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GEOTECHNICAL PROPERTIES OF MECHANICALLY COMPACTED KOŠEVO LAYERS

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ABSTRACT

This paper is an attempt of forming mechanical behavior and establishing behavior model of reconstructed clay compacting Koševo layers in road embankments derived by numerical analysis using the Plaxis software package. For the purposes of defining the parameters of the model behavior, geomechanical laboratory tests such as identification classification tests, and deformability test in oedometar conditions and strength in triaxial CU and CD test were performed. Based on defined model parameters of the mechanical behavior the check is performed which model best fit with tested material.

Key words: *koševo layers, deformability, strenght, numerical modeling*

INTRODUCTION

A large number of domestic and international geologists have studied issues related to freshwater complex of Sarajevo – Zenica coal basin. The first data on the geological structure of this part of Bosnia and Herzegovina were given by A. Boue (1840, 1858, 1862). Geological map dating from 1862 has served to later authors as a basis for detailed research. [1]

In the area of Zenica-Sarajevo neogene basins many researches on clay deposits were conducted. There are currently three deposits in the exploitation. Those are: Rapailo, figure 1, Golo Brdo and Čavka. The remaining seven deposits (Zenik, Kobiljača Bilalovac, Klokot, Pirići, Šljivčica, and Jardol) were not exploited. All these deposits were previously explored. All of them, except the Zenik deposits, were exploited, but now they can be treated as abandoned deposits, without a clear concept regarding their further investigations and possible exploitation. [2]

Figure 1 a) Geological map of Rapailo deposit; b) Exploitation pit Rapailo (Koševo layers)

AIM OF RESEARCH

The aim of this research is the understanding of the mechanical behavior and the establishment of model behavior of reconstructed clay "Koševo layers", because in this region, they have never been explored in triaxial conditions. The research presented in this paper was carried out for the purposes of a doctoral dissertation entitled: Numerical modeling of clay "Koševo layers" built into the embankments of roads. Sampling was performed on clay pits "Rapailo", in Rakovica, at clay deposit within the brick factory.

RESULTS OF LABORATORY TESTS

All laboratory basic classification tests were performed according to BAS CEN ISO/TS 17892 standard series.

According to the results of granulometric analysis, it can be concluded that the material is well graded containing particles smaller than 0.063 mm, about 84%, while the fraction smaller than 0.002 mm, about 38%, figure 2.

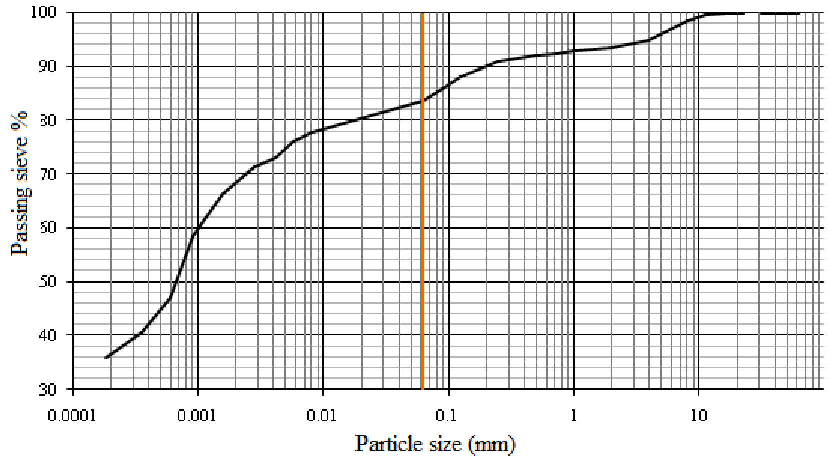


Figure 2 Granulometry diagram

Other numerical values of basic classification tests are:

- Specific gravity G_s=2,759
- Natural moisture w=25.21%
- Liquid limit w_l=47 %,
- Plasticity limit w_p=23,
- Plasticity index I_p=25,
- Consistency index I_c=0,89

According to the results of clay Koševo layer by USCS classification it can be classified as low plasticity clay.

