INTERNATIONAL STANDARD

ISO 22476-9

First edition
2020-09

Geotechnical 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

Reference number
ISO 22476-9:2020(E)

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Foreword

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This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical Investigation and Testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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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 the 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 a 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. The 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.

Geotechnical investigation and testing — Field testing —

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

1 Scope

This document 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 D.

NOTE 1 This document 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 document covers onshore and nearshore field vane testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Measurement management systems — Requirements for measurement processes and measuring equipment*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
cased extension rod
extension rod that is sleeved inside of *protective casings* (3.1.11) during *vane* (3.1.23) 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, an analogue-to-digital converter and recording unit.

3.1.5
downhole test
test configuration whereby the torque is measured close to the *vane* (3.1.23)

Note 1 to entry: The *rotation* (3.1.14) 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* (3.1.14) excluding torque caused by shearing of soil

Note 1 to entry: External friction is mainly caused by friction acting on extension rods, and it can be estimated with a *slip coupling* (3.1.16) immediately before engagement of the *vane* (3.1.23).

3.1.7
friction reducer
ring inserted between the *vane* (3.1.23) and the extension rods to reduce friction along *uncased extension rods* (3.1.20)

3.1.8
insertion length
distance from the ground surface or base of (bore)hole or trial pit to mid-height of the *vane* (3.1.23), measured along the axis of the extension rods

3.1.9
internal friction torque
torque due to friction inside the measuring equipment during *rotation* (3.1.14) when there is no torque acting on the *vane* (3.1.23) and no friction acting on the extension rods

3.1.10
protection shoe
equipment to protect the *vane* (3.1.23) while pushing into the soil

Note 1 to entry: 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* (3.1.24) to retract inside of the *protective casing* (3.1.11).

3.1.11
protective casing
tube that isolates the extension rods from the soil and gives support against buckling

3.1.12
protrusion length
distance between the bottom of the protective casing/shoe and the mid-height of the *vane* (3.1.23) when pushed to the *test depth* (3.1.17), measured along the axis of the rods

3.1.13
push-in equipment
equipment to push the *vane* (3.1.23) into the soil without predrilling.

3.1.14
rotation
change of angle by the circular movement of the *vane* (3.1.23) around its axis

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

3.1.15
rotation rate
rate of angular *rotation* (3.1.14) of the *vane* (3.1.23)

3.1.16
slip coupling
mechanism that allows the extension rods to rotate freely while the *vane* (3.1.23) remains stationary

Note 1 to entry: The function of slip coupling is to separate the rod friction from vane torque resistance. A slip coupling mechanism shall provide free rotation with minimal friction.

3.1.17
test depth
vertical distance from the ground surface, reference level or datum to the mid-height of the *vane* (3.1.23)

Note 1 to entry: According to Annex G, the *insertion length* (3.1.8) can be corrected with inclinometer measurements to correspond to the corrected test depth. Otherwise, the test depth is based on the sum of the lengths of the extension rods from reference level or datum owing to the uncertainty of inclination.

3.1.18
test location
plan position of a test or series of tests

3.1.19
time to failure
time from the beginning of application of torque to the *vane* (3.1.23) until the maximum torque is reached

3.1.20
uncased extension rod
extension rod that is not protected by protective casing allowing friction to develop between the extension rods and the soil

3.1.21
uncased vane
vane (3.1.23) pushed into the ground without protection

3.1.22
uphole test
test configuration whereby the torque is measured above the ground surface

Note 1 to entry: The *rotation* (3.1.14) is applied and measurements registered above the ground surface.

3.1.23
vane
device formed by four *vane plates* (3.1.24) fixed at 90° to each other

3.1.24
vane plate
thin and flat rectangular plate

Note 1 to entry: Most *vanes* (3.1.23) have a (nearly) rectangular shape. For practical reasons, vanes without *protection shoes* (3.1.10) often have slightly tapered lower ends of the vane plates or with rounded corners. Some equipment using *uncased extension rods* (3.1.20) and a *slip coupling* (3.1.16) 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.

3.1.25
vane shaft
cylindrical element of the *vane* (3.1.23) to which the *vane plates* (3.1.24) are fixed

Note 1 to entry: The vane shaft may be connected directly to the force or torque measurement equipment in a *downhole test* (3.1.5) or connected to it via extension rods in an *uphole test* (3.1.22).

