A Rational Approach to the Point Load Test

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SUMMARY Conversion factors correlating point load strength with uniaxial compressive strength are subject to errors. In addition, test results may be affected by sample anisotropy. Examples are given to show that provided these limitations are recognised the test can be successfully used to measure the strength of rock samples and classify rock.

1 INTRODUCTION

The point load test has been proposed as a quick, simple and accurate test to measure the strength of rock samples.

As originally described by Broch and Franklin (1972) and recently re-affirmed by Franklin (1977), the indirect tensile strength as measured by the point load test was postulated to be closely correlated with uniaxial compressive strength. A conversion of

UCS = 24 x Is(50)
where UCS = Uniaxial Compressive Strength
and Is(50) = Point Load Strength Index for 50 mm Diameter Core

was proposed and was incorporated in the methods for determining the point load strength index suggested by the ISRM Committee on Laboratory Tests (1973).

It is our experience that the suggested conversion factor of 24 cannot be universally applied. Also, test results may be affected by sample anisotropy requiring modifications to the specified sample length to diameter ratio.

Although these aspects represent changes from the concept proposed by Broch and Franklin, once appreciated they need not limit the usefulness of the test. Examples of the variability of the conversion factor and examples of meaningful applications of the test in investigation and construction are described.

2 CONVERSION FACTORS

As more and more data from various sources becomes available, it is increasingly apparent that a value of 24 cannot be used as a universal conversion factor. For example, after studying 13 different rock types, Pells (1975) concluded that :

- For certain rock materials the UCS value that is predicted using the point load test and a conversion factor of 24 is sufficiently accurate for many engineering design and classification purposes (error less than 20%).
- There are certain rock materials, not identifiable visually, for which the point load test predicts UCS values that are significantly in error (error greater than 20%).

Because of these conclusions Pells recommended that whenever point load test results are used to predict uniaxial or triaxial rock material strengths, at least some conventional UCS test should be performed.

Work on rocks found in the Melbourne area support these conclusions and recommendation.

Two groups of results are presented comparing Is(50) and UCS results for sedimentary rocks and basalts exposed in and around Melbourne.

2.1 Sedimentary Rocks

Three types were tested: sandstone, siltstone and laminated siltstone. A minimum of 14 Is(50) and 8 UCS tests were carried out on each category tested.

TABLE I

DEFINITIONS OF WEATHERING AND ALTERATION

WEATHERING		
Extremely (EW)	:	Texture of the original rock still evident but rock substance exhibits soil properties, i.e., can be remoulded and classified according to the Unified Soils Classification.
Distinctly (DW)	:	Weathering is distinct in that there is either a colour change and/or a marked change in physical properties from fresh rock substance. The porosity may be greater or lesser than the original rock substance due to leaching or deposition of minerals.
Slightly (SW)	:	Rock substance partially stained or discoloured but strength properties essentially those of fresh rock substance.
Fresh (Fr)	:	Rock substance apparently unaffected.
ALTERATION OF BASALT		
The rock substance shows a green-black or light blue colouration due to the formation of montmorillonite group minerals and vesicles become filled with clay minerals. There is usually some loss of strength compared with weathered rock.		

The Is(50) results are based only on diametral tests. Cores which failed along bedding, cleavage

ROCK TYPE	SILTSTONE	SANDSTONE	LAMINATED SILTSTONE
WEATHERING	D DISTINCTLY WEATHERED	S SLIGHTLY WEATHERED	F FRESH
PROJECT	1	2	3

