Simultaneous interpretation of CPT/DMT tests to ground characterisation

L'interprétation simultanée des essais CPT/DMT pour la caractérisation du sol

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ABSTRACT: This paper addresses the simultaneous interpretation of two well known in situ tests, namely CPT and DMT, to characterize the geotechnical conditions, particularly the stress history of clay sediments. The CPT/DMT tests had been carried out in order to recognize the geotechnical conditions in the foundations of design buildings at SGGW (WULS) Campus in Warsaw. The data for two layers of glacial boulder clays have been analysed simultaneously using CPT and DMT tests. Based on the results of analyses new formulas for determination of the OCR have been developed. The suggested relationships should be considered in future analyses for their improvement.

RÉSUMÉ : Cet article traite de l'interprétation simultanée de deux essais in situ bien connus, à savoir CPT et DMT, pour caractériser les conditions géotechniques, en particulier l'histoire des contraintes de sédiments argileux. Les essais CPT/DMT ont été réalisés dans le but de reconnaître les conditions géotechniques pour le dimensionnement des fondations des bâtiments SGGW (WULS) Campus à Varsovie. Les données de deux couches d'argiles glaciaires ont été analysées simultanément en utilisant les essais CPT et DMT. Sur la base des résultats des analyses, de nouvelles formules pour la détermination de l'OCR ont été développées. Les relations proposées devraient être pris en compte dans les analyses futures en vue de leur amélioration.

KEYWORDS: ground characterisation, CPT/DMT tests, join interpretation

1 INTRODUCTION

In engineering practice the cone penetration and dilatometer of Marchetti tests (see Figure 1) are commonly recommended to identify the geotechnical conditions for design structures (Lutenegger and Kabir 1988, Briaud and Miran. 1991, Lunne et al. 1997, Marchetti 1980). Although the CPT/DMT tests have been used for over 30 years in the same purposes, generally to recognize geotechnical condition in ground (Robertson 1990, Młynarek 2007), to date relatively little published regarding join interpretation (Mayne and Liao 2004, Robertson 2009). One of not numerous comparison between measured DMT parameters (I_D, K_D, and E_D) with depth and predicted parameters using the CPT at Moss Landing site (California) is showing in figure 2 (Robertson 2009). This site provides a good test for the proposed correlations since the soils range from soft to firm clay and loose to dense sand. The site is composed of about 2.6 m of silty sand to silt over about 4.4 m of sand. Below the sand is a deposit of firm plastic clay extending to a depth of 13.4 m. The ground water level is at a depth of about 2.2 m below ground surface but fluctuates somewhat with the tide. After an analysis of CPT/DMT correlations Robertson concluded that horizontal earth pressure index K_D from DMT tests correlate to normalized cone resistance $(q_c - \sigma_{v0})/\sigma'_{v0}$ and proposed formula as follows:

$$K_D = 0.8\left(\frac{q_c - \sigma_{vo}}{\sigma'_{vo}}\right)^{0.8} \quad (1)$$

Knowing the horizontal index K_D from DMT test and normalised cone resistance, the overconsolidation ratio OCR can be obtained using following formulas (Marchetti 1980, Robertson 2009):

$$OCR = (0.5 \cdot K_D)^{1.56} \quad (2)$$

$$OCR = 0.24 \cdot \left(\frac{q_t - \sigma_{vo} \cdot}{\sigma'_{vo}}\right)^{1.25} \quad (3)$$

According to Robertson (2009) the resistance of cone q_c can be determined based on the following equation:

$$q_c = 1.25 \cdot \sigma'_{vo} \cdot K_D^{1.25} + \sigma_{vo} \quad (4)$$

This paper presents the CPT and DMT tests carried out in order to recognize the geotechnical conditions for the design structures in frame of the SGGW (WULS) Campus development. Based on the results obtained from the extensive research (Rabarijoely et al. 2011) the relationships between CPT and DMT tests have been developed. For the determination of the cone resistance q_c new procedure was developed considering dilatometer index of horizontal stress K_D. Also, for determination of K_D index new procedure was proposed based on the cone resistance q_c. Moreover, the simultaneous interpretation of CPT/DMT tests was applied to determine the overconsolidation ratio of clay sediments.

