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Quantitative Estimation of Abrasion Loss from Strength of Sandstone Rocks of Salt Range, Pakistan

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ABSTRACT

Evaluation of degradation or abrasion loss through Los Angeles abrasion loss is tedious and time consuming due preparation of samples of different grading. Hence there is a need to explore relations through other indirect methods which are simple, fast and more economical such as Schmidt rebound hammer test and Point load strength index test. In this research work, an attempt is made to develop a quantitative relationship for the estimation of Los Angeles abrasion loss through Schmidt hammer hardness and Point load strength. The results of Schmidt rebound hammer test and Point load strength index test, carried out on thirty one Sandstone samples collected from various location of Salt Range Pakistan, were correlated with corresponding values of Los Angeles abrasion test. To evaluate the correlation equations and coefficients of correlations, the data of these tests was statistically analyzed through linear regression analysis. A strong inverse relationship exists between Los Angeles abrasion loss and Point load strength while the inverse relationship between abrasion loss and Schmidt hammer hardness is relatively weaker.

1. Introduction

The strength of various rock units has been determined by several direct and indirect methods by a number of researchers. For strength evaluation and design purpose, the estimation of abrasion loss is essential. In evaluating the engineering properties of rocks, the study of rock behavior, strength and other mechanical properties is very essential. It is very difficult to get specific design parameters due to the anisotropic nature of rock mass and presence of discontinuities which greatly affects the strength of rock mass. Therefore, engineers use empirical correlations among the different rock parameters to estimate the required specific properties of rocks [1].

Correlation of Los Angeles abrasion loss with different engineering properties of rocks including Schmidt hammer strength, Point load strength index, UCS, Unit weight and porosity has been studied by many researchers. Based on the investigation of abrasion characteristics of Igneous rocks, it was revealed that fine grained rocks have low abrasion loss as compared to coarse grained rocks [2]. A strong inverse relationship exists between Los Angeles abrasion loss, Point load strength index, Schmidt hammer hardness and UCS [3-5].

Simple regression equation is practical and reliable enough for estimation of Los Angeles abrasion loss from crushability index, density and porosity of different rock types collected from different parts of Turkey [6]. Based on the study of different rock types including Igneous, Metamorphic and Sedimentary, it was observed that Los Angeles abrasion loss can be easily estimated from Point Load Strength index as compared to Schmidt hammer hardness [7]. By studying the results of UCS and corresponding values of Point load strength index, Schmidt hammer hardness and Los Angeles abrasion loss, a linear relationship was observed between UCS and Los Angeles abrasion values when log-log scale was used [8]. By applying multiple linear regression analysis on carbonate rocks, a useful equation was obtained among Los Angeles abrasion loss, Dry density and UCS [9]. A good relationship was observed between UCS and different types of hardness including Schmidt hammer hardness and abrasion hardness [10]. In this research work, an attempt is made to evaluate the simple methods for the estimation of Los Angeles abrasion loss from Schmidt rebound hammer hardness and Point load strength.

2. Methodology

Thirty one samples of sandstone belonging to five different rock units were collected from various locations of Salt Range Pakistan. These samples were in the form of intact blocks, free from fractures and discontinuities. Samples were taken into laboratory for Schmidt rebound hammer test, Point load strength index test and Los Angeles abrasion test.

For Schmidt rebound hammer testing, standard guidelines of ASTM-D5873 were used [11]. Hammer

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spring was gradually compressed until the impact occurred. From the scale located on the side of hammer, rebound number was calculated. Average of ten readings was taken to calculate the hardness of the rock specimen. Unconfined compressive strength was calculated from the graph against the unit weight of rock specimen and rebound number.

Standard methodology of ASTM-D5731 was used for Point load strength index test [12]. The rock specimen of 30 to 85mm thickness was taken in the form of lump as test specimen and was inserted in the conical platens of machine. Distance D, which is the thickness of the specimen and average width of the lump was measured. The load was applied by gradually increasing until the sample break and failure load was noted.

For Los Angeles abrasion test the methodology was adopted from ASTM-C131 [13]. The test sample was of grading A for which 12 steel balls were used. Total weight of the sample was 5000 ± 10g. Machine was rotated for 500 revolutions at a speed of 30 to 33 revolutions per minute. Material coarser than 1.70mm (No. 12) sieve was determined to the nearest 1g. Difference between the initial weight and the final weight of the test sample (loss) was calculated as a percentage of the original mass of the test sample. This value was reported as the percent loss.

