PIT SLOPE MANUAL

supplement 3-1

LABORATORY CLASSIFICATION TESTS

This supplement has been prepared as part of the

PIT SLOPE PROJECT

of the
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Canada Centre for Mineral and Energy Technology
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THE PIT SLOPE MANUAL

The Pit Slope Manual consists of ten chapters, published separately. Most chapters have supplements, also published separately. The ten chapters are:

1. Summary
2. Structural Geology
3. Mechanical Properties
4. Groundwater
5. Design
6. Mechanical Support
7. Perimeter Blasting
8. Monitoring
9. Waste Embankments
10. Environmental Planning

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ABSTRACT

Tests for physical properties, index properties and uniaxial strength of the rock substance are described in this supplement. These tests are used mainly for classification; uniaxial strength may be used directly in stability analysis. The water content test is based on accurate weighing of a rock sample before and after oven drying. Porosity is determined by measuring the displacement in water of a sample sealed with paraffin wax. Swelling pressure and swelling strain indexes are measured in an apparatus similar to the soil consolidation test machine. The slake durability index measures the disintegration of a sample when agitated during two cycles of drying and wetting. Uniaxial strength and failure strain are determined from stress-strain measurements while loading to failure. The point load strength index is measured in an apparatus that subjects the specimen to opposed point loads. Tensile strength is determined from the Brazilian test.

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M. Gyenge and G. Herget were responsible for this chapter. Address enquiries to them at: 555 Booth Street, Ottawa, K1A 0G1, Canada.

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The Pit Slope Group consisted of D.F. Coates*, M. Gyenge*, G. Herget, B. Hoare, G. Larocque, D.R. Murray, R. Sage* and M. Service.

* successive Pit Slope Group Leaders.

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FIGURES

INTRODUCTION

1. Supplement 3-1 covers the tests related to the physical properties, index properties and uniaxial strength of the rock substance.

2. These tests are commonly required for classification or characterization of rock materials; however, in some cases the uniaxial strength of the rock substance is used directly for stability analysis.

3. Owing to the great variation in prevailing conditions, requirements and circumstances from one mining site to another, the supplement provides useful guidance on testing procedures, without attempting to set rigorous standards.

4. The specifications for the testing procedures are written as far as possible in general terms while at the same time providing the essential steps required for any particular type of test.

5. To facilitate effective communication, each type of test is demonstrated by an example. Each example is based on a particular type of test set-up and apparatus as a help to the reader and neither implies endorsement of any apparatus by CANMET nor represents a standard for testing procedures. The reader is encouraged to seek alternative testing arrangements and apparatuses best suited to his needs.

6. Some of the testing procedures, or part of them are based on the methods suggested by the Commission on Standardization of Laboratory and Field Tests of the International Society for Rock Mechanics, or on the Standards of the American Society for Testing and Materials, or both. Proper references are given in each case at the end of the supplement, with a list of selected publications related to the subject matter.

7. Certain tests common to a number of determinations have been repeated for each determination. This provides a complete specification for each case and is convenient for the reader.

DETERMINATION OF WATER CONTENT

SCOPE

8. The purpose of this test is to measure the weight of water contained in a rock sample, as a percentage of the oven-dry sample weight.

APPARATUS

9. a. an oven capable of maintaining a temperature of 105° C to within 3° C for a period of at least 24 hours

b. sample containers of non-corrodible material, including airtight lids

c. a desiccator to hold sample containers during cooling

d. a balance of adequate capacity, capable of weighing to an accuracy of 0.01 g.

PROCEDURE

10. a. The containers and lids are cleaned and dried and their weights, A, measured.

b. A representative sample is selected, preferably comprising at least five rock lump specimens, each weighing at least 50 g.

c. The specimens are placed in the containers and the lids replaced.

d. The weight, B, of each specimen together with container and lid is determined.

e. The lids are removed and specimens dried to a constant weight at a temperature of 105° C.

f. The lids are replaced and the specimens allowed to cool in the desiccator for 30 minutes.

g. The weight, C, of each specimen together with container and lid is measured.

11. To retain the original water content of the sample the time gap between steps 10(c) and 10(d) should be as brief as possible. Guidance for storing and handling samples is given in Supplement 3-5.

CALCULATION

12. Water content, $w\% = (W_w/W_s)\ 100$

where pore water weight, $W_w = B-C$

solid weight, $W_s = C-A$

REPORTING OF RESULTS

13. The water content should be reported to the nearest 0.1% in tabulated form with proper sample identification (rock type and origin) if being determined for several locations (eg the water content at various depths of a borehole or various sections and/or elevations of the pit wall).

14. The working sheets are adequate substitutes for a report if only a few sample locations are involved in the water content determination (Fig 1).

WATER CONTENT

Sample *altered carbonate of the shear zone*

Location *5th bench, toe elevation* Date *July 16, 1973*

Bore Hole _____ Depth _____ Tested by *W G*

Sample No. *North fault 5*

Specimen No.	Container No.	A	B	C	W_w	W_s	w %
F-21	52	13.01	65.91	61.28	4.63	48.27	9.6
F-22	47	12.98	68.91	64.34	4.57	51.36	8.9
F-23	16	12.79	72.85	67.99	4.86	55.20	8.8
F-24	29	12.86	62.99	58.81	4.18	45.95	9.1
F-25	5	12.95	71.24	66.43	4.81	53.48	9.0

Sample water content: *9.1* %

Remarks: *specimens were placed into containers at the site on July 15, kept in lab. until testing covered with damp rag.*

Fig 1 - Working sheet for water content determination.

DETERMINATION OF POROSITY/DENSITY

SCOPE

15. a. The purpose of this test is to measure porosity, dry density and related properties of a rock sample.

b. The method applies equally well to regularly shaped rock specimens, and rock samples in the form of lumps or aggregates of irregular shape.

c. The method can be applied to coherent rock materials as well as to those which may swell or disintegrate if immersed in water.

d. All procedures for determining porosity/density are based on the appropriate standards (1,3).

APPARATUS

16. a. an oven capable of maintaining a temperature of 105° C within 3° C for a period of at least 24 hours

b. specimen containers of non-corrodible material, including airtight lids

c. a desiccator to hold specimen containers during cooling

d. a balance of adequate capacity, capable of weighing to an accuracy of 0.01 g

e. evaporating dishes - two large and one smaller

f. a glass plate large enough to cover the small dish

g. a graduated cylinder (conveniently 200 cm^3)

h. a vacuum apparatus such as a vacuum pump or water faucet aspirator providing vacuum less than 0.1 psi (0.7 kPa)

i. grinding equipment to reduce the sample to a powder less than 0.42 mm (40 sieve) in grain size

j. a calibrated volumetric flask and stopper (conveniently 50 cm^3).

PROCEDURE

17. a. The containers and lids are cleaned and dried, and their weights, A, measured.

b. A representative sample is selected, preferably comprising at least five rock specimens. The shape and size of the pieces should suit the capacity of the measuring apparatus.

c. The specimens are placed in the containers and the lids replaced.

d. The weight, B, of each specimen container with lid is determined.

e. The lids are removed and the specimens dried to constant weight at a temperature of 105° C.

f. The lids are replaced and the specimens allowed to cool in the desiccator for 30 minutes.

g. The weight, C, of each specimen together with container and lid is measured.

18. a. A loop of thread is tied around each specimen so that approximately three inches extend beyond the knot.

b. Each specimen is dipped into melted paraffin by holding the end of the thread and then held in air for a few seconds until the paraffin coating hardens. The excess length of thread beyond the knot is removed and the specimen replaced in its container.

c. The weight, D, of the paraffin-coated specimens plus containers and lids is measured.

19. a. The small dish, placed in a larger one, is filled to overflowing with water, then covered with the glass plate so that the plate is flush with the top of the dish and no air is entrapped.

b. The outside of the small dish is wiped clean and placed in the second larger dish, which is clean and empty.

c. The glass plate is removed and the paraffin-coated specimen is submerged; the dish is then covered with the glass plate which is again placed flush with its upper surface. The small dish is removed from the larger one, allowing the water from its outside surface to drip back into the larger dish.

d. The water displaced by the paraffin-coated specimen is poured into a clean, empty graduated cylinder and its volume, E, recorded.