Figure 1. View of CPTu tip (a) and DMT blade (b) actually used in geotechnical investigation

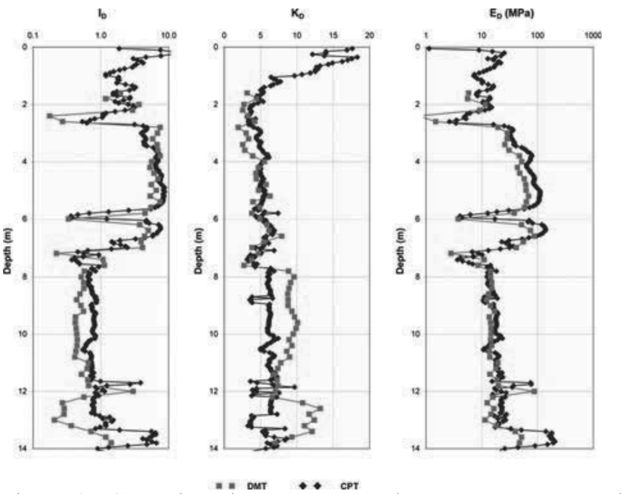

Figure 2. Comparison between measured DMT parameters and predicted parameters using the CPT at Moss Landing site (Robertson 2009)

2 CPT/DMT TESTS AT SGGW CAMPUS

In order to determine geotechnical conditions in the foundations of design buildings at SGGW Campus a total of 69 of CPT and DMT tests were conducted (see Figure 3). Analysing data gathered in the Ground Investigation Report, five geotechnical layers were identified in the Campus test site (see Figure 4), including a layer of brown glacial boulder clay noted in this paper as layer No. III (acc. to geotechnical classification sandy clay - saCL and sasiCL) of the Warta glaciation ($^{g}Q_pW$), for which liquidity index values $I_L = (0.0\div0.11)$ and a layer of grey glacial boulder clay of the Odra glaciation ($^{g}Q_pO$), sandy clay with boulders as layer No. IV, for which $I_L = (0.0\div0.12)$. The layers III and IV were pointed out as layers with suitable geotechnical conditions for foundation of the Campus buildings.

Typical distributions of the cone resistance q_c from CPT tests and the horizontal stress index K_D from DMT tests for III and IV layers (boulder clay sediments) are shown in figure 5. Relationships between measured values of q_c and K_D using CPT and DMT tests respectively are shown in figure 6. These relationships were obtained using statistical analysis (Solver modulus).

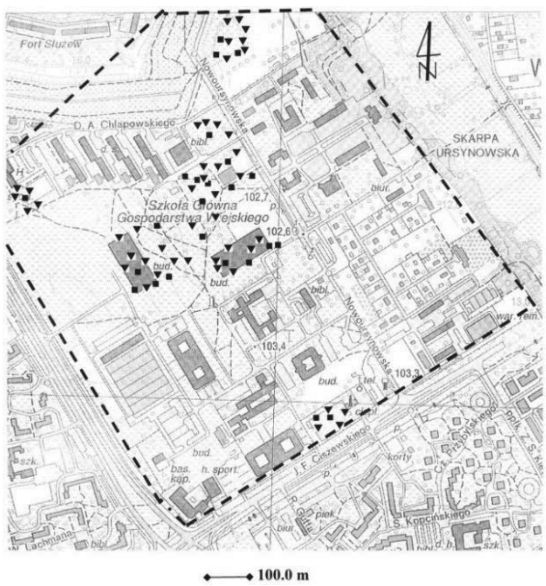

Figure 3. Map of the SGGW Campus with locations of CPT (▼) and DMT (■) tests (Rabarijoely et al. 2011)