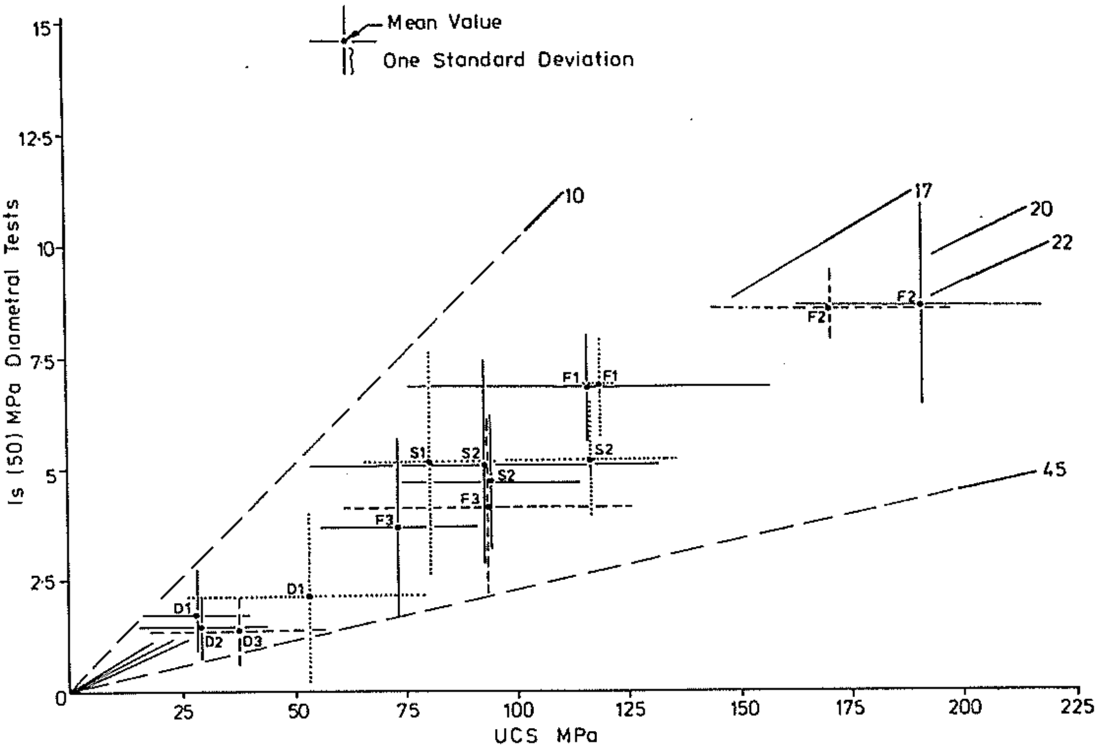

Figure 1 Test results, sedimentary rocks

or other obvious defects were discounted. The samples tested were subdivided on the basis of the project, rock type and degree of weathering as defined in Table I. The mean and standard deviation of the Is(50) and UCS results were then calculated and the comparison is plotted on Figure 1. Not every rock type and degree of weathering occurred at each project.

The line of best fit approximates a conversion factor of about 20 with a correlation co-efficient of 0.97. However, the results show a high degree of scatter, conversion factors ranging between 10 and 45. Within this range different lines of best fit can be recognised. For example, the line of best fit for distinctly weathered siltstone at Project Site 1, represented by Result D1, is about 17 and that for fresh siltstone at Project Site 2, represented by Result F2, is about 22.

2.2 Basalt

Basalt sampled from an area west of Melbourne was subdivided on the basis of degree of weathering and alteration as defined in Table 1. The results of 65 UCS and 304 Is(50) tests are summarised on Figure 2: the average number of UCS tests for each of the categories on Figure 2 was 7 and of Is(50) tests was 34.

From Figure 2 it is difficult to allocate a simple line of best fit passing through the origin although if there is one, it is obviously closer to 12 than 24. However, lines of best fit of 7.5, 11 and 16 can be allocated. On the basis of these lines the following general relationships can be recognised :

- Irrespective of the degree of weathering, the more vesicular the basalt the lower the conversion factor.
- If the basalt is altered the conversion factor increases to the next highest conversion factor.

In both of these cases the degree of alteration does not influence the relationship for the less vesicular basalt.

