AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Test Method for Determining Deformability and Strength of Weak Rock by an In Situ Uniaxial Compressive Test[1]

This standard is issued under the fixed designation D 4555; 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 the deformability and strength of large in situ specimens of weak rock by a uniaxial compressive test. The test results take into account the effect of both intact material behavior and the behavior of discontinuities contained within the specimen block.

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

1.3 *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. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *rock quality designation, RQD*—a method for quantitatively describing the nature of a rock mass from core borings. RQD is obtained by measuring the total length of all unweathered pieces of core greater than or equal to 100 mm and dividing the total by the length of the particular core run. This quantity is expressed as a percent and is used to classify in situ rock.

2.1.2 *weak rock*—rock containing numerous weathered joints spaced 30 to 500 mm, with gouge filling/waste rock with fines. Weak rock has both rock and soil properties depending on condition of use. The compressive strength is less than 35 MPa and the RQD is less than 50 %.

3. Significance and Use

3.1 Since there is no reliable method of predicting the overall strength and deformation data of a rock mass from the results of laboratory tests on small specimens, in situ tests on large specimens are necessary. Such tests also have the advantage that the rock specimen is tested under similar environmental conditions as prevailing for the rock mass.

3.2 Since the strength of rock is dependent on the size of the test specimen, it is necessary to test several specimens (laboratory or field, or both) of progressively increasing size until an asymptotically constant strength value is found. This value is taken to represent the strength of the rock mass.[2,3]

4. Apparatus

4.1 *Preparation Equipment*—Equipment is needed for cutting specimen blocks from existing underground exposed faces, for example, a coal cutting machine, pneumatic chisel, or other hand tools. No explosives are permitted.

4.2 *Loading System*:

4.2.1 *Hydraulic Jacks or Flatjacks*—This equipment is required to apply a uniformly distributed load to the complete upper face of the specimen. The loading system shall be of sufficient capacity and travel to load the system to failure. Multiple hydraulic jacks fed by a common manifold should be avoided.

4.2.2 *Hydraulic Pumping System*—This system is needed to supply oil at the required pressure to the jacks, the pressure being controlled to give a constant rate of displacement or strain, rather than a constant rate of stress increase.

NOTE 1—Experience has shown that deformation-controlled loading is preferable to stress-controlled loading because it results in a more stable, and thus safer, test. This result is a consequence of the strain softening nature of most rock or rock-like materials. A single stress level may correspond to different values of strain during any test, with the level of strain continuing to increase throughout a test. One way to achieve uniform deformation of the specimen is to use a separate pump for each jack and to set the oil delivery rate of each pump to the same value. Standard diesel fuel injection pumps have been found suitable and are capable of supplying pressures up to 100 MPa. The delivery rate of these pumps can be set very accurately.

4.3 *Equipment to Measure Applied Load and Strain in the Specimen*:

4.3.1 *Load Measuring Equipment*—This equipment, for example, electric, hydraulic, or mechanical load cells, permits the applied load to be measured with an accuracy better than ±5 % of the maximum in the test.

4.3.2 *Dial Gage*—A dial gage, or similar displacement measuring devices, with robust fittings to enable the instruments to be mounted so that the strain in the central third of each specimen face is measured with an accuracy better than ±

---

[1] This test method is under the jurisdiction of Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

Current edition approved May 25, 1990. Published July 1990. Originally published as D 4555 – 85. Last previous edition D 4555 – 85.

[2] Bieniawski, Z. T., and Van Heerdan, W. L., "The Significance of Large-Scale In Situ Tests," *International Journal of Rock Mechanics Mining Sciences*, Vol 1, 1975.

[3] Heuze, F. E., "Scale Effects in the Determination of Rock Mass Strength and Deformability," *Rock Mechanics*, Vol 12, 1980, pp 167–192.

10^{-5}. Strain is to be measured in the direction of applied load and also in a perpendicular direction if Poisson's ratio values are to be determined.

4.4 *Calibration Equipment*—Equipment to calibrate the loading and displacement measuring systems, the accuracy of calibration to be better than the accuracies of test measurement specified in 4.3.1 and 4.3.2.

5. Procedure

5.1 *Preparation of Specimens*:

5.1.1 Cut specimens of the required dimensions from the exposed rock faces (Fig. 1). The specimen shall have a height-to-minimum-width dimension ratio of 2.0 to 2.5. The ratio of the maximum width of the specimen to the minimum width shall be as near to 1.0 as practicable.

5.1.1.1 First, remove loose and damaged rock. Make vertical cuts as shown in Fig. 1 to form the vertical faces of the specimen. Dimensional uniformity of each vertical face of the test specimen should not deviate by more than 20 mm. If there is such deviation, abandon the specimen. Make a horizontal cut to form the top face of the specimen. Remove loose rock and trim the specimen to final size using hand tools.

