



Designation: **D2573/D2573M – 15 D2573/D2573M – 15<sup>ε1</sup>**

## Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils<sup>1</sup>

This standard is issued under the fixed designation D2573/D2573M; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

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

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<sup>ε1</sup> NOTE—Editorially corrected [Eq 1 and 2](#) in February 2018.

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### 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 or non-plastic silts, 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 used in marine exploration.<sup>2</sup>

1.3 This method is often used in conjunction with fluid rotary drilling (D5783), hollow-stem augers (D6151), or cone penetration testing (D5778). Some apparatuses have the vane retracted in a 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 Laboratory Vane Test (D4648).

1.5 *Units*—The values stated in either SI units or inch-pound units [presented in brackets] are to be regarded separately as standard. The values in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this test method.

1.5.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The rationalized slug unit is not given, unless dynamic ( $F = ma$ ) calculations are involved.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.6.1 The procedures used to specify how data are collected/ recorded or calculated in this standard are regarded as the industry standard. In addition they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives, and it is common practice to increase or reduce significant digits or reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design.

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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<sup>1</sup> 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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<sup>2</sup> ASTM STP 1014 on Vane Shear Strength Testing in Soils (1988).

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

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

- D653 Terminology Relating to Soil, Rock, and Contained Fluids
- D1587 Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
- D2166 Test Method for Unconfined Compressive Strength of Cohesive Soil
- D2488 Practice for Description and Identification of Soils (Visual-Manual Procedures)
- D2850 Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils
- 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 Saturated Fine-Grained Clayey Soil
- D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
- D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
- 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
- D6026 Practice for Using Significant Digits in Geotechnical Data
- 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](http://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.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *remolded undrained shear strength*—shear strength of fine-grained soil in rapid loading with essentially no drainage of pore water pressure after significant failure and remolding of the initial soil structure. (Also see D2850 and D4648).

3.2.2 *undrained shear strength*—shear strength of fine-grained soil (primarily clays and plastic silts) in rapid loading with essentially no drainage of porewater pressure. (Also see D2850 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 casing and cutting bit at the end in which the vane can be retracted while drilling or pushing

### 3.3 Symbols Specific to This Standard:

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

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

3.3.3  $S_{Tfv}$ —the ratio of peak undrained shear strength to remolded undrained shear strength measured in the field vane shear test:  $S_{Tfv} = (s_u)_{fv} / (s_{ur})_{fv}$ . The remolded shear strength is measured after large shearing strains (see 8.7 and 9.2).

NOTE 1—Previous and existing standards have specified different amounts of rotation, from 5 to 25 revolutions, for measurement of remolded strength.<sup>2</sup>

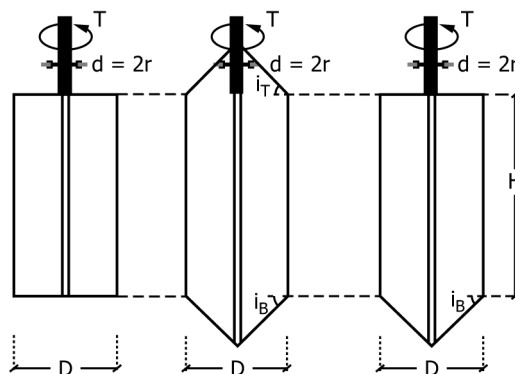


FIG. 1 Geometry of Field Vanes

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

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).

3.3.4  $T$ , (FL)—the measured torque required to rotate the vane.

3.3.5  $T_R$ , (FL)—the measured residual torque required to rotate the vane after rotating the vane for 5 to 10 revolutions.

3.3.6  $V_A$ —%—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).