2. Results and Discussion

The mean values of strength estimated from Schmidt rebound hammer test are shown in Table 1. These values range from 53MPa for Khewra Sandstone to 73.3MPa for Kussak Formation. Coefficient of variance has highest value of 12.9% for Khewra Sandstone and lowest value of 6.4% for Kussak Formation. The values for 95% confidence interval were also computed to check the validity of the purposed equations.

Table 1. Test results of Schmidt rebound hammer test performed on 5 rock units.

Rock type	Schmidt Hammer Hardness (MPa)	Standard Deviation	Co-efficient of Variance (%)	95% Confidence Interval
Khewra Sandstone	53.0	6.8	12.9	47.8 to 58.1
Kussak Formation	73.3	4.8	6.4	69.3 to 77.2
Baghanwala Formation	64.8	4.2	6.5	61.3 to 68.2
Tobra Formation	54.8	3.6	6.6	51.8 to 57.7
Dandot Formation	59.0	4.5	7.6	55.3 to 62.6

Table 2 shows the results obtained from Point Load Strength index test. These values range from 32.8MPa for Khewra Sandstone to 136.3 for Kussak Formation. The values of confidence interval are also listed in the table.

Table 2. Test results of Point load strength index test performed on 5 rock units

Rock type	Point Load Strength (MPa)	Standard Deviation	Co-efficient of Variance (%)	95% Confidence Interval
Khewra Sandstone	32.8	7.6	23.3	27.1 to 38.5
Kussak Formation	136.3	10.4	7.6	127.8 to 144.8
Baghanwala Formation	62.8	4.7	7.5	58.9 to 66.6
Tobra Formation	67.6	10.7	15.8	58.9 to 76.3
Dandot Formation	84.8	17.4	20.5	70.5 to 99.0

The mean values of Los Angeles abrasion test carried out on 31 rock samples are listed in Table 3. The loss values ranges from 16% for Kussak Formation to 53% for Khewra Sandstone. Coefficient of variance is the ratio of standard deviation to the mean.

Table 3. Test results of Los Angeles abrasion loss test performed on 5 rock units.

Rock unit	Los Angeles Abrasion loss (%)	Standard Deviation	Co-efficient of Variance (%)	95% Confidence Interval
Khewra Sandstone	53.0	2.6	4.9	50.0 to 55.9
Kussak Formation	16.0	2.2	13.6	14.2 to 22.7
Baghanwala Formation	25.0	2.2	9.0	23.2 to 26.8
Tobra Formation	40.5	1.4	3.4	39.3 to 45.6
Dandot Formation	46.6	3.2	6.8	41.0 to 49.2

To develop a quantitative relationship between strength and abrasion loss, the technique of regression analysis was used. Before applying regression analysis, scatter plots of data were plotted to visualize the test results. By plotting Schmidt hammer hardness and Point load strength against Los Angeles abrasion loss, it was observed that Baghanwala Formation has a different behavior than the normal trend of other rock units as shown in Fig. 1 and Fig. 2 respectively.

Due to this anomalous behavior, Baghanwala Formation is not included in the regression analysis. By plotting Schmidt hammer hardness as independent variable and Los Angeles abrasion loss as response, it was observed

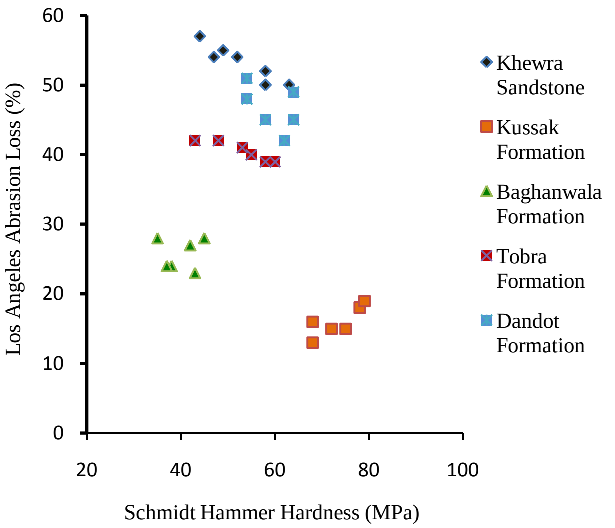

Fig. 1. Scatter plot of Schmidt hammer hardness vs Los Angeles abrasion loss.

that inverse linear relationship exists between strength estimated from Schmidt hammer and abrasion loss (Fig. 3).

