ON THE E50 MODULUS OF TAILINGS DAM MATERIALS

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ABSTRACT

From geological point of view tailings dam materials are different compared to regular types of soil. In mechanical aspects it is material that has regular mechanical properties like shear parameters and deformation moduli. Based on the huge expansion of the hardening soil model in the last 20 years, this paper discusses the E50 modulus and its relation to some of the well-known physical soil properties. Expressions of E50 in respect to water content, grain size distribution, void ration, site depth and confining pressure are introduced. Some data are analyzed and weak correlations are obtained. All the E50 modulus values are obtained of both undrained and drained triaxial tests on the tailings dam material samples taken from the Bulgaria biggest tailings dam. Regardless of its variability and ~~the~~ high standard deviation values, there were enough data to define at least the tendency for the E50 dependences on the tailings dam material properties. Remarks and suggestions in respect to the usage and compliance of the results are made.

Keywords: tailings dam, E_{50} modulus, hardening soil model, triaxial test

INTRODUCTION

This paper describes a small part of a more general topic related to the seismic reaction of one of the biggest tailings dam in Europe. Part of the topic was assigned to an academic team from the Bulgarian Academy of Sciences (BAS) and the University of Architecture, Civil Engineering and Geodesy (UACEG). Prof. Simeonov, BAS, was the main project leader and Professor Kostov was the leader of laboratory experiments at UACEG. Historic data could be found in [1]. For the seismic stability assessment, dynamic analysis should be performed. Such type of analyses is usually done with the help of FEM models. The physical soil properties used in the program solutions are often directly or indirectly defined. Identifying some of the parameters for the particular solution reveals some interesting relations. Based on the tailings dam material specifics, such type of relations are rarely described in scientific and technical literature. One of the parameters to obtain is the E50 Modulus. Over the past 20 years, as part of the HSM model E50 is one of the most commonly used parameters to describe the grain materials deformation behavior. This article will concentrate exclusively on the correlation of the E50 modulus and the standard physical parameters of the tailings material.

DETERMINE THE E50 MODULUS FOR THE TAILINGS DAM MATERIAL

At first the triaxial tests were conducted only for estimating the shear resistance of the material, since it is not common in the country to estimate the E50 modulus. Later, based on the inadequate first assumption of the performance of the tailings dam, more precise model of the material behavior and the performance of the dam was needed. A team of geotechnical material model experts stepped in. Even that was not enough for precise model solution, but the expectations were reached. Better solution would be performing some tests based on the methodology given in [2]. For the whole project would be valuable if it could be tasted on shaking table or equivalent procedure like that described in [3] could be performed.

E50 modulus is obtained based on the well-known methodology for determining the E50 modulus of the standard triaxial undrained and drained test (Figure 1). The values are determined for 1/2th of the maximal deviatoric stress, when it is clearly defined before reaching 10% deformation. If the maximal deviatoric stress is not reached within the deformation limit, the value corresponding to 10% axial strain is taken as representative.

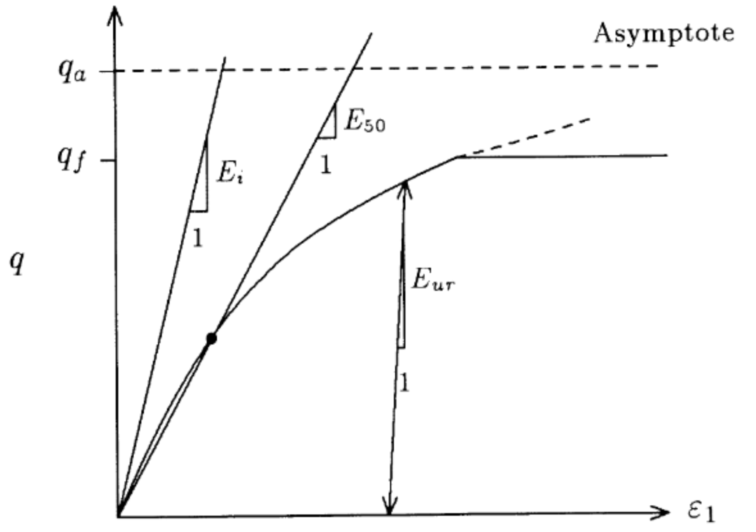

Figure 1. E50 modulus, [4]

The triaxial samples are tested for specific density, natural density, void ratio, water content, grain size distribution, etc. The depth of the samples is also noted. Based on the sandy and silty character of the material the consistency and the plastic properties of the material are not obtained. Part of the properties are shown in Table 1.

