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APPLICABILITY OF SDMT TEST IN EVALUATING THE MODULUS G_0 IN TAILINGS

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Abstract: The value of an initial shear modulus G_0 is essential for a safe use of objects subjected to dynamic loads. Such a situation occurs at the Żelazny Most dump where paraseismic activities are due to copper ore mining. The paper presents the results of field investigation with seismic cone SCPTU and a latest generation of seismic dilatometer SDMT, Dutch company A.P. van den Berg. The aim of the tests was to estimate the applicability of the latter through statistical analysis of results acquired from both methods.

The values of constrained moduli derived from CPTU and DMT tests are also compared.

1. INTRODUCTION

As is commonly known, geotechnical parameters may be defined in laboratory or in situ testing. The former way however is heavily restricted by the requirements for high-quality intact samples and reconstruction of stress state in the subsoil. This problem seems to be crucial, especially for post-flotation tailings deposited in the Żelazny Most dump whose structure exhibits numerous laminations and significant anisotropy [6]. Due to the above, modern in situ methods are preferred for defining the values of shear parameters and deformation moduli [5], [6].

Field methods of measuring the wave velocity can be divided into two groups:

- surface methods based on the Rayleigh wave velocity measurement,
- bore hole methods based on measurement of body wave velocity.

Bore holes methods fall into two kinds: cross-hole and down-hole.

Cross-hole techniques are found to be referential ones to other methods; however, they are time consuming and expensive, hence their application is being consequently limited. Instead, more and more often wave velocity is measured by down-hole method offering an acceptable compromise between quality of deriving results and cost of execution. Moreover, a number of tests proved that in normally consolidated soils the wave velocities achieved using both techniques are very much alike [1]–[3].

There are two possible configurations in the group of down-hole devices: those using single geophone (pseudointerval method) and those using two geophones (true interval method). The aim of research was to compare the shear wave velocities measured with two devices of different construction.

2. SITE AND METHODS OF INVESTIGATION

All the field tests were conducted in copper ore post-flotation tailings deposited in the Żelazny Most dump located in south-west part of Poland, half way between Lubin and Głogów. Its construction started in 1974, while simultaneous exploitation and development began in February 1977. Due to continuous deposition, the quantity of tailings has been increasing up to almost 350 Mio. m^3 in 2005. Tailings are sent to the dump by means of hydrotransport method and poured onto a beach from pipelines that run along the crown of embankments. Because of such a way of transport, the material is significantly inhomogeneous. Based on the grain-size distribution, tailings fall into fine grained material ranging from fine sand to silty clay.

Field tests were carried out in three selected test points located in different parts of the dump (figure 1).

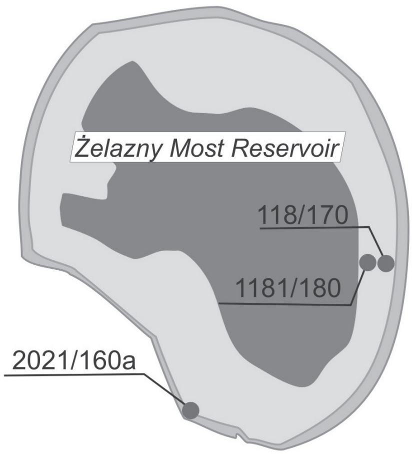

Fig. 1. Location of the points under investigation

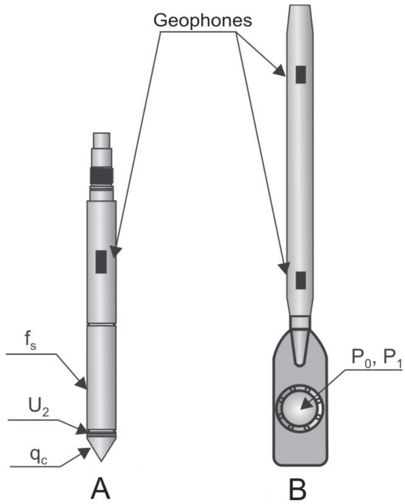

Fig. 2. SCPTU cone and Marchetti's SDMT blade

In each point, the following tests were carried out:

- cone penetration test using SCPTU cone (figure 2a),
- seismic dilatometer test using Marchetti's SDMT blade (figure 2b),
- collecting soil core samples for further laboratory tests.

The SCPTU cone, besides measuring the wave velocity, enables also definition of standard penetration parameters (q_c, f_s, U_c). Due to the use of a single receiver device, the wave velocity was measured using the "pseudointerval" method. On the other hand, in SDMT tests not only were the standard values of the pressure p_0 and p_1 measured, but also shear wave velocity V_s. Since this device incorporates two geophones located 0.5 m from each other, it allowed us to implement the "true interval" method and to eliminate trigger errors. In order to define ground water distribution in the profiles examined, dissipation tests were also conducted.