20. If a drill core specimen of cylindrical shape is used the bulk volume is calculated as follows:

a. The diameter, d, of the specimen is measured to the nearest 0.005 in. (0.1 mm) by averaging two diameters measured at right angles to each other at about the upper height, mid height and lower height of the specimen. The diameter used to calculate volume is then the average of the three diameters obtained at the upper height, mid height and lower height of the specimen.

b. Specimen height, L_o, is determined to the nearest 0.005 in. (0.1 mm) by averaging the four heights measured along the side of the specimen, at two diameters at right angles to each other.

21. a. The paraffin coating is removed from the specimens by scraping and chipping and the cleaned specimens are crushed together and ground to a grain size not exceeding 0.42 mm (40 sieve). A representative sub-sample of about 15 g of the pulverized material is selected and oven dried.

b. The weight, F, of a clean and dry volumetric flask together with stopper is measured.

c. The flask is filled with distilled water, then brought to an equilibrium temperature by keeping it at uniform room temperature for three hours. Its water level is adjusted accurately to the 50 cm^3 graduation mark with a medicine dropper. The flask is sealed with a stopper and its weight, G, measured.

d. The flask is emptied and dried and a 15 g sample of dry, pulverized rock added with the aid of a funnel. The weight, H, of the flask including sample and stopper is measured.

e. Sufficient distilled water is added to thoroughly wet the sample; the air from the flask and wet sample is then evacuated for about 20 minutes. Further distilled water is added, and the flask again carefully evacuated to remove air. Finally the water level is accurately adjusted to the 50 cm^3 graduation mark.

f. The stoppered flask with contents is kept for three hours at a uniform room temperature when its weight, J, is measured.

CALCULATIONS

22. a. Water content, $w\% = (W_w/W_s)\ 100$

where pore water weight, $W_w = B-C$

solid weight, $W_s = C-A$

b. Density of rock, $\gamma = W_b/V_b$

where bulk weight, $W_b = B-A$

bulk volume, $V_b = E-(D-C)/\gamma_p$

density of paraffin, $\gamma_p = 0.908\ g/cm^3$

or

bulk volume, $V_b = d^2\ \pi\ L_o/4$

where d = diameter of the cylindrical specimen

L_o = height of the cylindrical specimen,

c. Dry density of rock, $\gamma_d = W_s/V_b$

d. Grain density, $\gamma_g = G_w/G_v$

where grain weight, $G_w = G-F$

grain volume, $G_v = V[1-(J-H)/(G-F)]$

V = calibrated volume of flask, usually 50 cm^3

e. Porosity, $n\% = 100\ (1-\gamma_d/\gamma_g)$

f. Degree of saturation,

$$S_r\% = 100\ w\gamma_d/n\gamma_w$$

where density of water,

γ_w = 1.00 g/cm^3 or 62.4 lb/ft^3

REPORTING OF RESULTS

23. If the porosity/density and related properties are being determined for several locations (eg at various depths of a borehole or various sections and/or elevations of the pit wall) the results are reported in tabulated form, with proper sample identification (rock type and origin) and with accuracies indicated in Fig 2.

24. If the tests involve only a few samples the working sheets as shown in Fig 2 substitute adequately for a report.

POROSITY / DENSITY

Sample *weathered limestone*

Location *footwall outcrop, K zone* Date *July 23, 1973*

Bore Hole _____ Depth _____ Tested by *W.G.*

Sample No. *K*

Specimen No.	Container No.	A	B	C	D	E	D-C	$\frac{D-C}{\gamma_p}$	W_w	W_s	W_b	V_b	w%	γ	γ_d
K-6	16	12.79	80.20	75.91	80.46	36.5	4.55	5.01	4.29	63.12	67.41	30.99	6.8	2.17	2.04
K-7	5	12.95	89.53	84.19	91.17	42.0	6.98	7.69	5.34	71.24	76.58	34.31	7.5	2.23	2.08
K-8	38	13.16	78.80	74.11	79.56	37.5	5.45	6.00	4.69	60.95	65.64	31.50	7.7	2.08	1.93
K-9	14	13.05	74.99	71.21	76.07	32.5	4.86	5.35	3.78	58.16	61.94	27.15	6.5	2.28	2.14
K-10	43	12.88	76.47	71.98	77.14	34.0	5.16	5.68	4.49	59.10	63.59	28.32	7.6	2.24	2.09

F: *42.68*

G: *92.59*

H: *57.96*

J: *102.18*

$G_w = H - F =$ *15.28*

$G_v = V\left[1-(J-H)/(G-F)\right] =$ *5.70*

$\gamma_g = G_w/G_v =$ *2.68*

Sample water content, w: *7.2* %

bulk density, γ: *2.20* g/cm^3, *137* lb/ft^3

dry density, γ_d: *2.06* g/cm^3, *128* lb/ft^3

grains density, γ_g: *2.68* g/cm^3, *167* lb/ft^3

porosity, n: *23.1* %

degree of saturation, S_r: *64.2* %

Remarks: *specimens were collected on July 19, placed into containers, covered with damp rag in lab. until testing.*

Fig 2 - Working sheet for porosity/density determination.

DETERMINATION OF SWELLING PRESSURE INDEX

SCOPE

25. a. The purpose of this test is to measure the pressure necessary to constrain at constant volume an undisturbed rock specimen immersed in water.

b. All procedures for determining the swelling pressure index are based on the appropriate standards (2).

APPARATUS

26. The apparatus is adapted from that used for soil consolidation testing and consists essentially of the following:

a. a metal ring for rigid radial constraint of the specimen, polished and lubricated to reduce friction

b. porous plates to allow water access to the top and bottom of the specimen and plates

c. a cell to contain the specimen assembly filled with water to a level above the top porous plate (Fig 3)

d. a dial gauge with 0.001 in. (0.0025 mm) reading accuracy, mounted to measure the swelling displacement along the central axis of the specimen

e. a load measuring device capable of measuring to an accuracy of 1% the force required to resist swelling

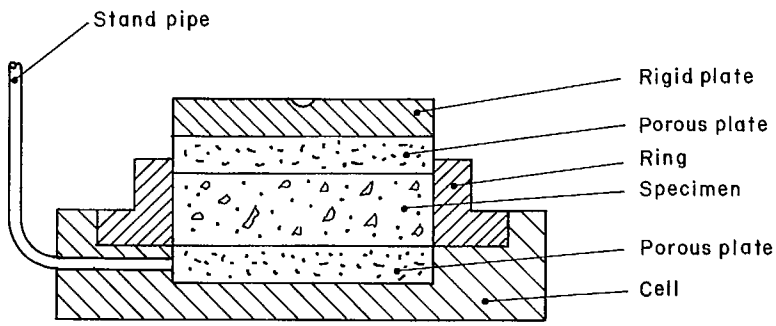


Fig 3 - Cell and specimen assembly for confined swelling tests.

f. a loading device capable of continuous adjustment to maintain the specimen at constant volume as swelling pressure develops. The force is applied through a rigid plate with a spherical seat to ensure that the top porous plate remains flat.

PREPARATION OF THE TEST SPECIMEN

27. a. The specimen should conform closely to the geometry of the right circular cylinder, with a diameter not less than 2.5 times its height. The height should exceed 0.5 in. (12 mm) or 10 times the maximum grain diameter, whichever is greater. The specimen should be a close fit within the ring.

b. Guidance for specimen preparation is given in Supplement 3-5.

c. The inclination of the bedding or foliation with respect to the specimen axis is to be recorded.

d. A specimen for determining water content is to be retained for each swelling specimen. This relates to either the in situ or to any artificially controlled initial value.

PROCEDURE

28. a. The specimen is inserted into the ring, the apparatus assembled and the specimen loaded axially to a surcharge pressure of 0.5 psi (3.5 kPa).

b. The cell is then flooded with water to cover the top porous plate and the swelling force is recorded as a function of elapsed time (see Fig 4).

c. The applied force is regularly adjusted to maintain zero specimen swell throughout the test by maintaining specimen height to within 0.001 in. (0.025 mm) of the original.

d. Swelling force is continuously recorded until it reaches a constant level or passes a peak.

