INTERNATIONAL SOCIETY FOR ROCK MECHANICS

COMMISSION ON TESTING METHODS

Working Group on Revision of the Point Load Test Method

SUGGESTED METHOD FOR DETERMINING POINT LOAD STRENGTH

(to replace original document published in 1972)

INTRODUCTION

The ISRM Commission on Testing Methods, formerly the Commission on Standardization of Laboratory and Field Tests, was established in 1967. Its main task is the drafting of "Suggested Methods" for rock testing. Its aim is to achieve some measure of standardization without inhibiting the development and improvement of techniques.

The Point Load Strength Test was one of the first to be published (in 1972) by this Commission, and is one of the first to be revised. The outcome of earlier "indirect tensile tests" such as those by Protodyakanov in Russia and by Hobbs in England, it was first described in its present form as a rock strength index test by Franklin *et al.*, and by Broch and Franklin (see Bibliography). References to the early history of the test may be found in the latter publication.

Subsequent research as detailed in the accompanying bibliography has added greatly to our understanding of the test and has led, for example, to much simpler, more direct and reliable size and shape correction procedures than those first published. The authors of this research were invited to form a working group for revision of the Suggested Method. The revised version is a concensus of their comments and opinions.

The test is primarily intended as an index for rock classification and characterization. As an index test it needs to be simple, and we have tried to retain its essential simplicity in this revised version.

Suggested Method for Determining Point Load Strength

SCOPE

1.(a) The Point Load Strength test is intended as an index test for the strength classification of rock materials. It may also be used to predict other strength parameters with which it is correlated, for example uniaxial tensile and compressive strength.[1]*

(b) The test measures the Point Load Strength Index ($I_{s(50)}$) of rock specimens, and their Strength Anisotropy Index ($I_{a(50)}$) which is the ratio of Point Load Strengths in directions which give the greatest and least values.

(c) Rock specimens in the form of either core (the *diametral* and *axial* tests), cut blocks (the *block* test), or irregular lumps (the *irregular lump* test) are broken by application of concentrated load through a pair of spherically truncated, conical platens.[2] Little or no specimen preparation is needed.

(d) The test can be performed with portable equipment or using a laboratory testing machine, and so may be conducted either in the field or the laboratory.

APPARATUS

2. The testing machine (Fig. 1) consists of a loading system (for the portable version typically comprising a loading frame, pump, ram and platens), a system for measuring the load P required to break the specimen, and a system for measuring the distance D between the two platen contact points (but see 5(e) below).

Loading system

3.(a) The loading system should have a platen-to-platen clearance that allows testing of rock specimens in the required size range. Typically this range is 15–100 mm so that an adjustable clearance is needed to accommodate both small and large specimens.

(b) The loading capacity should be sufficient to break the largest and strongest specimens to be tested.[3]

(c) The test machine should be designed and constructed so that it does not permanently distort during repeated applications of the maximum test load, and so that the platens remain co-axial within ± 0.2 mm throughout the testing. No spherical seat or other non-rigid component is permitted in the loading system. Loading system rigidity is essential to avoid problems of slippage when specimens of irregular geometry are tested.

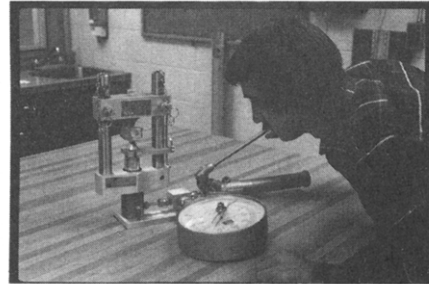(d) Spherically-truncated, conical platens of the standard geometry shown in Fig. 2 are to be used. The 60°

Fig. 1. Photograph of portable point load test machine.

cone and 5 mm radius spherical platen tip should meet tangentially.[4] The platens should be of hard material such as tungsten carbide or hardened steel so that they remain undamaged during testing.

Load measuring system

4.(a) The load measuring system, for example a load cell or a hydraulic pressure gauge or transducer connected to the ram, should permit determination of the failure load P required to break the specimen and should conform to the requirements (b) through (d) below.