Compaction characteristics are determined in accordance with BAS CEN ISO/TS 13286-2 with standard energy of compaction.

Maximum dry bulk density is 1,649 Mg/m^3 at optimum moisture of 20.8%, while the maximum wet density is 1,991 Mg/m^3,figure 3.

Oedometer test on sample compacted with standard energy at optimum moisture was performed by BAS CEN ISO/TS 17892-5.

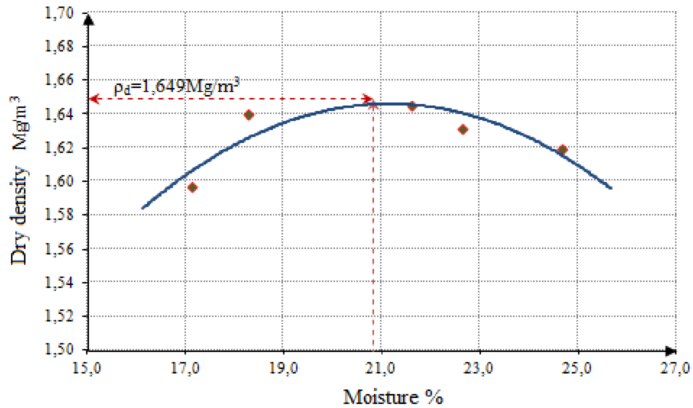


Figure 3 Compaction characteristics Proctor test

The results derived from oedometar test are presented in a diagram which gives ratio between porosity coefficients e and axial effective stress $log\sigma'$. The results can also be presented in a diagram which gives ratio between specific volume v and natural logarithm of main effective stress lnp'.
This dependence has a linear trend BC, after preconsolidation stress p_c, figure 4, and is called virgin compression line.

The slope of this dependence is known as compression index C_C [3]..

$$C_C = \frac{e_B - e_C}{\log(\sigma'_C / \sigma'_B)} \tag{1}$$

Unloading is performed in order to get to know characteristics of swelling soil in oedometer test, which causes increasing coefficient of porosity path 'BA', figure 4.

In the diagram e-$log\sigma_a$ swelling line is marked as C_S and called the swelling index [3].

$$C_S = \frac{e_A - e_B}{\log(\sigma'_B / \sigma'_A)} \tag{2}$$

Slope of the compression line can be expressed by:

$$\lambda = \frac{d\upsilon}{d(\ln p')} \tag{3}$$

Unloading parameter κ can be calculated in similar manner.

Parameters λ and κ are crucial for the use of critical state model such as the Cam Clay model [4, 5]. The phase of consolidation can also be used to determine the coefficient of permeability in the vertical direction k_v, for each increment of load.

Based on the results of performed tests, preconsolidation pressure is 157 kPa, figure 4.

- Compression index C_C=0,206
- Swelling index C_S=0,045
- Compression slope λ=0,089
- Swelling slope κ=0,019

Range of values λ and κ which represent the slopes of plastic and elastic one-dimensional compression line, according to J.H.Atkinson and P.L.Bransby [6] are:

- λ>0,3 highly plastic clay,
- 0,3>λ>0,15 high plastic clay ,
- 0,15>λ>0,075 medium plastic clay,
- 0,075>λ low plastic clay, silts and sands