29. The water content of the specimen, retained for this purpose, is calculated as described in paragraphs 10 and 12.

CALCULATION

30. The swelling pressure index is calculated as follows:

Swelling pressure index, $I_{sp} = \frac{F}{A}$

where F = maximum axial swelling force recorded during the test

A = cross sectional area of the specimen

REPORTING OF RESULTS

31. Results are to be presented for at least three specimens of each sample. The report should include the following information for each specimen:

a. sample identification (rock type and origin)

b. swelling pressure index to the nearest psi (kPa)

c. initial water content

d. specimen's initial diameter and height with inclination of bedding or foliation with respect to the specimen axis

e. brief remarks on specimen preparation and storage method prior to testing.

32. The working sheets substitute for a report if only a few sampling locations are involved in determining the swelling pressure index (Fig 4).

SWELLING PRESSURE INDEX

Sample *sandstone with various clay content, darker coloured bands of higher clay content at 75° to the core axis.*

Date *Nov. 17, 1972*

Tested by *W. G.*

Proving ring calibration factor *0.465* lb/div

Location *Zone 5*

Bore Hole *22* Depth *9' to 16'*

Sample No. *5-22-9*

Specimen No. *2*

Date	Time	Elapsed Time	Displacement gauge reading		Load gauge reading		Load, lb	Notes
			intermed.	adjusted	intermed.	adjusted		
NOV. 17	11:05 A.M.			127		1	0.465	0.5 psi applied
	11:06	0	127	127	2	2	0.93	cell flooded
		1 min.	127	127	3	3	1.4	
		2	127	127	4	4	1.9	
		5	128	127	7	8	3.7	
	11:16	10	128	127	14	15	7.0	
		20	128	127	23	24	11.2	
		30	128	127	33	35	16.3	
	12:06	60	128	127	52	54	25.1	
	1:00 P.M.	120	129	127	96	100	47	
	3:00	4 hrs.	130	127	172	182	85	
	5:00	6	130	127	250	261	121	
	7:00	8	129	127	331	336	156	
	9:15	10	128	127	369	377	175	
Nov. 18	6:45 A.M.	20	128	127	479	485	226	
	5:20 P.M.	30	128	127	510	514	239	
Nov. 19	11:00 A.M.	48	127	127	531	531	247	Test completed

Diameter: *1 5/8* in. (*41.3* mm) Area, A *2.07* in.^{2} (*13.4* cm^2)

Height: *0.616* in. (*15.6* mm) Initial water content: *5.3* %

Swelling pressure index, $I_{sp} = \frac{F}{A} = \frac{247}{2.07} =$ *119* psi (*882* kPa)

Remarks: *on Nov. 2nd, after cores were logged, samples were wrapped in plastic bags and stored in lab., specimens were cut-off and the ends were made smooth on machine shop lathe, the specimens are representing the higher clay content band of BX core.*

Fig 4 - Working sheet for swelling pressure index determination.

DETERMINATION OF SWELLING STRAIN INDEX

SCOPE

33. The purpose of this test is to measure the axial swelling strain developed against a constant axial pressure or surcharge when a radially confined undisturbed rock specimen is immersed in water.

APPARATUS

34. The apparatus is adapted from that used for soil consolidation testing, and consists essentially of the following:

a. A metal ring for rigid radial constraint of the specimen. The ring is polished and lubricated to reduce friction between it and the specimen. The ring height should be sufficient to accommodate the specimen when fully swollen.
b. Porous plates to allow water access at the top and bottom of the specimen. The top plate freely slides into the ring. Filter paper may be inserted between the specimen and plates.
c. A cell to contain the specimen assembly which can be filled with water to a level above the top porous plate. The principal features of the cell and specimen assembly are illustrated in Fig 3.
d. A dial gauge with 0.0001 in. (0.0025 mm) reading accuracy, mounted to measure the swelling displacement along the central axis of the specimen.
e. A loading device such as a dead weight or weight and lever system capable of applying sustained pressure of 0.5 psi (3.5 kPa) to the specimen and maintaining this pressure within 1% throughout swelling of the specimen. The force is applied through a rigid plate with a spherical seat to ensure that the top porous plate remains flat.

PREPARATION OF THE TEST SPECIMEN

35. a. The specimen should conform closely to the geometry of a right circular cylinder. It should have a diameter not less than 2.5 times its height. The height should exceed 0.5 in. (12 mm) or 10 times the maximum grain diamter, whichever is greater. The specimen should be a close fit within the ring.
b. Guidance for specimen preparation is given in Supplement 3-5.
c. The inclination of the bedding or foliation with respect to the specimen axis is to be recorded.
d. A specimen for determining water content is to be retained for each swelling specimen. This relates to either the in situ or to any artificially controlled initial value.

PROCEDURE

36. a. The initial height of the specimen is measured to the nearest 0.0001 in. (0.0025 mm).

b. The specimen is inserted into the ring, the apparatus is assembled and the specimen loaded axially to a surcharge pressure of 0.5 psi (3.5 kPa).

c. The cell is then flooded with water to cover the top porous plate, and the swelling displacement is recorded as a function of elapsed time.

d. Swelling displacement is continuously recorded until it reaches a constant level or passes a peak.

37. The water content of the specimen, retained for this purpose, is established as detailed in paragraphs 10 and 12.

CALCULATION

38. The swelling-strain index is calculated as follows:

Swelling strain index, $I_{ss} = \frac{d}{L} \times 100\%$

where d = maximum swelling displacement recorded during the test and

L = initial height of the specimen

REPORTING OF RESULTS

39. Results are to be presented for at least three specimens for each sample. The report should include the following information for each specimen:

a. sample identification (rock type and origin)

b. swelling-strain index to the nearest 0.1 per cent

c. initial water content

d. specimen's initial diamter and height with inclination of the bedding or foliation with respect to the specimen axis

e. brief remarks on specimen preparation and storage method prior to testing.

40. The working sheets substitute adequately for a report if only a few sampling locations are involved in determining the swelling strain index, (Fig 5).

SWELLING STRAIN INDEX

Sample *mudstone* Date *Oct. 5, 1972*

Tested by *W. G.*

Location *Section E*

Bore Hole *27* Depth *8'-4" to 10'-2"*

Sample No. *E-27-8* Specimen No. *3*

Date	Time	Elapsed Time, min	Dial gauge reading	Displacement 0.0001 in.	Notes
Oct. 5	10:10 A.M.		328		0.5 psi applied
	10:11	0	329	1	cell flooded
		1	330	2	
		2	333	5	
		3	334	6	
		4	336	8	
		5	338	10	
		6	339	11	
		7	340	12	
		10	342	14	
		15	344	16	
		20	345	17	
		25	345	17	
		30	345	17	Test completed
					Specimen became
					flaky after test.

Diameter: *1 5/8* in. (*41.3* mm)

Height: *0.523* in. (*13.3* mm)

Initial water content: *3.8* %

Swelling strain index, $I_{ss} = \frac{d}{L} 100 = \frac{0.0017}{0.523} 100 = 0.33$ %

Remarks: *no visible foliation or bedding on specimen, specimen was cut-off from BX core by using hack-saw, then ends were polished with sandpaper placed on flat surface, cores were collected at drill site on Oct. 3, wrapped in plastic bags until testing.*

Fig 5 - Working sheet for swelling strain index determination.

DETERMINATION OF SLAKE-DURABILITY INDEX

SCOPE

41. a. The purpose of this test is to assess the rock sample's resistance to weakening and disintegration when subjected to two standard cycles of drying and wetting.

b. All procedures for determining the slake-durability index are based on the appropriate standards (2).

APPARATUS

42. The apparatus consists essentially of the following:

a. A test drum, comprising a 2.00 mm mesh cylinder of unobstructed length 100 mm and of diameter 140 mm, fixed to a solid base. The drum has a solid removable lid held in place by three bolts located between the base and the lid. The mesh cylinder must be sufficiently strong to retain its shape during use but neither its exterior or interior should be obstructed, for example, by reinforcing members. The drum must withstand a temperature of 105° C.

b. A trough to contain the test drum supported horizontally by its axis to allow free rotation, and with water capacity to a level of 20 mm below the drum axis. The drum is mounted to allow 40 mm unobstructed clearance between the mesh cylinder and trough base. The principal features of the trough and drum assembly are illustrated in Fig 6.

c. A motor drive capable of rotating the drum at a speed of 20 rpm, speed to be held constant to within five per cent for a period of 10 min.

d. An oven with constant temperature of 105° C to within 3° C for a period of at least 12 hrs.

e. A balance capable of weighing the drum plus sample to an accuracy of 0.5 g.

