FIELD VANE TEST WITH NEW STANDARD

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ABSTRACT

New geotechnical investigation and testing standard EN ISO 22476-9:2020 Field vane test (FVT and FVT-F) provides necessary requirements for the test. It introduces various test equipment configurations without classifying their suitability or accuracy for specific ground conditions in details. Observing numerous failed FVTs was led to a research project to improve test specifications by the Finnish Transport Infrastructure Agency. The results show that test reliability can be improved by moderate upgrading device and procedure. The improvements are mirrored in the standard specifications. Despite the standard providing necessary basis for the test, the operator and geotechnical designer need specific knowledge to be able to assess the test results the reliability of shear strength measurements.

1. INTRODUCTION

New geotechnical investigation and testing standard EN ISO 22476-9:2020 "Field vane test (FVT and FVT-F)" was published three years ago as the last one of the main field test methods in geotechnics [1]. Active Nordic working group members and the project manager guaranteed that the new standard very well corresponds to the Nordic practices, and it also considers the Danish special heavy duty vane device (FVT-F).

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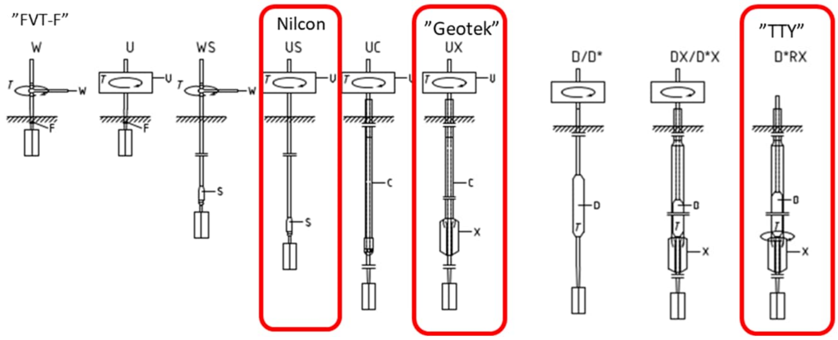

Figure 1. Test equipment configurations in EN ISO 22476-9:2020 [1]. The configurations to be discussed are highlighted and named.

The standard introduces various test equipment configurations without classifying their suitability or accuracy for specific ground conditions in details. In a FTIA (Finnish Transport Infrastructure Agency) project dealing with stability assessment of existing railway embankments called "RATUS", FVT results that indicate unrealistic low soil strength measured with US configuration test equipment were often observed [7]. Such results were common in silty soil layer units, typically beneath clay units, but also in full depth of soft soil unit composed of lean to fat clay. When the undrained soil strength being the most essential parameter in embankment stability analyses, it was necessary to improve the test method.

2. FIELD VANE TESTS IN FINLAND

In Finland, Field vane test (FVT) has been the main test method to measure undrained shear strength of soft clays and silty soils since the beginning of 1960's. It has also been utilized to measure shear strength in peat and in organic soils. At first the devices were equipped with torque wrench and later with torque measuring unit such as the Nilcon type [5]. During the past 20 years, multipurpose tracked sounding machines were equipped with electronic units to carry out vane rotating and torque moment measuring without any significant improvements on the test execution itself.

The test method was investigated in Tampere University in the beginning 2010's. The focus was on US type "Nilcon" device, which was the most common FVT test equipment. Slip coupling device misfunctioning was the major finding in the study. Slip coupling is sensitive to poor maintenance and cheaper quality devices were also discovered to enter the market [7].

In addition to the equipment condition and maintenance, the role of qualified operators was emphasized in discussion. Execution practice on site has a crucial role; That is, pushing into test depth and vane rotating with careful and precise manner without forcible movements. One relevant quality risk with uphole test is twisting of extension rods. Increase of testing depth also adds to the twisting. If casing is not used, bending of extension rods is not ensured.

FVT extension rods are small in diameter, only 22 mm. During the down pushing and series of shearing test in previous testing depth, the rods may not maintain straight linear line without the casing. Several meters long extension rods behave as torsion spring during the test and recorded readings may have little to do with actual soil strength.

Following to Geotek ltd proposal, FTIA tested improved configuration of Nilcon equipment: slip coupling was removed, and the device was equipped with protective shoe for vane and rod casing (Figure 2). The configuration corresponds with new "UX" category [1]:

- Continuous uphole measurement of torque versus rotation
- Transfer of torque by uncased extension rods with a slip coupling
- Torque – apparent rotation
- Electrical rotation unit

Figure 2. Upgraded "Geotek" field vane equipment of UX category with protective shoe and casing.

