TOWARDS A REALISTIC METHODOLOGY OF MODELLING A ROCK BLASTING PATTERN

KAYA PATLATMA DÜZENÎ MODELLEMESİNE GERÇEKÇİ BÎR YAKLAŞIM YÖNTEMÎ

Taha Abdallah*

Keywords : Modelling, Blasting, Explosives, Simulation, Regression Analysis

ÖZET

Kaya patlatması, tüm açık madencilik işlemlerinin verimlilik ve ekonomiklik tayininde önemli bir rol oynar. Patlatma verimliliğini etkileyen unsurlar yalnızca ocaktan ocağa değil aynı ocağın farklı aynaları arasında dahi değişmektedir. Önerilen yöntemin amacı patlatma verimliliğini arttırmaktır. Burada önerilen, arazide türetilmiş ilişkilere dayalı matematik bir model, hipotezlere dayalı ilişkilerden (formülasyondan) daha gerçekçi ve daha yararlı sonuçlar sağlayabilir. Önerilen modelleme yöntemini açıklıyan bir örnek de verilmiştir.

ABSTRACT

Rock blasting plays an important role in determining the efficiency and economics of the whole surface mining operations. The parameters influencing the blasting efficiency vary not only from one site to another but also within the different faces in the same quarry. The objective of the proposel methodology is to improve the efficiency of blasting. A proposed mathematical model, based on field relations, could yield more feasible and more realistic solution then those based on hypothetical relations. An example to ilustrate the proposed modelling methodology is given.

* **Associate Professor, Mining Dept, Faculty of Engineering, Cairo university.**

1. INTRODUCTION

In rock engineering practice, rock strength is considered an important and essential property for the design of surface and underground structures It represents also an essential parameter for classification of rock materials and judgment about their suitability for various construction purposes. One of the main problems in rock strength evaluation is to choose a test that can be carried out easily with the required accuracy.

The standard uniaxial compression test ; according to ISRM; is known to be the best way to determine the rock strength. However, it is time consuming and required relatively expensive equipments. In addition, a great number of well prepared specimens have tô be noted, and involves destructive tests, ifa representative value for a large rock exposure is considered. (SACHPAZIS,I990). Another disadvantage with the uniaxial compression that is the difficulty of carrying out the test in the field. Therefore substitution of this test with quick, reliable indirect tests would be of valuable help, at least, for the preliminary stage of design.

One of the common indirect methods for strength determination is the point-load test which requires no specimen preparation, and can be used easily in the field The point testing test has several important advantages. Firstly, the specimen fails at much tower loads tin« in compression, allewûtg use of testing machine which has a load eapaeity less than one tenth of that usuafly required. Secondly, the loading configuration Jfteaof that ftacture initiates away front platens, so that platen contact conditions are of Ğttie importance and the external geometry of the specimen has a minimum effect on its Strength. Hence the same strength index P/D* (where ^-applied load, D=Platen distance) is used whether the test specimen is diametrically loaded drill core, a core disc loaded axialry, or alt irregular lamp öf rock picked op or hammered from outcrop The capability of testing irregular lumps makes this test particularly suitable for the study of weathered rocks, many of which are either too broken or too friable to be machined into regularly Shaped specimens. Tests on irregular lumps show considerable scatter, as might be expected, but this disadvantage »ay be offset by rapidly number of specimens,(Fookes et al, I971).

The other promising technique is Schmidt rebound test. It has been increasingly used worldwide as an index for quick and acceptably reliable rock strength and defbrmabibty characterization. This is mainly due to its rapidity, easiness in execution, non-destructiveness, simplicity, portability and low cost.

The present work is essentially a comparative study concerning the determination of the compressive strength by the three previously mentioned testing methods applied to four Egyptian rocks: Helwan limestone, El-Okba sandstone from Aswan, El-Selsela sandstone from Aswan also and El-Dokhan granite from the Eastern desert. Test results are statistically analyzed with the objectives of finding out the reliable formulas for prediaing strength for the Egyptian rocks and study the influence of the size of the specimen on the measured strength. Furthermore, the possibility of relating the strength parameters with some of physical properties of the tested rocks are presented.