PROCEDURE

43. a. A representative sample is selected comprising 10 rock lumps, each weighing about 50 g. The lumps should be spheroidal in shape and the corners should be rounded during preparation.

b. The sample is placed in the clean drum and dried to a constant weight at a temperature of 105° C, usually requiring from two to six hrs in the oven. The weight, A, of the drum together with the sample is recorded. The sample is then immediately tested.

c. The lid is replaced and the drum mounted in the trough and coupled to the motor.

d. The trough is filled with tap water at 20° C to a level 20 mm below the drum axis and the drum is rotated at 20 rpm for 10 min.

e. The drum is removed from the trough, the lid removed from the drum and the drum with

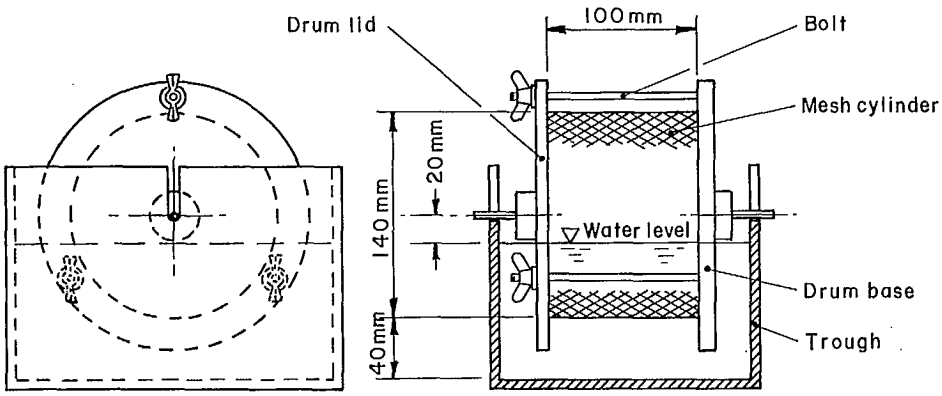


Fig 6 - Slake-durability test equipment.

retained portion of the sample dried to a constant weight at 105° C. The weight, B, of the drum including that of the retained portion of the sample is recorded.

f. Steps (c) - (e) are repeated and weight, C, of the drum including that of the retained portion of the sample is recorded.

g. The drum is cleaned and its weight, D, recorded.

CALCULATIONS

44. The slake-durability index (second cycle) is calculated as the percentage ratio of the final to initial dry sample weights as follows:

$$\text{Slake durability index, } I_{d2} = \frac{C-D}{A-D} \times 100\%$$

REPORTING OF RESULTS

45. The report should include the following information for each sample tested:

a. sample identification (rock type and origin).

b. slake-durability index (second cycle) to the nearest 0.1 per cent

c. general appearance of fragments retained in the drum

d. general appearance of material that has passed through the drum

e. nature and temperature of slaking fluid; this is usually tap water at 20° C, but could also be natural groundwater, sea water, etc.

46. The working sheets substitute for a report (Fig 7) if only a few sample locations are involved in determining the slake-durability index.

SLAKE-DURABILITY INDEX

Sample *shale of the hanging-wall contact zone* Date *July 4, 1972*

Tested by *W. G.*

Location *Section 21, second bench*

Bore Hole _____ Depth _____

Sample No. *H-S-3*

Weight A = *1263.0* g Weight C = *962.5* g

Weight B = *1179.5* g Weight D = *742.0* g

Slake-durability index, $I_{d2} = \frac{C-D}{A-D} \times 100\% = \frac{962.5 - 742.0}{1263.0 - 742.0} 100 =$ *42.3* %

Remarks: *approx. 3 mm thick wafer-like fragments in the drum and flaky fragments in the water, tap water at 19°C.*

Fig 7 - Working sheet for slake-durability index determination.

DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH

SCOPE

47. a. The purpose of this test is to measure the ultimate compressive strength of a cylindrical rock sample loaded axially.

b. The axial deformation of the specimen is also measured to obtain information on the deformation and failure characteristics of the rock substance to its ultimate strength.

c. All procedures for determining the uniaxial compressive-strength are based on the appropriate standards and suggested specifications (4,5,6).

APPARATUS

48. a. A suitable compression machine with sufficient capacity to apply an axial load continuously at a constant stress rate so that failure will occur within five to fifteen minutes of loading; alternatively the applied stress rate should be within the limits of 75 psi/s (0.5 MPa/s) to 150 psi/s (1.0 MPa/s). Principal features of a suitable hydraulically operated compression machine and specimen assembly are illustrated in Fig 8.

b. a device such as a proving ring with dial gauge to measure the applied load with 1% accuracy

c. steel discs at specimen ends, having the same diameter as the specimen. The thickness of the discs should be at least 5/8 in. (15 mm). Their surfaces should be ground and their flatness should be 0.0002 in. (0.005 mm). The Rockwell hardness of the disc material should be at least C 30. The upper disc should incorporate a spherical seat to ensure axial load application to the specimen.

d. a suitable device to measure axial deformation such as a dial gauge or compressometer.

PREPARATION OF THE TEST SPECIMEN

49. a. The test specimen should be cylindrical, having a length to diameter ratio of 2.5 to 3.0 and a diameter preferably not less than NX core size, or approximately 2-1/8 in. (54 mm). The diameter of the specimen should be related to the size of the largest grain in the rock by the ratio of at least 10:1. The ends of the specimen should be parallel and at right angles to the longitudinal axis.

b. Guidance for sample and specimen handling and storage, as well as the method of specimen preparation with allowable tolerances is given in Supplement 3-5.

c. The diameter of the test specimen is measured to the nearest 0.005 in (0.1 mm) by averaging two diameters measured at right angles to each other at about the upper height, and mid height

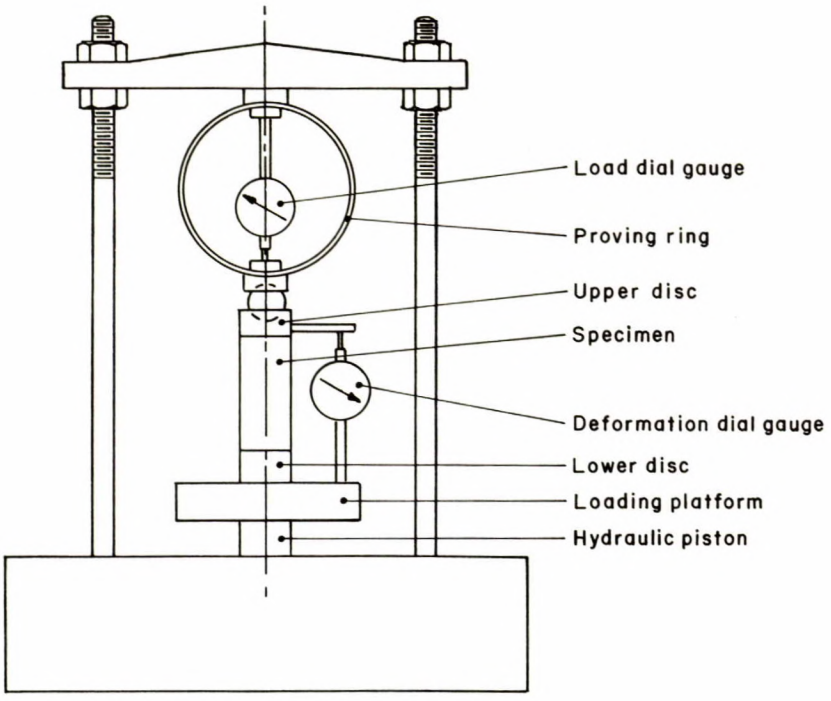


Fig 8 - Compression machine and specimen assembly for uniaxial compressive strength test.

and lower height of the specimen. The average diameter is used for calculating the cross-sectional area. The height of the specimen is determined to the nearest 0.05 in. (1.0 mm).

d. The inclination of bedding or foliation with respect to the specimen axis is recorded.

e. The number of specimens tested reflects practical considerations but at least three are preferred from each sample.