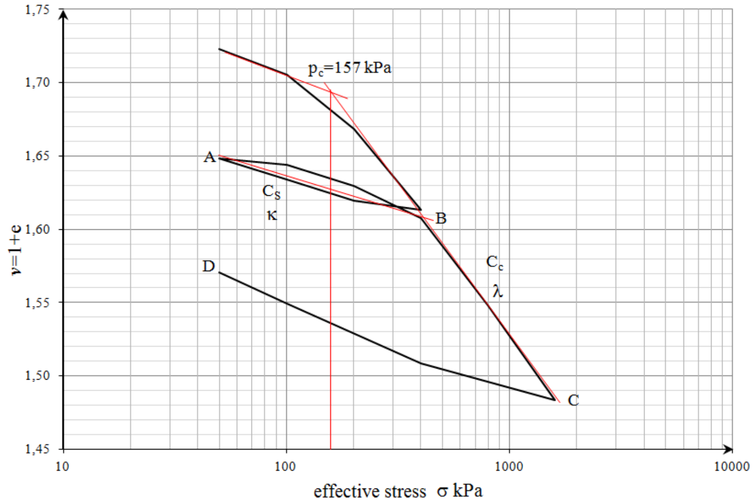


Figure 4 Specific volume *v*/effective pressure σ ratio

According to this classification Koševo layers belong to the medium plastic clay.

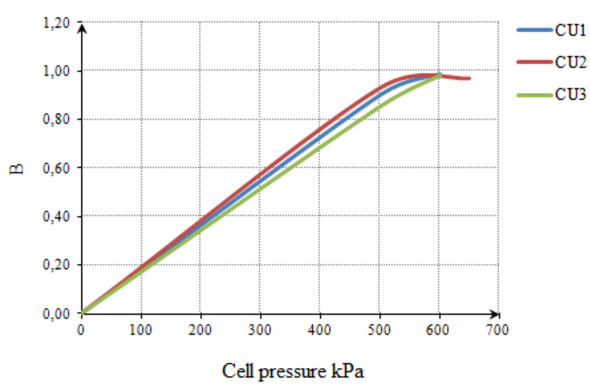
In order to define the shear characteristics of the compacted Koševo layer sample with standard energy at optimum moisture, CU consolidated undrained test and CD consolidated drained test were performed according to BAS CEN ISO/TS 17892-9 .

The phases that need to be done before and during the test are: check of apparatus, preparation and mounting of the sample, saturation, consolidation, increasing the deviator stress, software processing of the collected data, presentation of test results. For the purposes of saturation of Koševo layer clay, pressure increments of cell and back pressure are being applied. Difference between cell and back pressure is 10 kPa. The procedure is repeated until the Skempton parameter B is satisfied, which is equal to or higher than 0.95 when sample is considered saturated and isotropic consolidation phase can begin, figures 5 and 9.

In the phase of consolidation sample is isotropically consolidated. Draining of water leads to decrease of volume and to increase of effective stresses which after the consolidation phase are equal to the difference between the cell pressure and pore pressure in the sample, figures 6 and 10.

The failure time or rate of strain are being determined based on data collected during consolidation (change of volume or excess pore overpressure)

Results of triaxial CU test on clay sample from Koševo layers compacted with standard energy at optimum moisture content.



	B
CU1	0,99
CU2	0,97º
CU3	0,98

Figure 5 Saturation phase CU test

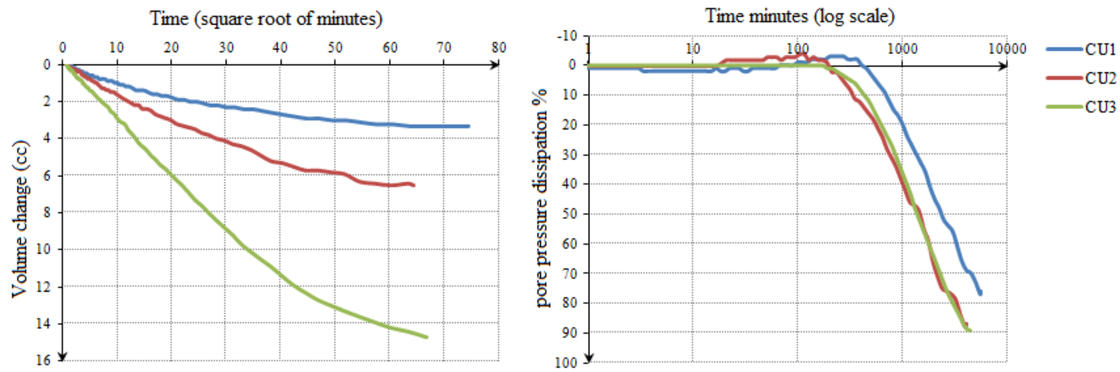


Figure 6 Consolidation phase

Table 1. Isotropic coefficient of consolidation $c_{vi,}$ coefficient of volume compressibility m_{vi} and permeability k

