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Evaluation of the relationships between Schmidt rebound number and strength of rocks

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ABSTRACT: Rock strength is commonly assessed directly by a test such as the uniaxial compressive strength test. However, testing of this mechanical property is time consuming, expensive and restricted to those rocks that can be machined into regular test samples. Therefore, indirect tests are often used to estimate this property. The Schmidt hammer is one of the widely used portable instruments for estimating rock strength indirectly. The Schmidt Hammer provides a quick and inexpensive measure of surface hardness that is widely used for estimating the mechanical properties of rock material. The Schmidt Hammer was developed in 1948 for non-destructive testing of concrete hardness, and later to estimate rock strength. Nowadays, L type Schmidt hammer are suggested for rock testing. N type Schmidt hammer generally found most civil engineering laboratories and building audit laboratories. In the civil engineering and mining industries, it is used for non-destructive testing of the quality of concretes and rocks, both in the laboratory and on exposures in situ.

This study aims to investigate the relationships between the Schmidt hardness rebound number (N) and uniaxial compressive strength (UCS) of rocks.

Core samples were taken from different rocks, such as marble, basalt and limestone. Physical properties and Schmidt rebound values were determined of these samples. Uniaxial compressive strength of these samples was also found out. Statistical analysis was carried out on these data and empirical relationships were developed.

1 INTRODUCTION

In parallel with the technologic and economic development, rocks have been used as building materials or main material for building big dams, nuclear power plants, tunnels, mining, viaducts, bridges, skyscrapers and etc. In designing such buildings; when designer take these parameters into consideration which are strength, long working life and economy, it must be known the engineering features of rocks.

Uniaxial compression strength is an important parameter in rock engineering, defining the features of deforming the rock material and classifying rock mass, has been commonly used. However, measuring of uniaxial compression strength is generally time consuming and expensive process. Index tests are proposed by many researchers to estimate uniaxial compression strength of rocks quickly and cheaply.

Schmidt hammer is a method which gets result rapidly, non-destructive and can be easily practiced in site. Schmidt hammer was firstly invented in 1948 to test concrete hardness. Since the early of 1960s, it has been used to determine rock hardness and uniaxial compression strength.

Schmidt hammer consists of a steel plunger and a mass which presses it with a spring. A spring-loaded mass is released against a plunger when the hammer is pressed on to the surface of a test material. The plunger impacts the surface and the mass recoils. The impact energy for N type is 2.207 Nm and it is 0.735 for L type. The rebound distance of the plunger is read directly from a numerical scale. The Schmidt hardness of surface is determined according to following proposed methods (ISRM (1981), Hucka (1960), ASTM (2001), Poole and Farmer (1980), Sumner and Nel (2002), etc.)

There is no need for any expenses such as collecting samples and preparing for defining surface hardness with Schmidt hammer. So, many researchers have studied to estimate strength of rocks with Schmidt hammer for about 50 years. International Society of Rock Mechanic (ISRM 1981) suggested using of Schmidt hammer to define discontinuity of rock masses. Singh et al (1983), Haramy and De Marco (1985), Shorey et al (1984), have found reliable correlation coefficient between Schmidt hardness value and uniaxial compression strength. Ghose and Chakraborti (1986) tried to determine Schmidt hardness value and uniaxial compression strength in the experiment which was practiced on Indian Coals. O'Rourke (1989) tried to determine a relationship between Schmidt hardness value and uniaxial compression strength by studying on sandstone, silt stone, limestone and anhydrite samples. The regression coefficient which he acquired is (R^2= 0.60) Sachpazis tested 33 different carbonated rocks and acquired R^2=0.92 as regression coefficient.

2 MATERIAL AND METHOD

In this study, different rock types' the relation between Schmidt hardness value and uniaxial compression strength has been researched by studying on marble, travertine, basalt, calcareous and sandstone samples.

For experimental studies, Rosso Levanto marble which is mined in Elazıg, Karayazi basalt, travertine, calcareous, Black Pearl marble which is mined in Diyarbakir Cungus, Crystal Emperador marble which is mined in Adiyaman, Malatya sandstone and Kayseri sandstone samples were taken.

Figure 1. Schmidt tests and core samples

Tests were done to define the values of Schmidt surface hardness and uniaxial compression strength, by taking drilling cores in diameter 6.63-6.35 cm and in height of 17.5-9.59 cm from the rock blocks which were taken from land to laboratory.

For experiments, the drilling cores were taken from 3 different marble types, one type of basalt, one type of travertine, 2 different sandstone type and one type of calcareous and the rocks which were taken from 4 different cities and then after eliminating the damaged drilling cores which can affect the results of experiment, 25 drilling core samples have been used for experiments.

Researchers suggested different test methods to define the value of rocks' Schmidt hardness. In this study, the test methods were used which were proposed by Poole and Farmer(1980) to define samples' Schmidt hardness of rocks. In this method, 5 hits at a time are done to 3 different points.

Figure 2. Core samples before uniaxial compression test.

For each point, the highest value is chosen and the average of this 3 values is calculated. In measurement of surface hardness, an N type Schmidt hardness hammer which has 2,207 Nm impact energy is used.

To define the surface hardness of drilling core, samples are pressed horizontally and Schmidt hammer is hit to 3 different points with the aim of 5 hits to each point by holding horizontally and then Schmidt hardness values are measured. Schmidt hardness values of samples determined by Poole and Farmer (1980).