PROCEDURE

50. a. The specimen is placed between the lower and upper discs (Fig 9), then centred on the loading platform. Initial contact is made between the elements of the load measuring device and the upper disc either by mechanical or manual operation. The axial loading of the specimen is checked.

b. A seating load equivalent to 1% of the estimated uniaxial strength is applied. The load measuring device is then set to zero.

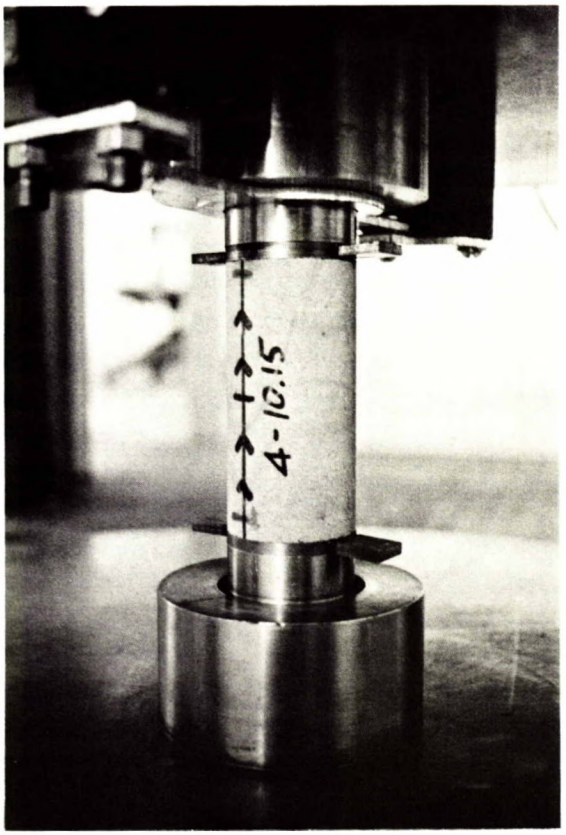


Fig 9 - Specimen in compression machine (Elliot Lake Laboratory, CANMET).

c. The axial deformation device is assembled and set at zero (Fig 10).
d. A cloth is wrapped around the specimen to prevent possible injury to the operator or any damage to the apparatus caused by flying rock fragments (alternatively a plexiglas or metal cylinder is placed around it as shown in Fig 11).
e. The loading rate is set and compression begun.
f. Load and axial deformation readings are taken approximately every 20 seconds for the first minute of the test.
g. Compression is continued until the specimen fails (Fig 12).
h. A sketch of the failed specimen and/or a note of the failure-mode is made.
i. If water content is required, the failed specimen is used for that purpose following the procedure specified in paragraphs 10 and 12.

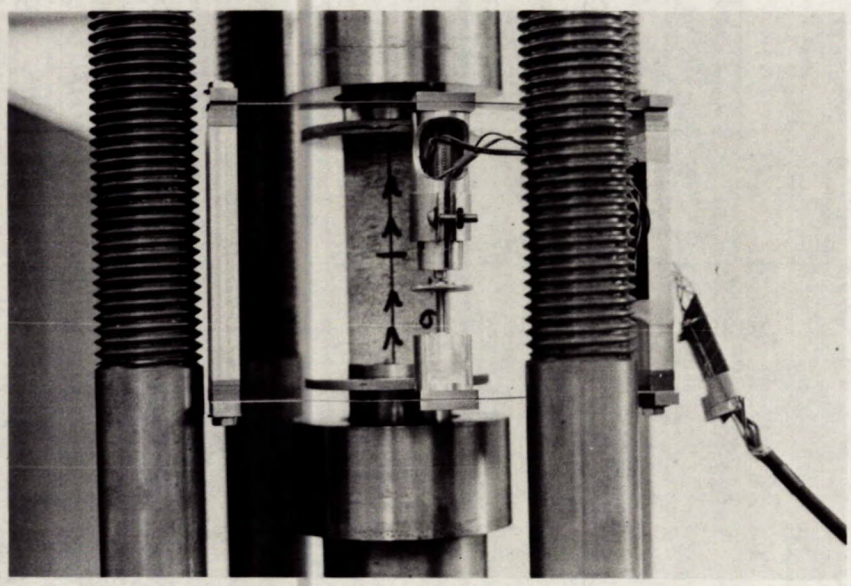


Fig 10 - Axial deformation measuring device is assembled (Elliot Lake Laboratory, CANMET).

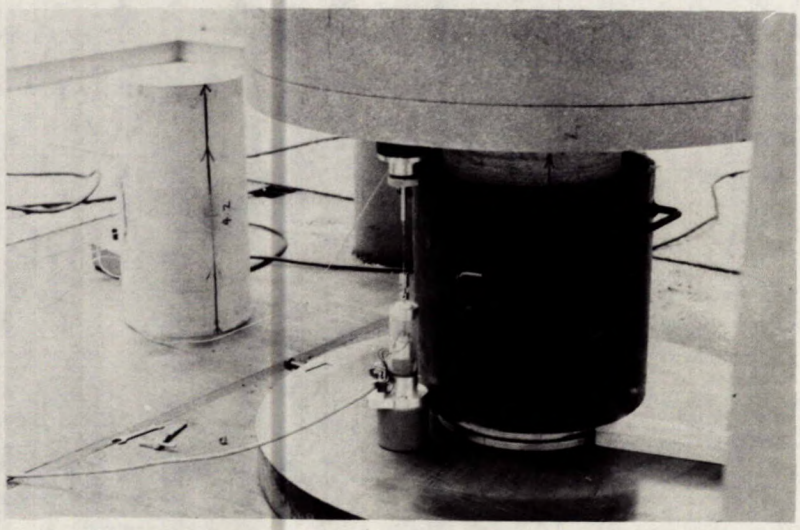


Fig 11 - Protective metal cylinder placed around specimen (Elliot Lake Laboratory, CANMET).

Fig 12 - Failed specimen.

CALCULATIONS

51. a. The uniaxial compressive strength is calculated as follows:

Uniaxial compressive strength, $Q_u = P_u/A$

where P_u = the maximum load carried by the specimen during the test

A = the original cross-sectional area calculated in accordance with the specifications given in paragraph 49(c)

b. The uniaxial failure strain is calculated as follows:

Uniaxial failure strain, $\varepsilon = \Delta L/L_o$

where ΔL = the maximum axial deformation sustained by the specimen during the test

L_o = the initial specimen length measured in accordance with the specifications of paragraph 49(c)

REPORTING OF RESULTS

52. The report should include the following information for each sample tested:

a. sample identification (rock type and origin)
b. average uniaxial compressive strength
c. average uniaxial failure strain
d. storage and environmental history
e. method and date of specimen preparation; storage history of specimens; number of specimens tested within the sample
f. information on testing such as date, type of apparatus and test rate
g. average water content and degree of saturation if critical
h. any other observations or available physical data.

53. In addition, the report should include the following information for each specimen in convenient tabulated form:

a. identification (specimen's number within the sample)
b. diameter, height and cross-sectional area
c. orientation of axis with respect to anisotropy, eg with respect to bedding plane, foliation, etc
d. test duration
e. uniaxial compressive strength
f. uniaxial failure strain
g. descriptive notes in the following terms on failure characteristics of the specimen, such as shape, mode and number of fragments (7):
    i. For failure shape:
        cone
        axial
        diagonal

parallel to discontinuity
no data

ii. For failure mode:
violent
quiet
no data

iii. For number of fragments:
three or less
more than three
crushed
no data

h. water content and degree of saturation if critical

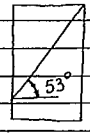
i. any other observation relating to the specimen.

