Comparison of piezocone, Marchetti dilatometer and vane test results for the Danube-Sava canal

La comparaison des résultats des essais de piézocône, de dilatomètre Marchetti et de scissomètre pour le canal Danube-Sava

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ABSTRACT: In order to improve interpretation of CPT and DMT tests results by taking into account local soil conditions along the future Danube - Sava canal, a special testing program was realized at three selected locations showing dry crust effects in stiff clay near the surface. The analyses showed that procedures for interpreting penetration testing results should be calibrated for local soil conditions wherever possible. In addition, major advantages of using modern geotechnical technology in characterising soil conditions in this region are presented.

RÉSUMÉ: Afin d'améliorer l'interprétation des résultats obtenus par les essais CPT et DMT qui ont été réalisés le long du futur canal Danube - Sava, et pour tenir compte des conditions de sol sur le chantier, un programme spécial d'essais a été réalisé à trois sites sélectionnés présentant les effets de la croûte sèche en argile compacte près de surface. Les analyses ont montré que les procédures d'interprétation des résultats de pénétration doivent être calibrées, autant que possible, en tenant compte des conditions locales. En outre, les avantages de la technologie géotechnique moderne pour la caractérisation des conditions de sol dans cette région sont également présentées.

1. INTRODUCTION

Geotechnical investigation program for the Danube - Sava canal in eastern Croatia was divided in two phases and consisted of classical geotechnical drilling, in situ penetration testing and laboratory testing of undisturbed samples. The first phase was supposed to provide guidelines for the second phase of investigation work, regarding scope and type of investigations taking into account the relevance and reliability of data for geotechnical design and for the determination of soil conditions. The canal length is 60 km and it is 6 m deep. Only 40 km of the canal has been investigated so far, due to limited access to zones influenced by the war. All soil types are present along the canal, from sand and clay to mixtures of these soils with addition of silt. Almost half the length of canal is in a stiff highly plastic clay, often having firm lenses with carbonate (calcite) bonds.

The penetration testing program, consisting of piezocone testing (over 2500 m) and Marchetti dilatometer testing (over 300 m), proved to be very cost and time effective. In order to verify influence of local soil conditions on standard interpretation procedures for these tests, a special investigation program was conducted at three locations. Unfortunately, there has been some delay in conducting the investigation program so that laboratory results are not presently available, which is why all the analyses in this paper will be limited to the in situ testing results.

2. SELECTED LOCATIONS AND RELATED INVESTIGATION PROGRAM

Three locations were selected for the special program of investigation. All of them showed dry crust effects and provoked significant negative pore pressures in piezocone testing during the first phase of investigation work. The special program of investigation consisted of the following activities: one 15 m deep borehole for soil identification, for SPT and vane testing (VT) and for taking undisturbed samples of soil; four piezocone soundings (CPT), two of which were done with glycerine in filter and two with fat without filter; two dilatometer soundings with Machetti dilatometer (DMT).

The purpose of this investigation was to check the repeatability of penetration tests, the effect of dry crust as related to different CPT techniques, the reliability of soil type identification via CPT and DMT, and the relation of the interpreted undrained shear strength from CPT and DMT to the value obtained by vane testing (VT) in the borehole.

The first location had a soil profile consisting of a highly plastic stiff clay, with calcite lenses of about 2 cm in diameter near the surface and decreasing in diameter with depth. The sandy clay was determined between 3.5 and 5.5 m of depth. SPT varied from 8 (at 4 m) to 18 (at 13 m). The ground water (GWL) level was at 2.5 m.

At the second location, the soil profile consisted of a highly plastic clay all the way down to 15 m with calcite lenses (from 2 cm in diameter at about 8 m in depth to several millimetres at other depths). SPT varied from 4 (at 13 m) to 13 (at 3m). The ground water level was at 5.5 m.

Third location consisted of a stiff clay down to 10 m in depth, followed by sandy clay to 11 m and then clayey sand down to 15 m. SPT varied from 4 (around 11 m) to 13 (at 7 m) and 10 (at 3 m). The ground water level was at 1.6 m.

CPT testing

Two soundings were performed with glycerine in filter and two with slot filter using fat (Esquivel, 1995, Larsson, 1995). In one sounding of each type the start was in the prebored hole at 1 or 1.5 m, and in the other in prebored hole at 2.5 m. The idea was to study the influence of water position and the dry crust effect on pore pressure measurements.

