**Designation: D 5407 – 95 (Reapproved 2000)**

# Standard Test Method for Elastic Moduli of Undrained Intact Rock Core Specimens in Triaxial Compression Without Pore Pressure Measurement[1]

This standard is issued under the fixed designation D 5407; 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 elastic moduli of intact rock core specimens in undrained triaxial compression. It specifies the apparatus, instrumentation, and procedures for determining the stress-axial strain and the stress-lateral strain curves, as well as Young's modulus, $E$, and Poisson's ratio, $v$.

NOTE 1—This test method does not include the procedures necessary to obtain a stress-strain curve beyond the ultimate strength.

1.2 For an isotropic material, the relation between the shear and bulk moduli and Young's modulus and Poisson's ratio are:

$$G = \frac{E}{2(1+v)} \quad (1)$$

$$K = \frac{E}{3(1-2v)} \quad (2)$$

where:

$G$ = shear modulus,

$K$ = bulk modulus,

$E$ = Young's modulus, and

$v$ = Poisson's ratio.

1.2.1 The engineering applicability of these equations is decreased if the rock is anisotropic. When possible, it is desirable to conduct tests in the plane of foliation, bedding, etc., and at right angles to it to determine the degree of anisotropy. It is noted that equations developed for isotropic materials may give only approximate calculated results if the difference in elastic moduli in any two directions is greater than 10 % for a given stress level.

NOTE 2—Elastic moduli measured by sonic methods may often be employed as preliminary measures of anisotropy.

1.3 This test method given for determining the elastic constants does not apply to rocks that undergo significant inelastic strains during the test, such as potash and salt. The elastic moduli for such rocks should be determined from unload-reload cycles, that is not covered by this test method.

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

1.5 *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.* Specific safety precautions are given in Section 6.

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[2]

D 4543 Practice for Determining Dimensional and Shape Tolerances of Rock Core Specimens[2]

E 4 Practices for Load Verification of Testing Machines[3]

## 3. Summary of Test Method

3.1 A rock core sample is cut to length and the ends are machined flat. The specimen is placed in a triaxial loading chamber, subjected to confining pressure and, if required, heated to the desired test temperature. Axial load is continuously increased on the specimen, and deformation is monitored as a function of load.

## 4. Significance and Use

4.1 Deformation and strength of rock are known to be functions of confining pressure. The triaxial compression test is commonly used to simulate the stress conditions under which most underground rock masses exist.

4.2 The deformation and strength properties of rock cores measured in the laboratory usually do not accurately reflect large-scale in situ properties because the latter are strongly influenced by joints, faults, inhomogeneities, weakness planes, and other factors. Therefore, laboratory values for intact specimens must be employed with proper judgment in engineering applications.

## 5. Apparatus

5.1 *Loading Device*—The loading device shall be of sufficient capacity to apply load at a rate conforming to the requirements specified in 9.6. It shall be verified at suitable time intervals in accordance with the procedures given in

---

[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.

Current edition approved Dec. 10, 1995. Published June 1996. Originally published as D 5407 – 93. Last previous edition D 5407 – 93.

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

[3] *Annual Book of ASTM Standards*, Vol 03.01.

Practice E 4 and comply with the requirements prescribed in this test method. The loading device may be equipped with a displacement transducer that can be used to advance the loading ram at a specified rate.

NOTE 3—If the load measuring device is located outside the triaxial apparatus, calibrations to determine the seal friction need to be made to ensure the accuracy specified in Practice E 4.

5.2 *Triaxial Apparatus*—The triaxial apparatus shall consist of a chamber in which the test specimen may be subjected to a constant lateral fluid pressure and the required axial load. The apparatus shall have safety valves, suitable entry ports for filling the chamber, and associated hoses, gages, and valves as needed.

5.3 *Flexible Membrane*—This membrane encloses the rock specimen and extends over the platens to prevent penetration by the confining fluid. A sleeve of natural or synthetic rubber or plastic is satisfactory for room temperature tests; however, metal or high-temperature rubber (for example, viton) jackets are usually required for elevated temperature tests. The membrane shall be inert relative to the confining fluid and shall cover small pores in the specimen without rupturing when confining pressure is applied. Plastic or silicone rubber coatings may be applied directly to the specimen, provided these materials do not penetrate and strengthen the specimen. Care must be taken to form an effective seal where the platen and specimen meet. Membranes formed by coatings shall be subject to the same performance requirements as elastic sleeve membranes.