NOTE 2—Specimen dimensions cannot be specified because they depend very much on the rock properties, for example, the thickness of strata and the ease with which specimens can be prepared. It is recommended that a number of tests be done with a specimen with a width of about 0.5 m and that the size of subsequent specimens should be increased until an asymptotically constant strength value is reached. It is probable that the largest test specimen will have a minimum width at least 10 times greater than the average dimension of the largest fragment defined by discontinuities.

5.1.2 Clean and inspect the specimen. Record in detail the geological structure of the block and nature of the reaction faces of the block. Measure specimen geometry, including the geometry of defects in the block, with an accuracy better than 5 mm. Prepare photographs and drawings to illustrate both geological and geometric characteristics.

5.1.3 Cast a concrete pad, suitably reinforced, to cover the top face of the specimen (Fig. 2). This pad shall be sufficient to give adequate strength under the full applied load. The top face of the pad shall be flat to within ±5° of the basal plane of the block.

5.1.4 Remove rock from above the specimen to make space for the loading jacks. Cut back the rock to a stratum of sufficient strength to provide safe reaction. Generally, a concrete reaction pad must be cast to distribute the load on the roof and to prevent undue deformation and movement of the jacks during the test. The lower face of the reaction block shall be flat to within ±5 mm and shall be parallel to the upper face of the specimen block within ±5°. Cure all concrete for a sufficient period to provide adequate strength under the fully applied load.

NOTE 3—If a suitably designed concrete cap to the specimen is not employed, the corners and sides of the specimen will often fail before the central portion. The corner jacks will then cease to operate, and the test results will be suspect. The concrete cap should, if possible, be designed to ensure that the stress distributions in the top and bottom thirds of the specimen are nearly identical.

5.1.5 Install the loading jacks, platen, and load measuring equipment and check to ensure that they operate as intended. Install and check displacement measuring equipment. Calibrate all measuring instruments both before and after each test series.

5.2 *Testing*:

5.2.1 Apply an initial load of approximately one-tenth of the estimated full test load and check the jacks to ensure that each is in firm contact with the loading platen. Again check displacement measuring equipment to ensure that it is rigidly mounted and is functioning correctly. Take zero readings of load and displacement.

5.2.2 Increase the specimen load by applying the same slow and constant oil delivery to each jack. The rate of specimen

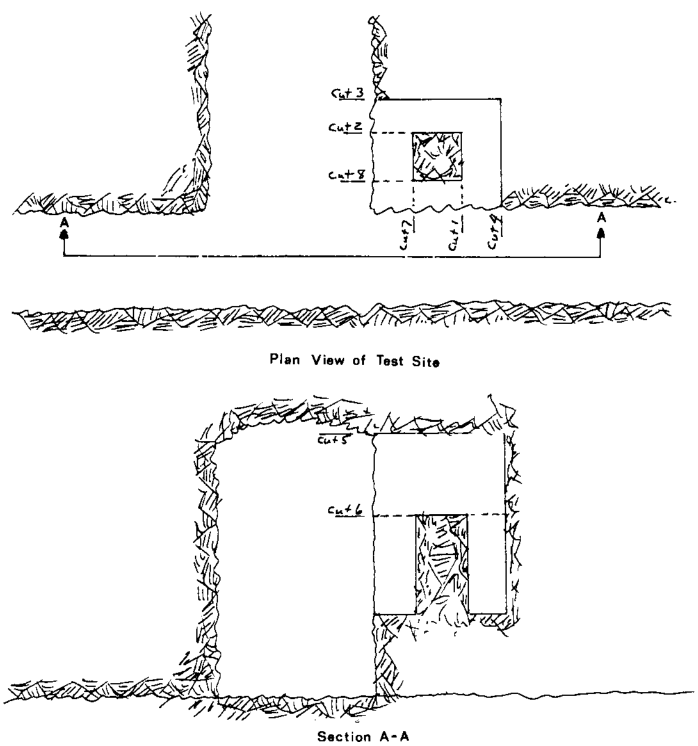

FIG. 1 Sequence of Cuts and Excavation for Specimen Preparation

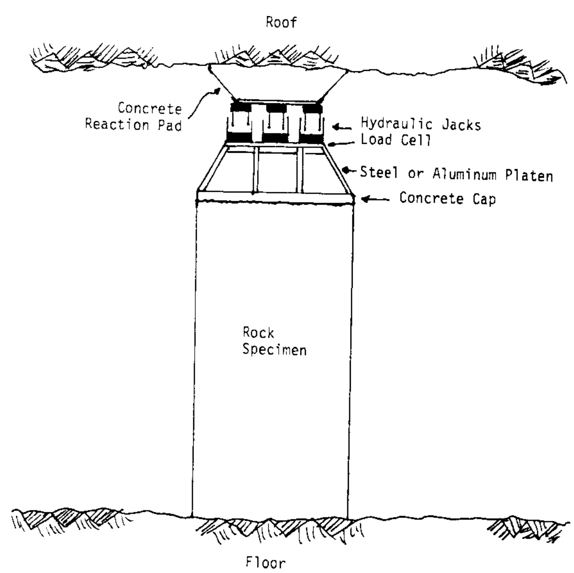

FIG. 2 Test Arrangement

strain shall be constant across the test surface, such that a displacement rate of between 5 and 15 mm/h is recorded at each of the four faces of the specimen block.