(b) Measurements of P should be to an accuracy of $\pm 5\% P$ or better, irrespective of the size and strength of specimen that is tested.[3,5]

(c) The system is to be resistant to hydraulic shock and vibration so that the accuracy of readings is not adversely affected by repeated testing.

(d) Failure is often sudden and a maximum load indicating device is essential so that the failure load is retained and can be recorded after each test.
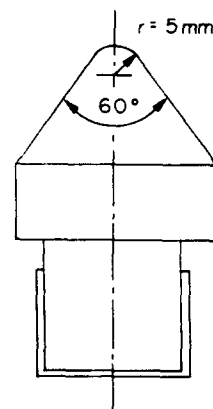
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* Superscript numbers refer to Notes at the end of the text.

Fig. 2. Platen shape and tip radius.

Distance measuring system

5.(a) The distance measuring system, for example a direct reading scale or displacement transducer, is to permit measurement of the distance D between specimen-platen contact points and should conform with requirements (b) through (d) below.[6]

(b) Measurements of D should be to an accuracy of $\pm 2\% D$ or better irrespective of the size of specimen tested.

(c) The system is to be resistant to hydraulic shock and vibration so that the accuracy of readings is not adversely affected by repeated testing.

(d) The measuring system should allow a check of the "zero displacement" value when the two platens are in contact, and should preferably include a zero adjustment.

(e) An instrument such as calipers or a steel rule is required, to measure the width W of specimens for all but the diametral test.

PROCEDURE

Specimen selection and preparation

6.(a) A test sample is defined as a set of rock specimens of similar strength for which a single Point Load Strength value is to be determined.

(b) The test sample of rock core or fragments is to contain sufficient specimens conforming with the size and shape requirements for diametral, axial, block or irregular lump testing as specified below.[7]

(c) For routine testing and classification, specimens should be tested either fully water-saturated or at their natural water content.[8]

Calibration

7. The test equipment should be periodically calibrated using an independently certified load cell and set of displacement blocks, checking the P and D readings over the full range of loads and displacements pertinent to testing.

The diametral test[2]

8.(a) Core specimens with length/diameter ratio greater than 1.0 are suitable for diametral testing.

(b) There should preferably be at least 10 tests per sample, more if the sample is heterogeneous or anisotropic.[7]

(c) The specimen is inserted in the test machine and the platens closed to make contact along a core diameter, ensuring that the distance L between the contact points and the nearest free end is at least 0.5 times the core diameter (Fig. 3a).

(d) The distance D is recorded $\pm 2\%$.[6]

(e) The load is steadily increased such that failure occurs within 10–60 sec, and the failure load P is recorded. The test should be rejected as invalid if the
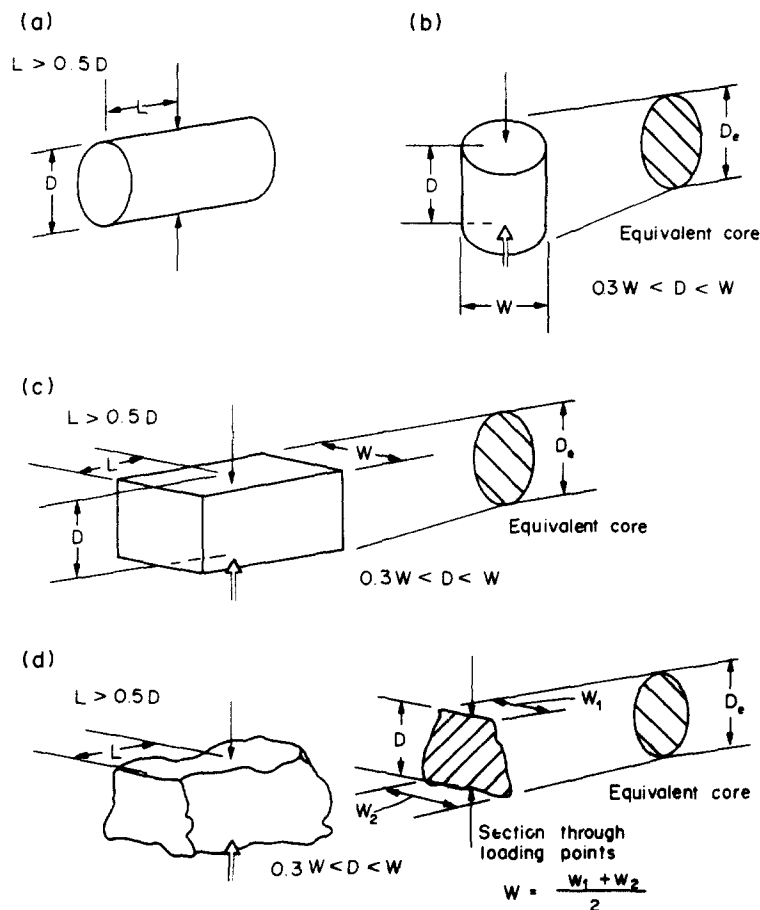