5.4 *Pressure-Maintaining Device*—A hydraulic pump, pressure intensifier, or other system of sufficient capacity to maintain constant the desired lateral pressure. The pressurization system shall be capable of maintaining the confining pressure constant to within ±1 % throughout the test. The confining pressure shall be measured with a hydraulic pressure gage or electronic transducer having an accuracy of at least ±1 % of the confining pressure, including errors due to readout equipment, and a resolution of at least 0.5 % of the confining pressure.

5.5 *Confining-Pressure Fluids*—For room temperature tests, hydraulic fluids compatible with the pressure-maintaining device should be used. For elevated temperature tests, the fluid must remain stable at the temperature and pressure levels designated for the test.

5.6 *Elevated-Temperature Enclosure*— The elevated-temperature enclosure may be either an internal system that fits in the triaxial apparatus, an external system enclosing the entire triaxial apparatus, or an external system encompassing the complete test apparatus. For high temperatures, a system of heaters, insulation, and temperature measuring devices are normally required to maintain the specified temperature. Temperature shall be measured at three locations, with one sensor near the top, one at midheight, and one near the bottom of the specimen. The average specimen temperature based on the midheight sensor shall be maintained to within ±1°C of the required test temperature. The maximum temperature difference between the midheight sensor and either end sensor shall not exceed 3°C.

NOTE 4—An alternative to measuring the temperature at three locations along the specimen during the test is to determine the temperature distribution in a dummy specimen that has temperature sensors located in drill holes at a minimum of six positions: along both the centerline and specimen periphery at midheight and each end of the specimen. The temperature controller set point shall be adjusted to obtain steady-state temperatures in the dummy specimen that meet the temperature requirements at each test temperature (the centerline temperature at midheight shall be within ±1°C of the required test temperature, and all other specimen temperatures shall not deviate from this temperature by more than 3°C. The relationship between controller set point and dummy specimen temperature can be used to determine the specimen temperature during testing provided that the output of the temperature feedback sensor (or other fixed-location temperature sensor in the triaxial apparatus) is maintained constant within ±1°C of the required test temperature. The relationship between temperature controller set point and steady-state specimen temperature shall be verified periodically. The dummy specimen is used solely to determine the temperature distribution in a specimen in the triaxial apparatus—it is not to be used to determine elastic constants.

5.7 *Temperature Measuring Device*—Special limits-of-error thermocouples or platinum resistance thermometers (RTDs) have accuracies of at least ±1°C with a resolution of 0.1°C.

5.8 *Platens*—Two steel platens are used to transmit the axial load to the ends of the specimen. They shall have a hardness of not less than 58 HRC. One of the platens should be spherically seated and the other a plain rigid platen. The bearing faces shall not depart from a plane by more than 0.015 mm when the platens are new and shall be maintained within a permissible variation of 0.025 mm. The diameter of the spherical seat shall be at least as large as that of the test specimen, but shall not exceed twice the diameter of the test specimen. The center of the sphere in the spherical seat shall coincide with that of the bearing face of the specimen. The spherical seat shall be properly lubricated to assure free movement. The movable portion of the platen shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated and tilted through small angles in any direction. If a spherical seat is not used, the bearing faces of the blocks shall be parallel to 0.0005 mm/mm of platen diameter. The platen diameter shall be at least as great as the specimen, but shall not exceed the specimen diameter by more than 1.50 mm. This platen diameter shall be retained for a length of at least one-half the specimen diameter.

5.9 *Strain/Deformation Measuring Devices*—The strain/deformation measuring system shall measure the strain with a resolution of at least $25 \times 10^{-6}$ strain and an accuracy within 2 % of the value of readings above $250 \times 10^{-6}$ strain and accuracy and resolution within $5 \times 10^{-6}$ for readings lower than $250 \times 10^{-6}$ strain, including errors introduced by excitation and readout equipment. The system shall be free from noncharacterizable long-term instability (drift) that results in an apparent strain of $10^{-8}$/s.

NOTE 5—The user is cautioned about the influence of pressure and temperature on the output of strain and deformation sensors located within the triaxial apparatus.

5.9.1 *Axial Strain Determination*—The axial deformations or strains may be determined from data obtained by electrical resistance strain gages, compressometers, linear variable differential transformers (LVDTs), or other suitable means. The design of the measuring device shall be such that the average of at least two axial strain measurements can be determined.