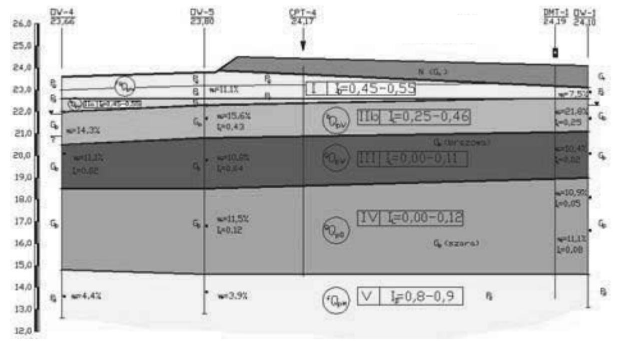

Figure 4. Typical geological conditions at the SGGW (WULS) Campus

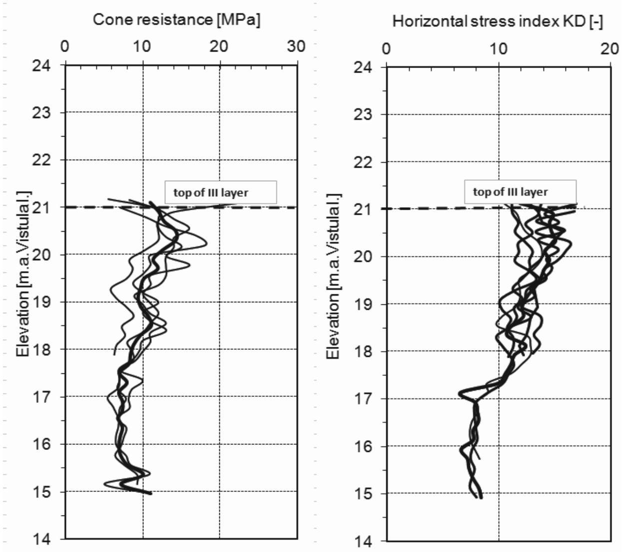

Figure 5. Profiles of cone resistance q_c from CPT tests and horizontal stress index K_D from DMT tests for III and IV layers of SGGW (WULS) Campus

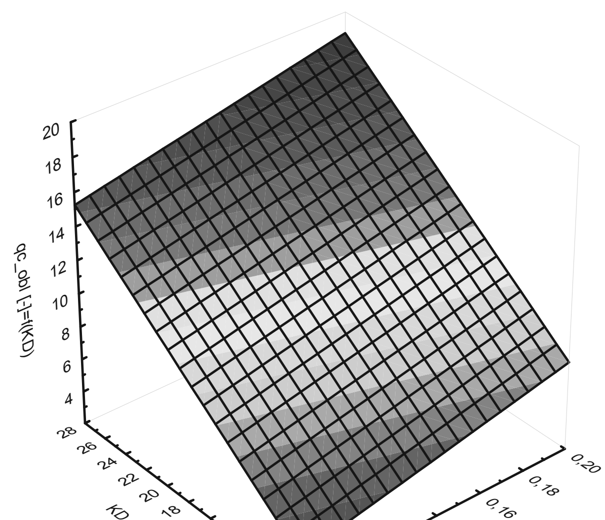

Figure 6. Comparison between calculated q_c (eq. 8) and K_D measured by DMT tests (σ'_{vo} - effective vertical stress in boulder clay layer)

3 CPT/DMT CORRELATIONS FOR OCR DETERMINATION

It is obvious that the values of overconsolidation ratio determined from both CPT and DMT tests should be the same. Therefore, the following equation is valid:

$$0.24\left(\frac{q_c-\sigma_{vo}}{\sigma'_{vo}}\right)^{1,25} = \left(0.5\cdot K_D\right)^{1.56} \quad (5)$$

In order to determine CPT/DMT correlations the statistical analysis (Solver modulus) to obtain the best fitting between calculated according to equation (1) and measured values of K_D in the SGGW Campus was applied. From statistical analysis the following relationship was estimated with Mean and Maximum Relative Deviations respectively MSRD=9,0%, MRD=20,0%:

$$K_D = 2{,}1\left(\frac{q_c-\sigma_{vo}}{\sigma'_{vo}}\right)^{0,40} \quad (6)$$

The similar statistical analysis was carried out for obtaining the best fitting of q_c distribution in profile of the SGGW Campus between calculated according to eq. (6) and measured values. Equation (6) was rearranged to determine the q_c values. The following relationship was determined with MSRD=20,0%, MRD=30,0%:

$$q_c = 0{,}45\cdot\sigma'_{vo}\cdot K_D^{2,0} + \sigma_{vo} \quad (7)$$

Finally, introducing to formula (eq.1) the proposed relationships (eq.6 and eq.7) the overcondsolidation ratio can be calculated using the following formulas:

$$OCR = 0.28\left(\frac{q_c-\sigma_{vo}}{\sigma'_{vo}}\right)^{0.82} \quad (8)$$

$$OCR = 0.48\cdot K_D^{1.2} \quad (9)$$

Comparison between K_D measured in the foundation of building No 34 in SGGW Campus and calculated using equations (eq.1) and (6) is presented in figure 7, whereas between q_c measured and calculated according to equation 7 in figure 8. The values of K_D and q_c calculated according to eq. (6) (7) are similar to measured. The distribution of OCR values in profile analysed is shown in figure 9.