Fig. 3. Specimen shape requirements for (a) the diametral test, (b) the axial test, (c) the block test, and (d) the irregular lump test.
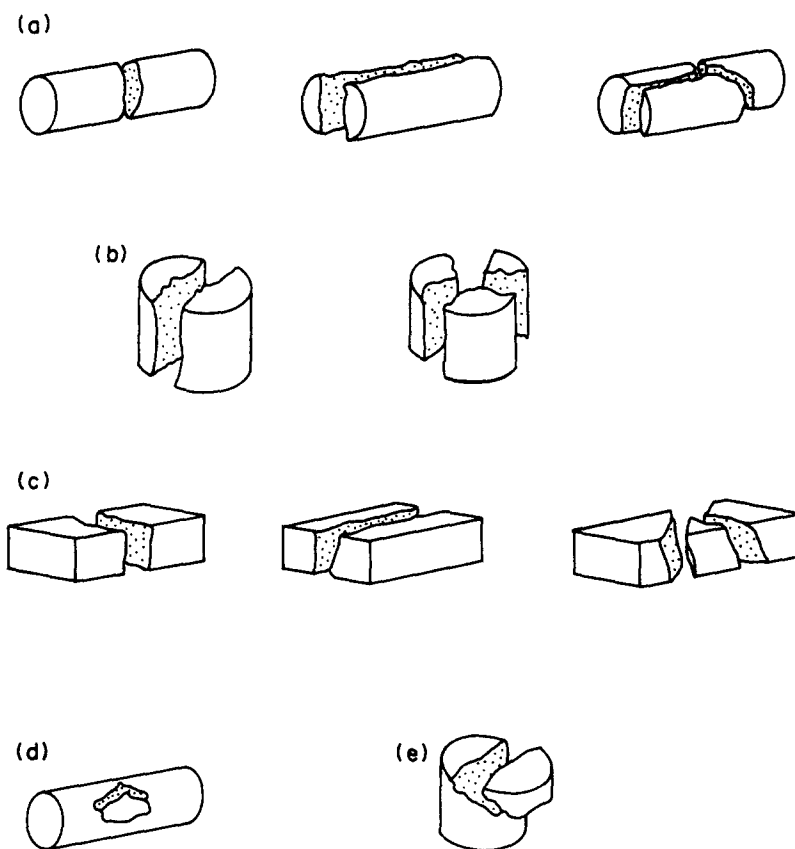
Fig. 4. Typical modes of failure for valid and invalid tests. (a) Valid diametral tests; (b) valid axial tests; (c) valid block tests; (d) invalid core test; (e) invalid axial test.

fracture surface passes through only one loading point (Fig. 4d).

(f) The procedure (c) through (e) above is repeated for the remaining specimens in the sample.

The axial test[2]

9.(a) Core specimens with length/diameter ratio of 0.3–1.0 are suitable for axial testing (Fig. 3b). Long pieces of core can be tested diametrally to produce suitable lengths for subsequent axial testing (provided that they are not weakend by this initial testing); alternatively, suitable specimens can be obtained by saw-cutting or chisel-splitting.

