

Relationship of Physical Properties of Limestone and Marble with Rock Strength Under Specific Geological Conditions from Khyber Region Hunza

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Abstract: The uniaxial compressive strength (UCS) is one of the input parameters mostly used in surface and underground designs. A literature review revealed that most of the empirical equations between UCS and Schmidt hammer rebound number (N) are not satisfactory because of the low coefficient of correlation. In most of the cases, a single formula is used for all types of rocks. In this study, a relationship UCS with N, slake durability, moisture content, and specific gravity has been developed for a particular limestone and marble deposit. These equations help to determine the strength of these deposits directly using N value and other properties. The UCS value increased with increasing N value, specific gravity, and slake durability. While the UCS value decreased with increasing moisture content. A relation between slaking cycles and slake durability index is also developed. In this study, the slake durability value decreased with increasing slaking cycles for both limestone and marble. The UCS showed a linear relationship with these physical properties.

Keywords: Uniaxial compressive strength, slake durability, Schmidt hammer, limestone, marble.

Introduction

This paper characterizes the physical and strength properties of limestone and marble of Khyber region (36° 34' 27.98" N, 74° 47' 46.998" E), an elevation 2723m above sea level of Hunza Gilgit, Pakistan (Fig. 1). The uniaxial compressive strength (UCS) is a geotechnical property that is most often quoted in rock engineering practices. The Schmidt hammer rebound number (N) is the most frequently used index in rock mechanics practice for estimating the UCS and the modulus of elasticity (E) of intact rock both in laboratory conditions and in situ. Schmidt hammer test or rebound test is a simple index test to determine the surface strength of the rock sample (Nazir et al., 2013). The test does not involve the destruction of the sample (non-destructive), and it can be repeated on the same sample (Yılmaz, and Yuksek, 2008). The index value obtained is rebound number (N), which is an indicator of the surface hardness of the sample (Betts and Latta, 2000). The relationship between N value and UCS helps determine the strength of rock. L-type of Schmidt hammer is used to predict the strength and compression of limestone rock samples (Nazir et al., 2013). The N value of the Schmidt hammer is used as an index for the intact strength of rock material (Aydin and Basu, 2005). The N value is a low cost, and non-destructive tests also used to indicate the compressive strength of rock material (Yılmaz and Sendir, 2002). The values of the test are recorded after the hammer is released by its spring against the rock surface, and the average value is

considered (Aydin, 2008). Another important parameter that controls the UCS is specific gravity. The rocks of high quality possess a high value of specific gravity (Hale and Shakoor, 2003). This value ranges from 2.48-2.88 for granite to gneiss.

The slake durability is an important property when determining the engineering properties of rocks (Sharma et al., 2011). The durability value depends on slaking cycles. The slake durability value decreased with increasing slaking cycles (Koncagül and Santi, 1999). In most of the previous studies, the slake durability value is mostly obtained from the second slaking cycle (Sharma and Singh, 2008). Tugrul and Zarif (1998) stated that the mineralogical composition of rock controls the slake durability value. The slake durability value correlates with UCS, and the best correlation between the slake durability index, and UCS was developed after the fourth slaking cycle (Yagiz et al., 2012).

There are variations in properties and strength of rock from one geological location to the other. Therefore, it is important to systematically characterize the rocks of a particular area and evaluate factors that control the compressive strength of rock to develop practical quality-control specifications. The present study aims to highlight the basic engineering properties of rock and integrate factors controlling them from this area. In this paper, a relationship between the slake durability

index, Schmidt hammer, and specific gravity was developed with UCS.

Materials and Methods

Fieldwork was carried out at different faces of Khyber limestone and Nasir abad marble of Gilgit-Baltistan. The detailed methodology of each process is given (Fig. 2).

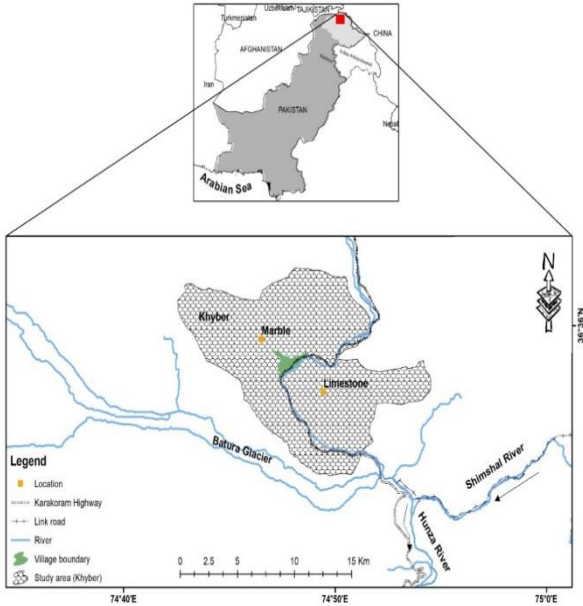


Fig. 1 Map of Khyber, Hunza, with the location of marble and limestone.