54. The working sheets substitute for a report if only a relatively few are tested (Fig 13).

UNIAXIAL COMPRESSIVE STRENGTH

Sample *footwall quartzite*
Date *January 12, 1971*
Tested by
Proving ring calibration factor *191* lb/div
Location
Water content %
Bore Hole *H-5* Depth *21'-3"*
Degree of saturation %
Sample No. *H-5-21*
Specimen No. *2*

Elapsed Time, min	Deformation gauge, 0.0001 in.		Strain	Load gauge	Load, lb	Stress, psi	Notes
				5	955	274	seating load
0	215	0	0	0	0	0	Loading rate set
	207			14			at ~80 psi/s
	198	17	.00028	29	5,539	1,592	
	194			45			
	191	24	.00039	62	11,842	3,403	failed specimen
	186			74			
1	183	32	.00052	88	16,808	4,830	
	178			120			
	173			146			
2	169	46	.00075	177	33,807	9,715	
	164			206			
	160			240			no bedding or
3	156	59	.00097	265	50,615	14,545	foliation on
	152			291			specimen.
	148			318			
4	138	77	.00126	352	67,232	19,320	failure characteristics
	128			412			shape: diagonal
	116	99	.00162	468	89,388	25,686	mode: violent
5	84	131	.00215	524	100,084	28,760	fragments: less
5'-08"				532	101,612	29,199	than three pieces



Diameter: *2.105* in. (*53.5* mm)
Height, L_o: *6.10* in. (*155* mm) Area, A: *3.48* in^2 (*22.5* cm^2)
Uniaxial compressive strength, $Q_u = \frac{P_u}{A} = \frac{101,612}{3.48} =$ *29,199* psi (*201* MPa)
Uniaxial failure strain, $\epsilon = \frac{\Delta L}{L_o} = \frac{0.0131}{6.10} =$ *0.00215 (approx.)*
Remarks: *NX core samples were collected on Dec. 20, specimens were prepared according to specifications, water content was not established since the hole was drilled in July 1970.*

Fig 13 - Working sheet for uniaxial compressive strength determination.

55. It is a worthwhile option to use available test data to plot the stress-strain history. The strain and stress are calculated for a convenient number of intermediate load levels and the relationship plotted (Fig 14).

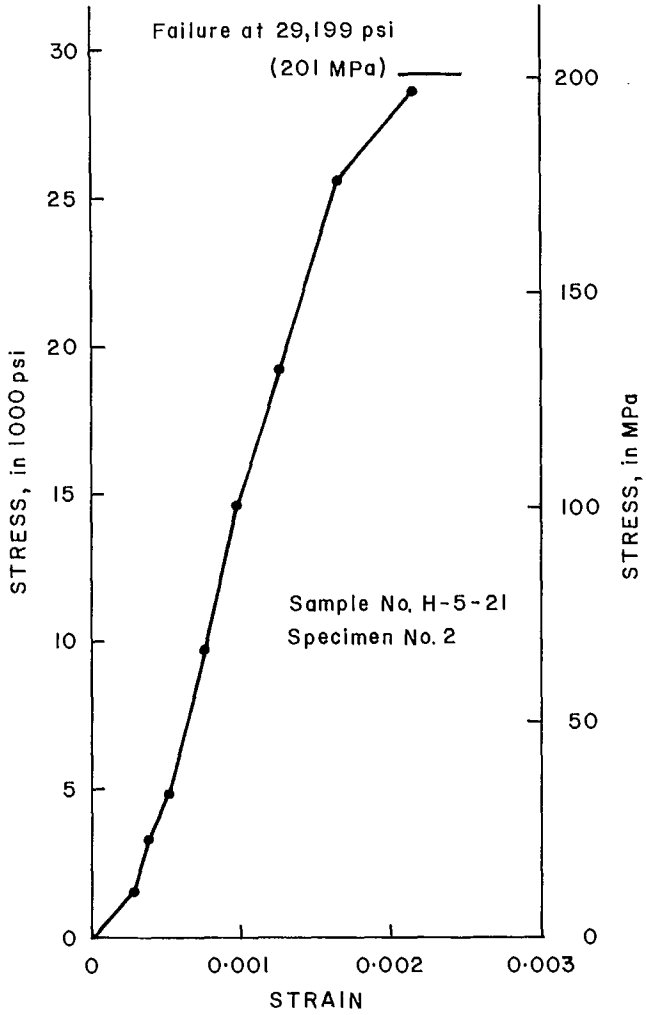


Fig 14 - Stress-strain relationship.

DETERMINATION OF POINT LOAD STRENGTH INDEX

SCOPE

56. a. The purpose of this test is to measure the rock specimen's strength by applying a concentrated load using a pair of conicalplatens.

b. Specimens are either in the form of rock cores or irregular lumps.

c. The test can be performed either in the laboratory or the field since the testing machine is usually portable.

d. The index thus obtained is used for rock strength classification.

e. All procedures for determining the point-load-strength-index are based on the appropriate standards (4).

APPARATUS

57. The testing machine incorporates a loading system, a system for measuring the load required to break the specimen and a system for measuring the distance between the two platen contact points (Fig 15 and 16). Essential features are as follows:

a. The loading system should be adjustable to accept 1 to 4 in. (25 to 100 mm) rock specimens, for which a loading capacity of up to 11,000 lb (approximately 50 kN) is usually required. To minimize delay between tests a quick retracting ram is desirable.

b. Spherically truncated conical platens (Fig 17) are used to transmit the load to the specimen. The platens should be hardened and accurately aligned during testing.

c. The load measuring system should indicate failure load to an accuracy of ± 2%. It should incorporate a maximum-indicating device, so that the reading is retained and can be recorded after specimen failure. It should be resistant to hydraulic shock and vibration.

d. The distance measuring system should indicate the distance between platen-contact points to an accuracy of ± 0.02 in. (0.5 mm). It should be designed to allow for zero check and adjustments and should be so robust that its accuracy is maintained during testing.

PREPARATION OF THE TEST SPECIMEN

58. a. Rock samples are grouped on the basis of both rock type and estimated strength. At least 10 specimens are selected for testing each sample if core samples are used, and at least 20 if using irregular specimens.

b. Specimens in the form of core are preferred for accurate classification. Acceptable minimum and maximum core sizes are AX and HX respectively.

c. The shape of irregular lump specimens should be

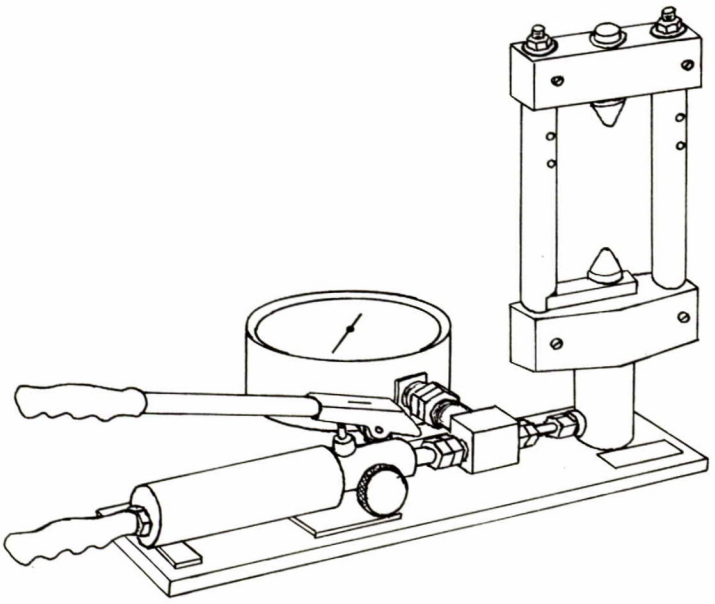


Fig 15 - Point load strength testing machine (manufactured by Engineering Laboratory Equipment Limited, England).

Fig 16 - Other type of point load strength testing machine (manufactured by Robertson Research Mineral Technology Limited, Wales).

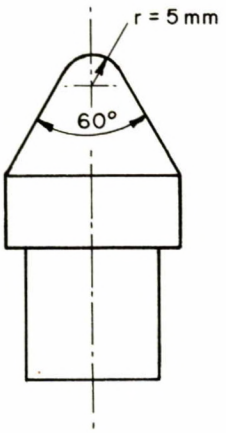


Fig 17 - Critical dimension of platen.

spheroidal with a preferred diameter of 2 in. (50 mm). Acceptable minimum and maximum diameters are 1 in. (25 mm) and 4 in. (100 mm) respectively. The acceptable ratio of the longest to shortest diameter of the specimen falls between 1.0 and 1.4.

d. Guidance for sample and specimen handling and storage, as well as method of specimen preparation, is given in Supplement 3-5.

e. Specimens for water content determination are taken from the specimens which have failed.