(b) There should preferably be at least 10 tests per sample, more if the sample is heterogeneous or anisotropic.[7]

(c) The specimen is inserted in the test machine and the platens closed to make contact along a line perpen-

dicular to the core end faces (in the case of isotropic rock, the core axis, but see paragraph 11 and Fig. 5).

(d) The distance D between platen contact points is recorded $\pm 2\%$.[6] The specimen width W perpendicular to the loading direction is recorded $\pm 5\%$.[9]

(e) The load is steadily increased such that failure occurs within 10–60 sec, and the failure load P is recorded. The test should be rejected as invalid if the fracture surface passes through only one loading point (Fig. 4e).

(f) The procedures (c) through (e) above are repeated for the remaining tests in the sample.

The block and irregular lump tests

10.(a) Rock blocks or lumps of size 50 ± 35 mm and of the shape shown in Fig. 3(c) and (d) are suitable for the block and the irregular lump tests. The ratio D/W should be between 0.3 and 1.0, preferably close to 1.0.
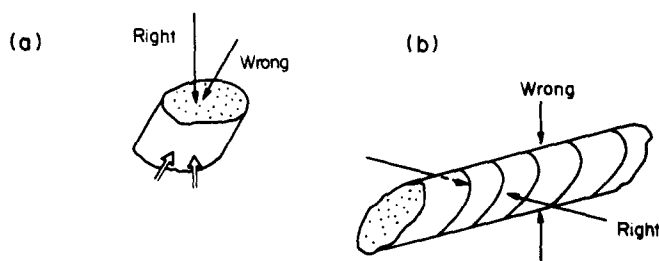

Fig. 5. Loading directions for tests on anisotropic rock.

The distance L (Fig. 3c and d) should be at least $0.5W$. Specimens of this size and shape may be selected if available or may be prepared by trimming larger pieces by saw-or chisel-cutting.

(b) There should preferably be at least 10 tests per sample, more if the rock is heterogeneous or aniso-tropic.[7]

(c) The specimen is inserted in the testing machine and the platens closed to make contact with the smallest dimension of the lump or block, away from edges and corners (Fig. 3c and d).

(d) The distance D between platen contact points is recorded $\pm 2\%$. The smallest specimen width W perpendicular to the loading direction is recorded $\pm 5\%$. If the sides are not parallel, then W is calculated as $(W_1 + W_2)/2$ as shown in Fig. 3d.[6] This smallest width W is used irrespective of the actual mode of failure (Figs 3 and 4)

(e) The load is steadily increased such that failure occurs within 10–60 sec, and the failure load P is recorded. The test should be rejected as invalid if the fracture surface passes through only one loading point (see examples for other shapes in Fig. 4d or e).

(f) The procedure (c) through (e) above is repeated for the remaining tests in the sample.

Anisotropic rock

11. (a) When a rock sample is shaly, bedded, schistose or otherwise observably anisotropic it should be tested in directions which give the greatest and least strength values, which are in general parallel and normal to the planes of anisotropy.

(b) If the sample consists of core drilled through the weakness planes, a set of diametral tests may be com-pleted first, spaced at intervals which will yield pieces which can then be tested axially.

(c) Best results are obtained when the core axis is perpendicular to the planes of weakness, so that when possible the core should be drilled in this direction. The angle between the core axis and the normal to the weakness planes should preferably not exceed 30°.

(d) For measurement of the I_s value in the directions of least strength, care should be taken to ensure that load is applied along a single weakness plane. Similarly when testing for the I_s value in the direction of greatest strength, care should be taken to ensure that the load is applied perpendicularly to the weakness planes (Fig. 5).

(e) If the sample consists of blocks or irregular lumps, it should be tested as two sub-samples, with load applied firstly perpendicular to, then along the observable planes of weakness.[10] Again, the required minimum strength value is obtained when the platens make contact along a single plane of weakness.

