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Technical Note

Estimating Rock Strength with the Equotip Hardness Tester

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INTRODUCTION

Unconfined compressive strength is the most widely used parameter for the classification and characterisation of rock material. However, the need for accurate preparation of the test specimen and complex and heavy test equipment makes the test expensive and difficult to execute in the field. Consequently, much time and effort has been expended in the past to developing portable equipment to provide an indication of rock strength. The best known index test in this context is probably the Point Load Test [1]. For this test even small irregular lumps of rock can be used, but, while attempts have been made to develop truly portable test equipment [2] the test is generally confined to a specific field set up. The equipment for another widely used test, the Schmidt hammer [3], is truly portable, but the high impact energy of the hammer makes it is less suitable for weak rock and for testing core samples. The Shore Scleroscope [3] delivers less energy, but its use is limited by the fact that the impacting hammer falls under gravity alone so that it can be used only vertically with obvious limitations for field use. The Equotip Hardness Tester is a relatively new product in the field of hardness testing by rebound and the Section of Engineering Geology of Delft University of Technology is presently investigating its use as an index test. This Technical Note reports preliminary results of this work.

THE EQUOTIP HARDNESS TESTER

A few years ago, Proseq SA (the company which manufacturers the Schmidt Hammer) introduced the Equotip Hardness Tester [4] (Figs 1 and 2). The Equotip is developed to measure the hardness of metallic materials. It is a small electronic, battery operated, spring-loaded device. A 3 mm dia. spherical shaped tungsten carbide test tip is mounted in an impact body and impacts under spring force against the test surface from which it rebounds. Impact and rebound velocities are measured and processed into the hardness value L which is shown on the digital display. The basic type D impact device delivers an impact

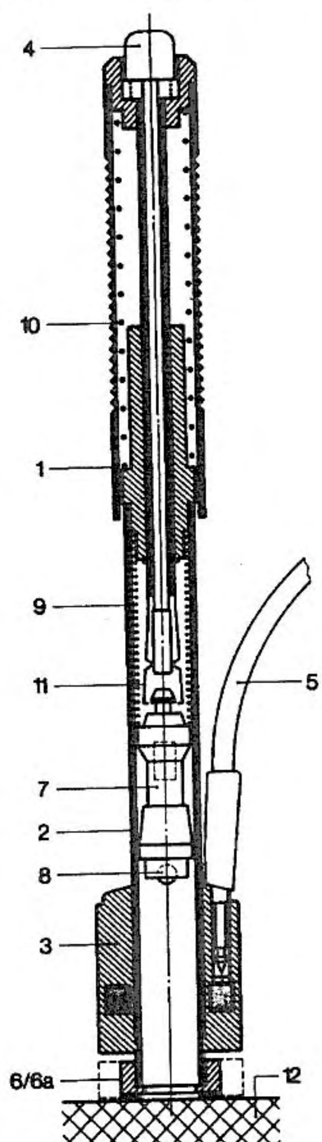

Fig. 1. Schematic design of the Equotip impact devices: (1) loading tube; (2) guide tube; (3) coil with coil holder; (4) release button; (5) connection cable leading to the indicating device with coil plug; (6) large support ring; (6a) small support ring; (7) impact body; (8) spherical test tip; (9) impact spring; (10) loading spring; (11) catch chuck; and (12) material to be tested.

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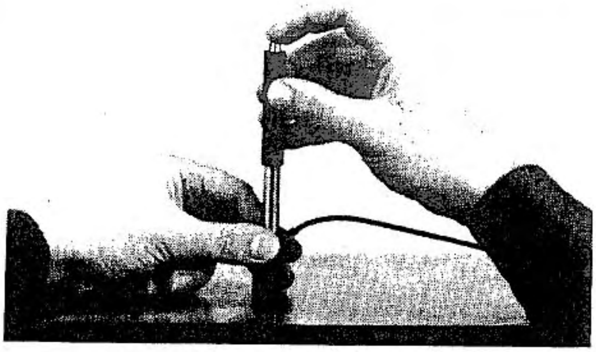

Fig. 2. Using the Equotip impact device.

