Designation: D4554 – 02(Reapproved 2006)

Standard Test Method for In Situ Determination of Direct Shear Strength of Rock Discontinuities[1]

This standard is issued under the fixed designation D4554; 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.

1. Scope*

1.1 This test method covers the measurement of peak and residual direct shear strength of in situ rock discontinuities as a function of stress normal to the sheared plane. This sheared plane is usually a significant discontinuity which may or may not be filled with gouge or soil-like material.

1.2 The measured shear properties are affected by scale factors. The severity of the effect of these factors must be assessed and applied to the specific problems on an individual basis.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *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:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

3. Terminology

3.1 *Definitions*—See Terminology D653 for general definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *discontinuities*—this includes joints, schistosity, faults, bedding planes, cleavage, and zones of weakness, along with any filling material.

3.2.2 *peak shear strength*—the maximum shear stress in the complete curve of stress versus displacement obtained for a specified constant normal stress.

3.2.3 *residual shear strength*—the shear stress at which nominally no further rise or fall in shear strength is observed with increasing shear displacement and constant normal stress (Fig. 1). A true residual strength may only be reached after considerably greater shear displacement than can be achieved in testing. The test value should be regarded as approximate and should be assessed in relation to the complete shear stress - displacement curve.

3.2.4 *shear strength parameter, c* (see Fig. 2) —the projected intercept on the shear stress axis of the plot of shear stress versus normal stress (see Note).

3.2.5 *shear strength parameter,* φ (see Fig. 2) —the angle of the tangent to the failure curve at a normal stress that is relevant to design.

3.2.5.1 *Discussion*—Different values of *c* and φ relate to different stages of a test (for example, $c`$, $c_r`$, φ_a , and φ_b, of Fig. 2).

4. Summary of Test Method

4.1 This test method is performed on rectangular-shaped blocks of rock that are isolated on all surfaces, except for the shear plane surface.

4.2 The blocks are not to be disturbed during preparation operations. The base of the block coincides with the plane to be sheared.

4.3 A normal load is applied perpendicular to the shear plane and then a side load is applied to induce shear along the plane and discontinuity (see Fig. 3).

5. Significance and Use

5.1 Because of scale effects, there is no simple method of predicting the in situ shear strength of a rock discontinuity from the results of laboratory tests on small specimens; in situ tests on large specimens are the most reliable means.

5.2 Results can be employed in stability analysis of rock engineering problems, for example, in studies of slopes, underground openings, and dam foundations. In applying the

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

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[2] 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

