RTH 203-80

METHOD OF TEST FOR DIRECT SHEAR STRENGTH OF ROCK CORE SPECIMENS

1. Scope

1.1 This method describes apparatus and procedures for determining the shear strength of a rock material in direct shear. The test can be made on rock core specimens from 2 to 6 in. (5 to 15 cm) in diameter. The test can be made on intact specimens to determine intact shear strength, on intact specimens with recognizable thin weak planes to determine the shearing resistance along these planes, on presawn shear surfaces to determine lower bound residual shear strengths, and on rock core to concrete bond specimens to determine the shearing resistance between the bond. The principle of the rock core direct shearing is illustrated schematically in Fig. 1.

1.2 A minimum of three test specimens of any rock type are subjected to different but constant normal stresses during the shearing process. For each type of intact rock, cohesion and an angle of internal friction are determined. For each type of rock with sawn failure surfaces, a lower bound residual angle of internal friction is determined.

1.3 The test is not suited to the development of exact stress-strain relationships within the test specimen because of the nonuniform distribution of shearing stresses and displacements. Care should be taken so that the testing conditions represent those being investigated. The results of these tests are used where field design requirements dictate unconsolidated, undrained parameters.

2. Apparatus

2.1 Test Specimen Saw - For cores of 3 to 6 in. (7.5 to 15 cm) in diameter, use a rock saw with 20-in.- (50-cm-) diam safety abrasive blade fitted for dry and for wet cutting. Alternatively for wet cutting, a diamond blade may be used. For cores 2 to 2-1/2 in. (5 to 6.25 cm) in diameter, a rock saw with 12-in.- (60-cm-) diam blade should be used.

