Designation: D2573 – 08

StandardTest Method for
Field Vane Shear Test in Cohesive Soil[1]

This standard is issued under the fixed designation D2573; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers the field vane test in saturated clay and silt soils for determination of undrained shear strength. Knowledge of the nature of the soil in which each vane test is to be made is necessary for assessment of the applicability and interpretation of the test. The test is not applicable for sandy soils which may allow drainage during the test.

1.2 This test method addresses testing on land and for testing in drill holes or by self drilling or continuous push methods from the ground surface. This method does not address specifically marine testing where special test requirements or variations in equipment may be required. The user is referred to ASTM STP 1014 for additional information on in-place vane shear testing.[2]

1.3 This method is often used in conjunction with fluid rotary drilling (D5783) or hollow-stem augers (D6151). Some apparatuses have the vane retracted in protective shoe for advancement and incremental testing. Sampling, such as with thin wall tubes (D1587) is often combined with vane testing. Subsurface geotechnical explorations are reported in accordance with practice (D5434).

1.4 Undrained shear strength and sensitivity of cohesive soils can also be measured in Unconfined Compression D2166 and Laboratory Vane Test (D4648).

1.5 The values stated in SI units are to be regarded as the standard. English (Imperial) units are given in parentheses.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2166 Test Method for Unconfined Compressive Strength of Cohesive Soil
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4648 Test Method for Laboratory Miniature Vane Shear Test for SaturatedFine-Grained Clayey Soil
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D6151 Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling

2.2 *Other Standards:*

Recommended Standard for Field Vane Shear Test, Swedish Geotechnical Society, SGF Report 2:93E, Swedish Geotechnical Institute, Linköping: www.swedgeo.se
EuroCode 7: Geotechnical Design–Part 3 Design Assisted by Field Testing, ENV 1997-3:1999E, CEN

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of terms in this standard, refer to Terminology D653.

3.1.2 *sensitivity*—the effect of remolding on the consistency of cohesive soil.

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[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Evaluations.

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[2] ASTM STP 1014 on Vane Shear Strength Testing in Soils (1988).

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

3.1.3 *vane shear test (VST)*—an in-place shear test in which a rod with thin radial vanes at the end is forced into the soil and the resistance to rotation of the rod is determined.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *remolded undrained shear strength*—shear strength of fine-grained soil in rapid loading with little or no drainage of pore water pressure after significant failure and remolding of the initial soil structure. (Also see D2166 and D4648).

3.2.2 *undrained shear strength*—shear strength of fine-grained soil (primarily clays and clayey silts) in rapid loading with essentially no drainage of porewater pressure. (Also see D2166 and D4648).

3.2.3 *vane*—a device with four, thin, flat metal blades or plates, fixed at an angle of 90 degrees to each other, which is inserted into the soil and then rotated about a vertical axis for shear testing (see Fig. 1).

3.2.4 *vane shoe*—a section of drill casing and cutting bit at the end in which the vane can be retracted while drilling or pushing

3.3 *Symbols:*

3.3.1 In accordance with ASTM D653.

3.3.2 *shear strength,* s_u—the maximum (undrained) resistance of soil to shearing stresses.

3.4 *Symbols Specific to This Standard:*

3.4.1 *peak undrained shear strength,* $(s_u)_{fv}$—the peak undrained shearing resistance measured during the initial rotation of the vane in a vane shear test.

3.4.2 *remolded undrained shear strength,* $(s_{ur})_{fv}$—the remolded undrained shear strength is measured after five to ten vane rotations in a vane shear test.

3.4.3 *sensitivity–*$S_{T\ fv}$—the ratio of peak undrained shear strength to remolded undrained shear strength measured in the field vane shear test: $S_{T\ fv} = (s_u)f_v/(s_{ur})f_v$. The remolded shear strength is measured after large shearing strains (see 8.7 and 9.3).

NOTE 1—Previous and existing standards have specified different amounts of rotation, from 5 to 25 revolutions, for measurement of remolded strength.[2] If sensitivity is reported, the number of revolutions must also be reported. Sensitivity can also be measured in unconfined compression testing (D2166) and laboratory vane testing (D4648).

