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Ground investigation and testing — Field testing —

Part 9: **Field vane test (FVT and FVT-F)**

Reconnaissance et essais géotechniques — Essais en place —

Partie 9: Essai au scissomètre de chantier

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Foreword

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This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*.

A list of all parts in the ISO 22476- series can be found on the ISO website.

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Introduction

The field vane test is used to determine the vane shear strength of soils in the undrained condition, by insertion of a rectangular vane into fine-grained soil and rotating it. During rotation, the torque and rotation can be measured, depending on the test configuration. From the measured torque and the dimensions of the vane, the peak shear strength, an indication of post-peak behaviour and the remoulded shear strength can be derived by limit equilibrium analysis. Soil sensitivity can be ascertained if peak and remoulded shear strengths have been determined.

The tests are carried out in boreholes, in trial pits and with pushed-in equipment. Torque and rotation are measured either above the ground surface using extension rods; or directly above the vane.

The field vane test is mainly applicable to saturated fine-grained soil. The vane shear strength determined by the test is commonly corrected before geotechnical analysis, using factors based on local experience.

Ground investigation and testing — Field testing —

Part 9: Field vane test (FVT and FVT-F)

1 Scope

This standard deals with the equipment requirements, execution and reporting of field vane tests for the measurement of peak and remoulded vane shear strength together with the sensitivity of fine-grained soils. In addition, post-peak shear strength behaviour can be evaluated. Two types of field vane test are described; the ordinary field vane test (FVT) and the fast field vane test (FVT-F).

The uncertainties of the vane test result are described in Annex C.

NOTE 1 This part of ISO 22476 fulfils the requirements for field vane tests as part of the geotechnical investigation and testing according to EN 1997-1 and EN 1997-2

NOTE 2 This part of ISO 22476 covers onshore and nearshore field vane testing

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10012:2003, *Measurement management systems — Requirements for measurement processes and measuring equipment*

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 14688-2, *Geotechnical investigation and testing — Identification and classification of soil — Part 2: Principles for a classification*

ISO 22475-1, *Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 General

3.1.1
Cased extension rod
Extension rods that are sleeved inside of protective casings during vane testing.

3.1.2
Cased borehole
Borehole that is cased to prevent collapse and minimize friction between the extension rods and soil.

3.1.3
Centralizer
Equipment to keep the extension rods straight and prevent buckling.

3.1.4
Data acquisition system
Measuring system, which converts physical quantities to digital format.

Note 1 to entry: The system typically includes sensors, signal conditioning, AD converter and recording unit.

3.1.5
Downhole test
Test configuration whereby the torque is measured close to the vane. The rotation can be measured close to the vane or above the ground surface.

3.1.6
External friction torque
Torque due to friction outside the measuring equipment during rotation excluding torque caused by shearing of soil. External friction is mainly caused by friction acting on extension rods and it can be estimated with a slip coupling immediately before engagement of the vane.

3.1.7
Friction reducer
A ring inserted between the vane and the extension rods to reduce friction along uncased extension rods.

3.1.8
Insertion length
Distance from the ground surface or base of (bore)hole or trial pit to mid-height of the vane, measured along the axis of the extension rods.

3.1.9
Internal friction torque
Torque due to friction inside the measuring equipment during rotation when there is no torque acting on the vane and no friction acting on the extension rods.

3.1.10
Penetration length
Sum of the lengths of the extension rods, the vane shaft and the distance to mid-height of the vane, relative to a fixed horizontal plane (normally the ground surface).

3.1.11
Protection shoe
Equipment to protect the vane while pushing into the soil. It assists with the insertion of the vane without drilling. Usually, the tip of the protection shoe consists of four plate slots allowing the vane plates to retract inside of the protective casing.

3.1.12
Protective casing
Tubes that isolate the extension rods from the soil and give support against buckling.

3.1.13
Protrusion length
Distance between the bottom of the protective casing/shoe and the mid-height of the vane when pushed to the test depth, measured along the axis of the rods.

3.1.14
Push-in equipment
Equipment to push the vane into the soil without predrilling.

3.1.15
Rotation
Change of angle by the circular movement of the vane around its axis.

Note 1 to entry: Apparent rotation is the rotation recorded by the rotation measurement equipment.