The Geotech probe was used for testing (a=0.58, filter 5 mm behind tip base), and the slot filter was of Geotech type, with 0.2 mm space behind the tip base for fat. The slot filter is suitable for soil conditions where significant negative pore pressures occur.

The interpretation of tests was made by means of the Conrad program (Larsson at all, 1995) which filters values along 20 cm depth intervals.

Tests with glycerine showed that the starting depth did not influence very much negative pore pressures in the upper zone, neither in the value nor in the depth where they became positive. Repeatability of the corrected tip resistance was remarkable.

The slot filter sounding had always positive values, although some unexpectedly high values were registered in the dry crust zone, which might be attributed to the mechanical interference with tip load. It was concluded that this type of filter should be carefully studied in laboratory conditions.

Fig. 1. shows pore pressures measured with CPT probe using glycerine and slot filter at the location No. 3. To a certain extent, differences in pore pressure values can be explained by uneven distribution of firm lenses and local heterogeneities.

DMT testing

This testing was performed according to Robertson and Schmertmann (1988) and interpreted according to Marchetti (1992). Two soundings had excellent repeatability at all three locations.

Vane tests (VT)

Vane tests were performed at location No. 2 and 3, by Geotech type electric vane apparatus (H:D=2:1). Maximum shear values have been corrected for rod friction only.

3. CLASSIFICATION OF SOIL

Soil type identification by CPT-glycerine was effected by high tip resistance and negative pore pressures in the dry crust zone so that sometimes sand and silt was identified instead of clay.

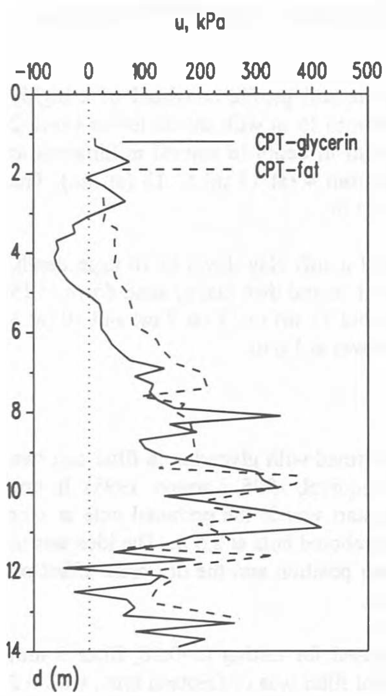

Fig.1. Pore pressures measured at location No.3.

Soundings with slot filter had higher pore pressures and silt was determined more often then sand in the crust zone.

The situation was quite similar in case of DMT; very stiff clay in crust zone was recognised as silt, but sandy soils determined in lower depths were in better agreement with borehole log than the CPT identification.

4. PREDICTION OF UNDRAINED SHEAR STRENGTH

CPT undrained shear strengths were about the same for glycerine tests and for fat (slot filter) tests, with similar repeatability for the same type of tests.