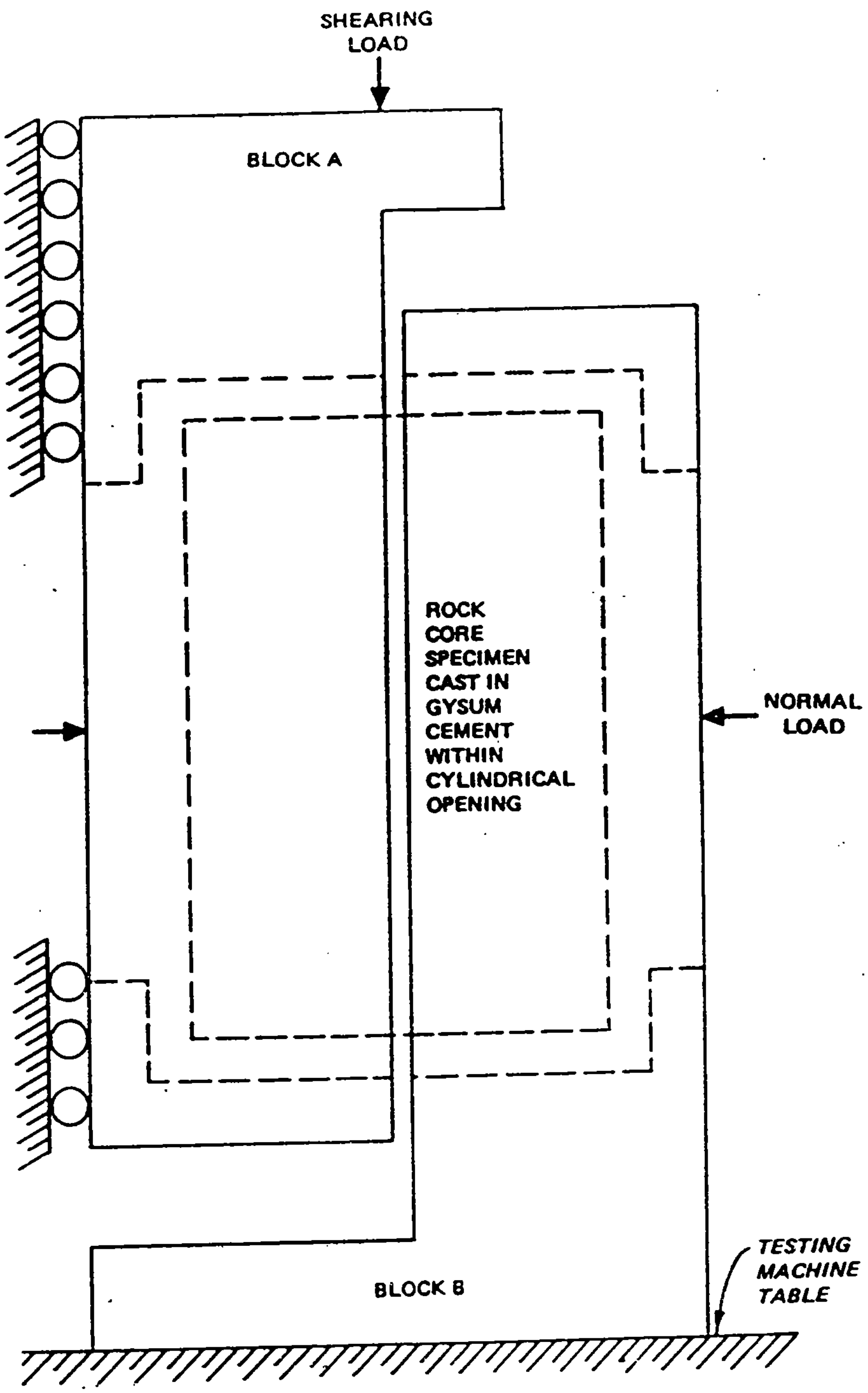

Fig 1. Schematic showing direct shear of rock core.

2.2 Shear Device - The shear device shall consist of a pair of shear boxes constructed so as to provide a means of applying a normal stress to the face of the specimen while applying a force to shear the specimen along a predetermined plane parallel to the vertical axis of the specimen. The device shall securely hold the specimen in such a way that torque cannot be applied to the specimen. The shear boxes that hold the specimen shall be sufficiently rigid to prevent their distortion during shearing. The various parts of the shear device shall be made of material not subject to corrosion by substances within the rock or moisture within the rock.

2.2.1 Shear boxes suitable for testing specimens from 3 to 6 in. (7.5 to 15 cm) in diameter should each have a recess 6-5/8 in. (16.6 cm) in diameter and 2-1/4 in. (5.67 cm) deep. Smaller shear boxes for 2- to 2-1/2-in.- (5- to 6.25-cm-) diam specimens should each have a recess 2-7/8 in. (7.36 cm) in diameter and 2 in. (5 cm) in depth. The shear boxes should be designed for a shear travel greater than 10 percent of the specimen shear plane length.

2.2.2 In both cases the two shear boxes assembled with the specimen shall be placed within a framework constructed so as to hold the boxes in proper position during testing. The framework shall include a pair of hardened stainless steel plates machined to accommodate roller bearings or ball bearings for minimizing friction of the moving shear box as indicated in Fig. 1. The roller plate device should ensure that resistance of the equipment to shear displacement is less than 1 percent of the maximum shear force applied in the test.

2.2.3 The shear device framework shall include capability of providing a submerging tank for tests in which maintaining specimen saturation is important to duplicate field conditions.

2.3 Loading Devices

2.3.1 Normal Force - The normal force device shall be capable of applying the specified force quickly without exceeding it and capable of maintaining it with an accuracy of ±2 percent for the duration of the test. The device shall have a travel greater than the amount of dilation or compression to be expected.

2.3.2 Shear Force - The device for applying the shear force shall distribute the load uniformly along one-half face of the specimen with the resultant applied shear force acting in the plane of shearing. The required capabilities will depend upon whether a controlled-displacement test or a controlled-stress test is used. Controlled-displacement equipment shall be capable of shearing the specimen at a uniform rate of displacement with less than ±15 percent deviation and shall permit adjustment of the rate of displacement over a relatively wide range. Controlled-stress equipment shall be capable of applying the shear force in increments to the specimen in the same manner and to the same degree of accuracy as that described in 2.3.1.

2.4 Displacement Indicators - Equipment for measuring shear and normal displacements may consist of mechanical devices, such as dial gages or electric transducers. Displacement indicators shall have a sensitivity of at least 0.001 in. (0.025 mm). The shear displacement measuring system shall have a travel greater than 10 percent of the specimen shear plane length. Normal displacement systems shall have the capability of measuring both dilation and compression of the specimen. Resetting of gages during the test should if possible be avoided. If electric transducers or an automatic recording system is used, a recent calibration shall be included in the report.

