Selection of High-Quality Aggregates for High-end Civil Engineering Projects such as Airport Runways

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Abstract

In civil engineering, aggregates normally comprise over 70% by volume in both concrete and asphalt mixes, so that the properties of aggregates mostly represent the overall properties of the mixture. Among these properties, mechanical properties such as toughness and abrasion resistance have a greater influence in construction-related projects since such properties directly affects for its durability. Therefore, it is important to assess the suitability of aggregates prior starting the construction, which can be quantitatively measured through laboratory testing. When it comes to the construction industry in Sri Lanka, finding a suitable aggregate source for high-end Civil Engineering projects have been quite difficult, due to the lack of research and interpretation of data.

In this study, all the IML/A grade quarries which are located within the Kalutara District has considered. To assess the suitability, Los Angeles Abrasion Value (LAAV) test and Aggregate Impact Value (AIV) were performed on the Aggregate-Base-Course (ABC) obtained from each. With the comparison performed on the results with respect to the specifications obtained from several high-end civil engineering projects, it was concluded that there are a limited number of quarries available in Kalutara District, which can be used for high-end civil engineering projects.

Keywords: AIV, Abrasion resistance, Durability, LAAV, Mechanical properties, Toughness

1. Introduction

In civil engineering, the term 'rocks' can be defined as a 'is a hard, consolidated and load bearing material that cannot be excavated by manual methods. Based on the factors such as origin and mineralogy, rocks can be classified as Igneous, Metamorphic and Sedimentary rocks [1]. Due to these differences in rock types, they yield different strength characteristics, which has to be considered during the material selection process in civil engineering projects. Moreover, size of the construction materials is also a major concern, and current production techniques produce such materials in a broad range, which is generally known as 'Aggregates'. This term can be further defined as 'a collection of hard, granular, materials, which are suitable for use either on their own or with the addition of cement, lime, or a bituminous binder in construction' [2]. In civil engineering, aggregates are mainly used in the construction projects such as concrete, mortar, road stone, asphalt, railway ballast, drainage courses and bulk fill [3].

When utilizing aggregates for the civil engineering purposes the suitability of the aggregates has to be measured and identified, prior starting the construction. This suitability is measured through the properties of aggregates, which can be either Physical, Mechanical, Chemical or Thermal [4]. These properties can be measured both qualitatively and quantitatively, but quantitative measurements are much considered, due to its applicability in theoretical instances.

When it comes to high-end construction projects such as highways and runways, durability, toughness, and abrasion resistance of aggregates are the three most considered mechanical properties [5].

To measure the properties of aggregates quantitatively, multiple tests can be performed on a laboratory scale. When conducting these tests, a global recognition for the test values is produced by developing several test standards such as ASTM, BS, AASHTO etc. Further, since these tests are conducted in a laboratory scale, it is necessary to obtain a general sample from the aggregate lot, which represents the properties of the whole sample. In order to do that, proper sampling techniques have also to be applied during the sampling process. In regarding the above-mentioned mechanical properties, Los Angeles Abrasion Value (LAAV) test, Aggregate Impact Value (AIV) test, Aggregate Crushing Value (ACV) test, and Micro-Deval test can be performed to obtain quantitative measurements of such properties [6].

Sri Lanka, as a developing country, has a higher demand for the aggregates as a construction material in civil engineering projects [7]. Aggregates required for the constructions in Sri Lanka has been fulfilled by the open-cast mining of hard crystalline rocks, where primary and secondary crushers are used to produce aggregates for a required size of particles. Considering the geology of Sri Lanka, most of the rocks that is used for construction purposes belongs as Charnockite or Charnockitic gneiss [8].

However, when it comes to the current situation in Sri Lanka, finding of high-quality aggregates for a high-end civil engineering projects has become a difficult due to lack of research and interpretation of data in this field. Rather than choosing a material directly with an aid of a database, engineers have to perform laboratory tests for a large number of aggregate samples, to assess the suitability of high-quality aggregates. Also, since multiple types of rocks can be found in a single aggregate quarry, the numbers of tests have to be performed by the engineers gets doubled within a single quarry, and it makes more difficult to obtain high-quality aggregates directly from the quarry sites. Since it should be done prior starting the construction, it directly affects the project's timeline since the laboratory tests costs a considerable amount of time and money allocated for the entire project.

Therefore, by conducting this study, it helps to fill the information gap on selection of suitable aggregate type for each high-end civil engineering construction. So as for the aim of this study, it can be suggested as to identify suitable sources of aggregates for the high-end civil engineering projects from the A-Grade quarries from Kalutara District.

