Estimating the Abrasion Resistance of Rock Aggregates from the P-wave Velocity

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Abstract

The prediction of Los Angeles (LA) abrasion loss from some indirect tests is useful especially for the preliminary. For this purpose, LA abrasion, P-wave velocity, density and porosity tests were carried out on 35 different rock types such as igneous, metamorphic and sedimentary rocks. The test results were analysed using the method of least squares regression. The LA values were correlated with the P-wave velocity values and no correlation was found between the two parameters for all rocks. The regression analysis was repeated for the rock classes respectively. An acceptable correlation was found only for sedimentary rocks.To check the possibility of obtaining the more significant relations, multiple regression analysis was applied to the data including porosity and density. However, the correlation coefficients of the multiple regression models were not strong. Multiple regression analysis was repeated for the rock classes respectively. Multiple regression models having good correlation coefficients were obtained for the rock classes. Concluding remark is that LA abrasion loss of aggregates can be estimated from the multiple regression models derived for the rock classes.

1. Introduction

The demand of crushed stone aggregates has increased from day to day in the world as a result of increasing expansion of highway and other construction works and decreasing natural aggregate resources. Different types of rocks such as igneous, metamorphic and sedimentary are used as aggregates in a wide variety of applications including portland cement concrete and asphalt production, road/rail base, drainage systems etc. The rocks to be used as an aggregate must have some physical and mechanical properties. Abrasion resistance is one of the important properties of crushed rock aggregates. Los Angeles (LA) abrasion test is a standard method to measure the abrasion resistance of aggregates. Although the method is relatively simple it is time consuming and expensive comparing to the indirect tests, such as ultrasonic test. In addition, at least 5000g sample is necessary for the LA abrasion test. Ultrasonic techniques are widely used in various fields such as mining, geotechnical, civil, and underground engineering, since they are non-destructive and easy to apply. These techniques are usually employed both in site and laboratory to characterize and determine the dynamic properties of rocks. If a strong correlation between LA abrasion loss and ultrasonic velocity are found, ultrasonic test can be used for the prediction of the abrasion resistance of aggregates especially for the preliminary investigations.

Several researchers [1-10] have investigated the relations between the the LA abrasion loss and some rock properties. However, any study on the relation between the LA abrasion loss and P-wave velocity could not be found. In this study, the possibility of estimating the abrasion resistance of aggregates from the P-wave velocity was investigated using the regression analysis.

2. Sampling

A total of 35 rock types were sampled, 9 of which were igneous, 11 of which were metamorphic and 15 of which were sedimentary. Quarries, granite and marble factories, and natural outcrops in Nigde, Kayseri, Konya and Antalya areas of Turkey were visited and rock blocks were collected. An attempt was made to collect rock samples that were large enough to obtain all of the test specimens of a given rock type from the same piece. Each block sample was inspected for macroscopic defects so that it would provide test specimens free from fractures, partings or alteration zones. The location and the name of the rocks are given in *Table 1*.

3. Experimental Studies

3.1. Los Angeles Abrasion Test

ASTM method C 131-66 was used for the LA abrasion test. Test samples were oven-dried at 105-110^{O}C for 24 hr and then cooled to room temperature before they were tested. There are four aggregate size grading to choose from in the ASTM method**.** Grading D was used in the tests. 6 steel spheres were placed in a steel drum along with approximately 5000g aggregate sample and the drum was rotated for 500 revolutions at a rate of 30-33 rev/min. After the revolution was complete, the sample was sieved through the No. 12 sieve (1.7 mm). The amount of material passing the sieve, expressed as a percentage of the original weight, is the LA abrasion loss or percentage loss.

3.2. Ultrasonic Test

NX (54 mm) samples were cored from the block samples in the laboratory. End surfaces of the core samples were cut and polished sufficiently smooth plane to provide good coupling. A good acoustic coupling between the transducer face and the rock surface is necessary for the accuracy of transit time measurement. Ultrasonic gel was used as a coupling agent in this study. Transducers were pressed to either end of the sample and the pulse transit time was recorded. P-wave velocity values were calculated by dividing the length of core to the pulse transit time. In the measurements, the PUNDIT and two transducers (a transmitter and a receiver) having a frequency of 1 MHz were used.

3.3. Density Test

Trimmed core samples were used in the determination of dry density. The specimen volume was calculated from an average of several calliper readings. The dry weight of the specimen was determined by a balance, capable of weighing to an accuracy of 0.01 of the sample weight. The density values were obtained from the ratio of the specimen weight to the specimen volume.