3.1.16
Rotation rate
Rate of angular rotation of the vane.

3.1.17
Slip coupling
Mechanism that allows the extension rods to rotate freely while the vane remains stationary.

3.1.18
Test depth
Vertical distance from the ground surface, reference level or datum to mid-height of the vane.

Note 1 to entry: According to Annex F, the penetration length can be corrected with inclinometer measurements to correspond the test depth. Otherwise, the test depth is based on the penetration length owing to the uncertainty of inclination.

3.1.19
Test location
Plan position of a test or series of tests.

3.1.20
Test type
Two types of field vanes test can be distinguished; ordinary field vane test (FVT) and fast field vane test (FVT-F).

3.1.21
Time to failure
Time from the beginning of application of torque to the vane until the maximum torque is reached.

3.1.22
Uncased extension rods
Extension rods that are not protected by protective casing allowing friction to develop between the extension rods and the soil.

3.1.23
Uncased vane
The vane pushed into the ground without protection.

3.1.24
Uphole test
Test configuration whereby the torque is measured above the ground surface. The rotation is applied and measurements registered above the ground surface.

3.1.25
Vane
Four vane plates fixed at 90˚ to each other.

3.1.26
Vane plate
Thin and flat rectangular plate.

Note 1 to entry: Most vanes have a (nearly) rectangular shape. For practical reasons, vanes without protection shoes often have slightly tapered lower ends of the vane plates or with rounded corners. Some equipment using uncased extension rods and a slip coupling to separate the rod friction from the torque on the vane are designed with slightly tapered, sharpened, pointed or conical, vane plates in order to disengage the slip coupling during the pushing stroke.

3.1.27
Vane shaft
Cylindrical element of the vane to which the vane plates are fixed. The vane shaft may be connected directly to the force or torque measurement equipment in a downhole test or connected to it via extension rods in an uphole test.

3.1.28
Waiting time
Time between reaching the test depth and beginning of application of the torque to the vane.

3.1.29
Zero shift
Difference between the internal friction torque readings of the measuring equipment prior and after completion of the test.

3.1.30
Sensitivity
The ratio between the undisturbed and remoulded undrained shear strengths.

3.2 Symbols

Symbol	Name	Description	Unit
$A_{cone,bott}$		Lateral shear surface area of the bottom cone	mm^2
$A_{cone,top}$		Lateral shear surface area of the top cone	mm^2
$A_{cylinder}$		Lateral shear surface area of the cylinder	mm^2
c_u	Undrained shear strength	Shear resistance of fine-grained soils in the undrained condition	kPa
c_{fv}	Field vane strength	Peak shear strength of soil, derived from the maximum torque measured by field vane test	kPa
c_{pv}	Post-peak field vane strength	Post-peak shear strength of soil, selected after desired rotation after field vane strength	kPa
c_{rv}	Remoulded field vane strength	Shear strength, as measured by field vane test, after remoulding the soil	kPa
$c_{fv\text{-}f}$	Fast field vane strength	Peak shear strength of soil, derived from the maximum torque measured by fast field vane test	kPa
D		Diameter of the vane	mm
d		Diameter of vane shaft immediately behind vane	mm
D_c		Diameter of lower end of protective casing	mm
D_{ps}		Diameter of protection shoe	mm
H		Height of the vane	mm
H_t		The height of the vertical side of the tapered vane excluding the height influence of tapering(s).	mm
i_T		Angle of taper at vane top	°
i_B		Angle of taper at vane bottom	°
l	Penetration length	sum of the lengths of the extension rods, the vane shaft and the distance to mid-height of the vane, relative to a fixed horizontal plane	m
R_a	Area ratio	Cross sectional area ratio of vane and vane shaft compared to circular shear surface	-
r		Radius of rounded corner of the vane plate	mm
$r_{cone,bott}$		Lever arm of lateral surface of the bottom cone of shear surface	mm
$r_{cone,top}$		Lever arm of lateral surface of the top cone	mm
$r_{cylinder}$		Lever arm of lateral surface of the cylinder	mm
s_{fv}	Field vane sensitivity	The ratio between the field vane and remoulded field vane strengths	-
s		Thickness of the vane plates	mm
T_{int}	Internal friction torque reading prior to test	Stable output of a measuring equipment during rotation when there is no torque acting on the vane and no friction acting on the extension rods	Nm