3. FIELD TEST RESULTS

FTIA ordered from Tampere University and Geotek Ltd field tests at three sites at Perniö, Kotka and Murro. Perniö site (in south-western Finland) is characterized with slightly over-consolidated fat clay with water content of 80 to 110%. Kotka (in south-eastern Finland) fine soil units compose of lean and fat clays with water content of 50 to 100%. Murro represent typical Österbotten clayey silts with low organic content and lean clay units in deeper depths. Water content is mostly 45 to 70%. The ground conditions are described in further detail in the reference studies [3] [4] [6].

In the field tests Tampere University executed two to three test parallel profiles (labelled as “TTY”). Geotek executed three parallel profiles and an additional one by resting time of 1 hour after the vane blade was pushed down to the test depth (Figure 3)

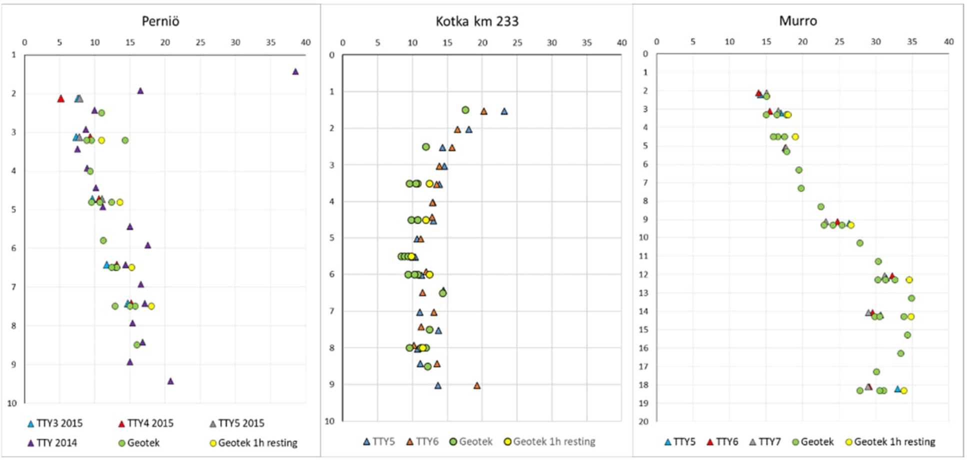

Figure 3. Field vane strength (kN/m²) versus depth (m) results at Perniö, Kotka and Murro sites carried out by Tampere University (TTY) and Geotek Ltd.

As presented in Figure 3, test results show that the upgraded Nilcon to UX device ("Geotek”) can provide similar soil strength as Tampere University’s D*RX downhole device. In Kotka the earlier site investigations indicated that the field vane strength is only 6 to 10 kPa measured with Nilcon device; i.e, some 50% of the latest measurements. On the other hand, in Murro site the old test results varied from similar strength to remarkably low strength in depths of 6 m and deeper in clayey silt soil. And in Perniö results in the old and presented test are in similar range. Another interesting finding was that the measured strengths after 1h resting time were not higher than in the standard procedure test on any test site (Figure 3.). Especially in RATUS project, 1h resting time procedure have been used to compensate for soil disturbance in sensitive silty unit.

Figure 4 presents remoulded field vane strength measured TTY D*RX and Geotek UX devices. In general, results with D*RX device present lower remoulded strength compared with UX device result. The measured values of UX type are significantly higher than measured by the D*RX device although the absolute difference is in similar scale of magnitude as the measured peak strengths differences.

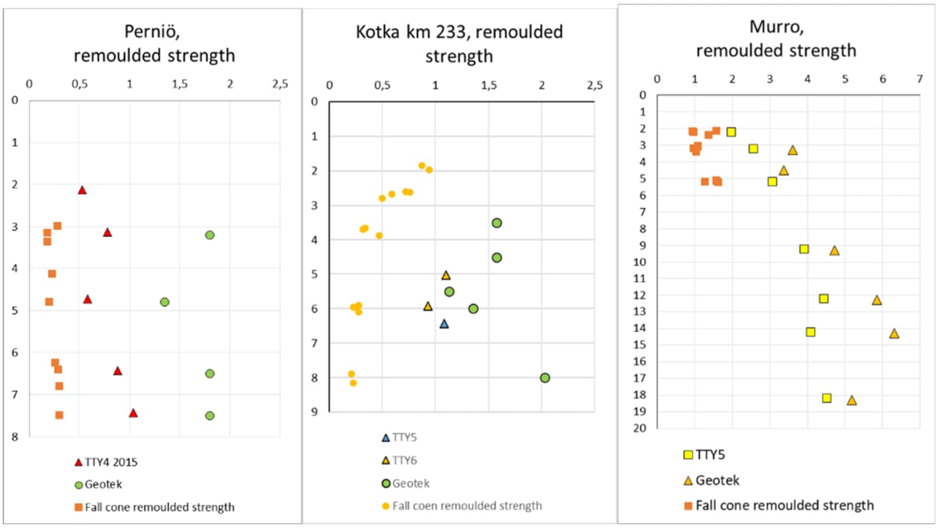

Figure 4. Remoulded field vane strength (kN/m^2) versus depth (m) results at Perniö, Kotka and Murro sites carried out by Tampere University (TTY) and Geotek Ltd and their comparison with fall cone remoulded strength.