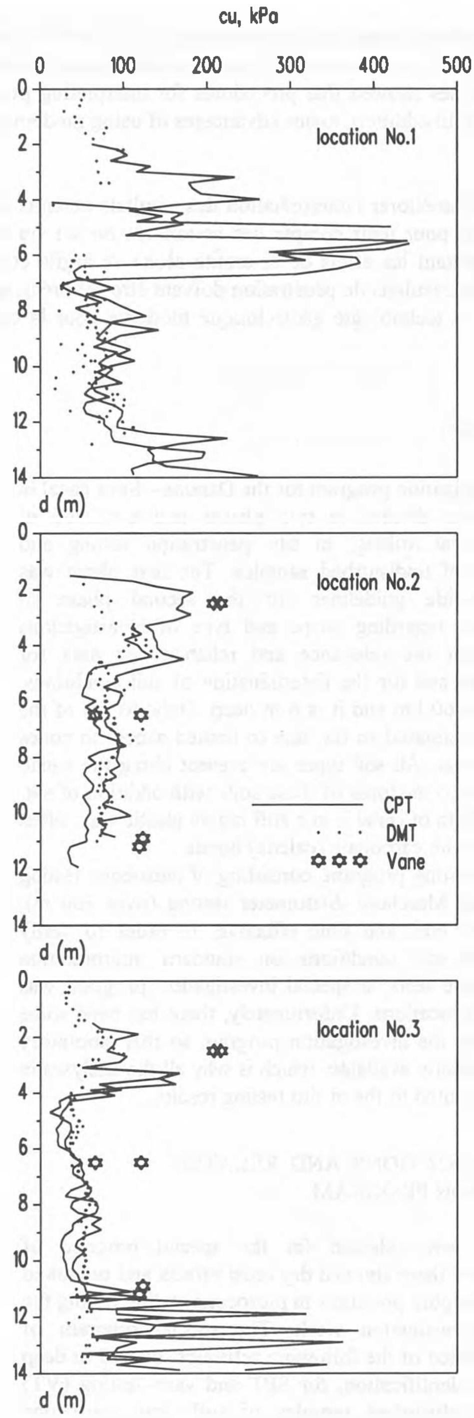

Fig. 2. Undrained shear strength profiles

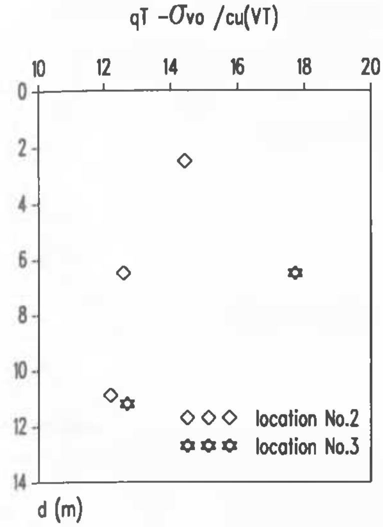

Fig.3. Cone factor for CPT shear strength

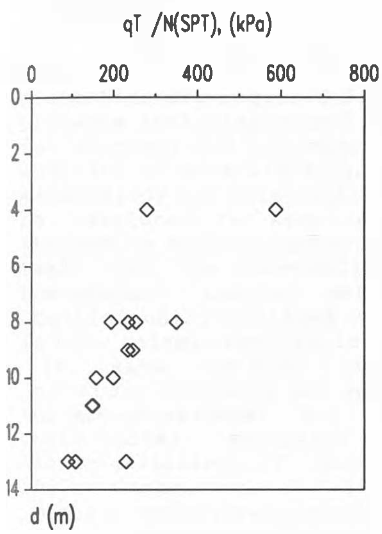

Fig.4. Corrected tip resistance related to N (SPT), all locations

DMT gave lower shear strengths in dry crust zone then CPT, but the values were quite similar below that zone.

Fig. 2. shows shear strength profiles for all locations in all three tests. CPT and VT shear strengths are additionally compared in Fig. 3. Glycerine CPT test results were used in these two figures. CPT shear strengths from Fig. 2 were calculated for clays using expression $(q_T-\sigma_{vo})/16.3$. It can be seen from Fig. 3 that the cone factor generally varies from 12 to 16, for the tested depths.

As an illustration, the ratio of corrected tip resistance to number of blows from SPT is presented in Fig. 4. This value is between 100 and 200 (q_T in kPa). A normalisation with plasticity would probably improve the correlation.

5. CONCLUSION

In situ penetration testing was extensively used and it was found to be very cost and time effective for investigating soil conditions along 40 km long part of the future Danube - Sava canal. A special testing program was conducted at three locations so as to take into account local soil conditions when interpreting in situ penetration test results (CPT and DMT). The locations were selected as representative zones of stiff clay having dry crust effects in 3-6 m near the surface.

The following conclusions may be drawn from the analyses of in situ test results:

- CPT and DMT can well recognize and reflect conditions in stiff clays, with good repeatability
- CPT is more sensitive to dry crust effects then DMT is
- both CPT and DMT tend to misinterpret clay as sand (or silt) in dry crust zones
- negative pore pressures in CPT soundings with glycerin are not significantly affected by the distance between test starting depth and GWL
- slot filter CPT test should be further investigated before being accepted as a routine test
- undrained shear strengths obtained by CPT and DMT are similar in value except in dry crust zone where CPT values are considerably higher; both values are lower then VT values
- the undrained shear strength from vane test (VT) could be higher then real values due to difference in the mode of failure around vane (bigger "soil cylinder" then vane) and theoretical assumptions
- laboratory test results, presently missing, will enable better analyses and correlations
- CPT and DMT are powerful tools for the investigation of site conditions and should be used taking into account local soil conditions

6. REFERENCES

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