Symbol	Name	Description	Unit
T_{ext}	External friction torque reading	Stable output of a measuring equipment during rotation when there is no torque acting on the vane (usually measured prior to the vane engagement by slip coupling)	Nm
τ	Shear stress		kPa
T		Torque measured during vane rotation, corrected for external friction torque reading	Nm
$T_{cone,bott}$		Torque caused by shearing of bottom cone of shear surface	Nm
$T_{cone,top}$		Torque caused by shearing of top cone of shear surface	Nm
$T_{cylinder}$		Torque caused by shearing of cylindrical shear surface	Nm
T_{corner}		Torque caused by shearing of a quarter circular shear surface	Nm
T_{max}	Maximum torque	Torque required to obtain failure in soil around the vane, corrected for internal and external friction torque reading(s) if relevant	Nm
$T_{meas,max}$	Maximum measured torque	Measured torque required to obtain failure in soil around the vane including external friction. The maximum torque (T_{max}) can be calculate by subtracting T_{ext} from $T_{meas,max}$ ($T_{max} = T_{meas,max} - T_{ext}$) otherwise $T_{meas,max}$ is T_{max}	Nm
T_{plate}		Torque caused by shearing of circular plate shear surface	Nm
T_{pv}	Post-peak torque	Post-peak torque selected after maximum torque, corrected for internal and external friction torque reading(s) if relevant	Nm
$T_{meas,pv}$	Measured post-peak torque	Measured post-peak torque selected after desired rotation after maximum torque including external friction torque. The post-peak torque is calculated by subtracting T_{ext} from $T_{meas,pv}$ ($T_{pv} = T_{meas,pv} - T_{ext}$) otherwise $T_{meas,pv}$ is T_{pv}	Nm
T_{rv}	Torque for remoulded conditions	Measured constant torque value after remoulding the soil, corrected for internal and external friction torque reading(s) if relevant	Nm
$T_{meas,rv}$	Measured torque for remoulded conditions	The constant measured torque value after remoulding including external friction torque. The torque for remoulded condition is calculated by subtracting T_{ext} from $T_{meas,rv}$ ($T_{rv} = T_{meas,rv} - T_{ext}$) otherwise $T_{meas,rv}$ is T_{rv}	Nm
α		measured total angle between the vertical axis and the axis of the vane	°
β_1		measured angle between the vertical axis and the projection of the axis of the vane on a fixed vertical plane	°
β_2		measured angle between the vertical axis and the projection of the axis of the cone penetrometer on a vertical plane that is perpendicular to the plane of angle β_1	°

4 Equipment

4.1 Test configurations

The test equipment includes a vane and vane shaft, extension rods, rotation equipment and a rotation/torque measuring equipment, configured in a number of combinations, see Figure 1.

Accessories to the vane equipment may include:

— a protective casing (C)

— a protective casing with protection shoe (X)

— friction reducer (F)

— a slip coupling (S)

which are used to increase the insertion or the penetration length that can be achieved and also will reduce the friction in the system. In addition, borehole casing may be used to allow predrilling prior to the insertion of the vane.

Vane test may be performed in either uphole or downhole configurations. Typical configurations are illustrated in Figure 1 and locations of torque and rotation measurements, torque transfers and accuracy of rotation measurements are explained in Table 1.

In the uphole configuration, torque (T) can be measured by a torque wrench or a dial indicator spring with variable lever arm (W) or by a continuous torque measuring equipment (U) located above ground surface at the point for insertion of the vane. For reading with an indicator spring, correction is needed due to the variation of the lever arm.

In the downhole configuration, the torque measuring equipment is located close to the vane, but the rotation can be measured either close to the vane (D*) or above ground surface (D). The rotation unit can be located close to the vane (R) or above the ground surface.

In the downhole configuration, the measuring unit can be covered by larger protective casing and the unit is installed between the vane shaft and the extension rods.

