Designation: D 5311 – 92 (Reapproved 1996)

Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil[1]

This standard is issued under the fixed designation D 5311; 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 determination of the cyclic strength (sometimes called the liquefaction potential) of saturated soils in either undisturbed or reconstituted states by the load-controlled cyclic triaxial technique.

1.2 The cyclic strength of a soil is evaluated relative to a number of factors, including: the development of axial strain, magnitude of applied cyclic stress, number of cycles of stress application, development of excess pore-water pressure, and state of effective stress. A comprehensive review of factors affecting cyclic triaxial test results is contained in the literature **(1)**.[2]

1.3 Cyclic triaxial strength tests are conducted under undrained conditions to simulate essentially undrained field conditions during earthquake or other cyclic loading.

1.4 Cyclic triaxial strength tests are destructive. Failure may be defined on the basis of the number of stress cycles required to reach a limiting strain or 100 % pore pressure ratio. See Section 3 for Terminology.

1.5 This test method is generally applicable for testing cohesionless free draining soils of relatively high permeability. When testing well-graded materials, silts, or clays, it should be recognized that pore-water pressures monitored at the specimen ends to not in general represent pore-water pressure values throughout the specimen. However, this test method may be followed when testing most soil types if care is taken to ensure that problem soils receive special consideration when tested and when test results are evaluated.

1.6 There are certain limitations inherent in using cyclic triaxial tests to simulate the stress and strain conditions of a soil element in the field during an earthquake.

1.6.1 Nonuniform stress conditions within the test specimen are imposed by the specimen end platens. This can cause a redistribution of void ratio within the specimen during the test.

1.6.2 A 90° change in the direction of the major principal stress occurs during the two halves of the loading cycle on isotropically consolidated specimens.

1.6.3 The maximum cyclic shear stress that can be applied to the specimen is controlled by the stress conditions at the end of consolidation and the pore-water pressures generated during testing. For an isotropically consolidated contractive (volume decreasing) specimen tested in cyclic compression, the maximum cyclic shear stress that can be applied to the specimen is equal to one-half of the initial total axial pressure. Since cohesionless soils are not capable of taking tension, cyclic shear stresses greater than this value tend to lift the top platen from the soil specimen. Also, as the pore-water pressure increases during tests performed on isotropically consolidated specimens, the effective confining pressure is reduced, contributing to the tendency of the specimen to neck during the extension portion of the load cycle, invalidating test results beyond that point.

1.6.4 While it is advised that the best possible undisturbed specimens be obtained for cyclic strength testing, it is sometimes necessary to reconstitute soil specimens. It has been shown that different methods of reconstituting specimens to the same density may result in significantly different cyclic strengths. Also, undisturbed specimens will almost always be stronger than reconstituted specimens.

1.6.5 The interaction between the specimen, membrane, and confining fluid has an influence on cyclic behavior. Membrane compliance effects cannot be readily accounted for in the test procedure or in interpretation of test results. Changes in pore-water pressure can cause changes in membrane penetration in specimens of cohesionless soils. These changes can significantly influence the test results.

1.6.6 The mean total confining pressure is asymmetric during the compression and extension stress application when the chamber pressure is constant. This is totally different from the symmetric stress in the simple shear case of the level ground liquefaction.

1.7 The values stated in both inch-pound and SI units are to be regarded separately as the standard. The values given in parentheses are for information only.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.09 on Dynamic Properties of Soils.

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[2] The **boldface** numbers in parentheses refer to a list of references at the end of the text.

1.8 *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:*

D 422 Test Method for Particle-Size Analysis of Soils[3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 854 Test Method for Specific Gravity of Soils[3]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[3]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[3]

D 2850 Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression[3]

D 4220 Practice for Preserving and Transporting Soil Samples[3]

D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table[3]

D 4254 Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density[3]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[3]

D 4767 Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils[3]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions for terms used in this test method (including *liquefaction*) are in accordance with Terminology D 653. Additional descriptions of terms are defined in 3.2 and in 10.2 and Fig. 1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *full or 100 % pore pressure ratio*— a condition in which Δu equals σ'_{3c}.

