Relationship between Los Angeles Abrasion Value and Mineral Content of Metamorphic Rocks

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Abstract

This research includes study of the relationship between Los Angeles Abrasion Value and the mineral content of rock aggregates narrowed down to the commonly found high grade metamorphic rocks in Sabaragamuwa Province. Los Angeles Abrasion Test and mineral content of each rock sample was determined at the laboratory. Thin section analysis was carried out to determine the mineral content with the help of petrological microscope equipped with a digital camera and AutoCAD software. The regression analysis was carried out to develop a relationship between Los Angeles Abrasion Value with engineering and mineralogical properties such as relative dry density, Quartz content, Feldspar content as well as Mica content. Another important achievement of this study was developing a field guide to assist the personnel at the field. It was completed with the photograph of each rock sample, microscopic view of the sample and their respective engineering and mineralogical properties such as Los Angeles Abrasion Value, dry density, Quartz content, Feldspar content and Mica content.

Keywords: Aggregates, Dry density, Field guide, Mineral content, Thin section analysis

1. Introduction

In Sri Lanka, during the past decade, demand for construction aggregates increased significantly with the rapid development in the road network and other infrastructures. Crushed rock aggregates of granite and granitic gneisses are the major aggregates used in road construction works. Variety of engineering properties such as high strength, abrasion resistance and structural and textural characteristics ensures their continued existence as a construction material.

With the lasting high demand for construction aggregates hundreds of new metal quarries of medium scale were started within Sabaragamuwa Province. Some of the quarries could not achieve expected demand and were shut down due to lack of required quality of its aggregate produced while few others are operating in small scale supplying materials for regional demand resulting financial losses to the owner. Therefore, when selecting an aggregate source, knowledge of the quarry rock's mineral properties can provide an excellent clue as to the suitability of the resulting aggregate. Cordon (1979). It is very beneficial if there is a possible methodology for identifying the aggregate properties by visually observing the rock mineralogical properties at the site itself.

There are four major types of aggregates used in Sri Lankan construction industry. This classification entirely depends on the size of the crusher output and particular usage of the aggregates. None of the physical properties are considered for this classification.

Table 1 - The common types of crushed rock aggregates used in Sri Lankan construction industry

Particle Size (mm)	General Identity
20 - 15 or 22 - 17	¾ (Thunkala Gal)
15 -10 or 17 -12	½ (Bage Gal)
10 – 5 or 12 – 5	Chip Gal
5 – 0	Quarry Dust

Anyhow, local demand for aggregates changes with the colour of rock changes. That means most of the consumers have an idea on the strength of different rock types at an eye glance based on their experience. But still there is no proper methodology to ensure the particular use of aggregates produced in hundreds of rock quarries all over the country, to safeguard the consumer. The successful implementation of such procedure positively depends on the amount of research and experiments carried out on that regard.

Providing of a series of photographs of different rock types and their properties as a field guide to the site engineers would be beneficial to overcome these types of problems. In this paper, it is aimed to develop such a field guide for some basic rock types found in Sabaragamuwa Province restraining to Los Angeles Abrasion Value which can be broaden for the other important tests and rock types.

Authors' major objectives of this research work are;

1. To develop relationship between quartz content and Los Angeles Abrasion Value (LAAV) of rock aggregates.
2. To develop relationship between non quartz mineral content and strength properties of crushed rock aggregates pertained to Los Angeles Abrasion Test
3. To determine the optimum content of minerals which, results higher value of LAAV.
4. To develop field guide for varieties of metamorphic rocks available in the Sabaragamuwa Province

2. Methodology

2.1 Loss Angeles Abrasion Value

1. Rock pieces of some quarry sites over the Sabaragamuwa province were collected and their textural and structural features were recorded.
2. 10 quarry sites were selected having varying content of quartz, feldspar and biotite by observing the collected rock pieces with magnifying lens.
3. Two large rock pieces of total weight 25-30kg was collected into sample bags
4. The collected rock samples were hammered and crushed to prepare sized sample in the range of 10-20 mm.

5. The crushed samples were sieved using 20mm, 12.5mm and 10mm standard meshes, washed to remove dust and oven dried at 105-110^0 C for 2-3 hours until the sample gained a constant weight.
6. 5kg of sample was weighed and mixed in the following size range.