During the field number of tests were performed on each limestone and marble samples. The test is done on an intact, uniform, and representative sample of each rock mass. The lowest five values of N are discarded. The average values of N and UCS were noted. Representative 19 tests for limestone and 14 tests for marble were conducted (Tables 1,2). The obtained N value is corrected according to the ISRM suggested method. Secondly, 40-60 grams of rock samples were dry for 10 minutes at 110±5C. The weight of the dry sample is measured at W1. After 10 minutes of the first cycle again, the dry weight at the same temperature is measured as W2. The slake durability index for the first cycle is calculated as

$$I_s = \left(\frac{W_2}{W_1} \right) 100 \dots \dots \dots (1)$$

For most reliable calculations the process is repeated and the index value for the second cycle is calculated as

$$(I_s)_2 = \left(\frac{W_3}{W_1} \right) 100 \dots \dots \dots (2)$$

The percent loss of mass is referred to as the slake durability index. The specific gravity is the density of solid to the density of reference material. The uniaxial compressive strength is determined by a Universal testing machine. A core sample of length to diameter

ratio 2-2.5 was prepared in the core drilling machine. The core has been cut and polished by core cutting and lapping machines, respectively.

Results and Discussion

Correlation Between N value and UCS

Represented the correlation between N value and UCS of Khyber limestone and Nasirabad marble. The N value showed a linear relationship with UCS. The linear equation has a slope of 3.3 and the R-square value of 0.8873 (Fig. 2).

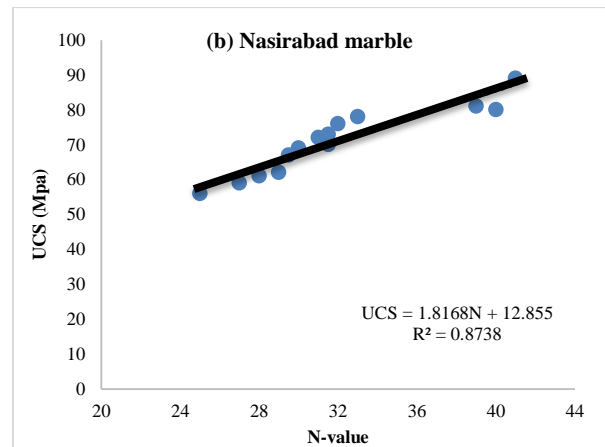
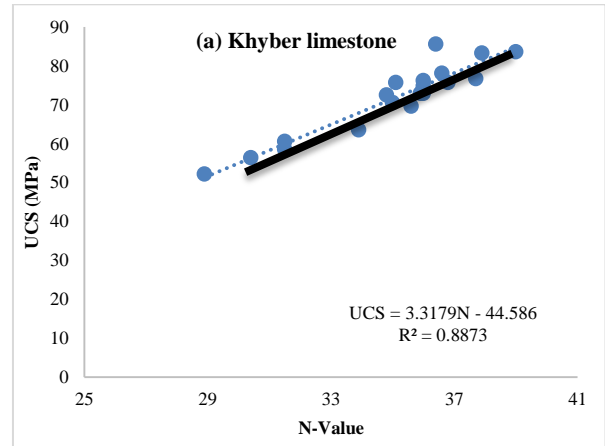


Fig. 2 Correlation between UCS and N value of (a) Khyber limestone and (b) Nasirabad marble.

For Nasirabad marble, the equation has a slope of 1.816 and an intercept of 12.855. The R-square value for Nasirabad marble is 0.8738. For both limestone and marble, the UCS value increased with increasing N value. These two equations showed the UCS and N values are rock dependent parameters.

Effect of Specific Gravity on UCS

In both limestone and marble, the UCS value increased with a specific gravity (Fig. 3). The specific gravity shows a linear relationship between UCS for limestone and marble, which provided slope 45.48 and 35.68 for limestone and marble, respectively. The effect of a specific gravity test produces a coefficient

correlation of R square about 0.898 and 0.897 for limestone and marble respectively.

Effect of Moisture Content on UCS

The moisture content showed a linear relationship with UCS for both limestone and marble (Fig. 4). Generally, the UCS value decreased with increasing moisture content. With marble, the UCS value is 110MPa at 0.13% moisture, and it decreased to 67MPa at 1.67% moisture. For limestone, the maximum value of UCS 111MPa has been achieved at 0.2% moisture, while a minimum of 64MPa has been achieved at 1.55% moisture content.