3.2.2 *peak pore pressure ratio*—the maximum pore pressure ratio measured during a particular loading sequence.

3.2.3 *peak (single amplitude) strain*—the maximum axial strain (from the origin or initial step) in either compression or extension produced during a particular loading sequence.

3.2.4 *peak to peak (double amplitude) strain*— the difference between the maximum axial strain in compression and extension during a given cycle under cyclic loading conditions.

3.2.5 *pore pressure ratio*—the ratio, expressed as a percentage, of the change of excess pore-water pressure, Δu, to the effective minor principal stress, σ'_{3c}, at the end of primary consolidation.

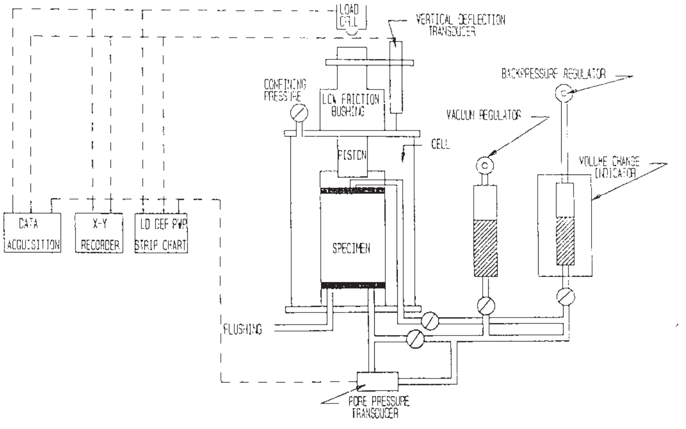

FIG. 1 Schematic Representation of Load-Controlled Cyclic Triaxial Strength Test Equipment

4. Summary of Test Method

4.1 A cylindrical soil specimen is sealed in a watertight rubber membrane and confined in a triaxial chamber where it is subjected to a confining pressure. An axial load is applied to the top of the specimen by a load rod.

4.2 Specimens are consolidated isotropically (equal axial and radial stress). Tubing connections to the top and bottom specimen platens permit flow of water during saturation, consolidation and measurement of pore-water pressure during cyclic loading.

4.3 Following saturation and consolidation, the specimen is subjected to a sinusoidally varying axial load by means of the load rod connected to the specimen top platen. The cyclic load, specimen axial deformation, and porewater pressure development with time are monitored.

4.4 The test is conducted under undrained conditions to approximate essentially undrained field conditions during earthquake or other dynamic loading. The cyclic loading generally causes an increase in the pore-water pressure in the specimen, resulting in a decrease in the effective stress and an increase in the cyclic axial deformation of the specimen.

4.5 Failure may be defined as when the peak excess pore-water pressure equals the initial effective confining pressure, full or 100 % pore pressure ratio (sometimes called initial liquefaction), or in terms of a limiting cyclic strain or permanent strain.

5. Significance and Use

5.1 Cyclic triaxial strength test results are used for evaluating the ability of a soil to resist the shear stresses induced in a soil mass due to earthquake or other cyclic loading.

5.1.1 Cyclic triaxial strength tests may be performed at different values of effective confining pressure on isotropically consolidated specimens to provide data required for estimating the cyclic stability of a soil.

5.1.2 Cyclic triaxial strength tests may be performed at a single effective confining pressure, usually equal to 14.5 lb/in.^{2}(100 kN/m^2), or alternate pressures as appropriate on isotropically consolidated specimens to compare cyclic strength results for a particular soil type with that of other soils, Ref **(2)**.

5.2 The cyclic triaxial test is a commonly used technique for determining cyclic soil strength.

5.3 Cyclic strength depends upon many factors, including density, confining pressure, applied cyclic shear stress, stress history, grain structure, age of soil deposit, specimen preparation procedure, and the frequency, uniformity, and shape of the

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[3] *Annual Book of ASTM Standards*, Vol 04.08.