Particle size	Amount
20-12.5mm	2.5kg
12.5-10mm	2.5kg

7. The prepared sample was introduced into the cylinder of the testing machine after cleaning it and 12 standard steel balls were added.
8. The cylinder of the LAAV machine was rotated for 500 revolutions at the specified speed.
9. The rotated sample was discharged from the cylinder completely and sieved with 1.7mm standard sieve.
10. The retained sample was washed and oven dried for 2-3 hours at 105-110^{0}C and weighed.
11. Los Angeles Abrasion Value is calculated with the formula (1).

$$LAAV = \frac{M1-M2}{M1} \times 100\% \text{............(1)}$$

M1 = Original weight introduced into the cylinder
M2 = Weight of particles retained on 1.7mm sieve

12. Three samples were tested from each rock sample and the average value was taken as the LAAV of the sample.

2.2 Dry Density

1. Three small rock pieces were dried in the oven for 2-3 hours at 105-110^{0}C.
2. Dry weight of the sample was measured using the electronic balance.
3. The buoyancy measuring apparatus was set over the electronic balance and the balance was set to zero.
4. The rock piece was submerged on buoyancy apparatus and the reading on the balance was taken.
5. Dry density was calculated using the formula (2).

$$Dry\ density\ = \frac{m1}{(m1-m2)} \times \rho_w \text{.....(2)}$$

m1 = dry weight of the sample
m2 = Reading of the balance after submerging the rock piece.

6. Three small rock pieces were tested for dry density and the average value was taken as the dry density of rock sample.

2.3 Thin Section Analysis

1. Thin section of each mineral specimen was observed under polarizing microscope and photograph was taken with the camera attached.
2. Without changing the position of view all mineral grains in that particular view was identified using polarized and non-polarized microscope and rotating the stage of the microscope.
3. The photographs of each view were uploaded to AutoCAD software and mineral grains were drawn into separate layers.
4. The area percentage occupied by each mineral is calculated and assumed represents the volume percentage occupied by each mineral.
5. Three views from one thin section were analyzed in same procedure and average content of each mineral was determined.

2.4 Results

Summary of laboratory test results are given in Table 2.

Table 2 - Summary of Test Results

Sample ID	Specific Dry Density	LAAV %	% Quartz Content	% Feldspar Content	% Mica Content
KE/S1	2.63	47.55	67.7	29.2	2.8
KE/S2	2.78	46.47	68.8	11.0	19.0
KE/S3	2.82	41.6	36.0	50.7	11.9
KE/S4	2.71	50.94	75.4	20.1	4.5
RT/S5	2.74	34.20	99.0	0.5	0.5
KE/S6	2.4	Omitted due to low relative density			
KE/S7	2.73	48.59	45.8	47.8	6.4
KE/S8	2.92	58.13	63.2	2.3	34.5
KE/S9	2.74	42	41.5	40.9	16.6
RT/S10	2.76	55	11.0	76.3	11.9

3. Discussion

Our aim of this research study was to examine and develop the relationship between Quartz Content and LAAV of rock aggregates. We also analyzed the other common rock forming minerals such as feldspar and mica to look for any relation to LAAV. While carrying out practical work tried as much as possible to keep the other influencing factors constant or negligible [2].

3.1 Quartz Content vs. LAAV

Figure 1 shows the first, second and third order regression lines fit for the plotted data of % LAAV against the % of quartz content in rock samples.

The best relationship observed by regression analysis of quartz content and LAAV is the third order polynomial relationship shown in Figure 1. The coefficient of determination or R^2 for this relationship is 0.7952 which says that 79.92% of analyzed data fits the proposed regression line. This relationship need to be improved by carrying more laboratory tastings of different samples.

By simply observing the data points it is visible there is a data gap in between10 - 30% and 80 – 90% of quartz content. If more data is fed in between these ranges would definitely improve the relationship.