Table 1. Parameters of the E50 samples

Number	Depth	Specific density	Density	Water content	Void ratio	Average conf. pressure	Average E50 Modulus
	m	g/cm^3	g/cm^3	%	-	kPa	kPa
1	12	2.78	2.05	24.6	0.685	186	9260
2	42	2.78	1.88	36.2	1.014	211	14000
3	82	2.74	1.97		0.81	154	7817
4	22	2.75	1.94	31.2	0.858	140	11117
5	72	2.72	1.96	27.8	0.778	231	11867
6	82	2.74	2.21	15.9	0.435	432	15167

7	72	2.74	1.93	31.5	0.864	172	9650	
8	62	2.77	2.09	22.7	0.692	233	11877	
9	62	2.76	1.9	34.2	0.944	200	7760	*
10	82	2.73	2.03	25.1	0.686	194	10503	
11	12	2.79	1.84	40	1.13	200	7507	*
12	82	2.75	2.02	25.7	0.708	129	6827	
13	42	2.75	1.97	23.1	0.719	222	9283	
14	22	2.75	1.88	36.1	0.993	280	10596	
15	72					341	14972	
16	52	2.74	2.04	24.5	0.671	307	11570	
17	82	2.71	1.86	20.2	0.748	172	10597	
18	15	2.72	1.91	28.2	0.766	160	13080	*
19	57	2.73	2.1	20.8	0.569	286	10935	*
20	80	2.7	1.93	30.1	0.812	114	6400	
21	78	2.71	2.06	19.9	0.54	361	20857	
22	69	2.72	2.08	21.7	0.591	343	18410	
23	49	2.74	2.01	26.4	0.723	194	8550	

** Drained test*

RELATIONS BETWEEN SOIL PHYSICAL PROPERTIES AND THE E50 MODULUS FOR THE TAILINGS DAM MATERIAL

The results were presented as they were obtained (no exclusions were made). That's why most of them are scattered over the whole plot area. Most of the relations are weak, but still tendencies are visible.

- **E50 with depth:** Figure 2 shows the scattered data based on the E50 modulus related to the depth of the material. Depth limits are wide, 10 to 85 meters. No significant relation can be obtained and even scattering the data with depth could be noted.

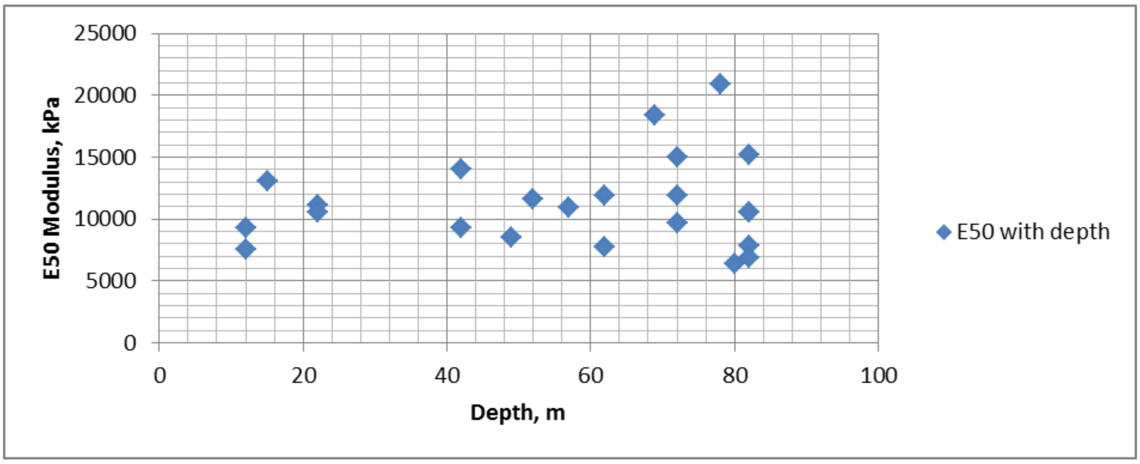

Figure 2. E50 modulus with depth

- **E50 and the natural density:** Figure 3 shows the scattered data based on the E50 modulus related to the natural density of the specimen. Limits are relatively tight, 1.8 to 2.2 g/cm^3.The data scatter has some tendency but no relation could be obtained. Even more, the natural behaviour of the material is still dominant compared to the anthropogenic factor.