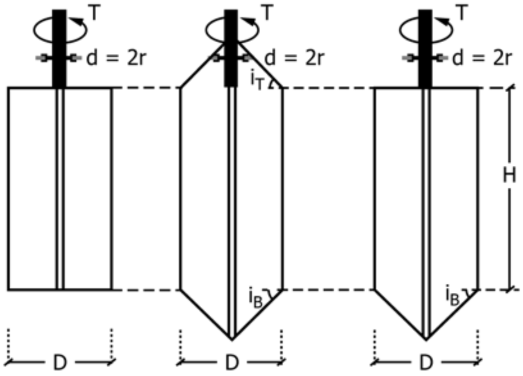


FIG. 1 Geometry of Field Vanes

3.4.4 *torque–T, (FL)*—the measured torque (or moment) required to rotate the vane.

3.4.5 *vane area ratio–*V_A*–%* —the ratio of the cross section area of the vane to the circular area of the rotated vane expressed as a percent (see Fig. 2).

3.5 *Acronyms:*

3.5.1 *VST*—vane shear test.

3.5.2 *FV*—field vane.

4. Summary of Test Method

4.1 The vane shear test consists of placing a four-bladed vane in the intact soil and rotating it from the surface to determine the torque required to shear a cylindrical surface with the vane. This torque, or moment, is then converted to a the unit shearing resistance of the failure surface by limit equilibrium analysis. Friction of the vane rod and instrument are either minimized during readings by special casings or housing, or else accounted for and subtracted from the total torque to determine the torque applied to the vane.

5. Significance and Use

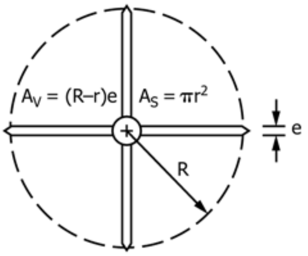
5.1 This test method provides an indication of in-situ undrained shear strength of fine- grained clays and silts or other fine geomaterials such as mine tailings, organic muck, and substances where undrained strength determination is required. The test is applicable to soils with undrained strengths of less than 200 kPa (2 tsf). Very sensitive soils can be remolded during vane insertion.

5.2 This test method is used extensively in a variety of geotechnical explorations to evaluate rapid loading strength for total stress analysis of saturated fine-grained clays and silts. The test is routinely performed in conjunction with other field and laboratory tests.

5.3 The peak undrained shear resistance of the vane test is commonly corrected to determine the undrained shear strength for geotechnical analysis. The agency requesting the testing must interpret these data to determine applicability for strength analysis. It is beyond the scope of this standard to recommend applicability of vane testing for geotechnical analysis. For information on the general use of these correction factors, consult Appendix X1.

5.4 This method is not applicable in sands, gravels, or other high permeability soils. With the shearing rates described in this standard, sand lenses, if present, will allow total or partial drainage. Soils with higher permeability, in rapid shear, can dilate or collapse and generate negative or positive pore pressures which may, or may not, dissipate in the shearing process. It is important to check the soil type being tested. It is very beneficial to sample the soil either before or after testing, to understand the drainage conditions (permeability) of the soil tested.

5.5 This test is often performed in drilled boreholes or with self-push or self-drilling or pushed (vane shoe) methods. This method also applies to hand held vane shear tests performed at shallow depths, however, hand held equipment may be less



$$V_A = \frac{4(R–r)e + \pi r^2}{\pi R^2}$$

Where: V_A = Vane Area Ratio
R = Radius of Failure Cylinder (in or mm)
r = Radius of Vane Shaft (in or mm)
e = Vane Blade Thickness (in or mm)

VANE TYPE	BLADE DIA. in (mm)	SHAFT DIA. in (mm)	BLADE THICKNESS in (mm)	AREA RATIO (%)
Miniature	0.50 (12.7)	0.1275 (3.5)	0.019 (0.05)	13.7

FIG. 2 Definition of Vane Area Ratio (ASTM D4648) (Note, r is radius of central shaft).

accurate, because it may be more difficult to maintain vane/rod stability and verticality.