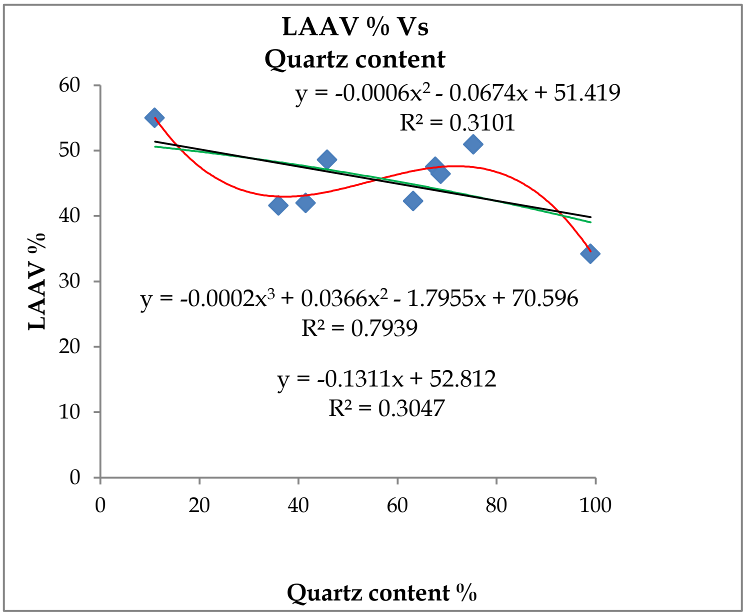

Figure 1 - LAAV Vs. Quartz content

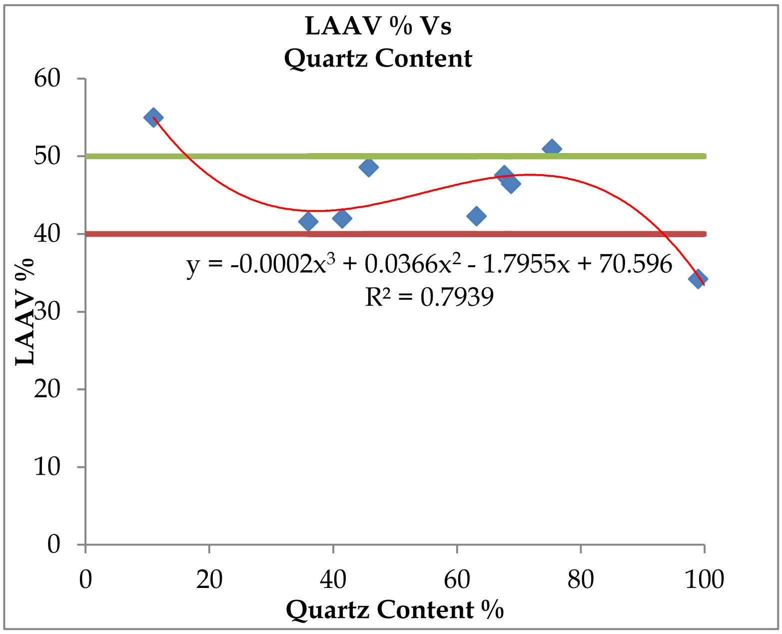

Figure 2 - Optimum Mineral Content

The observed data gap is basically due to poor sample selection. If test samples were selected based on thin section analysis data a good representative sample set would be obtained. But due to extreme difficulties in preparing thin sections the test samples were selected based on visual observation of the sample.
Most of the data falls in between 50 and 40 in the graph. That means more rock samples have their LAAV value in between 50—40%.

According to ICTAD Sri Lanka the LAAV of aggregate suitable for wearing course should be less than 40% while for the base course is less than 50%. The regression line lies almost over the 40% line of LAAV. Above 95% of quarts should be presents to have LAAV lower than 40%according to the regression analysis. It leaves bit confusion and need further clarification with more samples tested at the laboratory.

3.2 Feldspar content vs. LAAV

Developing a relationship between feldspar content and LAAV is unsuccessful because presence of orthoclase feldspar causes for higher strength while plagioclase feldspar reduces the strength of the sample.

3.3 Mica content vs. LAAV

The same relationships are studied for mica content and LAAV as well. When mica is scattered over the sample as pockets the strength reduces. If mica is dispersed with quartz the sample has higher strength.