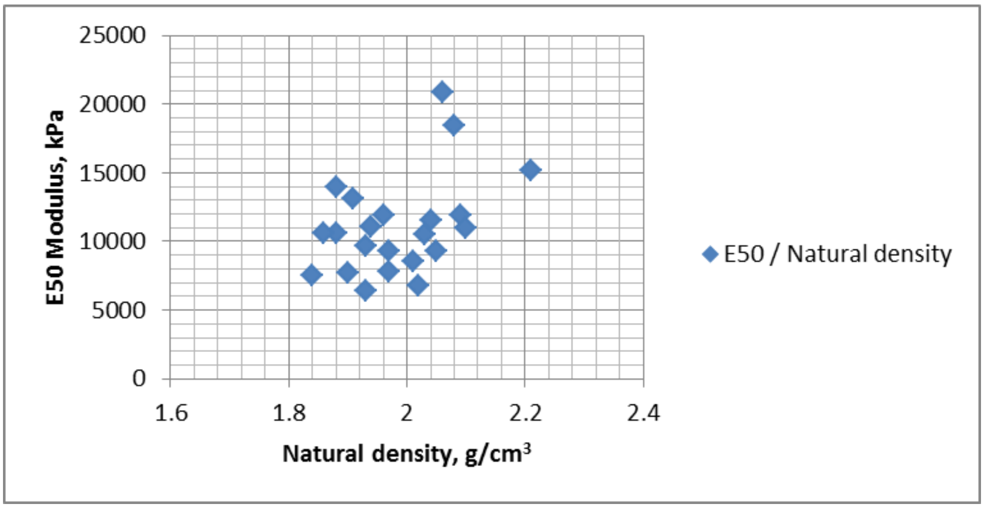

Figure 3. E50 modulus and natural density

- **E50 and the void ratio:** One of the best-known relations of E50 modulus is the one with ~~the~~ void ratio. Tailings dam materials are not excluded. Figure 4 shows the E50 modulus related to the void ratio of the specimen before the tests. Limits are relatively tight, 1.8 to 2.2 g/cm^3. The logarithmic curve fits best on the scatter and it corresponds to the expectance. These results could be explained with the small strain stiffness nature and the particle distribution of the dense material.

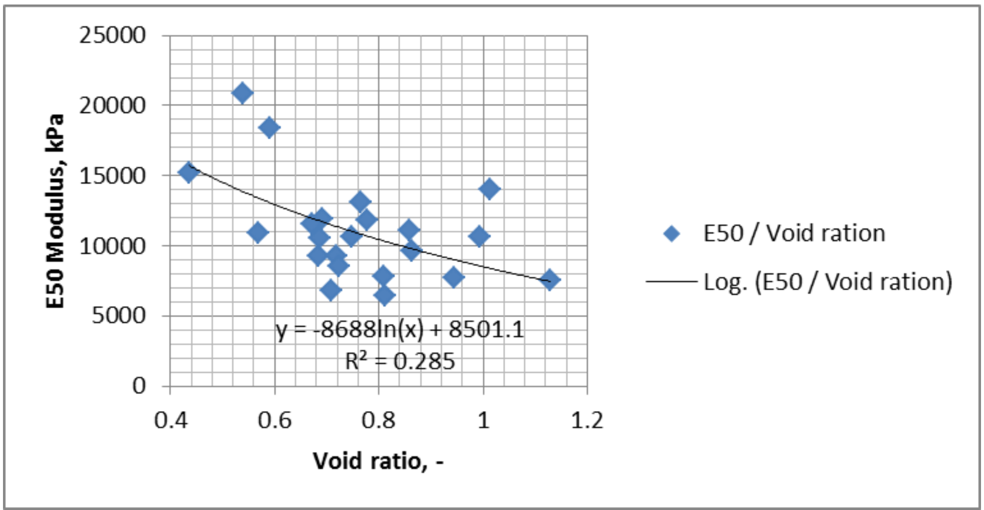

Figure 4. E50 and void ratio

- **E50 and the sand percentage:** As expected, the sand percentage of the samples shows the supposed relation to the E50 modulus (Figure 5.) It is well-known that the E50 modulus is the best for describing the granular material behaviour and is highly dependent on sand and gravel content. Most of the samples are granular material and consist of sand and silt, whereas gravel and clay are not presented. Uniformity coefficient (Figure 5) does also affect the E50 modulus but it has more indirect relation compared to the sand percentage of the samples.