2. CRITICAL REVIEW ANALYSIS :

2.1. Point-Load Test :

In order to predict the uniaxial compressive strength from the point-load test a factor of 24 is proposed by Brach and Franklin (1972). The Indian standard (IS. code:8764,1978) gives a conversion factor of 22. GHOSH et al (1991), found that this factor could be deduced from the straight line correlation with a slope of 16. This consideration enables a prediction for regional reconnaissance of strength of similar rocks. (Hodder et al, 1991).

The accuracy of the tests depends upon the size of the sample, its type (irregular, cube, cylinder), and finally the direction of loading relative to that of the foliation.

Empirical correction charts have been devised by Brock and Franklin (1972); Hassani, (1980); Hassani et al., (1980) Hussen (1971), Bieniawski (1975) as shown in figure (1) to standardize point load index. In 198S,TURK and DEARMAN have proposed some improvements in the determination of point-load strength. They proposed a simple method for determining standard point-load strength Is (SO), from test results obtained from a number of irregular, and regular prismatic specimens of different thickness (diameter) using log-log plot of Is against diameter. This relation is usually linear.

2.2. Schmidt Rebound Test :

Numerous empirical formulas have been proposed relating uniaxial compressive strength and modulus of elasticity of rocks with their corresponding densities and

Schmidt rebound indices A complete survey of these formulas is given by Helal and Abdallah (1987) They proposed an exponential formula for predicting the compressive strength of limestone sample collected from Attaka quarry (Suez)

SACHPAZIS (1990), found that there is a possibility of estimating both uniaxial compressive strength and tangent Young's modulus of various carbonate rocks from their Schmidt hammer rebound number, by using linear mathematical relations with acceptable accuracy, especially at the preliminary stage of designing a structure upon or inside a rock formation, or for assessing the properties of a building stone.

However, most of the existing empirical relationships tend to overestimate the strength of weak rock because they do not account for the healed fractures and linear fabric (lamination and schistosity). XU et al (1990), found exponential formulas for five types of rock containing weakness planes, but they quoted that, from an engineering point of view, it is important for each project to develop its own data base for deriving specific relationship to be used in the site.

3. EXPERIMENTAL DETERMINATIONS:

For each rock two types of specimens were prepared:

1. Irregular lumps, with a range of thickness (diameter) ranging from 1 to 8 cm produced by hammering the specimen.
2. Single size specimens with a range of thickness (height) from 1 to 10 cm. These specimens were prepared using a laboratory-coring machine. The diameter was kept constant at S cm, and for standard uniaxial compression testing, H/D is taken equal to 2.

Table (1) summarizes the number, types of specimens and conducting tests for the comparative study.

Before carrying out mechanical characterization, dry density, water absorption and ultrasonic velocity were determined for the regular specimens. The measured physical properties were used as a guide to reject the odd specimens having, for example, crack, fissures which would act as planes of weakness and cause an undesirable change of the real properties of the rocks.

Strength characterization of the selected specimens were conducted according to ISRM standards and specifications as follows:

- Schmidt hammer rebound tests on all the standard specimens (h/d=2), except for the sandstone where only a group of each type was used because of their low strengths.