3.3. Porosity test

Porosity values were determined using saturation and calliper techniques. Pore volumes were calculated from dry and saturated weights and sample volumes were obtained from calliper readings. The porosity values were obtained from the ratio of the pore volumes to the specimen volume.

The summarized results of LA abrasion, ultrasonic, density and porosity tests for each rock type are given in *Table 1*.

Table 1. The location and the name of the rocks tested and test results.

Location	Rock type	Rock class	LA abrasion loss (%)	P-wave velocity (km/s)	Porosity (%)	Density (g/cm^3)
Altinhisar/Nigde	Basalt	Igneous	17.2	4.5	5.50	2.58
Tepekoy/Nigde	Andesite	Igneous	18.2	3.8	7.19	2.53
Azatli/Nigde	Andesite	Igneous	18.3	4.9	1.15	2.57
Uckapili/Nigde	Granodiorite	Igneous	29.7	3.0	2.51	2.54
Uckapili/Nigde	Metagabro	Igneous	10.2	6.0	0.65	2.94
Uckapili/Nigde	Granite	Igneous	15.7	4.5	1.15	2.63
Ortakoy/Aksaray	Granite (Anadolu grey)	Igneous	33.7	5.0	0.62	2.55
Kaman/Kirsehir	Granite(Kaman Rosa)	Igneous	40.3	4.6	0.63	2.61
Kaman/Kirsehir	Granite (Kırcicegi)	Igneous	34.7	4.0	0.98	2.47
Gumusler/Nigde	Quartzite	Metamorphic	20.2	5.7	0.85	2.72
Gumusler/Nigde	Marble	Metamorphic	45.5	5.3	0.37	2.69
Uckapili/Nigde	Marble	Metamorphic	40.6	5.7	0.37	2.68
Altindag/Kutahya	Marble	Metamorphic	28.8	4.7	0.06	2.55
Iscehisar/Afyon	Marble	Metamorphic	47.2	5.1	0.13	2.55
Yatagan/Muğla	Marble	Metamorphic	73.2	4.0	0.30	2.57
Gumusler /Nigde	Amfibolsişt	Metamorphic	22.3	5.6	1.90	2.75
Gumusler /Nigde	Gneiss	Metamorphic	40.5	3.0	0.79	2.70
Gumusler /Nigde	Micaschist	Metamorphic	37.7	2.6	1.95	2.49
Gumusler /Nigde	Migmatite	Metamorphic	16.6	6.2	1.33	2.75
Kilavuzkoy/Nigde	Serpentinite	Metamorphic	15.9	5.4	0.91	2.73
Sogutalan/Bursa	Limestone	Sedimentary	33.3	6.1	0.69	2.56
Korkuteli/Antalya	Limestone	Sedimentary	28.9	6.2	0.38	2.57
Basmakcı/Nigde	Limestone	Sedimentary	23.3	5.5	0.18	2.69
Yahyali/Kayseri	Dolomitic limestone	Sedimentary	25.0	6.1	0.31	2.58
Fethiye/Mugla	Limestone	Sedimentary	35.6	6.1	0.18	2.57
Bunyan/Kayseri	Limestone	Sedimentary	24.7	6.0	0.93	2.57
Gokbez/Nigde	Travertine	Sedimentary	21.9	5.2	7.22	2.51
Yıldızeli/Sivas	Travertine	Sedimentary	31.4	5.4	3.12	2.40
Finike/Antalya	Travertine (Limra)	Sedimentary	42.3	4.3	5.93	2.31
Bucak/Burdur	Travertine (Limra)	Sedimentary	75.9	3.7	12.57	2.13
Demre/Antalya	Travertine (Demre stone)	Sedimentary	54.5	5.5	2.15	2.39
Demre/Antalya	Travertine (Limra)	Sedimentary	45.3	4.0	13.27	2.09
Godene/Konya	Travertine	Sedimentary	40.1	5.4	4.08	2.33
Mut/Icel	Travertine	Sedimentary	61.9	4.0	8.74	1.93
Karaman	Travertine	Sedimentary	39.0	5.4	4.04	2.29

4. Evaluation of the results

The test results were analysed using the method of least squares regression. Linear, logarithmic, exponential and power curve fitting approximations were tried and the best approximation equation with highest correlation coefficient was determined. The L A. values were correlated with the P-wave velocity values and no correlation was found between the two parameters for all rocks (*Figure 1*).

To see the correlation degrees for the rock classes, regression analysis were performed for igneous rocks, metamorphic rocks and sedimentary rocks, respectively (*Figures 2-4*). An acceptable correlation was found only for sedimentary rocks.