CALCULATIONS

Uncorrected point load strength

12. The Uncorrected Point Load Strength I_s is calcu-lated as P/D_e^2 where D_e, the "equivalent core diameter",

is given by:

$$D_e^2 = D^2 \text{ for diametral tests;}$$

$$= 4A/\pi \text{ for axial, block and lump tests;}$$

and

$$A = WD = \text{minimum cross sectional area of a plane through the platen contact points.}[6]$$

Size correction

13.(a) I_s varies as a function of D in the diametral test, and as a function of D_e in axial, block and irregular lump tests, so that a size correction must be applied to obtain a unique Point Load Strength value for the rock sample, and one that can be used for purposes of rock strength classification.

(b) The size-corrected Point Load Strength Index $I_{s(50)}$ of a rock specimen or sample is defined as the value of I_s that would have been measured by a diametral test with $D = 50$ mm.

(c) The most reliable method of obtaining $I_{s(50)}$, pre-ferred when a precise rock classification is essential, is to conduct diametral tests at or close to $D = 50$ mm. Size correction is then either unnecessary ($D = 50$ mm) or introduces a minimum of error. The latter is the case, for example, for diametral tests on NX core, $D = 54$ mm. This procedure is not mandatory. Most point load strength testing is in fact done using other sizes or shapes of specimen. In such cases, the size correction (d) or (e) below must be applied.

(d) The most reliable method of size correction is to test the sample over a range of D or D_e values and to plot graphically the relation between P and D_e^2. If a log–log plot is used the relation is generally a straight line (Fig. 6). Points that deviate substantially from the straight line may be disregarded (although they should not be de-leted). The value of P_{50} corresponding to $D_e^2 = 2500$ mm^2 ($D_e = 50$ mm) can then be obtained by interpolation, if
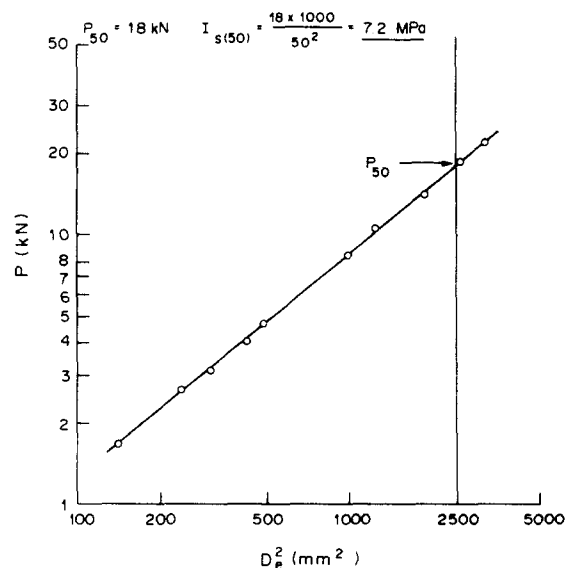

Fig. 6. Procedure for graphical determination of $I_{s(50)}$ from a set of results at D_e values other than 50 mm.
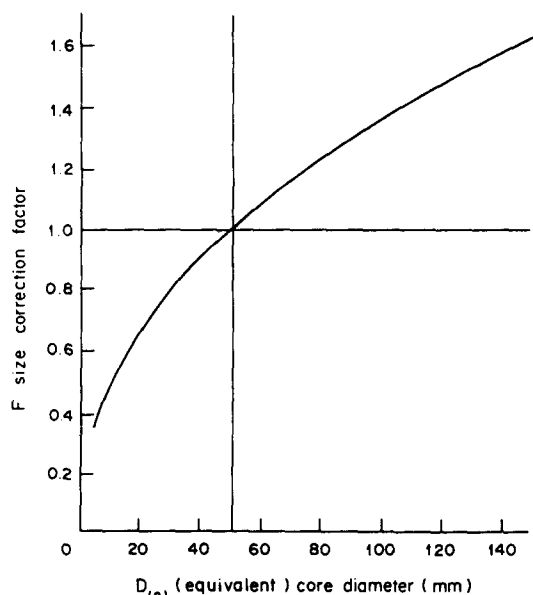
Fig. 7. Size correction factor chart.

necessary by extrapolation, and the size-corrected Point Load Strength Index calculated as $P_{50}/50^2$.