2. Methodology

2.1 Study Area

As for the study area for this experiment, Kalutara district was selected, which is located at the Western Province of Sri Lanka. This area was primarily selected based on the active supply of aggregates from the quarries, for the currently ongoing high-end Civil Engineering projects in Sri Lanka (i.e.: Ruwanpura Expressway, Airport Runway project, etc.). (Figure 1)

Moreover, to comply with the primary requirements (i.e.: quantity) of the high-end Civil engineering projects, IML/A grade quarries were selected within the study area. (Figure 2)

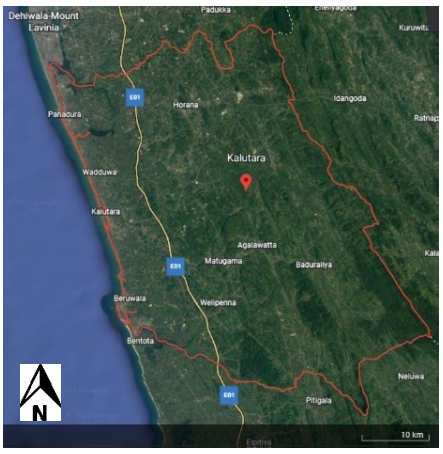

Figure 1: Study area - Kalutara District

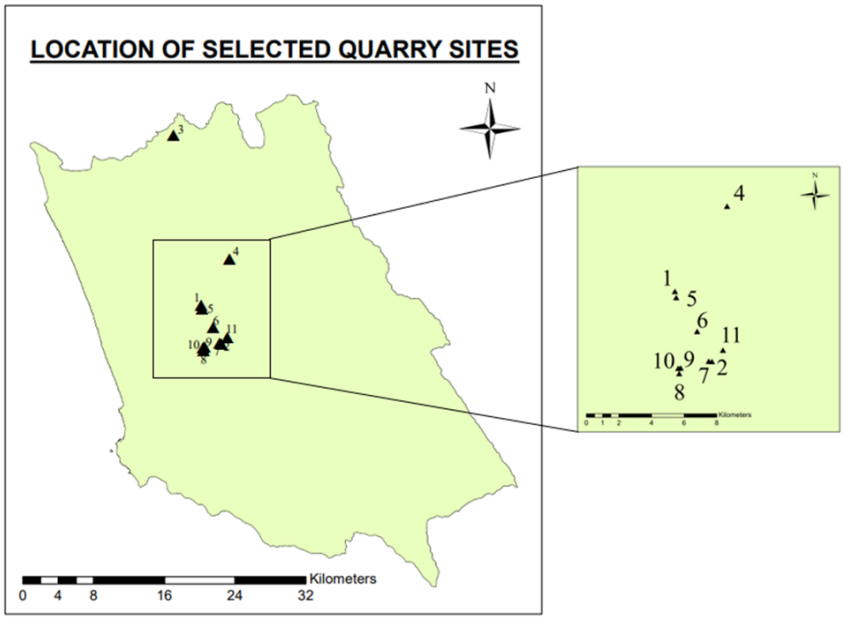

Figure 2: Selected quarry sites

2.2 Sample Collection

According to the prerequisites of the study, a total number of 11 metal quarries were selected for the study. From these quarries, sample collection was done by two methods. For the quarries that the aggregate is currently producing, samples were obtained from middle of a well-mixed stockpile. In several instances, several samples were obtained from multiple stockpiles in a single quarry site, to represent the current rock faces that are utilizing for the constructions.

For the quarries that the samples cannot be obtained, artificial samples were made by mixing several other samples in volumetric proportions. the composition of an artificial aggregate can be shown as below.

- Quarry dust = 20 – 40%
- Chip = 15%
- ¾″ aggregate = 20%
- 1 ½″ aggregate = rest

Furthermore, specification details of aggregates required for high-end civil engineering projects are also obtained.

2.3 Sample Analysis

For this experiment, Los Angeles Abrasion Value (LAAV) test and Aggregate Impact Value (AIV) test were selected to assess the mechanical properties. Los Angeles Abrasion test was carried out according to the ASTM C131 standard, whereas Aggregate Impact Value (AIV) test was carried under BS 812-112:1990 standard.

3. Results

3.1 Results from the sample testing

Table 1 shows the results obtained from the testing of aggregates from the Los Angeles Abrasion Value (LAAV) test and Aggregate Impact Value (AIV) test.

Table 1: LAAV and AIV test results of the samples

ID	LAAV (%)	AIV (%)
1	29.5	18.5
2	32.4	22.48
3	40.5	27.5
4	33.2	20
5	38	25.6
	37.1	17.3
6	43	13.7
	46	11.96
7	31.55	19.23
8	27.04	19.58
9	29.6	20.45
10	36.84	22.7
11	33.9	21.0

3.2 Specifications for high-end Civil Engineering projects

Moreover, aggregate specifications required for the high-end civil engineering projects are also obtained. The purpose these specifications are to act as a benchmark for the test results, so that the quarry sites that are suitable for supplying aggregates can be identified. Since the study is based mainly airport runways, the specification details of Remote Apron, Taxiway and Runner way Balance work Development Project in the BIA Development Project is stated in Table 2.