4 FINAL CONCLUSIONS

The objective of this paper is to compare the results of CPT and DMT tests obtained for boulder clay distinguished in SGGW Campus at Warsaw. Based on the statistical analyses of 69 CPT/DMT profiles the formulas for the cone resistance q_c as a function of horizontal stress index K_D and for K_D as a function of q_c were suggested. Moreover, the new formulas for determination of overconsolidation ratio are also proposed.

In general, the formulas proposed for boulder clay in foundation of SGGW Campus give smaller values of OCR to comparison with Robertson's proposal.

The suggested relationships should be considered in future analyses for their improvement.

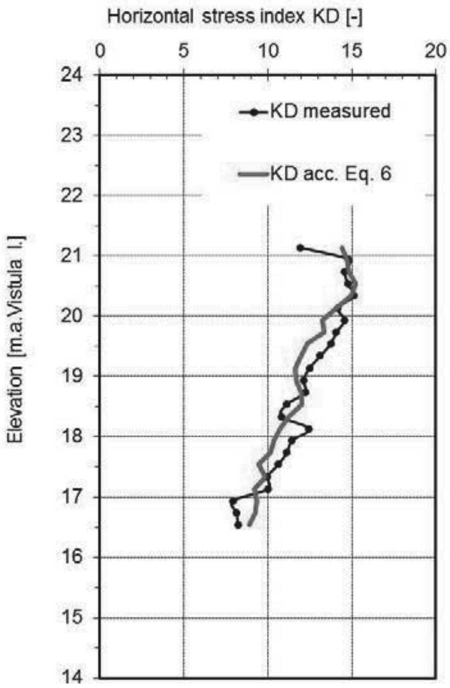

Figure 7. Profile of K_D under SGGW building No 34 in Warsaw SGGW Campus

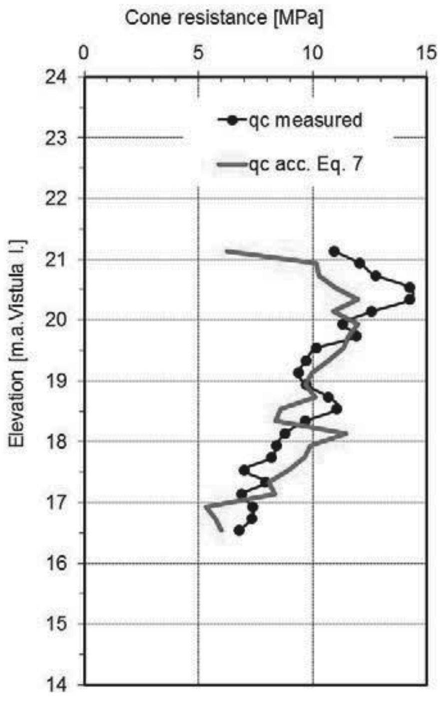

Figure 8. Profile of q_c under SGGW building No 34 in Warsaw SGGW Campus

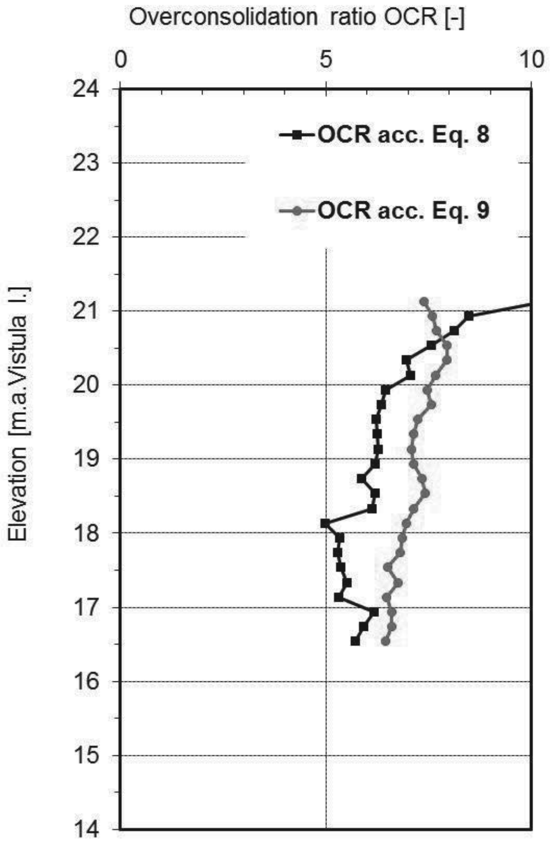

Figure 9. Profile of OCR under SGGW building No 34 in Warsaw SGGW Campus

5 ACKNOWLEDGEMENT

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