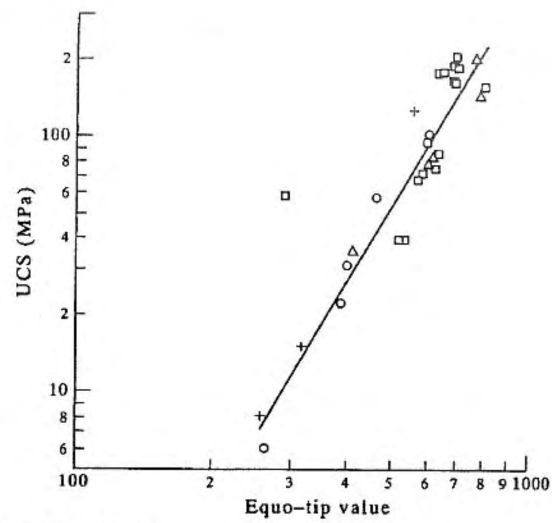

Fig. 3. Unconfined compressive strength against Equotip values: +(A) artificial; ○ (L) clastic limestone; □, (C) crystalline; and △ (S) sandstone.

energy of 11 Nmm. Impact devices with an impact energy of 3 Nmm (type C) and 90 Nmm (type G) are available.

EXPERIMENTS AND RESULTS

Equotip tests, using the impact device D, were performed on a series of rock samples prepared for the unconfined compressive strength test. During testing, the rock samples were placed on a table with a 10 cm thick rock table top. For tests across the diameter of the cores, the rock core was put in the V-notch in a 15 kg metal block (as used for the ISRM laboratory Schmidt Hammer test [3]) placed on the rock table. The rock cores used were mostly of limestone but granite, sandstone and man-made gypsum and building-stone were also tested. The cores tested were mostly of 30 and 40 mm dia. and 60 and 80 mm long, respectively, but for a few weaker rock types samples of 50 mm dia. and 100 mm length were prepared. For each sample, a total of 10 Equotip rebound values were taken, 5 on each loading surface of the sample; the average of the 10 readings was expressed as the hardness number L. The same samples were used to measure the unconfined compressive strength. If more than one specimen was tested from the same rock type, average results were used for correlation.

The results of the Equotip L number against the unconfined compressive strength are shown in Fig. 3, which shows a reasonable relation between the two

Table 1. Geotechnical properties of the rocks tested

Sample	Dia. (mm)	Equotip value	UCS (MPa)	E-modulus (GPa) tan 50% UCS	Unit weight (kN/m^3)	Porosity (%)	Rock type
A1	40	254.7	8	2	17.66	35.0	artificial fine grained gypsum rock
L1	50	261.5	6	1	13.15	50.1	medium grained calcarenite
C1	30	290.3	58	40	21.88	19.7	dolomite
A2	50	315.5	15	6	16.87	34.2	artificial calcareous sandstone
L2	50	387.3	22	9	21.09	19.8	detrital limestone
L3	50	400.0	31	12	19.03	37.9	fine grained limestone
S1	40	412.3	31	9	19.91	27.0	fine grained yellow sandstone
L4	50	464.4	57	24	22.37	15.7	fine grained limestone
C2	30	526.0	39	38	22.66	12.7	weathered dolomite
C3	30	538.9	39	37	23.35	8.1	weathered limestone
C4	30	573.0	67	32	23.94	10.7	fine grained dolomite
C5	30	586.7	71	51	23.74	4.2	fine grained crystalline limestone
C6	40	602.6	94	49	26.49	0.4	fine grained marble
S2	40	606.0	77	18	22.96	ND	fine grained sandstone
L5	40	608.0	101	26	25.02	5.4	fresh micritic fine grained limestone
S3	50	620.1	82	19	21.48	10.2	fine grained red sandstone
C7	30	626.8	74	52	24.62	4.9	fine grained micritic limestone
C8	40	637.4	85	59	26.29	1.1	coarse crystalline limestone
C9	40	640.1	174	59	25.31	3.8	medium grained limestone
C10	40	653.0	176	78	26.09	1.0	medium grained limestone
C11	40	686.9	163	69	26.59	0.5	fine grained limestone
C12	40	687.8	186	70	26.29	0.8	crystalline limestone
C13	40	695.7	159	76	26.19	0.6	medium grained limestone
C14	40	697.7	203	80	26.29	0.7	medium grained limestone
C15	50	705.0	183	72	25.90	ND	fine grained limestone
S4	40	769.7	198	54	26.49	0.8	massive micaceous calcareous sandstone
S5	50	788.0	142	44	25.31	ND	micaceous sandstone
C16	50	807.0	155	49	25.21	ND	medium grained granite