σ_3' (kPa)	CU1 100kPa	CU2 200kPa	CU3 400kPa
$\sqrt{t_{100}}$	24,81	37,37	44,806
t_{100}	615,64	1396,53	2007,65
c_{vi} (m^2/year)	12,94	5,80	4,025
m_{vi} (m^2/MN)	0,16	0,12	0,09
k (m/s)	$0{,}65 \cdot 10^{-9}$	$0{,}21 \cdot 10^{-9}$	$0{,}116 \cdot 10^{-9}$

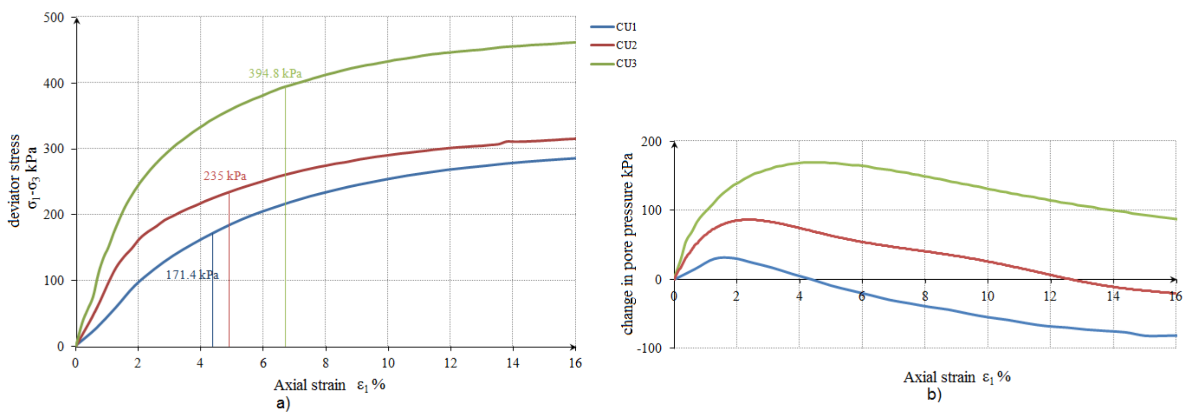


Figure 7 a) Deviator stress/axial strain ratio, b) pore pressure change/axial strain ratio

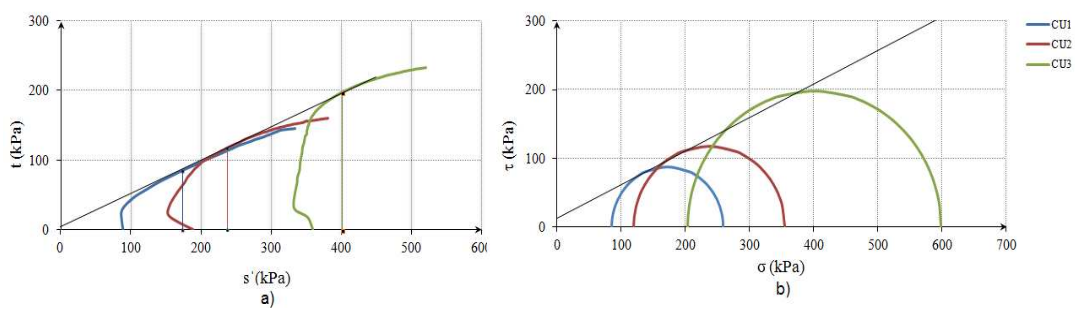
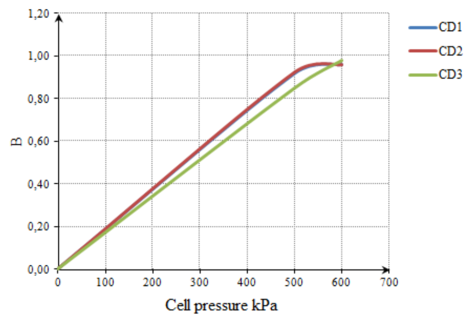


Figure 8 a) Shear illustrated by stress path, b) Shear strenght diagram

Adopted effective shear strenght parameters according to the failure criteria of maximum effective stress ratio for CU test are c'=12,5 kPa and φ'=26º.