Table 2: Aggregate Specifications required for an airport runway project

Test	Specification
Aggregate Impact Value (AIV), unsoaked	< 30 %
Los Angeles Abrasion Value (LAAV)	< 30 %
Bulk Density (Unit Weight) and Voids in Aggregates	As specified
Specific Gravity (Bulk specific gravity in oven dry condition, Bulk specific gravity in SSD, Apparent Specific gravity) and Absorption	As specified
Determination of Ten Percent Fines Value (TFV), unsoaked	> 100 kN
Soundness of Coarse Aggregates – Na2SO4	< 5 %
Gradation	As per given
Flatness Test for Coarse Aggregate (For Asphalt Pavement)	

Moreover, another list of specifications required for aggregates for a general highway construction was obtained, as shown in Table 3. These data on aggregate specifications were obtained from multiple construction and quarry sites, during the field visits.

4. Discussion

According to the LAAV and AIV test results displayed on Table 1, LAAV for all the samples ranges between 27.04 – 46.0%, and AIV for all the samples ranges between 11.96 – 27%. Prior conducting these tests, previous records of test results were able to gather from most of the quarries, so that those values can be kept as a reference value, to ensure that the results that are obtained through the testing process has an acceptable accuracy. When considering the aggregate specifications requested for both high-end Civil Engineering projects, both projects require LAAV and AIV less than 30%, which makes only three quarries are eligible to supply aggregates for such projects as construction materials. However, this also means that that the aggregates from these quarries can be used for other purposes, other than high-end Civil Engineering projects. Moreover, since all the aggregates considered in this study is Aggregate-Base-Couse (ABC), and the specifications of the crusher plants (screen sizes, crushing mechanism, etc.) are all quite similar to each other, physical properties such as Bulk Density and Gradation, etc. may not exhibit considerable differences from each other, which eliminates the purpose of performing such tests repetitively for all samples.

During the testing procedure of the aggregates, adequate samples were taken from each quarry to perform the correct amount of testing, as specified by the relevant test standard. However, based on the size of the sample, tests were able to perform for additional samples, so that more accurate value can be obtained as the average results. Therefore, when displaying the results, average value of LAAV and AIV obtained from each quarry are displayed on Table 1. Also, when collecting samples from quarries, there were multiple stockpiles in which the properties of aggregates have a significant difference, thus resulting different results in testing procedure. In

Table 3: Reference table for the evaluation of physical properties

No	Test	Concrete work	Unbound Base coarse aggregates	Bound Base Course Aggregate, bitumen base and surfacing & asphalt concrete	Cover aggregates (seal coat treatment)	Required quality of Quarry material
1	Aggregate impact value (AIV)	<45 * <30**	<30	<30		<30
2	Los Angeles Abrasion Value (LAAV)	<30		<40	<40	<40
3	Ten percent finest Value	>110KN		>110KN	>110KN	
4	Water absorption			<2%		<2%
5	Aggregate Crushing Value	<35%	<35%		<35%	
6	Loss on sodium Sulphate soundness test			<12%	<12%	<12%

such instances, samples from both stockpiles were obtained, and labelling was done accordingly to distinguish the samples in later use.

Since this study is based on the evaluation of physical and mechanical properties of aggregates, the quality of the study strongly depends on the number of laboratory tests that are conducted which is relevant for the construction. For instance, considering the aggregate specification sheets provided by the high-end Civil Engineering projects, more laboratory testing such as Aggregate Crushing Value (ACV), Ten Percent Fines Value (TFV) test, and Soundness test on Coarse aggregates can be recommended to perform, so that the final outcome of the study will be more accurate and correspond more with the interests of the people in the industry.

5. Conclusion

In this study, the suitability of aggregates was examined for the high-end Civil engineering projects such as airport runways. It was assessed through the mechanical properties of aggregates, especially in the aspects of toughness and abrasion resistance. Los Angeles Abrasion Value (LAAV) test and Aggregate Impact Value (AIV) test is carried out to assess the above-mentioned mechanical properties of aggregates.

As for the study area, all IML/A grade quarries located at Kalutara District was selected, and within that area, 11 quarry sites were selected for the study.

Based on the results obtained from the tests and specifications obtained from the high-end projects, only three quarry sites (Quarry no. 1, 8 and 9) were selected as most suitable to supply high-end civil engineering projects. Based on the details available at each quarry site, these quarries also have sufficient rock-resources to supply aggregates, even for a large-scale project. However, according to the specification sheets, aggregates from several other quarries can also be utilized for the minor construction works.

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