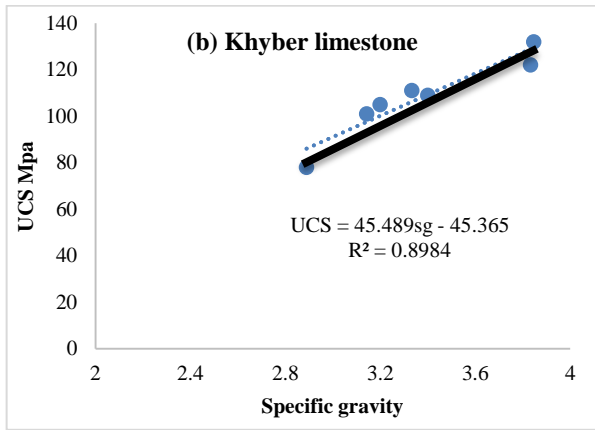
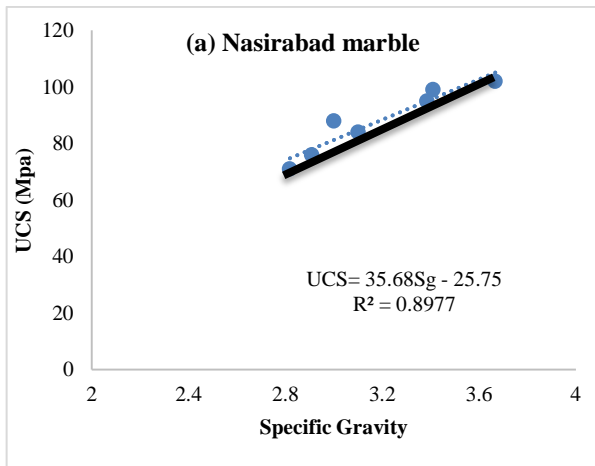
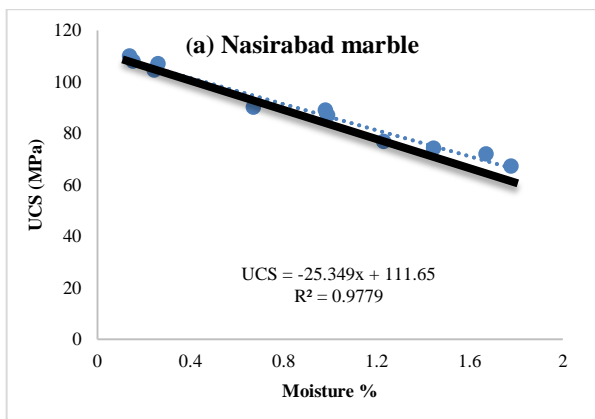


Fig. 3 Effect of specific gravity on UCS of (a) Nasirabad marble and (b) Khyber limestone.



Effect of Slaking Cycle on Slake Durability

The slaking cycle has a great effect on slake durability, and its value decreased with increasing slaking cycles. For Khyber limestone, the slake durability value decreased from 100 to 97.24 when the slaking cycle is increased by 8. For Nasirabad marble, this value decreased from 100-96.42 when the slaking cycles increased to 9.

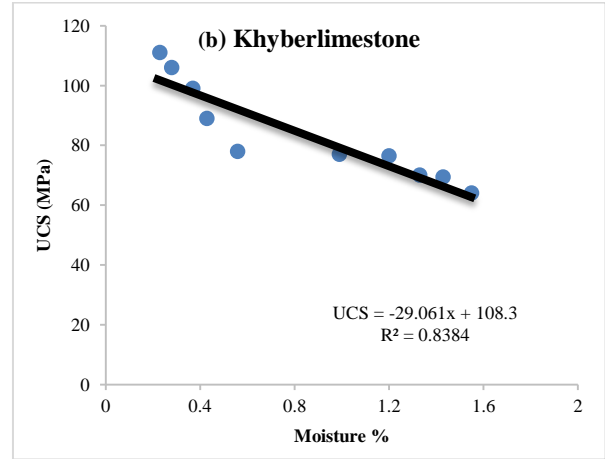


Fig. 4 Effect of moisture content on UCS of (a) Nasirabad marble and (b) Khyber limestone.

