be recorded. Tests were performed on a small press with a scale of 100 kN load application per second. The results of the test after 28 days are shown in Figure 6.

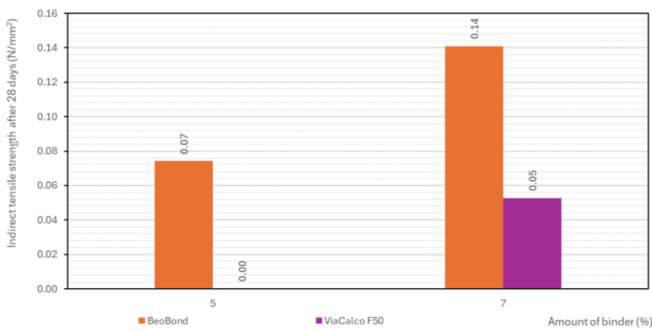

Figure 6: Indirect tensile strength after 28 days

4. Conclusions

The paper presents an examination of sediment using a cement binder that contains a certain percentage of lime and ash and a lime binder with an admixture of ash. The following tests were done: granulometric composition of the clean sediment material, determination of the optimal amount of water to obtain the maximum compaction of the material, the California load-bearing index of the material, uniaxial compressive strength after 7 and 28 days and indirect tensile strength at splitting after 28 days. Based on the obtained test results, it can be concluded that with an increase in the amount of binder, there is an increase in the physical and mechanical properties of the material and a better performance is achieved in terms of CBR number, uniaxial compressive strength, as well as indirect tensile strength. An important conclusion is that the cement binder shows significantly better test results than the lime binder because the sludge was dry enough and didn't have too much moisture.

Acknowledgments

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