(e) When neither (c) nor (d) is practical, for example when testing single sized core at a diameter other than 50 mm or if only a few small pieces are available, size correction may be accomplished by using the formula:

$$I_{s(50)} = F \times I_s$$

The "Size Correction Factor F" can be obtained from the chart in Fig. 7,[11] or from the expression:
$$F = (D_e/50)^{0.45}$$

For tests near the standard 50 mm size, very little error is introduced by using the approximate expression:

$$F = \sqrt{(D_e/50)}$$

(f) The size correction procedures specified in this paragraph have been found to be applicable irrespective of the degree of anisotropy I_a and the direction of loading with respect to planes of weakness, a result that greatly enhances the usefulness of this test.

Mean value calculation

14.(a) Mean values of $I_{s(50)}$ as defined in (b) below are to be used when classifying samples with regard to their Point Load Strength and Point Load Strength Aniso-tropy Indices.

(b) The mean value of $I_{s(50)}$ is to be calculated by deleting the two highest and lowest values from the 10 or more valid tests, and calculating the mean of the remaining values. If significantly fewer specimens are tested, only the highest and lowest values are to be deleted and the mean calculated from those remaining.[12]

Point load strength anisotropy index

15. The Strength Anistropy Index $I_{a(50)}$ is defined as the ratio of mean $I_{s(50)}$ values measured perpendicular and parallel to planes of weakness, i.e. the ratio of greatest

to least Point Load Strength Indices. $I_{a(50)}$ assumes values close to 1.0 for quasi-isotropic rocks and higher values when the rock is anisotropic.

REPORTING OF RESULTS

16. Results for diametral tests, axial tests, block tests and irregular lump tests, and for tests perpendicular and parallel to planes of weakness should be tabulated separately (see typical results form, Fig. 8). The report should contain calibration data for the test machine and at least the following information for each sample tested:

(a) The sample number, source location and rock type, and the nature and *in situ* orientation of any planes of anistropy or weakness.

(b) Information on the water content of the rock at the time of testing.

(c) Information on which specimens were loaded parallel ($/\!/$), perpendicular ($\perp$), or at unknown or random directions with respect to planes of weakness.

(d) A tabulation of the values of P, D, (W, D_e^2 and D_e if required), I_s, (F if required) and $I_{s(50)}$ for each specimen in the sample.

(e) For all isotropic samples, a summary tabulation of mean $I_{s(50)}$ values.

(f) For all anisotropic samples, a summary tabulation of mean $I_{s(50)}$ values for sub-samples tested perpendicular and parallel to the planes of weakness, and of the corresponding $I_{a(50)}$ values.

NOTES

1. When first introduced, the point load strength test was used mainly to predict uniaxial compressive strength which was then the established test for general-purpose rock strength classification. Point load strength now often replaces uniaxial compressive strength in this role since when properly conducted it is as reliable and much quicker to measure. $I_{s(50)}$ should be used directly for rock classification, since correlations with uniaxial com-pressive strength are only approximate. On average, uniaxial compressive strength is 20–25 times point load strength, as shown in Fig. 9. However, in tests on many different rock types the ratio can vary between 15 and 50 especially for anisotropic rocks, so that errors of up to 100% are possible in using an arbitrary ratio value to predict compressive strength from point load strength. The point load strength test is a form of "indirect tensile" test, but this is largely irrelevant to its primary role in rock classification and strength characterization. $I_{s(50)}$ is approximately 0.80 times the uniaxial tensile or Brazilian tensile strength.

2. Of the four alternative forms of this test, the diametral test and the axial test with saw-cut faces are the most accurate if performed near the standard 50 mm size, and are preferred for strength classification when core is available. Axial test specimens with saw-cut faces can easily be obtained from large block samples by coring in the laboratory. Specimens in this form are

Sample Details	Point Load Test	Date *17/11/83*

1 block sample from Gamblethorpe Opencast site.

Fine grained pale grey Coal Measures sandstone
with numerous coaly streaks along horizontal
bedding planes.

Specimens 1-6 chisel cut blocks, air-dried 2 weeks;
7-10 sawn blocks, air-dried 2 weeks;
11-15 cores, air-dried 2 weeks;
16-20 cores, air-dried 2 weeks;
- tested in laboratory.