3. RESULTS OF SCPTU AND SDMT TESTS IN POSTFLOTATION SEDIMENTS

Figure 3 shows the results of SCPTU and SDMT at one of the test points. When comparing the changes of q_C and f_S (SCPTU) and p_0 and p_1 (SDMT) with depth it can be observed that these parameters respond in a very similar way to variations of both grain-size distribution and state of the sediments. The variations are also confirmed by the changes in registered values of excess pore pressures u_1 and u_2.

The same was noticed in the case of seismic wave values with depth – the values acquired in both SCPTU and SDMT tests present significant resemblance.

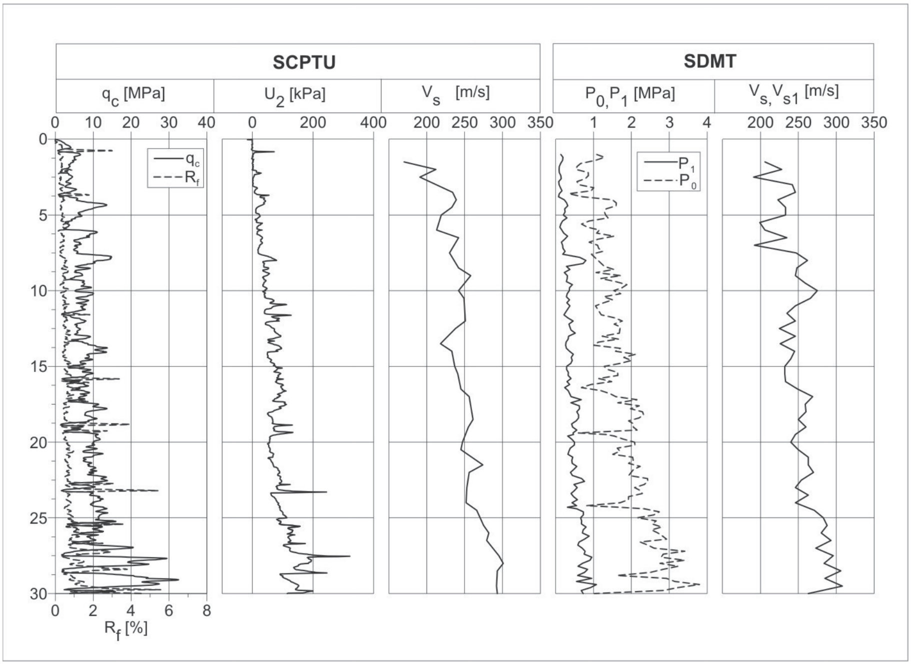

Fig. 3. Comparison of the test results at the test point No. 1181/180

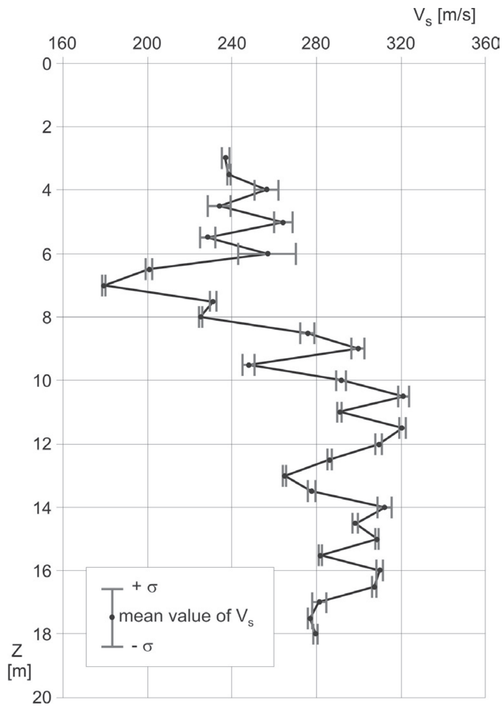

Fig. 4. Replication tests of wave velocity measurement – point No. 118/170

Main advantage of the SDMT acquisition system is the possibility of executing numerous replications of wave velocity measurement which enabled statistical assessment of test errors. The results of wave velocity replication tests at the point No. 118/170 show that the device exhibits a significant repeatability and depth does not affect the quality of the results (figure 4). Major scatter may be observed in inhomogeneous layers which is probably caused by deflection and reflection of waves coming into contact with two media of different density.