PROCEDURE

59. The diametral test.

a. Core specimens with a length to diameter ratio greater than 1.4 are suitable for diametral testing.

b. The inclination of bedding, foliation or other plane of weakness is recorded, with respect to the line of loading.

c. The specimen is inserted in the test machine and the platens advanced to make contact along a core diameter, ensuring that the distance, L, between the contact point and the nearest free end is at least 0.7 D (Fig 18a).

d. The diameter, D, is recorded and the load increased to failure.

e. The failure load, P, is recorded.

f. Fragments of the broken specimen are retained for water content determination which is performed after all specimens of the sample are tested for point-load strength, as specified in paragraphs 10 and 12.

60. The axial test.

a. Core specimens with a length to diameter ratio of 1.1 ± 0.05 should be used (Fig 13b). Long pieces of core can be utilized to obtain both diametral and axial strength values. The core is tested diametrally first, ensuring that a suitable length is retained for subsequent axial testing (ie ensuring that L/D = 1.1 ± 0.05)

b. The steps detailed in paragraphs 65(b) to 65(f) are repeated.

61. The irregular lump test.

a. Rock lumps of roughly spherical shape with a preferred diameter of approximately 2 in. (50 mm) and with a ratio of longest to shortest diameters between 1.0 and 1.4 are selected. The number of irregular specimens within a test sample should be at least 20.

b. The specimens are trimmed, loose particles removed and sharp corners rounded; any convenient tools and techniques may be used.

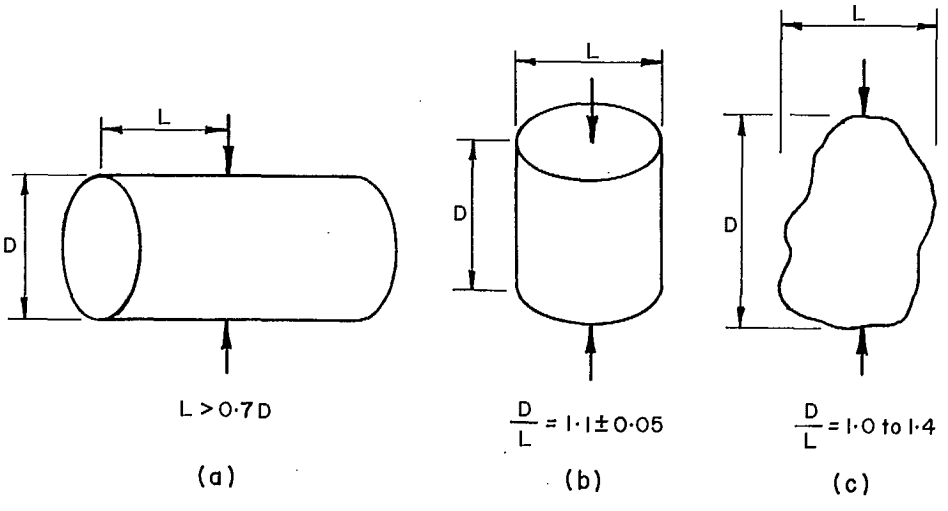


Fig 18 - Types of the point load strength tests.

c. The inclination of the bedding, foliation or other plane of weakness is recorded, with respect to the line of loading.

d. The lump specimen is inserted in the testing machine and the platens are advanced to make contact along the longest diameter of the lump, away from any edges or corners.

e. The steps of paragraphs 65(d) to 65(f) are repeated.

62. Tests for anisotropic strength.

a. Tests should be made in both the weakest and strongest directions where the rock is bedded, schistose or where it shows observable anisotropy

b. Care should be taken to ensure that the loading is strictly in and perpendicular to the direction of the weakness plane.

c. The procedure for testing should follow the appropriate steps of paragraphs 65, 66 and 67 by strictly observing the size specifications.

CALCULATIONS

63. a. The point-load strength index is calculated as follows:

Point - load strength index, $I_s = P/D^2$

where P = the load required to break the specimen and

D = the distance between the two platen contact points

b. For classification purposes the corrected index, I_{sc}, should be used. It is obtained by correcting the calculated value I_s to a reference diameter of 50 mm by using the correction chart in Fig 19.

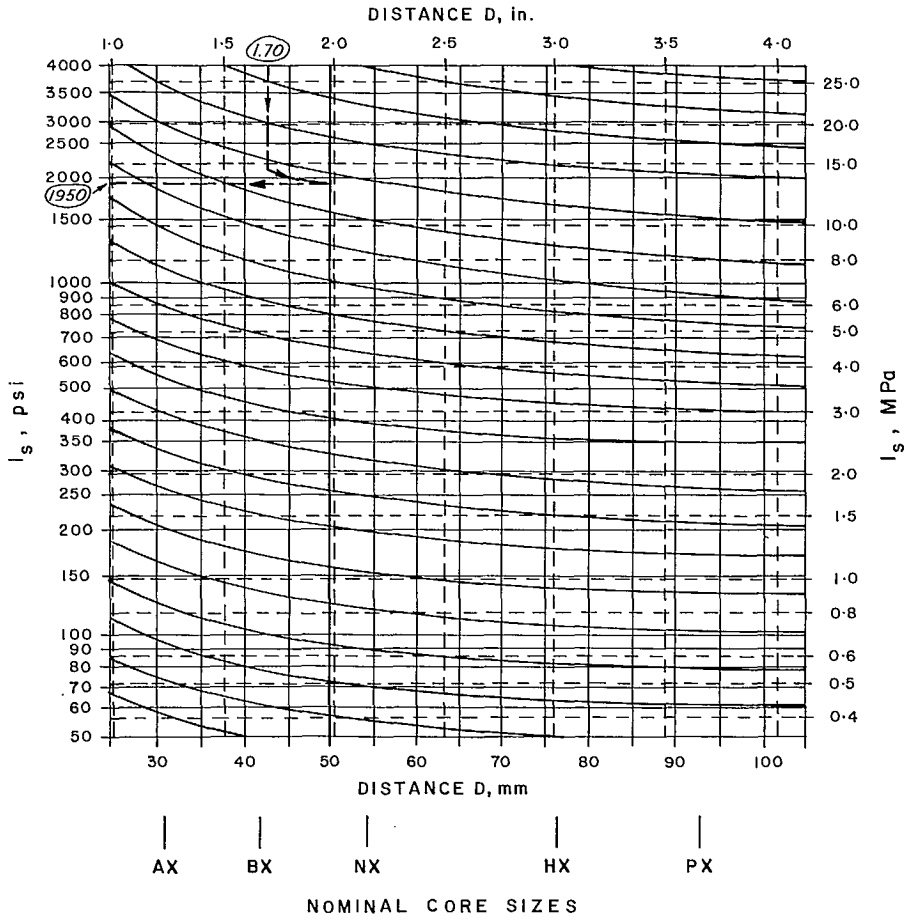


Fig 19 - Point load strength test size correction chart.

c. The median value may be found from a set of test results by systematically deleting the highest and lowest values until only two remain. The average of these is the required median value.

d. In diametral testing where the core diameter, D, is effectively constant the median failure load, P, may first be found then the index, I_s, applicable to that load is calculated and the size correction applied. In axial and irregular lump testing, however, the index for each test must first be obtained and corrected for size. The median value of these corrected results is then computed.

e. The strength anisotropy index, I_a, may be computed as the ratio of the corrected median strength indices obtained for the tests perpendicular to and parallel to the planes of weakness.

REPORTING OF RESULTS

64. The report should include the following information for each sample tested:

a. sample identification (rock type and origin)

b. median value of the corrected strength index, I_{sc}, obtained parallel to the plane of weakness

c. median value of the corrected strength index, I_{sc}, obtained perpendicular to the plane of weakness

d. anisotropy index, I_a

e. storage and environmental history

f. method and date of specimen preparation; type of testing machine

g. average water content and degree of saturation if critical

h. any other observation or available physical data.

65. The following information tabulated separately for each type of test (diametral, axial, irregular lump), and for each direction relative to the plane of weakness (parallel, perpendicular), should also be included:

a. specimen identification (specimen's number within the sample)

b. failure load, P

c. platen separation, D

d. computed values of I_s and I_{sc} that can, however, be omitted in case of diametral test results. In this case the median value of failure load, P, and the corresponding index values should be reported.

e. any other observations related to the specimen.