Results of triaxial CD test on clay sample from Koševo layers compressed with standard energy at optimum moisture content



	B
CD1	0,96
CD2	0,96
CD3	0,98

Figure 9 Saturation phase CD test

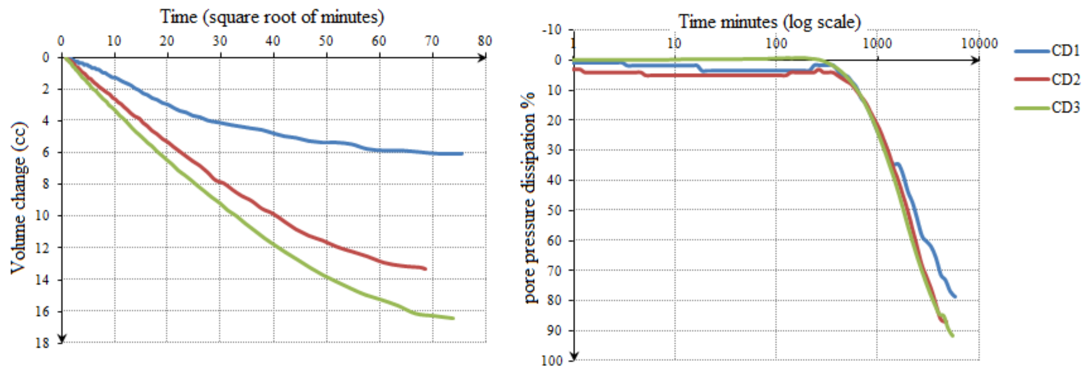


Figure 10 Consolidation phase

Table 2. Isotropic coefficient of consolidation c_{vi}, coefficient of volume compressibility m_{vi} and permeability k

σ_3' (kPa)	CD1 100kPa	CD2 200Pa	CD3 400kPa
$\sqrt{t_{100}}$	39,34	44,96	41,65
t_{100}	1547,99	2021,33	1734,38
c_{vi} (m^2/year)	5,23	4,06	4,71
m_{vi} (m^2/MN)	0,297	0,19	0,10
k (m/s)	0,481*10^{-9}	0,24*10^{-9}	0,149*10^{-9}

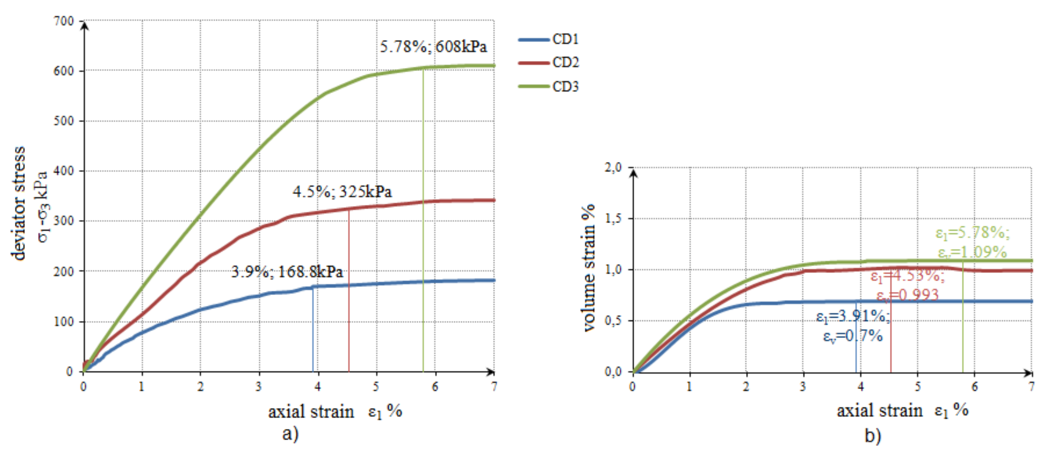


Figure 11 a) Deviator stress /axial strain ratio, b) volume strain/axial strain ratio