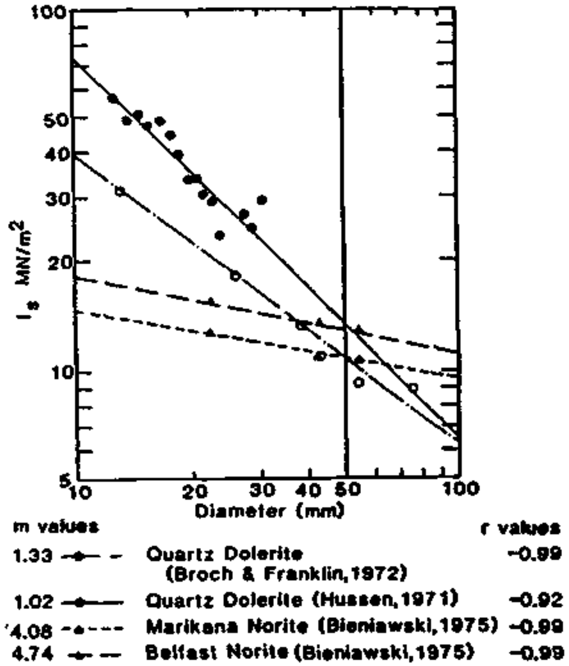

Figure (1) Relation Between Point Load Index And Diameter For Some Selected Igneous Rocks (After, Turk & DEARMAN,1985)

Table (1) Summary Of The Number And Types Of Specimens Used

Source of Rock	1 st Group		2 nd. Group			
	Point Load Test		Regular Specimens			
	Regular Specimens	Irregular Lumps	Rc	Rn	Is	Rt
Helwan Limestone	51	32	20	33	33	33
El-Selsela Sandstone	32	43	18	20	18	16
El-Okba Sandstone	57	49	38	20	20	20
El-Dokhan Granite	27	18	9	9	19	-
TOTAL	635 SPECIMENS					

Table (2) Statistical Analysis Of Results Obtained From Point - Load Test On Different Types Of Rocks With Different Thicknesses

Type Of Rock	No. Of Specimens	Thickness Limits (mm.)	Mathematical Relation	Correlation Coefficient	Standard Error Of Estimation	Limits From Math. Relations
El-Dokhan Granite	27	12 < D < 54	1/Is = -2.48 E-3 + 2.64 E-3 * D	0.705682	0.004	9.3 < D < 60
Helwan Limestone	51	6.5 < D < 78	1/Is = -0.0179129 + 0.0102638 * D	0.88806	0.009	6.5 < D < 70
El-Okba Sandstone	57	8.5 < D < 52.5	1/Is = -8.83 E-3 + 0.0172136 * D	0.835246	0.015	6 < D < 60
El-Selsela Sandstone	32	5.5 < D < 46	1/Is = -8.90 E-3 + 0.0159143 * D	0.982687	0.004	5.5 < D < 50

- Unconfined compression test on the standard specimens.

- Point-load test was conducted on two stages.

- Study of the effect of the height and the volume of the specimens on the obtained index. This was done using specimens of different heights.

- Point load index of irregular specimens.

4. INFLUENTIAL PARAMETERS AND STATISTICAL ANALYSIS :

4.1. Effect Of Specimen Thickness On Point Load Index :

In order to study the effect of thickness variation (D) on the strength index (Is), 167 cylindrical samples of different heights (thicknesses) from Dokhan granite, Helwan limestone, El-Okba sandstone, El-Selsela sandstone were tested. Results were subjected to regression analysis, using STATGRAPHICS software, to find out the mathematical relation between the thickness of sample and its strength index. Table (2) and figure (2) summarizes the obtained results Several regression models could be obtained for the available data with higher correlation coefficient (.85 - .9) than that shown in table(2). However these models are not significant and can not explain the physical meaning of the boundary conditions such as the effective thickness (diameter). In addition the criteria of having the lowest error of estimation is considered of first periority with reference to other parameters.

Therefore, the reciprocal model as illustrated in table (2) and figure (2) where the lower limit is shown by the straight line is the best model to fit the experimental measurements. The smallest thickness of specimens used was ranging from 5.5 mm in case of El-Selsela sandstone to 12 mm in case of granite. The point load test is very sensitive to thickness less than 10 mm, where a great dispersion is observed in this range. Therefor, it is recommended not to use samples of depth lower than 10 mm.

On the other hand, the upper limit of depth could be extended up to 80 mm. However, in case of limestone, the point load test is not significant in the limits between 70 - 80 mm where the slope of the curve is almost horizontal (fig. 2)which means no sensitivity to the variation of depth (i.e. the same Is). Consequently, it is recommended to use specimens with thickness up to 70 mm.