2.5 Casting Compound - High-strength gypsum cement (such as hydrostone) or a capping compound (such as leadite) should be used to hold the test specimen in the recesses of the test device.

2.6 Spacer Plate - The spacer plate separating the shear boxes for development of the shear zone shall be 1/16 in. (1.6 mm) thick and constructed of a noncorrosive material.

3. Test Specimen

3.1 Intact Specimens

3.1.1 Test specimens shall be prepared by sawing rock cores into 3- to 4-in. (7.5- to 10-cm) lengths (Note 1). The diameter of each specimen shall be measured to the nearest 0.01 in. (0.025 mm) at several different positions along the length of the specimen axis. The average diameter shall be used to compute the cross-sectional area of the specimen. The volume of the specimen shall be determined by the volumetric or displacement method presented in EM 1110-2-1906, "Laboratory Soils Testing." The initial weight of the specimen shall be determined to the nearest 0.1 g for subsequent use in determining initial moisture content and density.

NOTE 1—Soft rock such as clay shales may be as short as 2-1/2 in. (6.25 cm) if material is scarce. Although helpful in the setup, ends of the test specimens need not be smooth, flat, nor square with the axis of the core. Generally, harder rocks are best cut in the wet; softer rocks are best cut in the dry, depending on fissility and reaction to pressure of cutting water.

3.1.2 A block of the shear box shall be set on a flat surface with the shear surface up. The inside of the recess shall be lightly coated with lubricant. A grout of the gypsum cement (hydrostone) and water shall be placed in the recess to approximately the one-third or midpoint. After approximately three minutes of setting, the specimen shall be set or pushed into the grout until the approximate midpoint (desired shear plane) of the specimen is opposite the top recess (Note 2). Excess grout shall be screeded off at the shear plane (Note 3).

NOTE 2—To prepare intact test specimens for testing along recognizable thin weak planes, orient the specimen so that the plane of weakness is parallel with the 1/16-in. (1.6-mm) shear gap provided by the spacer plate.

NOTE 3--Gypsum cement grout has only a few minutes pot life; hence a fresh mix will have to be prepared for each block. An alternative to gypsum cement grout for holding the test specimen in the recesses is capping compound, such as leadite. The procedure for preparing specimens with a capping compound is essentially the same as for gypsum cement. Capping compound has a shorter pot life after pouring than gypsum cement and must be heated to proper temperature and handled quickly and with great care. An overnight curing period is generally required. Capping compound is stronger in compression and shear than gypsum cement and is preferred for hard rock testing. Because capping compound must be placed hot, it should not be used to secure specimens subject to structural damage with loss of natural moisture or for tests in which it is desirable to maintain natural moisture.

3.1.3 A 1/16-in.- (1.6-mm-) thick spacer plate having a hole equal to the diameter of the specimen and split on a diameter from the front to the back of the block shall be coated with lubricant and placed on the block around the specimen. The spacer separates the two blocks of the shear box to prevent friction between the blocks during shearing. The recess of the remaining shear box block shall be lightly coated with lubricant and the block placed over the now protruding half of the specimen. The two blocks shall be aligned and temporarily clamped together with C clamps. The recess between the top block and specimen shall then be filled with the gypsum cement grout using appropriate tools to rod the grout thoroughly around the specimen. For soft rock such as clay shale, a 2-hour curing is usually sufficient before loading. For hard rocks, the grout must be allowed to cure overnight.

3.1.4 At the end of the curing period, the two halves of the spacer shall be pulled out and the C clamps removed. The specimens secured in the shear boxes are then ready for further assembly and shear testing.

3.2 Presawn Shear Surfaces - Test specimens shall be prepared the same as presented in paragraphs 3.1.1 to 3.1.4, except that the specimen shall be sawn in half near the center length before grouting the specimen in the shear box blocks. The presawn shear surface shall be smooth and oriented in the shear box so as to be centered within the 1/16-in. (1.6-mm) shear gap provided by the spacer plate.