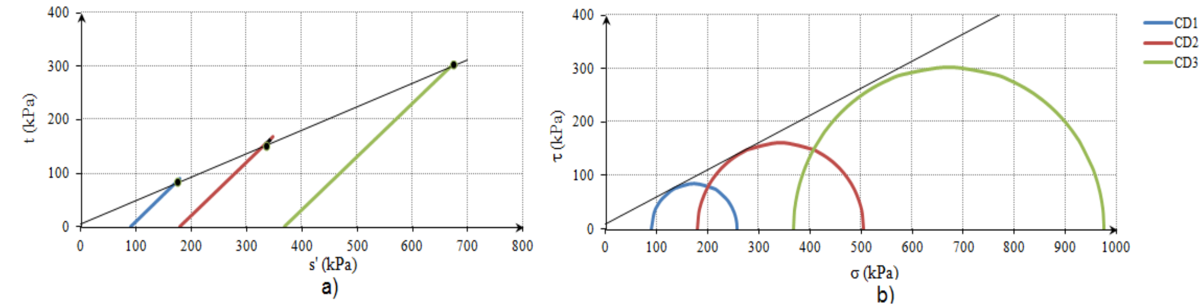


Figure 13 a) Shear illustrated by stress path, b) Shear strenght diagram

Adopted effective shear strenght parameters according to the failure criteria of critical state for CD test are: c'=8 kPa and φ'=27º.

COMMENT OF OBTAINED RESULTS

On the basis of laboratory tests Koševo layers belong to the medium plasticity clay.
Oedometer tests determined: compression index, the swelling index, the compression and swelling line slope that all classified Koševo layers as medium deformable clay.

Hyperbolic stress-strain dependence is obtained by shearing in CU and CD test, figures 7a and 11a.
The maximum principal effective stress ratio σ'_1/σ'_3 is used as criterion of the failure point for CU test [7,8].

Change of pore pressures during shearing in CU test with effective consolidation stresses of 100kPa and 200kPa shows that the material behaves like a mildly overconsolidated material, while at the effective consolidation stress of 400 kPa changes in pore pressure corresponds to normally consolidated clay, figure 7b.

Adopted effective shear strenght parameters from CU test are *c*'=12.5kPa and φ'=26º, figures 8a and 8b. In a concrete case the effective shear strength parameters obtained by the CU test represent the shear strength of the embankment being built fast or the one of the rapid construction of embankments on a natural slope, which means there can be changes in the parameters of shear strength during a time of consolidation and this represents shear strenght in the short term.

According to the diagram of the volume strain and axial strain ratio during shearing in the CD test, figure 11b material behaves as normally consolidated, dilatancy ψ=0.

Failure point was adopted on the basis of the critical state criterion in which the sample continuously deforms at constant volume under constant effective consolidation stress [7,8].

Adopted effective shear strenght parameters from CD test are *c*'=8 kPa and φ'=27º, figures 12a, 12b

Coefficient of permeability, k, for CU and CD test is obtained from the coefficient of volume compressibility m_{vi} and coefficient of consolidation c_{vi}, tables 1 and 2.

In the concrete case, the shear strength parameters obtained in the CD test represent the effective shear strength of embankment being built very slowly in layers, that is, shear strength of the material in the long term.

The main advantage of the CU test compared to the CD test is the duration of the test. CD test is up to ten times slower than the CU test.

CONCLUSION

As it is mentioned in the introduction, due to the increasing need to build new roads and corriodor Vc, it is necessary to consider the possible use of other available materials that will decrease the price of construction compared to incoherent materials.

The aim of this paper is to contribute to understanding of the basic geotechnical properties of Koševo layer clay which are needed for the numerical analysis of the embankment behavior constructed from these materials.

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