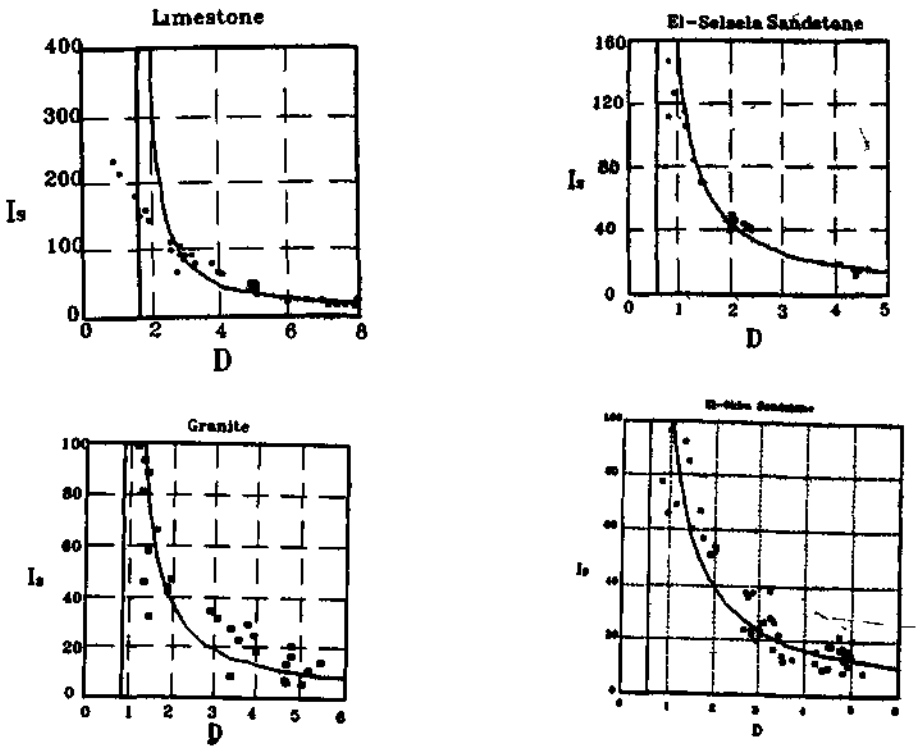

Figure (2) Regression Analysis Of Selected Rocks

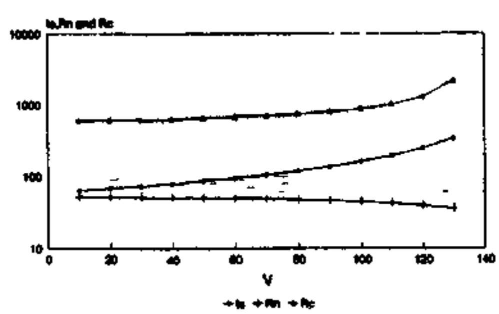

Figure (3) Proposed Chart» Relating
RcRn, **And** Is With Volume

4.2. Conversion Factors For Strength Classification :

The principal objective of the present work is to find out a conversion factor to help in converting any one of the known strength parameters - point load index (Is),Schmidt rebound number (Rn), and tensile strength (Rt)- into the equivalent value of compressive strength (Re)

Summary statistics of strength classification parameters for each type of the chosen rocks is shown in table (3) The estimated conversion factor, the standard deviation and coefficient of variation are calculated and given in table (4) Analysis of these results could reveal that

* The conversion factor (C F) depends essentially on the type of rock. For estimating the compressive strength from Schmidt hammer rebound number (Rn) the C F. is about 3 for sandstones and 5 for limestone and about 13 for granite while the estimation of Re from point load index (Is) varies from 5 for El-Selsela sandstone and limestone to about 7 for El-Okba sandstone and granite It should also be stated that these obtained values are too low with respect to the published C.F. This may be due to the shape of the specimen and the size effect on the measured strengths.