5.2.3 Record readings of applied load and displacement at intervals such that the load - displacement or stress - strain curve can be adequately defined. There shall be at least ten points on this curve, evenly spaced from zero to the failure load.

5.2.4 Unless otherwise specified, terminate the test when the specimen fails. Specimen failure is indicated by a drop of hydraulic pressure to less than one-half the maximum applied, or by disintegration of the specimen to an extent that the loading system becomes inoperative or the test dangerous to continue. Record the mode of specimen failure and make a sketch of all developed cracks and failure surfaces.

6. Calculation

6.1 Calculate the uniaxial compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the original cross-sectional area of the specimen.

6.2 The deformation modulus for the specimen shall, unless otherwise specified, be calculated as the tangent modulus E_{t50} at one-half the peak uniaxial compressive strength. This modulus is found by drawing a tangent to the stress - strain curve at 50 % maximum load, the gradient of this tangent being measured as E_{t50}. Show on the stress - strain curve the construction and calculations used in deriving this, and any other modulus values.

6.3 A number of specimens of different sizes can be tested, and the trends in strength values due to size effects can be plotted graphically, as shown in Fig. 3.

7. Report

7.1 Report the following information:

7.1.1 A diagram showing the details of the locations of specimens tested, the specimen numbering system used, and the situation of each specimen with respect to the geology and geometry of the site.

7.1.2 Photographs, drawings, and tabulations giving full details of the geological and geometrical characteristics of each specimen, preferably including index test data to characterize the rock. Give particular attention to a detailed description of the pattern of joints, bedding planes, and other discontinuities in the specimen block.

7.1.3 A description, with diagrams, of the test equipment and method used.

7.1.4 Tabulated test results, including recorded values of load and displacements, together with all derived data, calibration results, and details of all corrections applied.

7.1.5 Graphs showing load versus displacement or stress versus strain, including points representing all recorded data, and a curve fitted to these points. Show the uniaxial compressive strength value, together with all constructions used in determining the deformation modulus and other elastic parameters. Show by diagram and describe the mode of specimen failure.

7.1.6 Summary tables and graphs giving the values of uniaxial compressive strength and deformation modulus, and showing how these values vary as a function of specimen shape and size and the character of the rock tested.

8. Precision and Bias

8.1 *Precision*—Due to the nature of rock materials tested by this test method, it is, at this time, either not feasible or too costly to produce multiple specimens that have uniform physical properties. Therefore, since specimens that would yield the same test results cannot be tested, Subcommittee D18.12 cannot determine the variation between tests since any variation observed is just as likely to be due to specimen variation as to operator or laboratory testing variation. Subcommittee D18.12 welcomes proposals to resolve this problem that would allow for development of a valid precision statement.

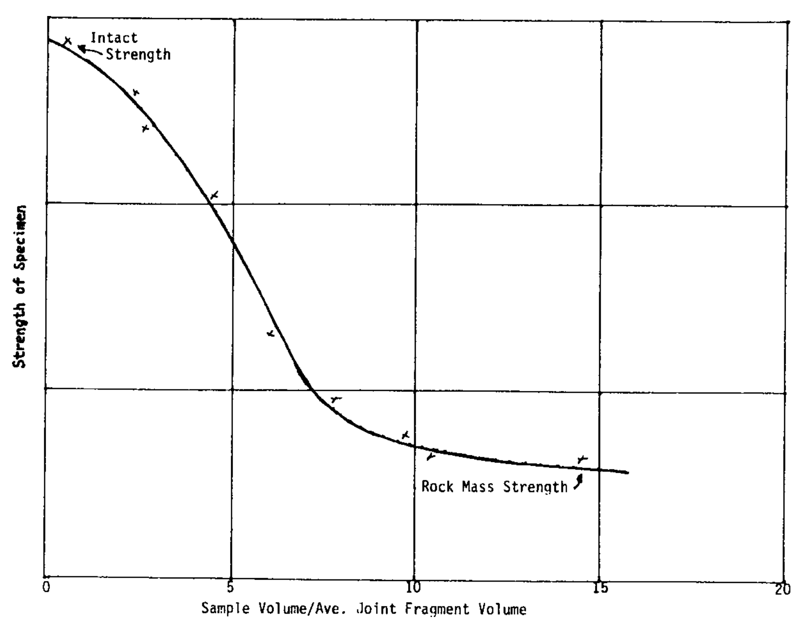

FIG. 3 Hypothetical Example Showing the Representation of Strength Data

8.2 *Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

9. Keywords

9.1 compression testing; deformation; in situ stress loading tests