NOTE 2—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Standard Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 The vane shall consist of a four-bladed vane as illustrated in Fig. 1. Vanes are normally constructed of steel. Different alloys of steel such as nickel-chromium, or steel treatment processes such as hardening, can be used to reduce blade thickness. The ends of the vane may be flat or tapered. Vane dimensions are as follows with notation from Fig. 1.

Vane Diameter, D: 35 to 100 mm (1.5 to 4 in.)
Vane Shaft Diameter, d: 12.5 to 16.5 mm (0.5 in.)
Vane Height, H: 1D ≤ H ≤ 2.5D
Taper Angle, *i*: usually 0 (rectangular) or 45 degrees (tapered)

6.1.1 For good torque resolution, select a vane diameter that is large enough to provide optimum torque resolution. The diameter selected is directly related to the consistency of the soil being tested. For softer soils, larger sizes are required for good resolution. In stiffer soils, smaller vanes are required to avoid damage to the torque measurement device (6.2). When used in drill holes, the maximum vane size is dependent on the inside diameter of the boring or casing.

6.1.2 *Blade Thickness*—Maximum blade thickness is limited to e < 3 mm (0.006 to 0.125 in.). The average thickness shall be e = 2 mm. Vane blade edge or dimension (e) on Fig. 2 can be tapered to be thinner at the edges to reduce disturbance from insertion.[2]

6.1.3 The vane shaft diameter, d (shown also as 2r in Fig. 1) above the top of the vane blades shall be less than 17 mm. The vane shaft diameter (d) shall not exceed 14 mm at the center of the vane.

6.1.4 *Vane Area Ratio*—As shown on the detail in Fig. 2, the vane blade edges and fillet rod and welds shall be sufficiently small to minimize soil disturbance during insertion. The Vane Area Ratio, V_A, must be less than 12 %. With blade tapering and tapering reduction of the vane shaft (d = 2r), V_A can be reduced less than 10 %.

6.1.5 The distance, 1, from the top edge of the vane to an increase in torque rod diameter (6.3) is 5d where d is the vane shaft diameter at the top of the vane. If a large diameter friction coupler or torque rod sleeve is used, distance 1 is 150 mm (6-in.).

6.1.6 A vane with the upper tapered edges has the advantage that the vane will not get caught on an exterior casing upon withdrawal.

6.1.7 The bottom edge of the vane blades can be sharpened to facilitate penetration into the soil. The edges of the blades can be sharpened and beveled to counter-rotate against a friction coupler (6.4).

6.2 *Torque Measurement Device*—Torque shall be applied to the rods, hence to the vane. This is accomplished with a clamping device and torque application apparatus set at the top of the rods. The accuracy of the torque reading shall be such that it will produce a variation not to exceed ±1.0 kPa (±20.9 lb/ft^2) in computed shear strength.

6.2.1 It is preferable to apply torque to the vane with a geared drive. In the absence of a geared drive, it is acceptable to apply the torque directly by hand with a torque wrench or equivalent. If torque is applied by hand an asterisk shall be placed next to the resultant shear stress and "hand torqued" shall be noted. The duration of the test shall be controlled by the requirements of 8.6.

6.2.2 Some torque measurement devices are capable of making hard copy or computer records of the load-displacement history. Other manually read systems use torque rings and dial gauges. These automatic reading systems have an advantage over manually read systems, because operator error is reduced, and a permanent record of the test is generated during the test.

6.3 *Torque Rods*—The vane shall be connected to the surface by means of steel torque rods. Typical rod diameter ranges from 18 to 25 mm (0.5 to 1 in.). These rods shall have sufficient diameter such that their elastic limit is not exceeded when the vane is stressed to its capacity (Note 3). They shall be so coupled that the shoulders of the male and female ends meet to prevent any possibility of the coupling tightening when the torque is applied during the test.