4. COMPARISON OF MODULI DERIVED FROM SCPTU AND SDMT TESTS

Main purpose of the tests conducted was to assess the applicability of SDMT method to evaluation of the modulus G_0. As a reference, SCPTU results were assumed.

Initial shear modulus was found using the solutions based on the elasticity theory that defines it as a function of shear wave velocity and soil density (equation (1)). Wave velocity was derived from SCPTU and SDMT seismic tests, whereas the density of tailings was evaluated in laboratory tests carried out on core samples collected with the MOSTAP sampler:

$$G_0 = \rho \cdot V_s^2, \tag{1}$$

where:

V_s – the shear wave velocity,

ρ – the soil density.

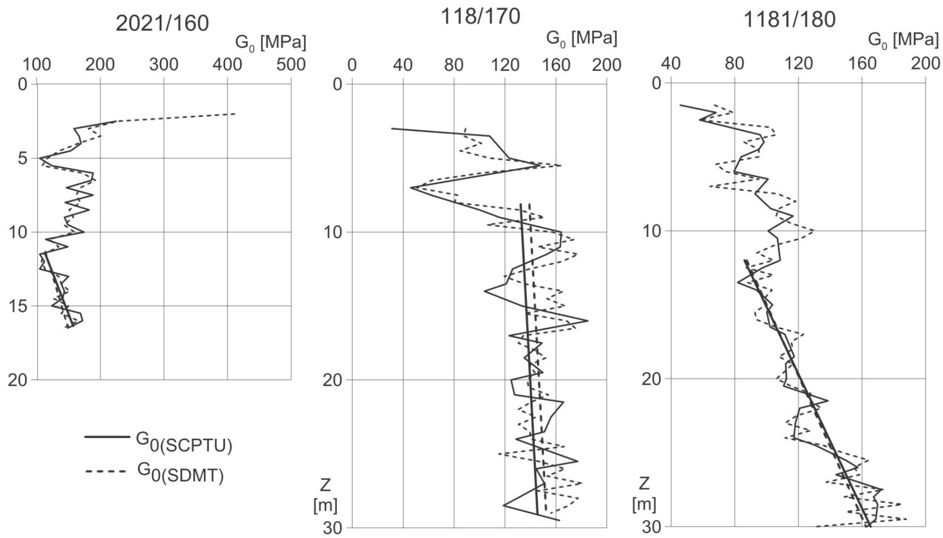

Fig. 5. Changes of $G_{0(\mathrm{SCPTU})}$ and $G_{0(\mathrm{SDMT})}$ with depth

Table 1

Results of statistical analysis for relationship G_0 from SDMT and SCPTU

The point investigated	F	p-value	$k(0.05)$
2021/160a	0.187	0.669	4.183
118/170	0.040	0.841	3.991
1181/180	0.161	0.689	4.007
p-value – statistical significance. k– critical value at the significance level $\alpha = 0.05$.			

To estimate the differences in forecasting the values of G_0 obtained by both methods, the significance of differences between the coefficients of regression of straight line was examined. It appeared (table 1) that the coefficients of regression at each test point do not differ statistically at the level of $\alpha = 0.05$. This conclusion enables us to formulate an explicit opinion that estimation of the values G_0 obtained using both devices and their changes with variations of the geostatic stress state in the subsoil is very similar.

In our research, the values of constrained modulus defined based on the results derived from both seismic penetration test SCPTU (equation (2) [7]) and seismic dilatometer test SDMT (equation (3) [4]) were compared and assessed.

$$M = m(q_t - \sigma_{v0}), \tag{2}$$

where:

m – the constant dependent on the type of tailings [5],
q_t – an effective cone resistance,
σ_{v0} – the overburden pressure.

$$M = R_M \cdot E_D, \tag{3}$$

where:

R_m – the value dependent on I_D (material index) and K_D (horizontal stress index),
E_D – dilatometer modulus.