2.3 Errors

The ISRM suggested method states :

"Rocks to be classified are first divided into

		WEATHERING & ALTERATION		
		DW	SW	SW & ALTERED
VESICULARITY	>20%	A (7·5)	B (7·5)	C (11)
	10-20%	D (11)	E (11)	F (16)
	8-10%		G (16)	H (16)
	DENSE			I (16)

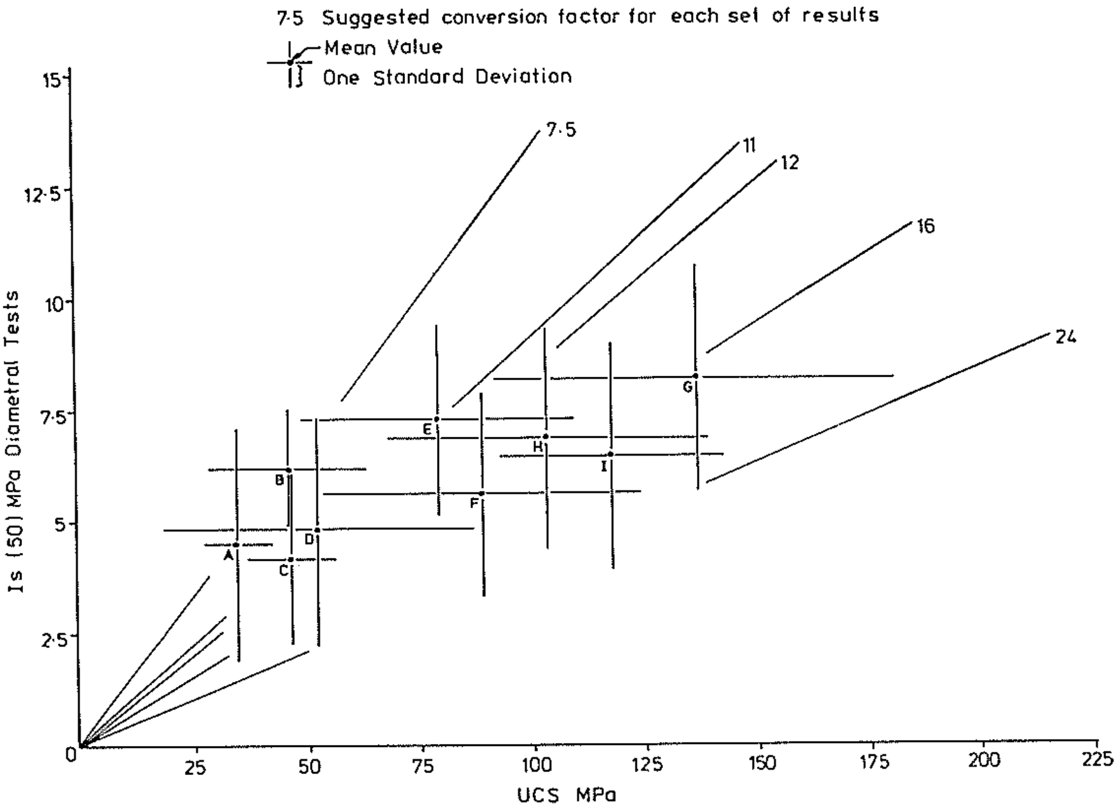

Figure 2 Test results, basalt

units, each of which is considered on the basis of preliminary inspection to have uniform strength.

One sample of rock containing sufficient material for the required number of test specimens is then selected from each unit."

During normal core logging the sample suggested by the ISRM will usually be much smaller than those represented on Figures 1 or 2. The errors involved in using a conversion factor on such small samples should be appreciated. For instance, Figure 3 shows the results obtained for dense, slightly weathered altered basalt. Using a conversion factor of 16 and the mean result of the 56 Is(50) tests for Group I (Fig. 2) the derived UCS value is 103 MPa, 12% under the actual mean UCS value of 118 MPa.

Also, if a smaller sample is considered the Is(50) value used may not be the mean but would tend to be within the range of 3.9 to 9 MPa, as shown on Figure 3. Using the conversion factor of 16 provides derived UCS values ranging from 62 to 144 MPa.

However, the actual range of UCS results determined by testing was from 93 to 143 MPa. Therefore, the derived values have underestimated the UCS by 33% in one case and overestimated it by 1% in the other.