3.1.26
waiting time
time between reaching the *test depth* (3.1.17) and beginning of application of the torque to the vane

3.1.27
zero shift
difference between the *internal friction torque* (3.1.9) readings of the measuring equipment prior to and after completion of the test

3.1.28
sensitivity
ratio between the undisturbed and remoulded undrained shear strengths

3.2 Symbols

Symbol	Name	Description	Unit
$A_{\text{cone,bott}}$		Lateral shear surface area of the bottom cone	mm^2
$A_{\text{cone,top}}$		Lateral shear surface area of the top cone	mm^2
$A_{cylinder}$		Lateral shear surface area of the cylinder	mm^2
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 field vane on a fixed vertical plane	°
β_2		Measured angle between the vertical axis and the projection of the axis of the field vane on a vertical plane that is perpendicular to the plane of angle β_1	°
C	Protective casing	Defined by term 3.1.11	
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
$c_{\text{fv-f}}$	Fast field vane strength	Peak shear strength of soil, derived from the maximum torque measured by fast 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
D	Downhole measuring equipment	Equipment for measuring torque and rotation are located close to the vane	
D*	Downhole measuring equipment	Equipment for measuring torque is located close to the vane, but equipment for measuring rotation is located above the ground surface	
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
F	Friction reducer	Defined by term 3.1.7	
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 the taper at vane top	°
i_{B}		Angle of the taper at vane bottom	°

Symbol	Name	Description	Unit
R	Rotation unit	Rotation unit can be located close to the vane or above the ground surface	
R_a	Area ratio	Cross-sectional area ratio of vane and vane shaft compared to circular shear surface	—
r		Radius of the rounded corner of the vane plate	mm
$r_{cone,bott}$		Lever arm of the lateral surface of the bottom cone of shear surface	mm
$r_{cone,top}$		Lever arm of the lateral surface of the top cone	mm
$r_{cylinder}$		Lever arm of the lateral surface of the cylinder	mm
S	Slip coupling	Defined by term 3.1.16	
S_{fv}	Field vane sensitivity	The ratio between the field vane and remoulded field vane strengths	—
s		Thickness of the vane plates	mm
T	Torque	Torque measured during vane rotation, corrected for external friction torque reading	Nm
$T_{cone,bott}$		Component of torque required to shear the bottom cone of the shear surface	Nm
$T_{cone,top}$		Component of torque required to shear the top cone of the shear surface	Nm
T_{corner}		Component of torque required to shear a quarter circular shear surface	Nm
$T_{cylinder}$		Component of torque required to shear the side surface of the cylinder	Nm
T_{ext}	External friction torque reading	Stable output of measuring equipment during rotation when there is no torque acting on the vane (usually measured prior to the vane engagement by slip coupling)	Nm
T_{ext^*}	External friction torque reading after remoulding the soil	Stable output of measuring equipment during rotation after remoulding the soil when there is no torque acting on the vane (usually measured prior to the vane engagement by slip coupling)	Nm
T_{int}	Internal friction torque reading prior to test	Stable output of measuring equipment during rotation when there is no torque acting on the vane and no friction acting on the extension rods	Nm
T_{max}	Maximum torque	Torque required to obtain failure in the 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 the soil around the vane, including external friction. The maximum torque (T_{max}) can be calculated by subtracting T_{ext} from $T_{meas,max}$ ($T_{max} = T_{meas,max} - T_{ext}$) otherwise $T_{meas,max}$ is T_{max}	Nm
$T_{meas,pv}$	Measured post-peak torque	Measured post-peak torque selected after the desired rotation (post peak strength measurement) 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
$T_{meas,rv}$	Measured torque for remoulded conditions	The constant measured torque value after remoulding including external friction torque. The torque for the 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
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_{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

Symbol	Name	Description	Unit
τ	Shear stress	Stress acting along the failure surface due to external shear force	kPa
U	Uphole measuring equipment	A continuous torque measuring equipment located above the ground surface at the point for insertion of the vane	
W	Mechanical measuring device	A torque wrench or a dial indicator spring with variable lever arm	
X	Protective casing with protection shoe	Protective casing defined by term 3.1.11 and accordingly protective shoe by term 3.1.10	

4 Equipment and configurations

4.1 Test equipment

The test equipment shall include a vane and vane shaft, extension rods, rotation unit and a rotation/torque measuring equipment.

Accessories to the test equipment may include:

— a friction reducer;

— a slip coupling;

— a protective casing;

— a protective casing with protection shoe,

which are used to increase the insertion length that can be achieved and will reduce or enable to measure the friction in the system.

4.1.1 Vane and vane shaft

The vane shall consist of four identical vane plates fixed at 90° to each other with a tolerance of ±1°, see Figure 1.