3.4 *Abbreviations Specific to This Standard:*

3.4.1 VST—vane shear test.

3.4.2 FV—field vane.

**4. Summary of Test Method**

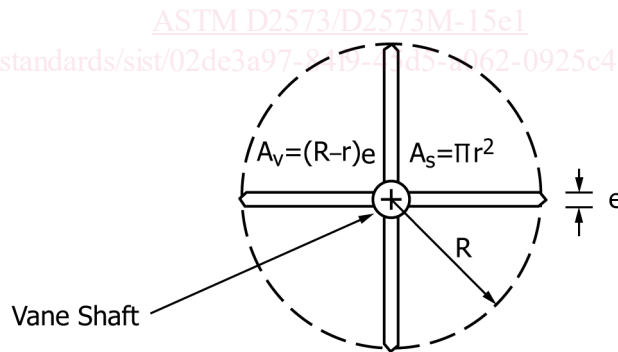
4.1 The vane shear test consists of placing a four-bladed vane in the intact soil and rotating it from the surface to determine the torque required to shear a cylindrical surface with the vane. This torque, or moment, is then converted to a unit shearing resistance of the failure surface by limit equilibrium 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 saturated fine-grained soils (clays and silts) or other saturated fine-grained geomaterials, such as mine tailings and organic muck. 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. Since vane shear strength values are most always higher than field strengths for analyses (5.3) they often are checked or compared with other methods of measuring undrained shear strength. Cone Penetrometer Tests (Test Method D5778) and Unconsolidated Undrained Triaxial Compression (D2850) tests are most often performed for direct comparison to the vane shear strength data. Unconfined Compression (D2166) testing could also be performed, but suffers from many possible errors from disturbance especially in fissured clays, and should only be performed with experience. For more information on how these tests are used for soft ground site exploration refer to Ladd and DeGroot.<sup>(1)</sup>

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.



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

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

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

<sup>4</sup> The boldface numbers in parentheses refer to a list of references at the end of this standard.

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 unsaturated soils or in non-plastic silts, 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. Unsaturated soils and 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 method also applies to hand held vane shear tests performed at shallow depths, however, hand held equipment may be less 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 *Vane*—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 [1.4 to 4 in.]  
 Vane Shaft Diameter, d: 12.5 to 16.5 mm [0.5 to 0.6 in.]  
 Vane Height, H:  $1D \leq H \leq 2.5D$   
 Taper Angle,  $\alpha$ : usually 0 (rectangular) or 45 degrees (tapered)

6.1.1 The size of the vane selected should be the largest suitable for the anticipated conditions to be encountered. The diameter selected is directly related to the consistency of the soil being tested. For softer soils, larger vane diameters, 75 to 100 mm [3 to 4 in.] are recommended and in stiffer soils, smaller vane diameters, 35 to 50 mm [1.5 to 2 in.] 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*—The vane blade shall have a thickness of 0.8 to 3 mm [0.031 to 0.118 in.]. The average thickness shall be 2 mm [0.08 in.]. Vane blade edge or dimension (e) on [Fig. 2](#) can be tapered to be thinner at the edges to reduce disturbance from insertion.<sup>2</sup>

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 20 mm [0.75 in.]. The vane shaft diameter (d) shall not exceed 14 mm [0.55 in.] at the center of the vane.

6.1.4 *Vane Area Ratio ( $V_A$ )*—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 must be less than 10 %.

6.1.5 The distance 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 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  $\pm 1.0$  kPa [ $\pm 21$  lb/ft<sup>2</sup>] in computing undrained 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.

6.3 *Torque Rods*—The vane shall be connected to the surface by means of steel torque rods. Typical rod diameters range from 18 to 36 mm [0.75 to 1.5 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. Most steel torque rods meeting the requirements in this standard do 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 is established in degrees per metre [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.

6.3.1 *Protective Casing and Vane Shoe*—When using conventional drilling methods, torque rods can be sleeved in a 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. These bearings shall be provided with seals that prevent soil from entering them. The casing may require venting of water pressures. The test setup shall prevent friction from developing between the torque rods and the walls of the casing or the boring (for example, by guiding the torque rods).

6.3.2 Rod friction measurements under no-load conditions can be performed by replacing the vanes with a blank stem only if the torque is applied by a balanced moment that does not result in a side thrust. Some practitioners suggest the use of a vane that allows some free rotation of the rod prior to loading. While this could be done to measure rod friction under no-load condition, it is not a recommended practice. 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.

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 predrilled 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.

8.2 If necessary, set a reaction casing to transfer forces to the torque head without twist or slippage.

8.3 When drilling, stop the drill hole advancement at a depth such that the vane tip may penetrate intact soil for a depth of at least five times the outside diameter of the bore hole. In the case where a vane housing is used, advance the housing to a depth at least five vane housing diameters less than the desired depth of the vane tip.

8.4 Advance the vane or vane housing from the surface or the bottom of the hole in a single thrust to the depth at which the test is to be conducted. The vane shall be pushed down without any use of blows, vibration, or rotation. No torque should be applied to the rods during the thrust.

8.5 *Friction Determinations:*

8.5.1 *Friction from Slip Couplings*—For vanes equipped with slip couplings, after pushing the vane, the first part of the test will be to apply torque and measure the force to turn the torque rods above the slip coupling. Apply the force at the same rate as the actual vane loading given in 8.6. Record the rod friction.

8.5.2 *Blank Rod Friction Tests*—In the case where soil is in contact with the torque rods, and there is no slip coupling, determine the friction between the soil and the rod by means of torque tests conducted on similar rods at similar depths with no vane attached. These tests can be performed in between vane tests. Conduct the rod friction test at each site by conducting a series of torque tests at varying depths.