* The error in estimating Re from Is, Rn, or Rt is less than 10 % in case of El-Selsela sandstone and 15 % in case of Helwan limestone and El-Dokhan granite. Only in the case of El-Okba sandstone, the error is much higher (about 27%) due to the heterogeneity of this type of rock

4.3. Testing Of Irregular Specimens :

The objective was to study the specimen size effect on the point load test The only significant result was obtained for granite specimens after many eliminating heterogeneous specimens having thickness less than 20 mm The following relation was found .

1 / Is = 0.0191656 - 1 28527 E -4 * V

N = 18 r = -81 o = 2.18

where : V = sample volume in cm^3, N = no of samples, r = correlation coefficient, o= standard error of estimation.

Table (5) Statistical Analysis Of
Granite Strength Parameters

Mathenuckal Relation	Continua Coefficicot	Standard Error Of Ealhnauoo
l/Rc-9tE-4 + 47E-5«S	071	00003
l/Rc--2 2E-3<-7 6E-5*Rn	069	0 0003
l/Rc - 1 4 E-J + 5 2 E-5 • Rn + 3 3 E-5 • S	0 82	0 0003
l/Rn - 0 0 1 9 6 9 3 t + 2 4 E-3 • W	0 71	0 001
l/Rn-00172847+ 3 3 E-5 «Is	0 74	0 001
h-USSBfiRnH)"""	0 74	0 246
I l - e •"—•«—•	0 72	0 252
1/It - 0 0169364 .1 0730S E-l • V	•067	0 003

Where Re - Comprenve Strength (kg/cm.2), Rn - Rebound Number
Is - Strength Index. S « Sound Velocity < on/sec), W - Water Absorption
d - Demtry (gm/can.3). V» Volume Of Sample (cm 3)

Table (3) Summary Statistics
Of Strength Parameters

		D M t a Granit*	Harran I lınaiınoj	El-Sehola SandMone	El-Okba
Re	N	9	33	20	38
	U	66364	22673	85 57	114 53
	o	US 03	3142	9 65	3765
Ro	N	9	33	10	20
	H	SO	4649	35 2	40
	0	3 61	3 3SS	27	6 74
b	N	9	20	IS	20
	n	Mil	4002	1643	1548
	9	3261	599	137	336
Rt	*H*		20	16	20
	tt		417t	14 9	16 51
	o		1247	193	277

Where N-Number Of Simple«, ^ = Mean,
o • Sundaıd Deviation

Table (6) Statistical Analysis Of El - Selsela
Sandstone Strength Parameters

Matkanuucal Relation	Correlation Coefficient	Standard Error Of Eatbmation
Re - 1 9 2 166 • Rf"""'	-o85	0 033
1/Rt-0 63779-0 18168* S	-0 68	001
l/|j = 00754536-5 1E-3·S	0 77	0004
d = 7 1667-1 5681 'S	-0 74	0 06S

Rt • Rock Tennle Strength (kg/cm2)

Table (4) Summary Statistics Of Conversion Factors

	El-Dokhaa Granite			Hehran Limestone			U-Scada Sandstone			El-Okba Sandstone		
	CF.	o	CV.	CF.	*a*	CV.	CF.	*a*	CV.	CF.	o	CV.
Rn	13 27	95 52	14 39	481	22 33	986	2 43	809	9 45	286	30 83	26 94
b	782	98 23	14 8	5 67	3417	IS 38	5 21"	7 07	8 26	74	30 67	26 78
Rt		-	-	5 43	2603	1148	5 74	7 32	155	694	30 65	26 76

when C F - Convert*» Factor o « Standard Deviation Of The Esnnwed Value Of Re.
C V -CocffioewOfVanauonOfTheEtumaled Value OfRc

This relation seams to be in contradictory with what is known about the volume influence on point load index. This, may be due to the heterogeneity of the granite, (a = 2.18).

by choosing samples having the same range of water absorption and sound velocity. This step led to a great reduction in the number of samples used for regression analysis.