66. The working sheets are adequate substitutes for a report if only a relatively small number of samples are tested (Fig 20).

POINT LOAD STRENGTH INDEX

Sample *hanging-wall carbonate*

Date *June 16/70*

Tested by *WG*

Location *Zone H*

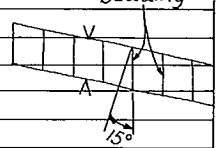
Bore Hole *H-3* Depth *15' to 17'*

Sample No. *H-3-15*

Average water content: *3.1* %

Average degree of saturation: ____ %

Test Type	Specimen No.	D	P	D^2	I_s	$I_s(50)$	Median Value	Notes
Diametral	1-A		2120					
	2-A		2650					
	3-A		2380					
	4-A		2130				P	
	5-A	1.60	2710	2.56	920	820	2365	
	6-A		3250					
	7-A		1960					
	8-A		2350					
	9-A		2390					
	10-A		2200					
Axial	1-B	1.68	4820	2.82	1710	1560		
	2-B	1.74	5760	3.03	1900	1700		
	3-B	1.70	4190	2.89	1450	1300		
	4-B	1.70	6360	2.89	2200	1950	$I_s(50)$	
	5-B	1.82	5300	3.31	1600	1450	1380	
	6-B	1.78	3870	3.17	1220	1150		
	7-B	1.78	3300	3.17	1040	980		
	8-B	1.76	4620	3.10	1490	1390		
	9-B	1.80	4320	3.24	1340	1250		
	10-B	1.68	4090	2.82	1450	1290		
	11-B	1.80	4860	3.24	1500	1380		



Median values of strength index, $I_s(50)$

Parallel to plane of weakness: *820* psi (*5.65* MPa)

Perpendicular to plane of weakness: *1380* psi (*9.51* MPa)

Anisotropy index, $I_a(50) = \frac{1380}{820} = 1.68$

Remarks: *the sample constituted three pieces of solid Bx core, tested at the site within an hour after drilling, water content samples were retained and tested in lab. on June 17.*

Fig 20 - Working sheet for point load strength index determination.

DETERMINATION OF TENSILE STRENGTH

SCOPE

67. a. The purpose of this test is to establish the tensile strength of a disc shaped rock sample loaded diametrically (Fig 21).

b. The test is commonly referred to as the Brazilian test. The tensile strength is determined indirectly, from the diametric compressive load at failure.

c. The tensile strength values obtained by this method of testing are usually greater than those that had been obtained by a direct-pull type test (8); however, the Brazilian test method is preferred, because of its simplicity.

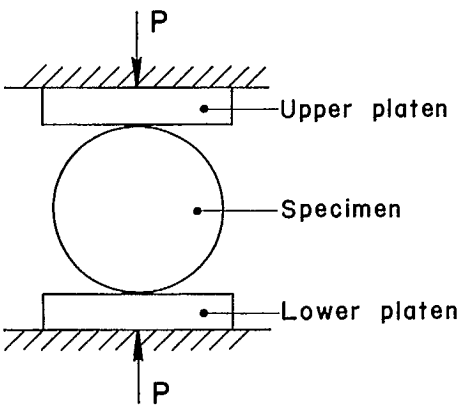


Fig 21 - Schematic arrangement of Brazilian test.

APPARATUS

68. a. A suitable compression machine, of sufficient capacity, capable of applying the necessary diametric compressive load at a constant rate of 50 lb/sec (222 N/sec).

b. A load measuring system for indicating the failure load to within an accuracy of ± 2%. This system should incorporate a maximum-load indicating device, ie one which retains the maximum load so that the latter can be recorded after specimen failure. It should be resistant to shock and vibration.

c. Loading platens with a thickness of at least 5/8 in. (15 mm). The surfaces of the platens should be ground to a flatness of 0.0002 in. (0.005 mm). The Rockwell hardness of the platen material should be at least C 30.

PREPARATION OF THE TEST SPECIMEN

69. a. The specimen should conform closely to the geometry of a right circular cylinder, with a diameter preferably not less than NX core size, ie approximately 2-1/8 in (54 mm), and with a thickness of 1/2 in. (12.7 mm). The two ends of the

specimen should be parallel to each other.

b. Guidance for sample and specimen handling and storage as well as method of specimen preparation together with allowable tolerance specifications, is given in Supplement 3-5.

c. The diameter of the test specimen is determined to the nearest 0.005 in. (0.125 mm) by averaging two diameters measured at right angles to each other at the mid thickness of the specimen. The thickness of the specimen is established to the nearest 0.005 in. (0.125 mm) by averaging the thickness measured at four points 90° to each other.

d. The inclination of the bedding and/or foliation, with respect to the diameter of loading, is recorded.

e. The number of specimens to be tested depends on practical considerations; however, preferably at least ten specimens should be tested from each sample.

f. Following preparation the test specimens are allowed to air-dry for 15 days, prior to testing.

PROCEDURE

70. a. The lower platen is placed at the center of the compression machine's loading platform.

b. The specimen is placed at the centre of the platen and while the upper platen is being inserted, a slight load of approximately 10 lb (44.5 N) is applied.

c. After proper positioning of the specimen and platens the loading rate of the compression machine is set and loading started.

d. The load is applied at a constant rate of 50 lb/sec (222 N/sec) until the specimen fails.

e. The failure load is recorded.

CALCULATIONS

71. The tensile strength is calculated as follows:

$$\text{Tensile strength, } \sigma_t = \frac{2P}{\pi Dt}$$

where P = load at failure
D = diameter of the specimen
t = thickness of the specimen.

REPORTING OF RESULTS

72. The report should include the following information for each sample tested:

a. Sample identification (rock type and origin).

b. Average tensile strength of the sample.

c. Storage and environmental history of the sample.

d. Method and date of specimen preparation; storage history of specimen; number of specimens tested within a sample.

e. Testing information, such as date, type of testing apparatus, loading rate, etc.

f. Any other relevant observations or available physical data.

73. In addition to the foregoing data, the report should also include, in a convenient tabulated form, the following information for each specimen:

a. Specimen identification (specimen's number within the sample).

b. Specimen diameter and thickness.

c. Orientation of loading with respect to bedding or foliation.

d. Tensile strength.

e. Descriptive notes on the failure characteristics of the specimen.

f. Any other observation relating to the specimen.

74. If only a relatively low number of samples were tested, the working sheets are adequate substitutes for a report (Fig 22).

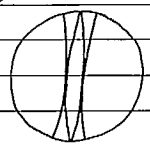
TENSILE STRENGTH (BRAZILIAN TEST)

Sample *east end sandstone*

Location *Section B-2*

Bore Hole *H-15* Depth *17.5'* Date *OCT. 2, 1973*

Sample No. *FW-3* Tested by *W.G.*

Specimen No.	D in.	t in.	P lb	σ_t psi	Notes
U-1	2.015	0.495	3350	2138	
U-2	2.015	0.495	3203	2044	failure mode:
U-3	2.015	0.490	3530	2276	
U-4	2.015	0.500	3671	2320	
U-5	2.015	0.500	3277	2071	
L-1	2.090	0.500	3324	2025	
L-2	2.090	0.485	3592	2256	for all specimens
L-3	2.090	0.490	3629	2256	except L-2 and L-3
L-4	2.090	0.505	3450	2081	which failed along
L-5	2.090	0.495	3562	2192	vertical line.
					no bedding or
					foliation.

Remarks: *H-15 hole was drilled on Sept. 3, sample FW-3 contained two pieces of NX core of about 5 in. long each, specimens were prepared on Sept. 15 using roller lapper, diamond saw and lapidary wheel, specimens were air-dryed.*

Fig 22 - Working sheet for tensile strength determination.

REFERENCES

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3. "Procedures for testing soils"; American Society for Testing and Materials; 1964.

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5. "Standard method of test for unconfined compressive strength of rock core specimens"; Designation: D2938-71a; American Society for Testing and Materials; Annual Book of ASTM Standards; 1974.

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8. "Standard method of test for direct tensile strength of rock core specimens"; Designation: D2936-71; American Society for Testing and Materials; Annual Book of ASTM Standards; 1974.