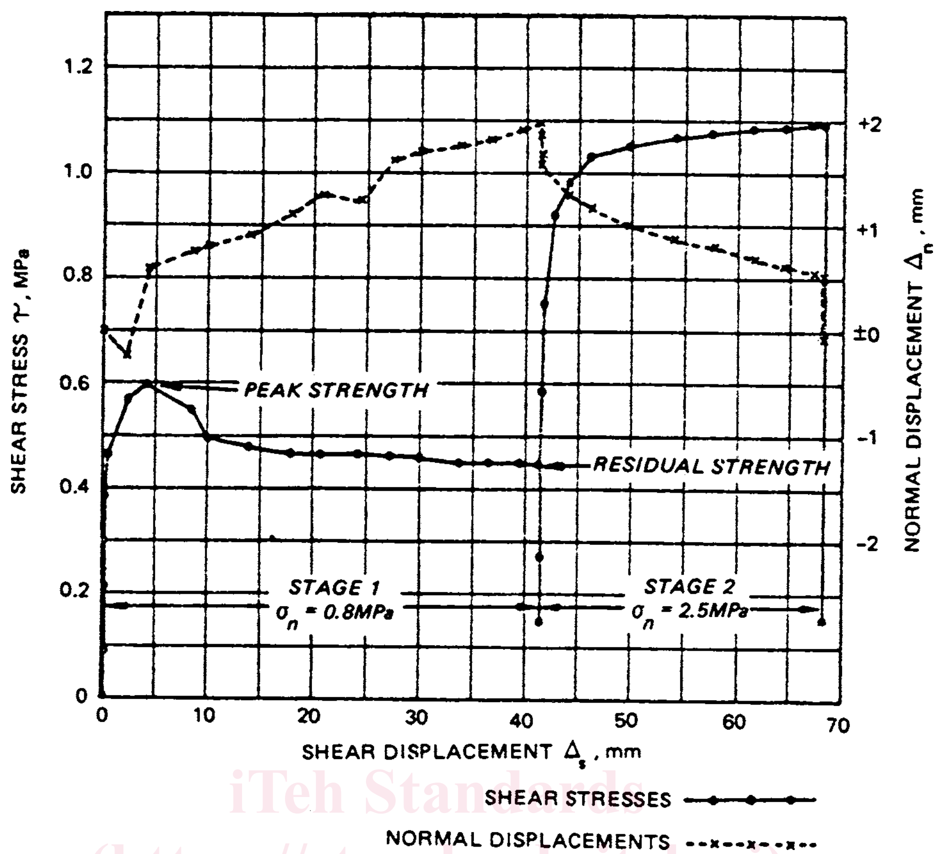


FIG. 1 Shear Stress – Displacement Graphs

test results, the pore water pressure conditions and the possibility of progressive failure must be assessed for the design case, as they may differ from the test conditions.

5.3 Tests on intact rock (free from planes of weakness) are usually accomplished using laboratory triaxial testing. Intact rock can, however, be tested in situ in direct shear if the rock is weak and if the specimen block encapsulation is sufficiently strong.

NOTE 1—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/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Equipment for Cutting and Encapsulating the Test Block*—This includes rock saws, drills, hammer and chisels, formwork of appropriate dimensions and rigidity, expanded polystyrene sheeting or weak filler, and materials for reinforced concrete encapsulation.

6.2 *Equipment for Applying the Normal Load (see Fig. 3)*—This includes flat jacks, hydraulic rams, or dead load of sufficient capacity to apply the required normal loads.

NOTE 2—If a dead load is used for normal loading, precautions are required to ensure accurate centering and stability. If two or more hydraulic rams are used for loading, care is needed to ensure that their operating characteristics are identically matched and they are in exact parallel alignment.

6.2.1 Each ram should be provided with a spherical seat. The travel of rams, and particularly of flat jacks, should be sufficient to accommodate the full anticipated specimen displacement. The normal displacement may be estimated from the content and thickness of the filling and roughness of the shear surfaces. The upper limits would be the filling thickness.

6.2.2 *Hydraulic System*—A hydraulic system, if used, should be capable of maintaining a normal load to within 2 % of a selected value throughout the test.

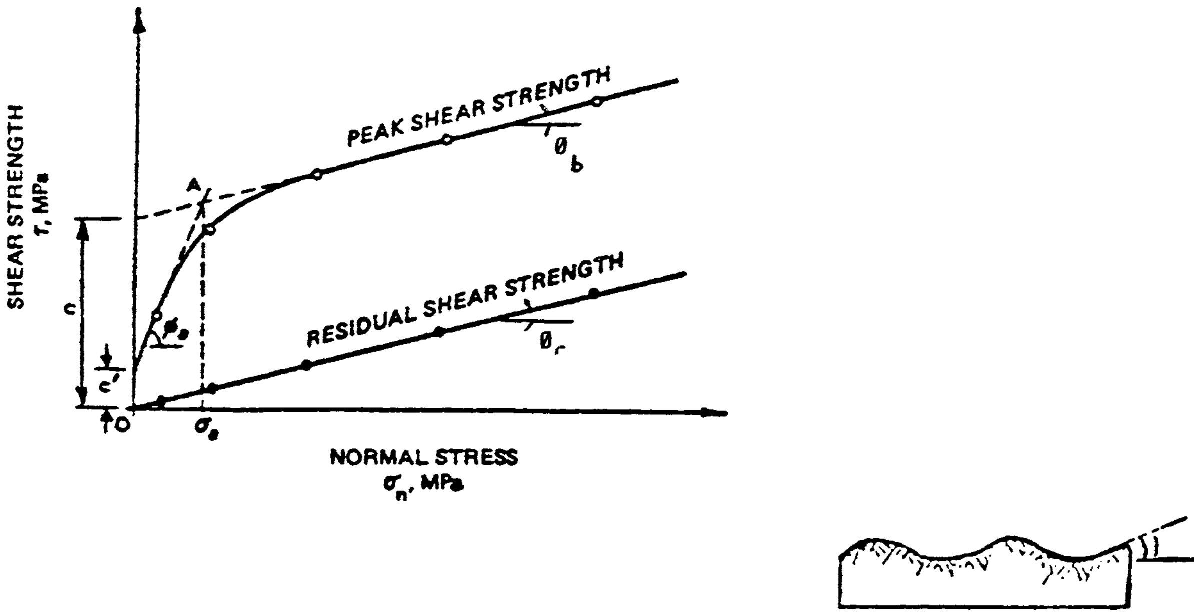
6.2.3 *Reaction System*—A reaction system to transfer normal loads uniformly to the test block includes rollers or a similar low friction device to ensure that at any given normal load, the resistance to shear displacement is less than 1 % of the maximum shear force applied in the test. Rock anchors, wire ties, and turnbuckles are usually required to install and secure the equipment.