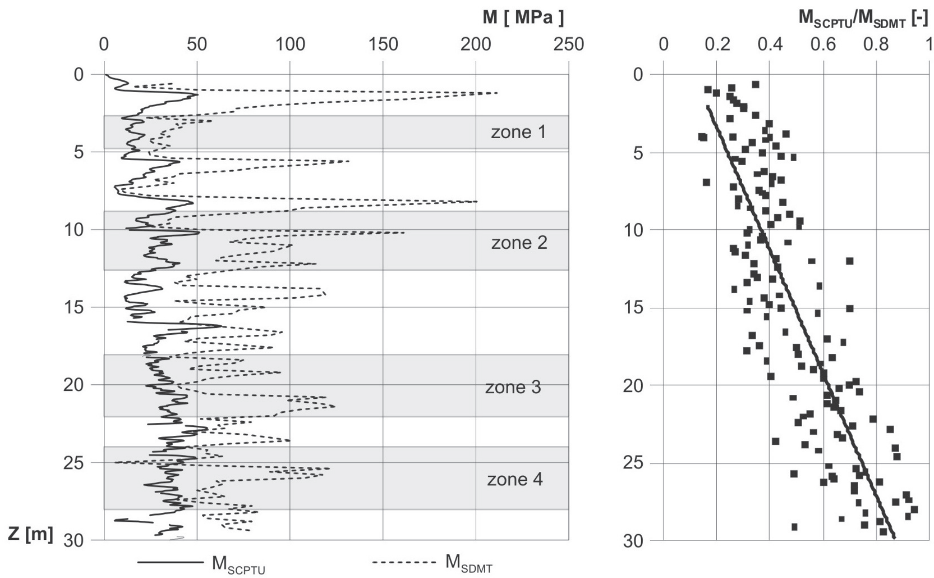

Fig. 6. Changes of M_{SDMT} and M_{SCPTU} with depth

Comparing the changes in the constrained modulus values with depth we clearly see that these values measured by means of the SDMT method significantly outnumber those measured in the CPTU test (figure 6). The largest differences appear in the zone of small values of σ_{v0} at high values of the density ratio and slowly vanish with depth. Such differences seem to be fully justified for the tailings that exhibit strong anisotropic macrostructure in the form of laminations. Moreover, the mechanism of forming plastic areas under the cone is different from the mechanism of deformation during the DMT test.

Statistical evaluation of the significance of the differences in the forecasted values of deformation moduli was made in those zones of the profiles which exhibited small variation of the density ratio. Statistical analysis revealed that the mean values of the constrained moduli did not differ at the significance level of $\alpha = 0.05$ in all the zones of σ_{v0}.

Table 2

Results of statistical analysis for relationship G_0 from SDMT and SCPTU

Zone	Mean value *M*		*p*-value
	SCPTU	SDMT	
1	15.66	35.74	0.000
2	29.08	73.81	0.000
3	32.11	72.62	0.000
4	36.62	66.67	0.000

5. CONCLUSIONS

The tests showed the applicability of the SDMT method in evaluating the modulus G_0 in tailings and revealed its some important features. First of all, the values of G_0 modulus derived from SDMT strongly resembled those from SCPTU assumed as reference ones. Secondly, the former allows us to conduct a number of replications of shear wave velocity measurement which not only show an excellent repeatability, but are also of great importance for further statistical evaluation. Finally, the SDMT blade due to its construction provides additional information on horizontal deformation of tailings.

Taking into consideration all the facts given above we have to state that under complex soil conditions such as tailings, both SDMT and SCPTU methods should be applied.

LITERATURE

[1] CAMPANELLA R.G., ROBERTSON P.K., GILLESPIE D., *A seismic cone penetrometer for offshore applications*. Chapter 51, Proc. of Oceanology International ’86, Brighton, 1986, UK.

[2] EIDSMOEN T., GILLESPIE D., LUNNE T., CAMPANELLA R.G., *Tests with UBC seismic cone at three Norwegian research sites*, Norwegian Geotechnical Institute, Oslo, 1985, Norway, Report 59040-1.

[3] LARSSON R., MULABDIC M., *Shear moduli in Scandinavian clays. Measurement of initial shear modulus with seismic cone. Empirical correlations for the initial shear modulus in clay*, Swedish Geotechnical Institute, Linkoping, 1991, Report 40.
[4] MARCHETTI S., MONACO P., CALABRESE M., TOTANI G., *The flat dilatometer test*, 1999, A report to the ISSMGE Committee TC-16.
[5] MŁYNAREK Z., TSCHUSCHKE W., LUNNE T., *Techniques for examining parameters of post flotation sediments accumulated in the pond*, Proceedings of the Third International Conference. *Re-use of Contaminated Land and Landfills*, University of Edinburgh, Press London, 1994.
[6] MŁYNAREK Z., *Effectiveness of in-situ tests in evaluation of strength parameters of post-flotation sediments*, Proceedings of 2000 Geotechnics, Geotechnical Engineering, Conference, Bangkok, 2000.
[7] SENNESET K., JANBU N., SVANO G., *Strength and deformation parameters from cone penetration tests*, Penetration Testing "ESOPT-II", Amsterdam, Balkema, Rotterdam, 1982.