No.	Type	W (mm)	D (mm)	P (kN)	D_e^2 (mm^2)	D_e (mm)	I_s	F	$I_{s\,(50)}$
1	i ⊥	30.4	17.2	2.687	666	25.8	4.03	0.75	~~3.03~~
2	i ⊥	16	8	0.977	163	12.8	5.99	0.54	3.24
3	i ⊥	19.7	15.6	1.962	391	19.8	5.02	0.66	3.31
4	i ⊥	35.8	18.1	3.641	825	28.7	4.41	0.765	3.46
5	i ⊥	42.5	29	6.119	1569	39.6	3.90	0.875	3.49
6	i ⊥	42	35	7.391	1872	43.3	3.95	0.935	~~3.69~~
7	b ⊥	44	21	4.600	1176	34.3	3.91	0.84	3.29
8	b ⊥	40	30	5.940	1528	39.1	3.88	0.89	3.46
9	b ⊥	19.5	15	2.040	372	19.3	5.48	0.655	~~3.59~~
10	b ⊥	33	16	2.87	672	25.9	4.27	0.75	~~3.20~~
11	d //	-	49.93	5.107	-	-	-	-	2.05
12	d //	-	49.88	4.615	-	-	-	-	1.85
13	d //	-	49.82	5.682	-	-	-	-	~~2.29~~
14	d //	-	49.82	4.139	-	-	-	-	~~1.67~~
15	d //	-	49.86	4.546	-	-	-	-	1.83
16	d //	-	25.23	1.837	-	-	2.89	0.74	2.14
17	d //	-	25.00	1.891	-	-	3.02	0.735	2.22
18	d //	-	25.07	2.118	-	-	3.37	0.735	~~2.48~~
19	d //	-	25.06	1.454	-	-	2.32	0.735	~~1.70~~
20	d //	-	25.04	1.540			2.46	0.735	1.81

d = diametral;
a = axial;
b = block;
i = irregular lump test;
⊥ = perpendicular;
// = parallel to planes of weakness.

Mean $I_{s\,(50)}$ ⊥	3.38
Mean $I_{s\,(50)}$ //	1.98
$I_{a\,(50)}$	1.71

Fig. 8. Typical results form.

particularly suitable when the rock is anisotropic and the direction of weakness planes must be noted.

3. Loads of up to 50 kN are commonly required for the larger hard rock specimens. The maximum specimen size that can be tested by a given machine is determined by the machine's load capacity, and the smallest by the machine's load and distance measuring sensitivity. Tests on specimens smaller than $D = 25$ mm require particular precautions to ensure that the measuring sensitivity is sufficient. The range of required test loads should be estimated before testing, from approximate assumed strength values, to ensure that the load capacity and sensitivity of the equipment are adequate. It may be necessary to change the load measuring gauge or load cell, or to test smaller or larger specimens to conform with the capacity of available equipment or with the accuracy specifications for this test.

4. The conical platen design is intended to give standardized penetration of softer specimens. When testing is confined to hard rocks and small (less than 2 mm) penetrations the conical design is unimportant provided that the tip radius remains at the standard 5 mm. For such testing the platen can be manufactured by embedding a hard steel or tungsten carbide ball in a
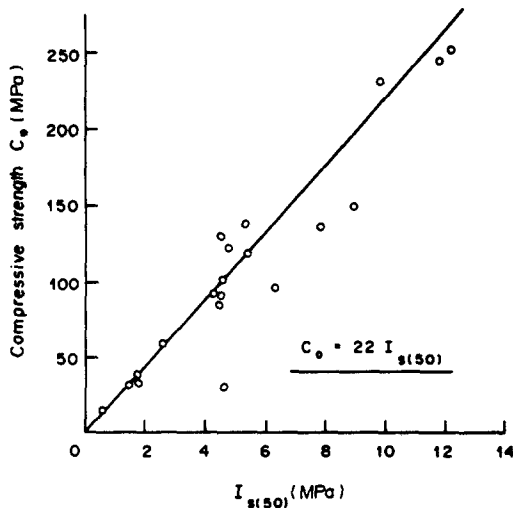
Fig. 9. Example of correlation between point load and uniaxial compressive strength results.

softer metal base of any geometry that will ensure that only the platen tip is in contact with the rock.