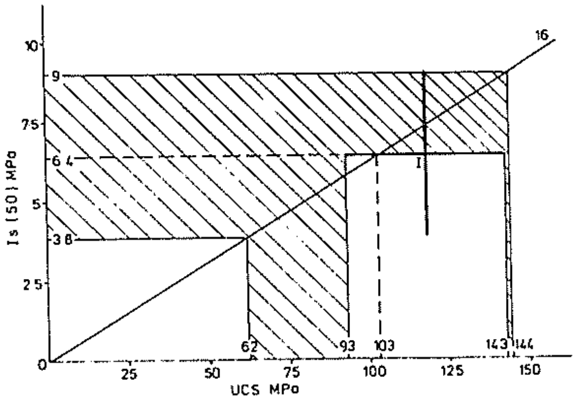

Figure 3 Example of conversion errors

The range of errors obviously vary from rock type to rock type. The example quoted is by no means unique and, in fact, there are many rock types in which the errors involved in conversion from Is(50) to UCS on a small sample (but acceptable within the guidelines suggested by the ISRM) are much larger.

2.4 Implications

The implication of the data presented above generate two conclusions :

- Errors in derived UCS values vary from rock type to rock type and can be significant.
- Because of the wide range of results that can be obtained, it is necessary to establish an appropriate conversion factor for particular rock types from particular areas by testing, especially if the derived UCS values are to be used in further calculations.

Together, these two conclusions suggest that it would in fact be preferable to base rock strength on either Is(50) or UCS results and not to relate the two tests. One is an indirect tensile test, and the other a compressive test. Whilst general comparisons may be made geological factors such as differences in composition and texture exist which make particular rock types behave differently in the two types of tests.

3 ANISOTROPY

As described above, only failure through the rock substance were used for the diametral Is(50) results presented above. This was necessary as it has been found that test results may be grossly affected by sample anisotropy. With bedded rocks, for example, failure may occur along bedding planes rather than through the rock substance. Pells (1975) found that it was impracticable to use diametral Is(50) results to derive UCS values for a highly anisotropic sandstone. We have had the same experience and have also found that when bedding is inclined at more than about 20^{o} to the axis of a sample, it is difficult to perform a satisfactory test using the ratio specified for axial tests.

At one project site the dip of an interbedded sequence of siltstone and sandstone ranged from 10^{o} to 70^{o} but was mostly about 30^{o}. Totally inconsistent diametral test results were obtained and the diametral test was discontinued. However, it was found that when axial tests were attempted at the specified length to diameter ratio of 1.1 the samples either rotated between the platens or broke off at the edges. After some experimentation, it was found that consistent results could be obtained when a ratio of 0.65 was used. This value was therefore adopted as the site standard.

4 APPLICATIONS

Criticisms of the point load test, based on experiences similar to those described above, have been voiced and doubts as to the usefulness of the test have been expressed.

We believe that many of the opinions are unnecessarily harsh. As with many other methods of investigation, geophysics for example, it is more a matter of being aware of the limitations of the test and ensuring that it is used only when and as appropriate.

Three inter-related examples involving the proving of rock durability, rippability assessment and rockfill control measures are presented to demonstrate how the point load test can be meaningfully and successfully applied. The examples are all from the project mentioned above, where a site standard of 0.65 was developed and adopted for axial tests on a sequence of interbedded and folded siltstone and sandstone. It involved the use of Is(50) results rather than derived UCS values.

4.1 Durability Testing

The point load test was one of several tests used to demonstrate the long term durability of fresh or slightly weathered siltstone which was regarded as a potential source of rockfill. The tests were carried out on samples taken from 90 year old spoil dumps as well as on samples taken from the potential quarry and exposed for 2 weeks after recovery from cored boreholes. The results from the spoil dumps averaged 5.1 MPa for slightly weathered siltstone which was slightly stronger than the average 4.6 MPa obtained for the 2 weeks old slightly weathered siltstone. In conjunction with the other tests, which included aggregate crushing tests and long term observational weathering tests, this result was taken as good proof of the long term durability of the fresh or slightly weathered siltstone when it was kept in a stable moisture environment away from the effects of sun, rain and frost.