To define core samples uniaxial compression strength, an electronic controlled press is used with the capacity of 3000 KN load. Proportion of diameter/ height of core samples are changing between 1.58 and 2.67 core samples cannot cut with the proportion of Standard height/diameter = 2/1. The reason of this, insufficient sizes of rock blocks brought from site. Because of proportion of height/diameter is not standard, it is known that the results uniaxial compression test would be incorrect. So the measured values of uniaxial compression strength are corrected by using the equation which was proposed by Kahraman and Alber(2006).

$$UCS_2 = \frac{8.UCS}{\left(7+2.\frac{D}{L}\right)} \tag{1}$$

3 FINDINGS

Results of Schmidt hardness tests and uniaxial compression tests are available in Table 1.

Table 1. Measured and corrected uniaxial compression test results and Schmidt rebound numbers

Sample name	**No**	**UCS (MPa)**	**UCS_2 (MPa)**	**N**	**Sample name**	**No**	**UCS (MPa)**	**UCS_2 (MPa)**	**N**
Black Pearl Marble	1	104.42	104.01	50.3	Karayazi Basalt	14	85.92	86.22	47. 7
	2	116.24	114.63	47.3		15	109.79	110.72	47.3
Travertine	3	26.38	25.65	34.3	Malatya Sandstone	16	107.85	109.74	56. 7
	4	50.03	48.57	37		17	102.42	105.74	62
	5	28.53	27.6	32.7	Kayseri Sandstone	18	60.10	57.49	45
	6	46.65	44.95	30.3		19	50.25	49.2	42.3
	7	23.76	22.93	29.3		20	58.52	57.62	44.3
	8	52.85	51.73	32.3		21	59.45	58.91	43.7
	9	58.91	57.01	35		22	61.18	60.42	42.7
	10	49.14	48.14	33. 7	Calcareous	23	58.61	60.04	45.3
Rosso Levanto Marble	11	67.62	67.46	34. 7		24	51.69	51.45	38.7
Crystal Emperador	12	49.83	49.51	39.3		25	88.50	86.69	43
	13	49.37	49.42	42					

Figure 3. is created by the results of experiments which were done on the core samples. By doing a simple regression analysis among these results, a relation R^2 =0.66 between rocks' uniaxial compression strength and Schmidt hardness values can be seen.

$$UCS=26.01+0.241xN \tag{2}$$

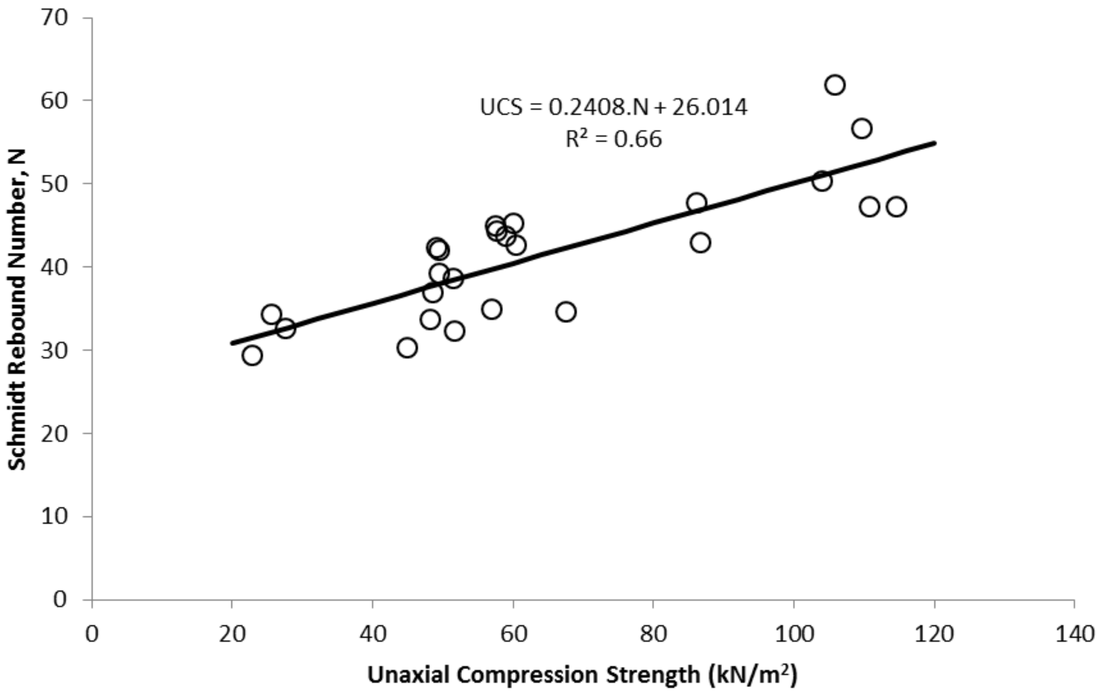

Figure 3. Uniaxial test results vs. Schmidt rebound numbers.

4 CONCLUSION

It is essential to know rocks' engineering features because rocks are used in many engineering construction as a construction material and foundation material. But determining rocks' engineering features is generally time consuming and expensive. So, nowadays many studies are carried out to determine rocks' engineering features in a fast, easy and cheap way.

In this study, to get a correlate which can be used in many rock types, it is studied on 25 drilling core samples brought from 4 different cities in Eastern Anatolia and rocks' uniaxial compression strength and Schmidt hardness value are analysed.

When the number of samples used in experiments taken into consideration, correlate's regression coefficient (R^2=0.66) may be increased.

Determining uniaxial compression strength via measure of surface hardness is not a reliable data for designing despite high regression value. The correlates which acquired with the help of multiple regression analysis will be more reliable for designing. The studies which consist of physical properties such as porosity, density, uniaxial compression strength and Schmidt hardness can more reliable for design purposes.

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