6.3.1 *Protective Casing and Vane Shoe*— Torque rods can be sleeved in an small diameter casing to reduce rod friction. If a torque rod sleeve or casing and vane shoe is used, the torque rods shall be equipped-with well-lubricated bearings where they pass through the housing.[4] These bearings shall be provided with seals that prevent soil from entering them. The casing may require venting of water pressures. The torque rods shall be guided so as to prevent friction from developing between the torque rods and the walls of the casing or the boring.

6.3.2 Rod friction measurements under no-load conditions (such as the use of a blank stem in place of the vanes, or a vane that allows some free rotation of the rod prior to loading is discouraged, however) are permissible only if the torque is applied by a balanced moment that does not result in a side thrust. As torque becomes greater during a test, a side thrust in the instrument will result in an increase in friction that is not accounted for by initial no-load readings. Instruments involving side thrust are not allowable. The vane rod may be of sufficient rigidity that it does not twist excessively under full load conditions; otherwise a correction must be made for plotting torque-rotation curves. Most steel torque rod meeting the requirements in this standard does twist during testing and requires a correction if vane rotation is to be determined.

NOTE 3—If torque versus rotation curves are to be determined, the torque rods can be calibrated. The amount of rod twist are established in degrees per meter (foot) per unit torque. This correction becomes progressively more important as the depth of the test increases and the calibration must be made at least to the maximum depth of testing anticipated. Alternately, rod twist can be calculated based on the properties of the rod. If twist is calculated, the material property assumption must be reported.

6.4 *Friction Coupling*—The connection between the vane and the rods may include a friction coupling or slip coupling device. This device is used with single rod systems where the vane may be advanced far in advance of the protective casing. This device is designed not to engage the vane until a certain amount of rotation, typically 15 degrees has occurred, and thus allows for determination of rod friction prior to the test. Use of this coupling is preferred over blank rod testing for determination of rod friction, because measurements are made directly in the soil tested.

6.5 *Centralizers*—For tests performed in drill holes, it will be necessary to equip the torque rods with centralizers to assure a vertical push and to prevent torque rod buckling. They are designed to support the rods, while minimizing any rod friction when deflected. Centralizers must be smaller in diameter than the drill hole. They shall be designed to allow the passage of drill fluids.

6.6 *Advancement Equipment*—When used in drill holes, the drive head and pull-down capability of the drill rig can be used to push the vane below the base of the hole. Some equipment is designed to push the vane from the surface. It is important to push the vane vertically and straight. A top centralizer and rod centralizers can be used with casings to assure straight push.

6.7 *Reaction Casing*—In drill hole applications, where the torque head clamps to the casing, it may be necessary to use an upper finned casing to assure torque reaction. Typically, hollow stem augers (D6151) provide sufficient reaction for a torque head without fins. The need for casing reaction can be determined by slippage of the casing or augers during testing causing periodic/intermittent drops in torque. If slippage occurs, use finned casing, or perform less cleaning of the augers flights.

6.8 *Vane Housing/Casing*—Some vane systems are designed to retract into a casing equipped with a cutting bit (four-bladed drag bit). Fluid can be circulated through the cutting bit. When the test depth is reached, the vane can be pushed into the test interval.

7. Calibration

7.1 The torque measurement device is calibrated by inserting a rod with a moment wheel in the device. Known weights (w) are hung from the wheel with set radius (R_w), and the torque measurements are taken and compared with the applied moments ($T = W \cdot R_w$).

7.2 The torque measurement device must be calibrated at regularly scheduled intervals of time or amount of use, in accordance with a systematic quality assurance plan of the company performing the testing. Records of the calibrations of each instrument shall be maintained and available for review during testing.

7.3 If the torque measurement device is damaged or repaired, a new calibration shall be performed.

7.4 The report must include the calibration data for the instrument, date of calibration, and a note on the amount of use since the last calibration.

8. Procedure

8.1 Locate the advancement equipment over the test location. The test can be performed in a pre-drilled hole, pushing from the surface, or with drilling through a vane housing.

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[4] *Earth Manual*, Part II, Third Edition, 1990, U.S. Department of the Interior, Bureau of Reclamation, U.S. Government Printing Office.