5. If a quick-retracting ram is used to reduce the delay between tests, either the ram return spring force and ram friction should together be less than about 5% of the smallest load to be measured during testing, or an independent load cell rather than an oil pressure gauge should be used for load determination. These forces can be significant when testing weaker and smaller specimens.

6. If significant platen penetration occurs, the dimension D to be used in calculating point load strength should be the value D' measured at the instant of failure, which will be smaller than the initial value suggested in paragraphs 8(d), 9(d) and 10(d). The error in assuming D to be its initial value is negligible when the specimen is large or strong. The failure value may always be used as an alternative to the initial value and is preferred if the equipment allows it to be measured (for example by electrical maximum-indicating load and displacement measurement). When testing specimens that are smaller than 25 mm, such as rock aggregate particles, equipment with electrical readout is usually necessary to obtain the required measuring accuracy, and should be designed to record D' at failure. Measurements of W or D made perpendicular to the line joining the platens are not affected and are retained at their original values. The value of D_e for strength calculation can then be found from:

$$D_e^2 = D \times D' \quad \text{for cores}$$

$$D_e^2 = \frac{4}{\pi}(W \times D') \quad \text{for other shapes}$$

7. Because this test is intended primarily as a simple and practical one for field classification of rock materials, the requirements relating to sample size, shape, numbers of tests etc, can when necessary be relaxed to overcome practical limitations. Such modifications to procedure should however be clearly stated in the report.

It is often better to obtain strength values of limited reliability than none at all. For example, rock is often too broken or slabby to provide specimens of the ideal sizes and shapes, or may be available in limited quantities such as when the test is used to log the strength of drill core. In core logging applications, the concept of a "sample" has little meaning and tests are often conducted at an arbitrary depth interval, say one test every 1 m or 3 m depending on the apparent variability or uniformity of strength in the core and on the total length of core to be strength-logged.

8. As for all strength tests on rocks, point load strength varies with the water content of the specimens. The variations are particularly pronounced for water saturations below 25%. Oven dried specimens, for example, are usually very much stronger than moist ones. At water saturations above 50% the strength is less influenced by small changes in water content, so that tests in this water content range are recommended unless tests on dry rock are specifically required.

All specimens in a sample should be tested at a similar and well-defined water content, and one that is appropriate to the project for which the test data are required. Field testing of chisel-cut samples, not affected by drilling fluids, offers a method for testing at the *in situ* water content. If possible, numerical values should be given for both water content and degree of saturation at the time of testing. The ISRM Suggested Method for Water Content Determination should be employed. Whether or not water content measurements can be made, the sample storage conditions and delay between sampling and testing should be reported.

9. Some researchers argue in favour of measuring W as the minimum dimension of the failure surface after testing rather than of the specimen before failure (the German standard for this test is an example). Point load strengths computed using the two alternative W definitions may differ slightly. The minimum specimen dimension alternative has been adopted in this Suggested Method mainly because it is quicker and easier to measure, particularly in the field when fragments of broken specimens are easily lost.

10. Commonly the shortest dimension of naturally occurring anisotropic rock lumps is perpendicular to the weakness planes.

11. The size correction factor chart (Fig. 7) is derived from data on cores tested diametrally and axially and from tests on blocks and irregular lumps, for rocks of various strengths, and gives an averaged factor. Some rocks do not conform to this behaviour, and size correction should therefore be considered an approximate method, although sufficient for most practical rock classification applications. When a large number of tests are to be run on the same type of rock it may be advantageous to first perform a series of tests at different sizes to obtain a graph of load vs D_e^2 as in Fig. 6. If the slope of such a log–log graph is determined as "n", the size correction factor is then $(D_e/50)^m$ where $m = 2(1 - n)$. This can either be calculated directly or a chart constructed.

12. Mean results for small populations are generally better measures when the extreme values are not included in the calculation.

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