8.5.2.1 When using an apparatus in which the torque rod is completely isolated from the soil (vane shoe push/drill system), testing is performed in increments. The vane is retracted in the casing, when the test zone is reached the vane is pushed out of the shoe 35 to 50 cm [14 to 20 in.]. Vane rod friction in this case should be negligible.

8.6 The time from the end of vane penetration to beginning rotation shall be no more than five minutes. With the vane in position, apply the torque to the vane at a rate of 6 deg/min. Permissible variations are in the range of 3 to 7 deg/min. This generally requires a time to failure of 2 to 5 min, except in very soft clays where the time to failure may be as much as 10 to 20 min. In stiffer materials, which reach failure at small deformations, it may be desirable to reduce the rate of angular displacement so that a reasonable determination of the stress-strain properties can be obtained. During the rotation of the vane, hold it at a fixed elevation. Record the maximum torque. With apparatus using manually read gauges, it is desirable to record intermediate values of torque at intervals of 15 s or at lesser frequency if conditions allow. Note all unusual occurrences during testing, such as slippage or shape of the loading curve.

8.7 Following the determination of the maximum torque, rotate the vane rapidly through a minimum of five to ten revolutions. The determination of the residual torque ( $T_R$ ) shall be started immediately after completion of rapid rotation and never more than 1 min after the remolding process (Note 4). Repeat the procedure in 8.6.

NOTE 4—In many sensitive clayey soils, residual torque may be obtained within one to two revolutions or less. If such soils are being tested, it is recommended that several remolded torques be obtained using the standard five to ten revolutions for verification. If no major remolded torque differences are noted, remolded torque may be obtained at less than the recommended five to ten revolutions.

8.8 When combined with rotary drilling methods it may be advantageous to take thin wall tube or double tube auger (D6151) samples over the tested interval. Over-sampling will allow for inspection of soil in the test zone. Often evidence of the shear zone can be found in the sample. If a sample is recovered and the shear zone is detected, describe the soil sample (D2488) and the soils in the shear zone.

8.9 Conduct intact and remolded vane tests at intervals between 0.50 m [2 ft] to 0.75 m [2.5 ft] throughout the soil profile when conditions will permit vane testing (Note 5). Do not conduct the vane test in any soil that permits drainage or dilates during the test period, such as stiff clays, sands or sandy silts, or soils where stones or shells are encountered by the vane in such a manner as to influence the results. Unreliable data can be evaluated by the torque rotation curves, or by subsequent sampling of the test zone.

NOTE 5—This spacing may be varied only by the agency/engineer in charge of the boring program.

## 9. Calculations

9.1 *Peak Undrained Shear Strength*—Calculate the peak undrained shear strength, ( $s_u$ )<sub>*f<sub>v</sub>*</sub>, from the maximum recorded torque for the first loading of the vane test. (See Note 6.)

NOTE 6—The peak undrained shear strength from the field vane test needs to be multiplied by a vane correction factor ( $\mu$ ) to give a mobilized field value of undrained strength ( $s_u$ )<sub>field</sub> for geotechnical analysis. It is essential in reports to discern between raw field results and corrected data. See 5.3 and Appendix XI.

9.1.1 For a rectangular vane of  $H/D = 2$ ;

$$(S_u)_{f_v} = \frac{6T}{7\pi D^3} \tag{1}$$

$$(S_u)_{f_v} = \frac{6T}{7\pi D^3} \times K \tag{1}$$

where:

$(S_u)_{f_v}$  = peak undrained shear strength from the vane, kPa [lbf/ft<sup>2</sup>],

$T$  = maximum value of measured torque ( $T_{max}$ ) or residual torque ( $T_R$ ) corrected for apparatus and rod friction, N·m [lbf·ft],

$D$  = vane diameter, mm [in.] (Fig. 1), and

$K$  =  $1 \times 10^6$  (SI units) and 1728 (inch-pound units).

9.1.2 *For Tapered and Other Vanes*—The general expression for rectangular, both ends tapered, bottom taper only, as well as rhomboidal vanes for any angles is given by:

$$(S_u)_{f_v} = \frac{12 \cdot T}{\pi D^2 \cdot \left( \frac{D}{\cos(i_T)} + \frac{D}{\cos(i_B)} + 6H \right)} \tag{2}$$

$$(S_u)_{f_v} = \frac{12 \cdot T}{\pi D^2 \cdot \left( \frac{D}{\cos(i_T)} + \frac{D}{\cos(i_B)} + 6H \right)} \times K \tag{2}$$