ND = not determined.

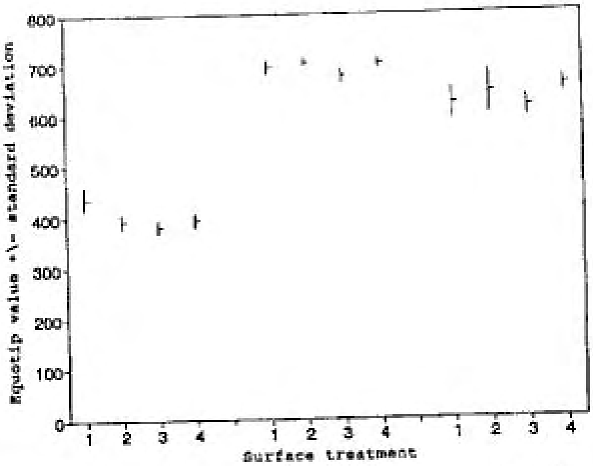

Fig. 4. Equotip values on 3 types of limestone each with 4 different surface treatments.

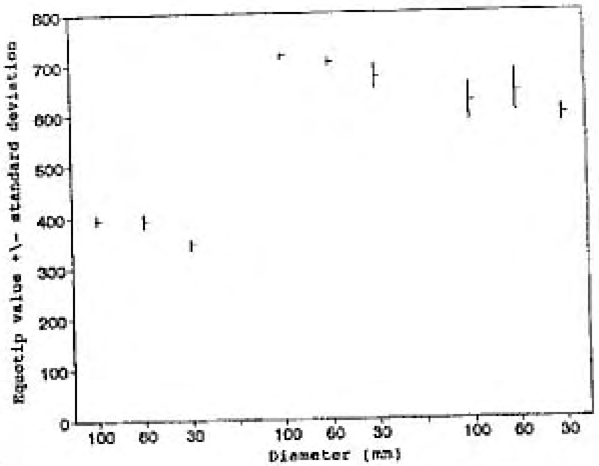

Fig. 6. Equotip values on 3 types of limestone, axially taken on cores with a height of 150 mm and of various diameters.

parameters. Only sample C1, a dolomite with a high porosity, gave an L-value which did not fall within the general trend of correlation. This correlation is as good as may be expected, since the volume of sample tested by Equotip rebound is much smaller than that tested by the compression of the rock core. Thus, a flaw in the UCS sample, outside the volume influenced by the rebound test, may cause the sample to fail at strengths lower than those assessed by rebound. Further information about the rock specimens used is given in Table 1.

SURFACE ROUGHNESS OF TEST AREA

It is generally accepted that surface roughness of the test specimen will affect results in rebound testing. The *Users Manual* for the Equotip specifies that, for testing metals, the roughness of the testing surface should not exceed 10 μm (ISO 4287 [5]) and the arithmetical average roughness should not exceed 2 μm = N7 (N7 = roughness classification according to ISO/R 1302 [6]). To determine the influence of rock surface roughness on Equotip L-values, tests were performed on three types of limestone, each with 4 different surface treatments to give grades of roughness.