3.3 Concrete to Rock Core Bond

3.3.1 Test specimens shall be prepared by sawing rock cores into 1.5- to 2-in. (3.75- to 5-cm) length. The sawn specimen shall be tightly encased in the bottom of a 3- to 4-in.- (7.5- to 10-cm-) high mold (Note 4) with the smooth sawn surface (shear plane) facing upward and perpendicular to the axis of the mold. The remaining portion of the mold shall be filled with concrete, which is then consolidated and cured according to the procedures presented in CRD-C 10-73 (Note 5). The concrete mix design shall be compatible in consistency and strength with the anticipated field design mix and have a maximum aggregate no larger than 1/6 of the specimen diameter.

NOTE 4—Molds shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Mold diameters shall conform to the dimensions of the rock core test specimen. Molds shall hold their dimensions and shape and be watertight under conditions adverse to use.

NOTE 5—"Handbook for Concrete and Cement," U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, published in quarterly supplements.

3.3.2 Procedures for measuring specimen weight, diameter, and volume are the same as presented in paragraph 3.1.1. Procedures for securing the test specimen in the shear box are the same as presented in paragraphs 3.1.2 to 3.1.4.

4. Procedure

4.1 Following the removal of the spacer plates and C clamps, transfer final assembly operations to the test shear and normal load area. Final assembly of the testing apparatus, to include orientation of the resultant normal and shear loads, will depend on the equipment utilized in the testing. In general, the resultant of the normal load shall react through the axial center of the specimen, and the shear load shall react through the radial center of the specimen so as to pass through the shear plane. Position or activate, or both, the displacement indicators for measuring shear deformation and changes in specimen thickness.

4.2 Apply the selected normal force (normal stress " cross-section area) to the specimen as rapidly as practical (Note 6). Record and allow any initial elastic compression of the specimen to reach equilibrium. For those tests where applicable, as soon as possible after applying the initial normal force, fill the water reservoir to at least submerge the shear plane.

NOTE 6—The normal force used for each of the three or more specimens will depend upon the input information required for field analysis and/or design.

4.3 Shear the specimen.

4.3.1 After any elastic compression has reached equilibrium, apply the shearing force and shear the specimen. In a controlled-displacement test, the rate of displacement shall be less than 0.004 in./min (0.1 mm/min) until peak strength is reached. Approximately 10 sets of readings should be taken before reaching peak strength. If it is desired to determine the ultimate strength, the normal load shall be relieved and the specimen recentered. The normal load is then reapplied and the specimen sheared again. The rate of shear displacement to determine the ultimate strength shall be no greater than 0.01 in./min (0.25 mm/min). Readings should be taken at increments of from 0.02- to 0.2-in. (0.5- to 5-mm) shear displacement as required to adequately define the force-displacement curves.

4.3.2 In a controlled-stress test the rate of stress application should not exceed 5 psi/min (34.47 kPa/min) for soft rock (such as clay shale) and up to 100 psi (689.4 kPa) for the very hardest rock.

Concurrent time, shear load, and deformation readings shall be taken at convenient intervals (a minimum of 10 readings before reaching peak strength). After reaching peak strength, the ultimate strength may be determined as presented in paragraph 4.3.1.

5. Calculations

5.1 Calculate the following:

5.1.1 Initial cross-sectional area.

5.1.2 Initial water content.

5.1.3 Initial wet and dry unit weights.

5.1.4 Shear stress data.

5.1.5 Initial and final degrees of saturation, if desirable.

6. Report

6.1 The report shall include the following:

6.1.1 Description of type of shear device used in the test.

6.1.2 Identification and description of the sample.

6.1.3 Description of the shear surface.

6.1.4 Initial water content.

6.1.5 Initial wet and dry unit weights.

6.1.6 Initial and final degrees of saturation, if desirable.

6.1.7 All basic test data including normal stress, shear displacement, corresponding shear resistance values, and specimen thickness changes.

6.1.8 For each test specimen, a plot of shear and specimen thickness change versus shear displacement and a plot of composite maximum and ultimate shear stress versus normal stress.

6.1.9 Departures from the procedure outlined, such as special loading sequences or special wetting requirements.