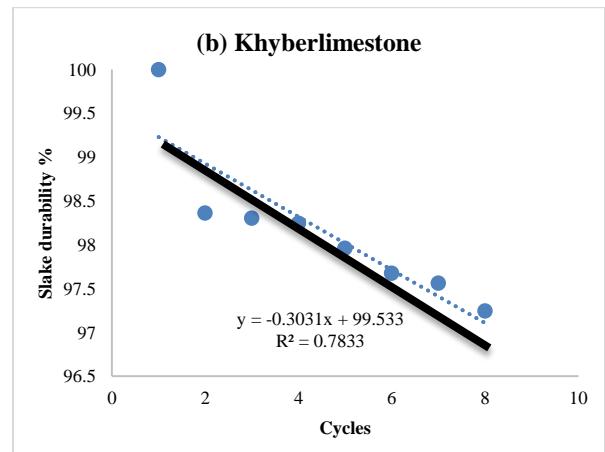
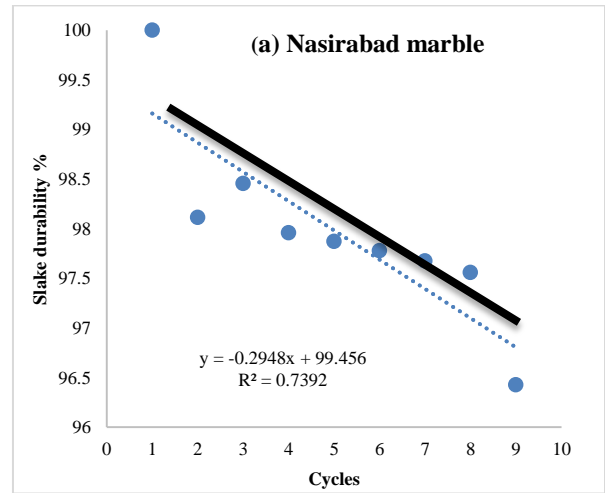
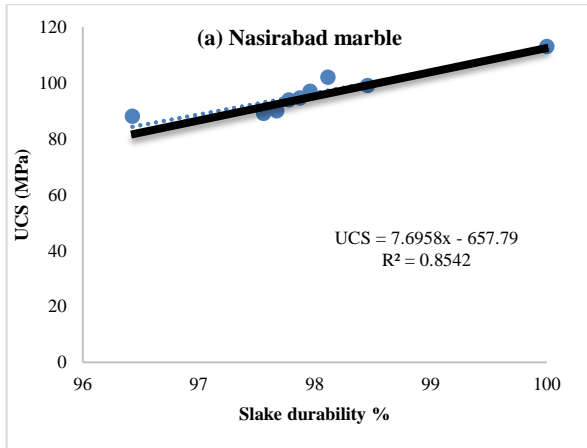


Fig. 5 Effect of slaking cycle on slake durability of (a) Nasirabad marble and (b) Khyber limestone.

Effect of Slake Durability on UCS

The effect of slake durability on UCS of Nasirabad marble and Khyber limestone is shown in Figure 6. Generally, the value of UCS increased with increasing value of slake durability. At 99% slake durability value, the UCS is 112MPa, and a minimum value of 88MPa has been achieved at 96.4% slake durability for marble. The slake durability value showed little effect on UCS of marble.



The correlation of Khyber limestone has a slope of 8.05 with 0.815 R-square value. While for Nasirabad marble, the correlation equation has a slope of 7.69 and an R-square value of 0.854.

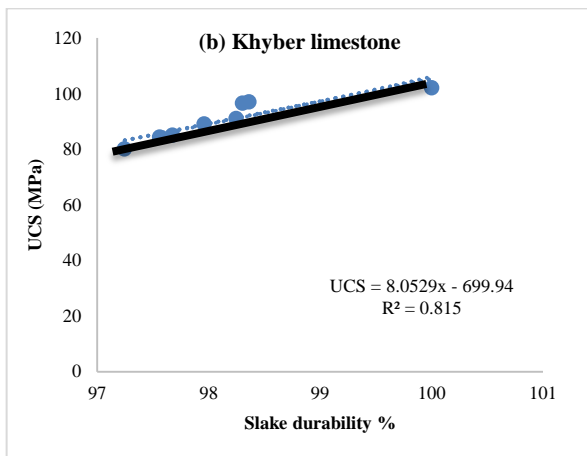


Fig. 6 Effect of slake durability on uniaxial compressive strength (UCS) of (a) Nasirabad marble and (b) Khyber limestone.

Conclusion

The UCS value increased with increasing Schmidt hammer rebound number, slake durability index, and specific gravity. The UCS value decreased with increasing moisture content for limestone and marble. The UCS showed a linear relationship with Schmidt hammer, slake durability index, specific gravity, and moisture content. The slake durability index sharply decreased with increasing slaking cycles. The present study shows that the UCS is rock dependent property. The moisture content in the rock sharply decreased the

value of UCS. The strength of limestone and marble of the study area can now be determined by using the proposed equations directly.

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