4.4. Relation Between Physical Properties And Strength Parameters ;

Statistical analysis of the obtained measurements and tests is demonstrated by the relations shown in tables (S) and (6). For granite, the uniaxial compression strength have been correlated with point load index and Schmidt rebound number. The correlation coefficients are about 0.7. The correlation has been improved to 9.8 when the sound velocity was introduced. Other formulas have been obtained relating the physical properties with the strength indices; with correlation coefficient about 0.7. On the other hand, these relation could help in constructing some chart? for this type of rocks. Knowing one of these physical properties, it will be easy to find out the expected strength parameters, (fig. 3).

Only some relations are obtained for El-Selsela sandstone as shown in table (6). For El-Okba sandstone and also Helwan limestone, the statistical analysis could not provide significant correlations. Although, the heterogeneity of samples was overcome

5. CONCLUSION :

From engineering point of view, strength classification of rocks is of vital interest,, for designing rock structures. The standardized uniaxial compression test has been accepted to be the most suitable method for strength determiaation. However other indirect techniques, more easier and reliable, became actually of frequent use, such as point load index and Schimdt rebound number.

The relationship between these three different technics has been thoroughly studied applied to four Egyptian types of rocks. The compressive strength could be estimated from other strength indices using estimated conversion factors. Generally, the obtained conversion factors appeared to be rock type dependant, and are relatively low for Egyptian rocks. It means that for rock type a regional conversion factor should be evaluated.

The accuracy of using these conversion factors is reasonably accepted, taking into consideration the cost and time of conducting standard compression tests.

Another important concluding remark is the dépendance of point load index on **the thickness** of **the** specimen. Thickness should range between 10 to 70 mm, otherwise **the test** is **not** significant.

6. ACKNOWLEDGEMENT :

The authors would like to thank prof. Hassan F Imam - Head of Geotechnical Group in Mining Department, Cairo University- for his valuable suggestions and support during the realization of this works. Thanks are going also to Eng. Ayman Hamed - **Research** assistant - for his help in laboratory work.

7. REFERENCES :

BROCH, E., FRANKLIN, J. A., 1972; "Point-Load Strength Test", Int. J. Rock Mech. Min. Sei. 9, pp.669-697.

FOOKES, P.G., DEARMAN, W.R., FRANKLIN, J.A., 1971; "Some Engineering Aspects Of Rock Weathering With Field Examples From Dartmoor And Elsewhere", Q. J. Eng. Geol., Vol. 4, pp. 139-185.

GHOSH, K, SRTVASTAVA, M., 1991; "Point-Load Strength: An Index For Classification Of Rock Material", Bulletin of the Int. Assoc, of Eng. Geology, No. 44, pp. 27-33.

HELAL, H., ABDALLAH, T., 1987; "Use Of Schmidt Hammer For Limestone Testing", Proceeding of the 1" Regional Symp. of Material Science (in Arab States), 29-31 December, Alexandria, A. R. E. J

HODDER, A.P.W., HETHERINGTON, JR., 1991; "A Quantitative Study Of The Weathering Of Greywake", Eng. Geol. No. 31, pp. 353-368.

INDIAN STANDARDS INSTITUTION CODE, 1987, LS. Code 8764.

SACHPAZIS, C.I., 1990; "Correlating Schmidt Hardness With Compressive Strength And Young's Modulus Of Carbonate Rocks", Bulletin of the Int. Assoc, of Eng. Geology, No. 42, pp. 75-83.

TURK, N., DEARMAN, W.R., 1985; "Improvements In The Determination Of Point-Load Strength", Bulletin of the Int. Assoc, of Eng. Geology, No. 31, pp. 137-142.

XU, S., GRASSO, P., MAHTAB, A., 1990; "Use Of Schmidt Hammer For Estimating Mechanical Properties Of Weak Rock",*6* Int. I.A.E.G. Congress, Balkema, Rotterdam, pp. 511-519.