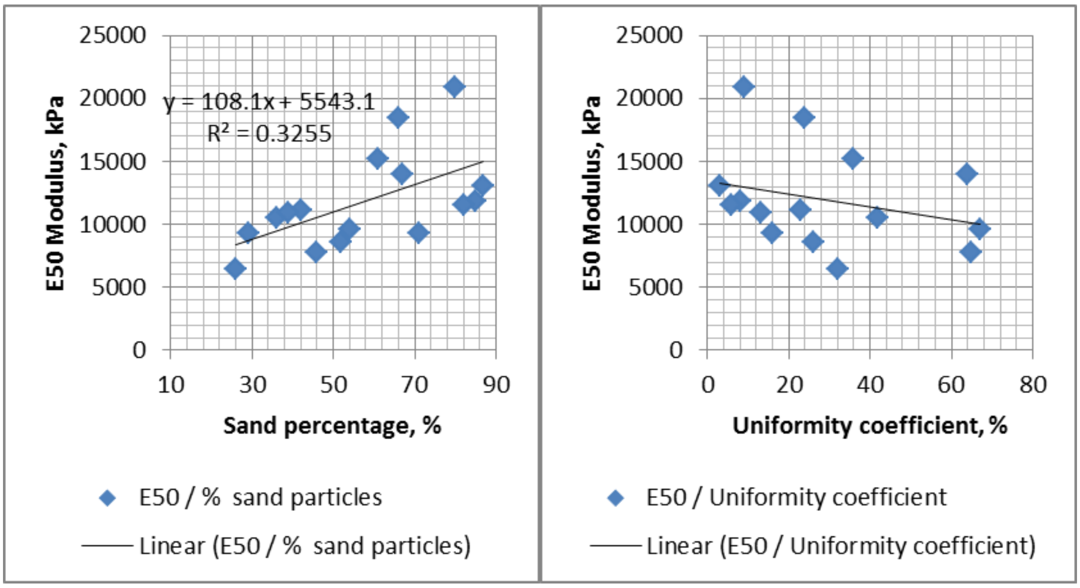

Figure 5. E50 and sand percentage/uniformity coefficient

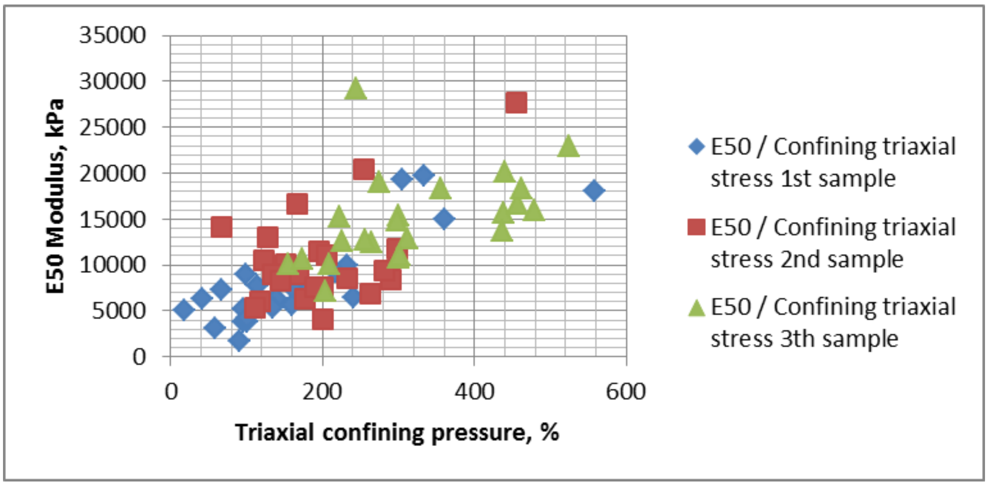

Figure 5. E50 and sand percentage

- **E50 and the confining pressure during the tests:** Well-known E50 modulus association is the confining pressure correlation. Figure 6 shows all the triaxial samples group in first, second and third sample based on the raising level of the confining pressure. The tendency is noticeable, but surprisingly, the correlation is not so tight. This could also be explained with the natural behaviour of the material and also the different tailings dam material processes throughout the years.

CONCLUSION

This article concentrates exclusively on the E50 modulus and its correlation with the standard physical parameters of the tailings material. E50 modulus is obtained based on the well-known methodology using standard triaxial tests. The triaxial samples were also tested for specific density, natural density, void ratio, water content, grain size distribution, etc. Most of the relations of the E50 modulus and physical soil properties are weak and could not be trend line correlated. Tendencies are noticeable even on the most scattered graphs, which confirms the physical accuracy of the results. Since the results are presented as they are obtained, the data could be used for further evaluation and correlations. Exclusions based on statistical methods and other assumptions could be made. Data scattering is mostly due to the natural behaviour of the material, which is still dominant compared to the anthropogenic factor. Scattering could also be based on the different tailings dam material processes throughout the years, since the different processes when obtaining the properties were not taken into account. The results are adequate but not sufficient. It is highly recommended when further investigating the tailing dam material more complex method of testing to be used.

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