3.4 Relative Dry Density vs. LAAV

Dry density is a physical property influenced by the specific gravity of the composition minerals and the degree of compaction of the minerals. The following petrographic factors have been revealed as the most important ones for LAAV of rock aggregates: the size of crystals, the form, arrangement and dimensions ratio of crystals and the presence of micro fractures in parent rock. Thin sections are to be carefully analyzed with polarizing microscope for remarkable variations in above factors. Restraining to objective of this study authors only concerned the relationship between major rock forming minerals; quartz, feldspar and mica. But the content of some unsound minerals in parent rock may also have influence on LAAV of rock aggregates which need further studies.

The microscopic view was mineral vise separated into different layers manually and the area percentage of each layer objects was calculated using AutoCAD software and assumed to be represents the actual volume percentage occupied by the minerals.

The petrographic analysis of thin sections for determining mineral content is wholly personnel dependent. Colour and colour intensity changes with the thickness of the mineral section where hindering of mineral grains results. The standard thickness of a section should be 2-3 microns.

3.5 Field Guide

Authors have developed a field guide for aggregates with this study which may be useful to the engineers and other technical persons to quickly check the suitability of aggregates used at construction sites. This field guide can be further developed by including other important engineering properties related to the aggregates such as Aggregate Impact Value, Aggregate crushing value, 10% fines value and polished stone value.

This field guide can be used for following purposes at field works.

- To study the possibility of predicting LAAV of rock aggregates by visual comparison with the field guide.
- To study possibility of comparing samples of aggregate from new sources with samples of aggregate from one or more sources, for which test data or performance records are available.

4. Conclusion

1. Los Angeles Abrasion value of most of the rock varieties found in Sabaragamuwa province is in between 40-50%.
2. The regression line fit for the relationship between Los Angeles Abrasion Value and Quartz Content is a third order polynomial.
3. The best fit line for the test data is
4. $y = -0.0002x^3 + 0.0366x^2 - 1.7955x + 70.596$ with coefficient of determination equals 0.7939.
5. A reasonable relationship was not found on feldspar and mica content with LAAV.
6. A small field guide was developed with which the LAAV of basic rock types in Sabaragamuwa province could be predicted.

5. Recommendation

1. The observed relationship between quartz content and LAAV needs to be further developed and proved with more laboratory testing of samples.
2. The field guide for aggregates found in Sabaragamuwa Province need to be further developed with other important aggregate properties such as aggregate impact value, aggregate crushing value, 10% fines value and polished stone value.

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References

[1] Frank Dawson Adams, Canadian Journal of Research, 1929, 1(5): 425-465, 10.1139/cjr29-025

[2] Kahraman S and Toraman O Y. (200, April 2). Predicting Los Angeles abrasion loss of rock aggregates from crushability index.Bull. Mater.Sci, pp. 173-177.

[3] Michael A. Nwachukwu1 and Maureen I. Nwachukwu.(2011). Petrographic analysis for naming and classifying an igneous intrusive rock in the Lower Benue Trough.Journal of Geology and Mining Research Vol. 3(3), 63-72.

[4] Petrographic Image Analysis ActaGeodyn.Geomater., Vol. 7, No. 4 (160), 431–443, 2010(1989).

[5] Ranatunge N.B.M., Muthurathna S.S.K. and Kodippili D.P.A. (n.d.).A review of the quality of crushed rock aggregate based on NBRO test. Building Materials Research and Testing Division, National Building Research Organisation.

[6] ŠárkaŠACHLOVÁ ,Vladimír SCHENK and Zdeňka SCHENKOVÁ (2010). Microstructure of selected metamorphic rock types– Application of Petrographic Image Analysis, ActaGeodyn.Geomater., Vol. 7, No. 4 (160), 431–443 (2010).

[7] Satndard Specification for Construction and Maintenance of Roads ad Bridges. Institite for Construction Training and Development, Sri Lanka.

[8] TayebehKeikha, Hamed A. Keykha. (2013). Correlation between Mineralogical Characteristics and Engineering Properties of Granitic Rocks.Vol. 18 [2013], Bund. S.

[9] U De S Jayawardena, DMS Dissanayake, Journal of the National Science Foundation of Sri Lanka, Vol 36, No 3 (2008)