When the field vane tests are compared with fall cone test results, the difference can be considered remarkable. Fall cone test results indicate that remoulded strength is approximately 25…35 % of remoulded strength of results measured by the D*RX device. The difference is even greater when compared to UX measurement. The difference between remoulded vane strength and fall cone remoulded strength is also influenced by different test boundary conditions.

Figure 5 presents another type of problem that was recently identified. Quite high soil strength is measured under embankment slope and old replacement fill. A geotechnical designer may trust in such a result, unless the unusually high remoulded strength is recognized as an indication of quality problem. In this case, the torsion moment-rotation angle graphs provided essential data of the test and proved that the natural strength of soil is not being measured at all. This complete data is not normally available for designers. Possible soil was intruded between the casing and extension rods causing extremely high remoulded strength too. The protection shoe or lower part of casing should be designed so that it prevents soil intrusion inside the casing without increasing external friction.

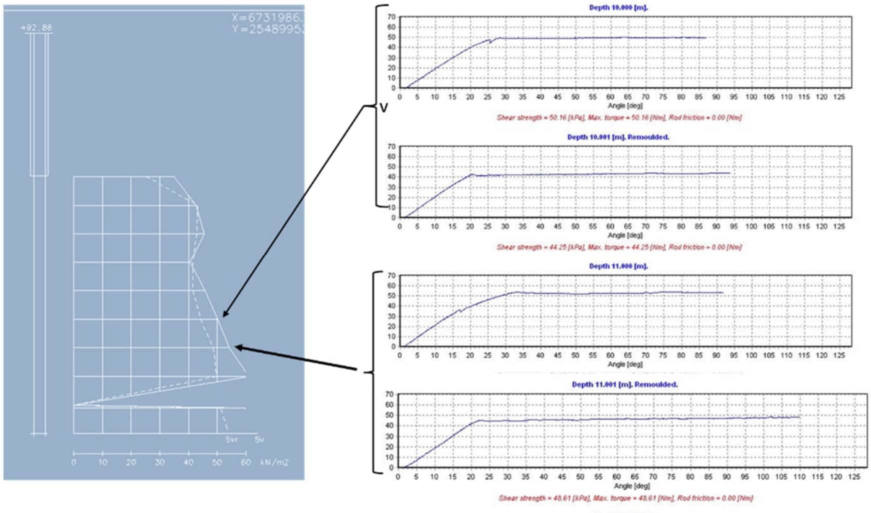

Figure 5. Field vane strength (kN/m^2) versus depth (m) and torsion moment versus rotation angle in two depths as examples.

4. DISCUSSION AND CONCLUSIONS

FTIA field test results demonstrate that in typical Finnish soft soil conditions a qualified operator can reach similar investigation test results with the moderately upgraded Nilcon field vane ("Geotek") compared to the sophisticated and high-quality commercial D*RX device used by Tampere University.

The tests indicate that with UX or D/D* type devices a better straightness of the rod system is ensured via casing due to the greater bending stiffness for inner rods. Moreover, the external friction can be remarkably reduced. In addition to mechanical support, the protection shoe can provide cleaner vane blades when penetrating through sticky soil units.

The remoulded strength comparison shows that the strength of fall cone tests is significantly lower that field vane test indicates. Determining the sensitivity based on field vane tests may lead to under estimation of risks related to subsoil disturbance.

The most important factor for high quality FVT results is the operator. FVT execution requires a person who has knowledge of all the factors that have influence on test results. The operator needs time to carry out this sensitivity test in a careful manner and to conduct the system checks before testing.

Finnish Geotechnical Society (SGY) has published a new national guideline in which the new standard requirements are adopted and the findings of the trial tests, with UX and D*RX devices, are considered [2]. The new guideline also gives practical guidance for the operators for checking equipment and to maintain good quality in testing. According to the FTIA's experience, the quality of FVT results have improved since the request for UX devices was published in 2017, but results with unrealistic low strength do occasionally occur.

New EN1997 states that in Ground investigation report, the geotechnical designer shall verify that ground investigation is executed according to the relevant standard. EN ISO 22476-9:2020 provides excellent bases for FVT, when it defines all the basic test parameters and execution procedure. Unfortunately, it cannot support the operator or geotechnical designer assessing the test results. They still need deep knowledge of test and possibility to assess the results from measured data.

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