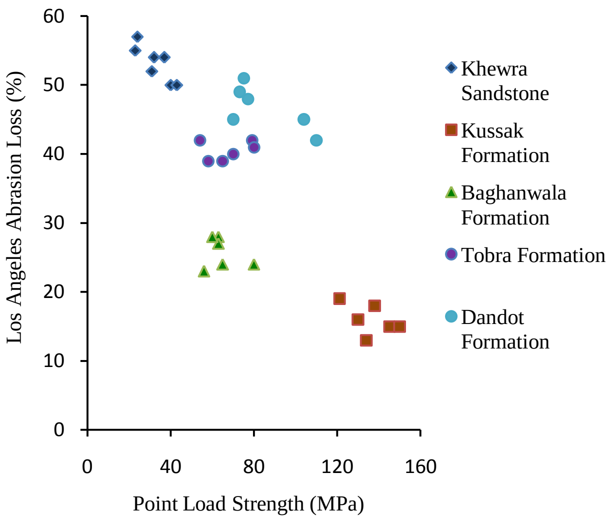

Fig. 2. Scatter plot of Point load strength vs Los Angeles abrasion loss.

The equation of determination of loss from strength, and their correlation coefficient is given as below.

$y = -1.137x + 107.1 \quad R^2 = 0.62$ (1)

Where

y = Los Angeles abrasion loss (%)

x = Strength estimated from Schmidt rebound hammer (MPa)

R^2 = Coefficient of correlation

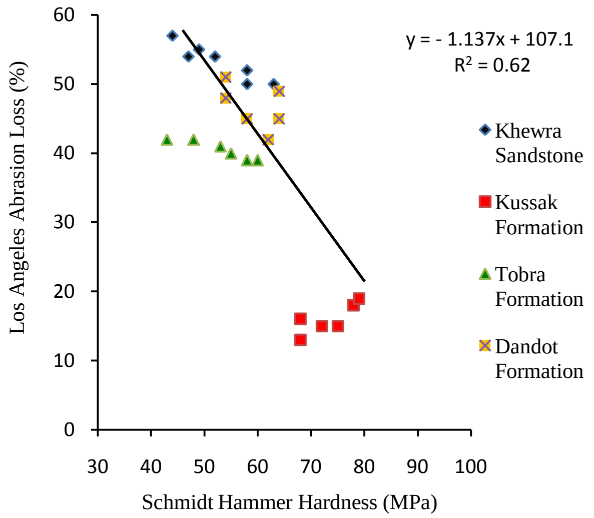

Fig. 3. Relationship between strength and abrasion loss.

Similar inverse linear relationship was observed between Point load strength and abrasion loss (Fig. 4). The equation of determination of abrasion loss from Point load strength and coefficient of correlation is determined as below.

$y = -0.327x + 65.38 R^2 = 0.82$ (2)

Where

y = Los Angeles abrasion loss (%)

x = Point load strength (MPa)

R^2 = Coefficient of correlation

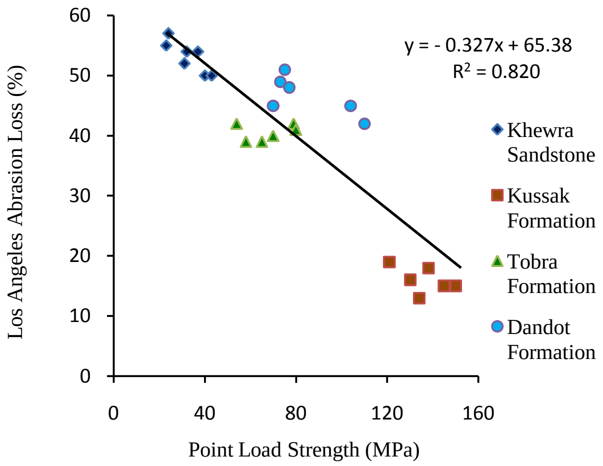

Fig. 4. Relationship between Point load strength and abrasion loss.

The relationship between Point load strength and Los Angeles abrasion loss is relatively stronger than the relationship between strength estimated from Schmidt hammer and abrasion loss due to high value of coefficient.

Table 4. Estimated values of abrasion loss from equation 1 and 2.