6.3 *Equipment for Applying the Shear Force (see Fig. 3):*

6.3.1 *One or More Hydraulic Rams* , of adequate total capacity with at least 150-mm travel.

6.3.2 *Hydraulic Pump,* to pressurize the shear force system.

6.3.3 *Reaction System*—A reaction system to transmit the shear force to the test block. The shear force should be distributed uniformly along one face of the specimen. The resultant line of applied shear forces should pass through the



NOTE 1—In this case, intercept c_r on shear axis is zero.

ϕ_r = residual friction angle,

ϕ_a = apparent friction angle below stress σ_a; point A is a break in the peak shear strength curve resulting from the shearing off of major irregularities on the shear surface. Between points O and A, ϕ_a will vary somewhat; measure at stress level of interest. Note also that $\phi_a = \phi_u + i$ where:

ϕ_u = friction angle obtained for smooth surfaces of rock on rock, and

i = inclination angle of surface asperities.

ϕ_b = apparent friction angle above stress level σ_a (Point A); note that ϕ_a will usually be equal to or slightly greater than ϕ_r and will vary somewhat with stress level; measure at the stress level of interest, *r*.

c' = cohesion intercept of peak shear strength curve; it may be zero.

c = apparent cohesion at a stress level corresponding to ϕ_b, and

c_r = cohesion intercept of residual shear strength which is usually negligible.

FIG. 2 Shear Strength – Effective Normal Stress Graph

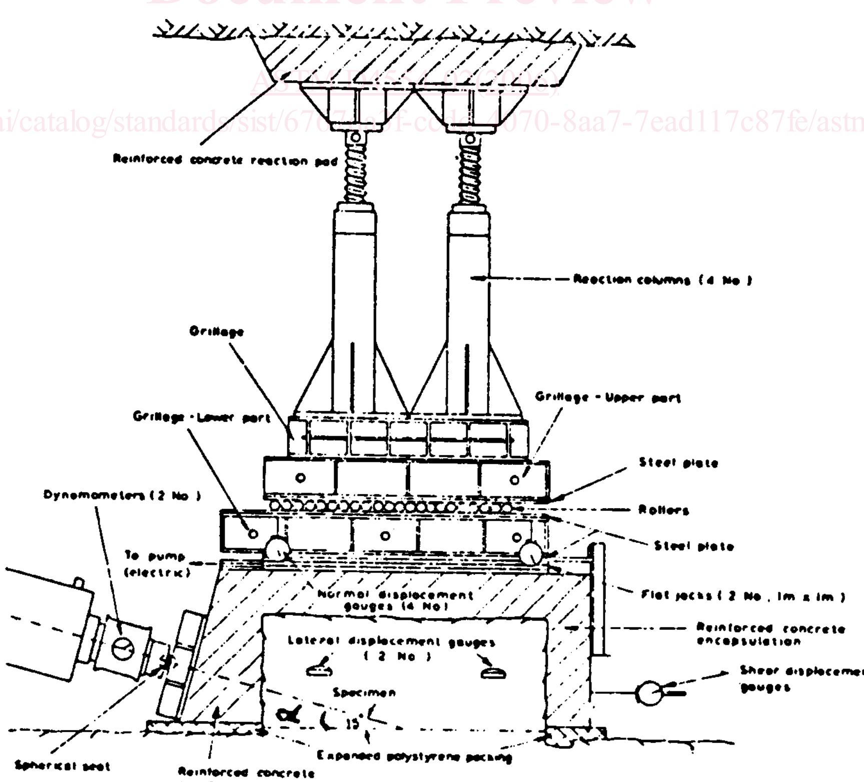


FIG. 3 Typical Arrangement of Equipment for In Situ Direct Shear Test