NOTE 1 For practical reasons, uncased vanes can have rounded corners or can be tapered.

The shape should be rectangular with an H/D ratio of 2.

NOTE 2 An example of a mould to measure and verify the dimensions and H/D ratio requirements of the vane is given in Annex C.

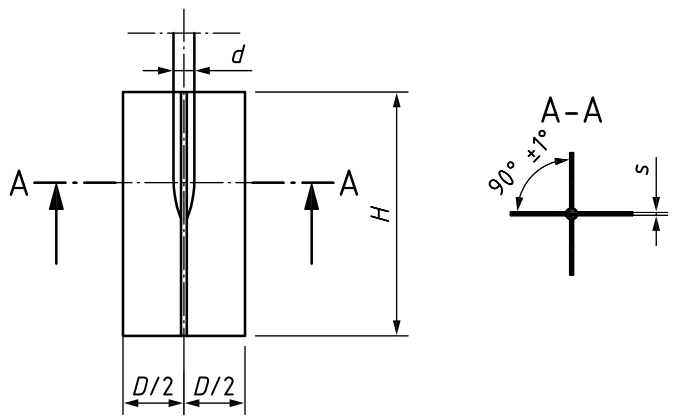
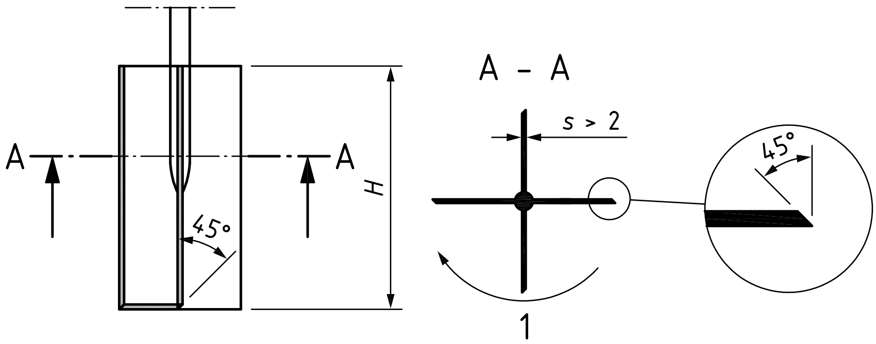


Figure 1 — Principal design of the vane

For testing of soils with a sensitivity more than 30, the vane plate thickness *s* shall not exceed 2 mm. For testing of soils with a sensitivity less than 30, the vane plate thickness may be thicker but shall not exceed 3 mm. For vane plates with a plate thickness exceeding 2 mm, the vane edges shall be sharpened with 45° edges, as shown in Figure 2.

Dimensions in millimetres



Key

1 rotation direction

Figure 2 — Principle for sharpening the vane blades for rectangular vane

The diameter of the vane shaft immediately behind the vane should be less than 16 mm for testing soils with a sensitivity more than 15 and at a maximum 20 mm for testing soils with sensitivity less than 15.

The diameter of the vane shaft, including welding seams in the centre of the vane, shall be small enough to minimize the effects of disturbance on the measured torque.

NOTE 3 Disturbance causes a loss of peak shear strength of fine-grained soil, which increases with increasing sensitivity of the soil.

The length of the vane shaft above the vane shall be at least 5 times the difference of the diameter of the friction reducer/slip coupling/extension rod and the diameter of the vane shaft for testing soils with a sensitivity higher than 15.

NOTE 4 For non-sensitive soils, the friction due to the vane shaft can be reduced by assembling a friction reducer or slip coupling close to the vane, as the disturbance is not as relevant.

The diameter of the vane shaft can gradually increase to the diameter of the friction reducer/slip coupling/extension rods over the length of the vane shaft.

4.1.2 Friction reducer

The diameter of the friction reducer shall be at least 15 % larger than the diameter of the extension rods to reduce the friction between the extension rods and the adjacent soil.

4.1.3 Slip coupling

The slip coupling should be equipped with bearings. The structure shall prevent soil from entering the slip coupling.

The distance between the top edges of the vane plates and bottom part of the slip coupling should be at least 5 times the difference of the diameter of the vane shaft and the slip coupling.

4.1.4 Extension rods, protective casings, protection shoe

Extension rods shall have a torsional stiffness large enough to transmit torque from the rotation unit to the vane. Joints, through which torque is transferred, shall be tightened to a higher torque than needed to reach the maximum torque in the soil.