Sample No.	x = Schmidt hammer hardness (MPa)	(Eq. 1) y = -1.137x + 107.7 y = Los Angeles abrasion loss(%)	x = Point load strength (MPa)	(Eq. 2) y = -0.327x + 65.38 y = Los Angeles abrasion loss(%)
		Khewra Sandstone		
1	58	39.2	40	52
2	49	49.8	23	58
3	52	46.3	32	55
4	58	39.2	31	55
5	47	52.1	37	53
6	44	55.6	24	58
7	63	33.4	43	51
		Kussak Formation		
1	68	27.5	130	23
2	78	15.8	138	20
3	68	27.5	134	22
4	72	22.9	145	18
5	79	14.7	121	26
6	75	19.4	150	16
		Tobra Formation		
1	43	56.8	79	40
2	48	50.9	54	48
3	53	45.1	80	39
4	55	42.8	70	42
5	58	39.2	58	46
6	60	36.9	65	44
		Dandot Formation		
1	54	43.9	77	40
2	58	39.2	104	31
3	54	43.9	75	41
4	64	32.2	70	42
5	64	32.2	73	42
6	62	34.6	110	29

of correlation. Los Angeles abrasion loss can be easily estimated from Point load strength. Similar observation was made by Kahraman and Fener [7].

To check the validity of derived equations for the estimation of abrasion loss, concept of confidence interval was used. 95% confidence interval was determined for all test results. The values of abrasion loss were estimated by using derived equations (Table 4). It was observed that all the values of abrasion loss estimated from equation 1 (estimation of abrasion loss from Schmidt hammer hardness) does not lies within the confidence interval range. By plotting measured values of abrasion loss from Los Angles abrasion loss test and estimated values of abrasion loss from equation 1, it was observed that most point lies away from the slope line (Fig. 5). This fact as well as low correlation coefficient (0.62) shows the invalidity of this relationship.

On the other hand, all the estimated values of abrasion loss from equation 2 (estimation of abrasion loss from Point load strength) lies within the confidence interval range. By plotting measured values of abrasion loss from Los Angeles abrasion loss test and estimated values of abrasion loss from equation 2, it was observed that all the point lies near the slope line. This fact as well as high correlation coefficient (0.820) shows the strength and validity of this relationship.

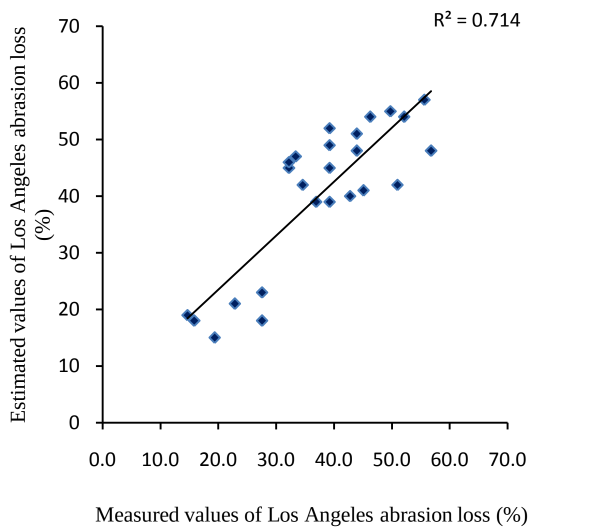

Fig. 5. Measured and estimated values of Los Angeles abrasion loss from equation 1.

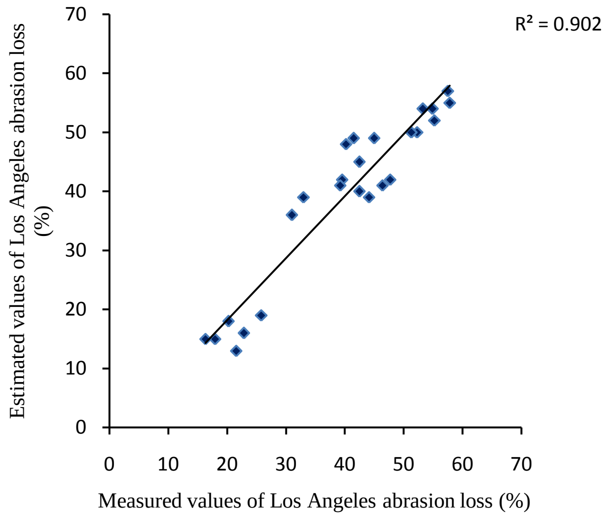

Fig. 6. Measured and estimated values of Los Angeles abrasion loss from equation 2.

3. Conclusions and Recommendations

On the basis of this study, it was concluded that inverse relationship exist between strength and abrasion loss. Strength was calculated from Schmidt rebound hammer test and Point load strength index test while the abrasion loss was calculated from Los Angeles abrasion loss test. Quantitative relationship developed for the estimation of abrasion loss from Point load strength is relatively stronger than the relationship developed from Schmidt hammer hardness. Abrasion loss can be easily estimated from Point load strength.Baghanwala Formation should be studied separately for developments of correlations due to its different behavior keeping in mind its mineralogical composition and depositional environment. Developed correlations depends upon mean values, therefore number of samples should be increased for more valid relationships.

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