These were:

1. A rough surface on a large block sample (about 20 kg) treated with a small grinding stone in a battery operated hand-held drilling machine.
2. A sawn plane perpendicular to the axis of a 60 mm diameter rock core.
3. As 2, but after sawing the surface was lapped.
4. As 3 but after lapping the surface was polished.

The results are shown in Fig. 4. No major difference was found between the measurements taken on the different surface treatments.

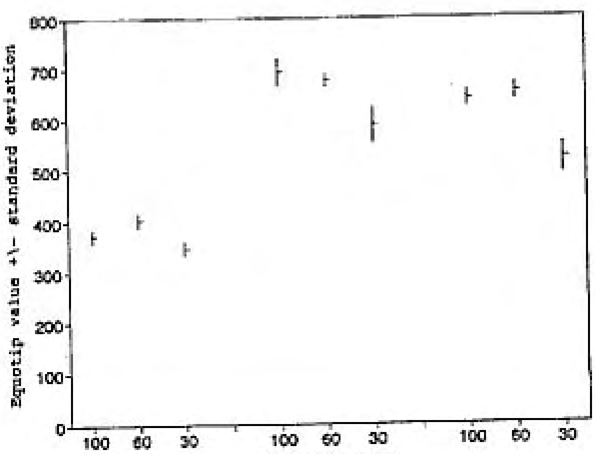

Fig. 5. Equotip values on 3 types of limestone, radially taken on cores with a height of 150 mm and various diameters.

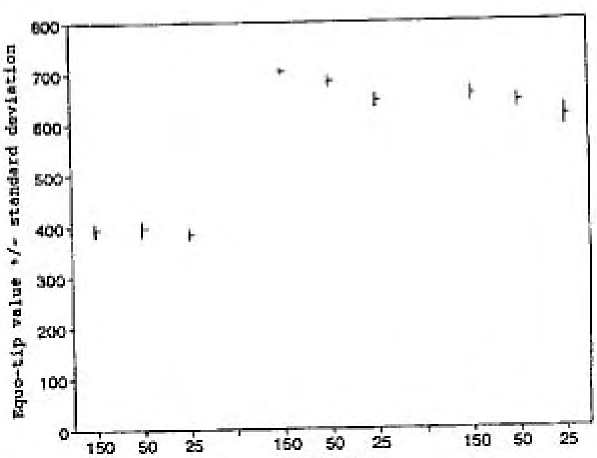

Fig. 7. Equotip values, on 3 types of limestone, axially taken on cores with a diameter of 60 mm and of various heights.

SAMPLE DIMENSIONS

Despite the small mass of the impact body and the low impact energy, a relatively large impact force of short duration is generated at the moment the impacting body hits the measuring surface. This suggests that very small and light samples would give results relating more to the background material than the rock. To examine the influence of specimen size, three types of limestone were tested in cores of varying size. Cores 150 mm long with diameters of 100, 60 and 30 mm were axially and radially tested. Results are given in Figs 5 and 6. Axial tests were also performed on cores of 60 mm dia. with lengths of 150, 50 and 25 mm. Results are given in Fig. 7. From these results, it may be concluded that tests performed on rock cores with a diameter of 30 mm gave L-values lower than tests on cores with diameters of 60 and 100 mm. Axial tests on cores with a length of 25 mm give lower L-values than tests on core lengths greater than 50 mm.

CONCLUSIONS

The Equotip seems to be a convenient portable tool for estimating the unconfined compressive strength of rock material. The possibility to make diametral measurements on rock cores makes the Equotip very useful for core logging.

If the test area shows some excessive roughness, as it may do in the field, it appears sufficient to grind the test spot with a small grinding stone in a (battery operated) hand-held drilling machine before testing. Although the results in Fig. 3 are based on core samples with a diameter of 30, 40 and 50 mm, tests on samples with dimensions below 50 mm seem to give lower results than larger samples. Further investigation is necessary to confirm this and perhaps it is possible to find a correction factor for testing small samples, although this is unlikely to prove a handicap in core logging because most cores taken are larger than the N size (54 mm). The influence of larger than usual mineral grains in rock samples has yet to be investigated.

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