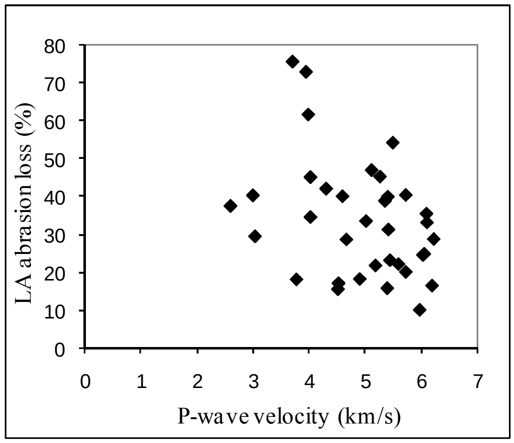

Figure 1. The relation between P-wave velocity and LA abrasion loss.

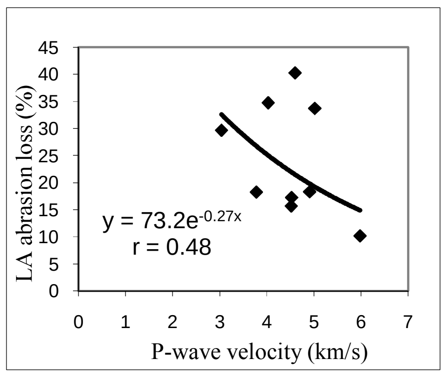

Figure 2. The relation between P-wave velocity and LA abrasion loss for igneous rocks.

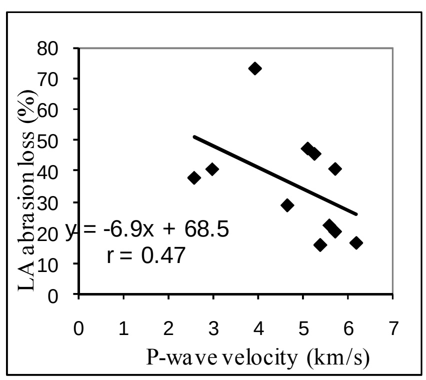

Figure 3. The relation between P-wave velocity and LA abrasion loss for metamorphic rocks.

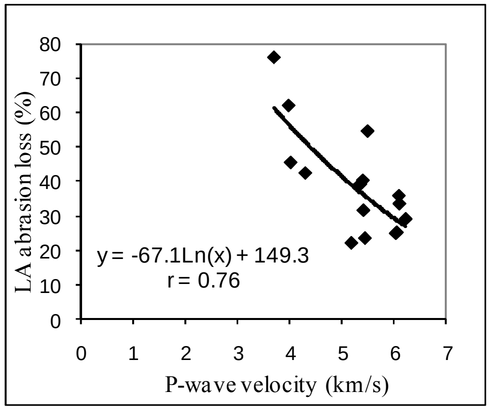

Figure 3. The relation between P-wave velocity and LA abrasion loss for sedimentary rocks.

To check the possibility of obtaining the more significant relations, multiple regression analysis was applied to the data including porosity and density. However, the correlation coefficients of the multiple regression models were not strong. The derived models are given below:

$$LA = 216.8 - 1.6n - 64.2\gamma - 3.3V_p \qquad r = 0.68 \qquad (1)$$

$$LA = 52.7 - 1.1n - 4.4V_p \qquad r = 0.43 \qquad (2)$$

$$LA = 158.9 - 44.4\gamma - 2.5V_p \qquad r = 0.65 \qquad (3)$$

where, LA is the LA abrasion loss (%), n is the porosity (%), γ is the density (g/cm^3) and V_p is the P-wave velocity (km/s).

Multiple regression analysis was repeated for the rock classes respectively. Multiple regression models having good correlation coefficients were obtained for the rock classes. These models are given following:

For igneous rocks, $LA = 157.2 - 2.5n - 44.6\gamma - 2.5V_p$ r = 0.77 (4)

For metamorphic rocks, $LA = 161.8 - 12.4n - 32.5\gamma - 6.2V_p$ r = 0.73 (5)

For sedimentary rocks, $LA = 208.5 - 1.2n - 52.0\gamma - 7.6V_p$ r = 0.82 (6)

As shown above the correlation coefficients of multiple regression models for the rock classes are higher than that of multiple regression models for all rocks.

5. Conclusions

To investigate the predictability of LA) abrasion loss from the P-wave velocity, 35 different rock types such as igneous, metamorphic and sedimentary rocks were tested. The test results were first analysed using the simple regression analysis. Then, including porosity and density multiple regression analysis was performed for all rocks and the rock classes respectively. Multiple regression models for the rock classes have good correlation coefficients. It was concluded that LA abrasion loss of aggregates can be estimated from the derived multiple regression models for the rock classes especially for the preliminary studies.

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