4.2 Rippability

For any particular tractor and ripper arrangement used, the rippability of a rock mass will depend on the rock substance strength and the nature of the rock mass defects, including their strength, spacing, orientation and continuity.

Up to a certain substance strength the rock at the site usually broke readily through the substance regardless of the nature of the rock mass defects. Above this strength it was usually increasingly difficult to break the rock through the substance and ripping proceeded only if the rock mass was intersected by a suitable pattern of defects along which it could break up.

Ripping trials and production ripping with Caterpillar D7, D8, D9 and Komatsu D355A tractors were monitored and showed that the largest tractor could rip a distinctly weathered siltstone/sandstone rock mass with an average rock substance Is(50) of up to 2.5 MPa with little difficulty.

Above 2.5 MPa there was increasing substance resistance and rippability depended increasingly on the pattern and nature of the defects. Ripper penetration decreased from 500 mm at 3 MPa to 300 mm at 4.4 MPa, with fracture initiating along the defects and further breakdown occurring under the tracks. Over 4 MPa there was a reduction in the maximum particle size from 1000 to 300 mm. There was also a marked effect on the fines content with 50% minus 20 mm at 3 MPa reducing to 15% minus 20 mm at 4.4 MPa.

As a result of these observations it was possible to correlate the degree of weathering, Is(50) and rippability for the rock mass throughout the project site. As described below, this correlation was then used as the basis of a rock classification system used to control rockfill quality on the project.

4.3 Rockfill Quality Control

The degree of weathering and the Is(50) of the rock substance were combined with seismic velocity, rippability and visual appearance of the rock mass,

TABLE II

ROCK MASS CLASSIFICATION

GRADE	DEGREE OF WEATHERING OF SUBSTANCE	SUBSTANCE STRENGTH Is(50), MPa	SEISMIC VELOCITY m/sec.	ROCK MASS USUALLY RIPPABLE BY	APPEARANCE	EXCAVATED MATERIALS SUITABLE FOR
5	DW to EW	1.5	1000	D7	Brown, orange-brown reddish-brown	Unsuitable for random fill or rockfill
4	DW	1.5 to 2.5	1000 to 2200	D9	Dominantly brown with up to 50% light grey or grey-brown laminae	Random Fill, < 20% fines after compaction
3	DW to SW	2.5 to 4.0	2200 to 3000	D9 with favourable defect pattern	Dominantly dark to light grey with up to 50% grey-brown laminae	
2	SW	4 to 6	> 3000	Not rippable	Dark to light grey with up to 10% grey-brown laminae	Rockfill, < 10% fines after compaction
1	Fr	6	> 3000	Not rippable	Dark to light grey	

and the results of field embankment compaction trials to produce the rock classification shown on Table 2.

Quarry control measures were related to the end product in the embankment combined with a visual assessment and a point load test of the rock in each bench in the quarry. The Is(50) values indicated in Table II were used in the initial stages but, as more data became available, they were modified to fit a statistically derived minimum standard. This required that not less than 50% of each sample had an Is(50) of greater than 4 MPa and not more than 25% had an Is(50) less than 3 MPa. To check this at least 10 lumps of rock were sampled from a bench firing. Ten samples were cored normal to the bedding in each lump, trimmed to the site standard of 0.65 and then tested axially giving at least 100 results for statistical comparison with the required minimum standard.

Once the necessary procedures had been standardised, one person could carry out the complete test within a day.

5 CONCLUSIONS

The following conclusions are made :

- The point load test is a relatively quick, simple and inexpensive method of determining rock strength and classifying rocks.
- If a relationship between Is(50) and UCS is to be used it should be obtained by testing.
- The errors involved in deriving UCS values from Is(50) values may be significant. Certain of these errors are numerical. However, one test is an indirect tensile test and the other is a compressive test, and it may not be valid to make other than general comparisons.
- Anisotropy may seriously affect point load test results and may necessitate the adoption of a non-standard test specification.
- Despite the limitations imposed by the conclusions above, it is possible to successfully and meaningfully apply the point load test provided these limitations are realised and the test is not misapplied.

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