POLISHED STONE VALUE OF AGGREGATES AND ITS RELATIONSHIP TO MINERALOGY AND GRAIN SIZE

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Abstract : Safe and durable roads are the main aim of highway engineers and are directly related to the road surface especially where skidding is of much concern. The use of geological material represents a large proportion especially in construction of highways which is focused on the use of rock aggregates in the pavement structure. The skidding resistance is very much related to the types of aggregates used in the pavement material, therefore, thorough understanding and basic knowledge to ensure materials selection and used for pavement construction is correctly specified and gives optimal results is of high importance. The study focused on the various types of texture and mineralogy of aggregates from different quarries in the Klang Valley which shows variation on the skid resistance as measured using the Polished Stone Value (PSV) test in the laboratory. Measuring the polishing action of vehicle tyre under conditions similar to those occurring on the surface of road is vital to determine principally the inherent qualities of the aggregate which is one of the main ingredients of pavement. This has lead to effort into identifying, ranking and locating quality aggregates most suitable for road construction which varies from high specification aggregate to aggregates which possess the minimum requirement. The study on the petrography in relation to the PSV of the aggregate is focused. Findings show there is variability in the PSV with different quartz and material matrix of the aggregate. A positive relationship is noticeable from petrography test showing percentage of quartz content in relation to PSV.

Keywords: Aggregate, Texture, Mineralogy, Polished Stone Value (PSV), Skid resistance

INTRODUCTION

Aggregate is the granular material used in asphalt concrete mixtures which make up 90% to 95% of the mixture weight and between 80 and 85 percent of the volume of the mixture. The quality and physical properties of the aggregates are critical to the pavement performance because the aggregates are primarily responsible for the load supporting capacity of the asphalt mixtures which may lead to serviceability problem due to poor performance of aggregate. Gradation of the aggregate is one of the factors that must be carefully considered in the design of asphalt paving mixtures, especially for heavy duty highways. Increasing demand for better road surface to maintain adequate resistance to skidding has led to considerable effort into locating sources of aggregate capable of meeting specification requirement. Quantifiable data with standardized method to assess the performance of aggregate based on rock type was first provided by Lovegrove et al.. In this study, four different bulk samples of granites were collected from Rawang, Puchong, Cheras and Kuala Selangor in the Klang Valley (Figure 1).

A minimum polished stone value was recommended by the Department of Transport specification for Road and Bridge Works (1992) for aggregates to be used in flexible road surfacing depending on various categories of roads. Roads which are heavily trafficked and likely to have skidding accidents should have a PSV of 65. For a normal trafficked road the minimum PSV is 55. Travers Morgan (Thompson et al., 1993) [3] reported that aggregate considered as High Specification Aggregate (HSA) should possess a minimum requirement as shown in Table 1.

Table 1: Minimum Requirement for High Specification Aggregate

Property	Limiting Value
Polished Stone Value (PSV)	≤58
Aggregate Abrasion Value (AAV)	≤16
Aggregate Impact Value (AIV)	≤30
Ten Percent Fines (TFV)	≥140 kN

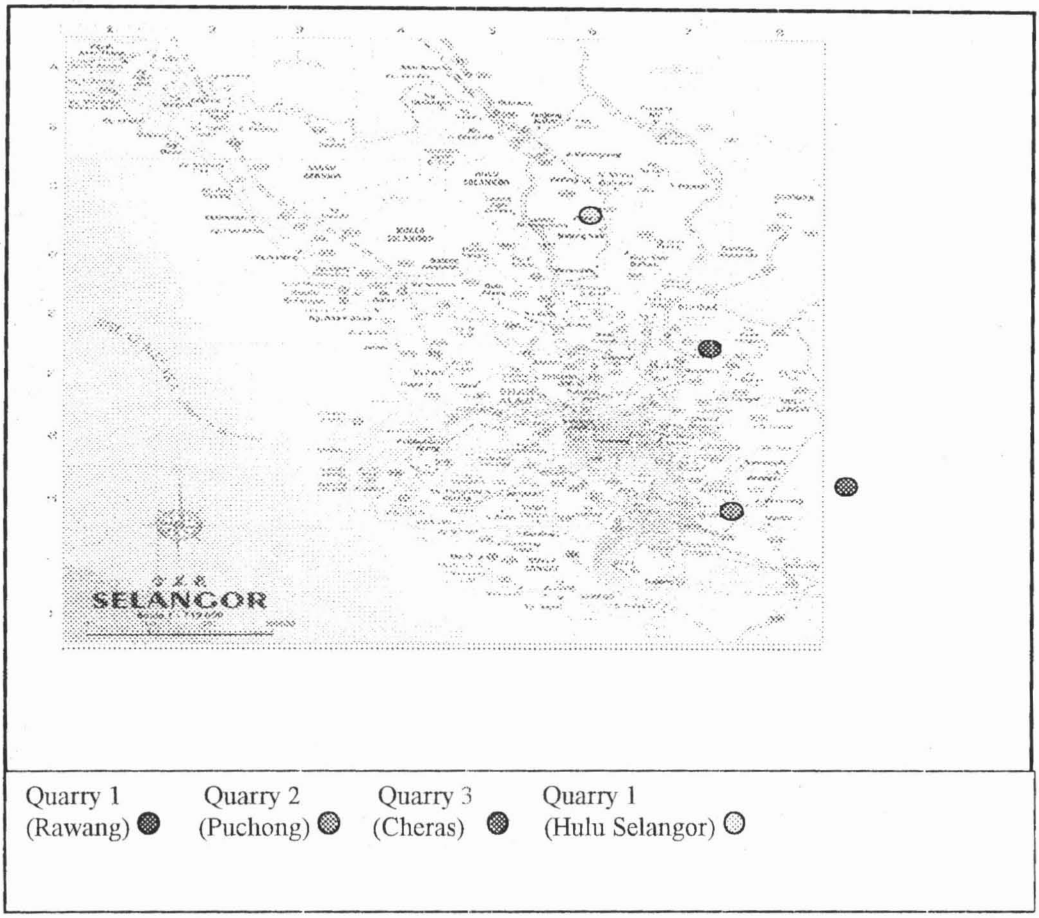

Figure 1: Location of Granite Quarry

MATERIALS AND METHODS

Aggregates vary from rock types and not all aggregates make good road stone. Therefore it is very important to evaluate and assess how an aggregate performs by testing each aggregate source so that the properties conform to the requirements as road aggregates. However, the mineralogy content and grain size of the aggregates are important because it is also a contributing factor towards good performance of the aggregates. For granite aggregates, quartz is the main mineral present in the rock and has a hardness rating scale of 7, which is the highest among the other minerals present. Table 2 highlights the general classification and mineralogy of granite rock in this study.

Table 2: General Classification, Chemical and Mineralogical of Granite

Rock Type	Granite
Typical Chemical	SiO_2; Al_2O_3; Fe_2O_3; FeO; MgO; CaO; Na_2O; K_2O; H_2O; CO_2
Average % Mineralogical Composition	Quartz; Orthoclase; Plagioclase; Biotite; Muscovite;
Compressive Strength	Approximately 36,000 kPa – 380,000 kPa
Tensile Strength	Approximately 3000 kPa – 16,000 kPa
Acidic Content based on SiO_2 content	Acidic rock (SiO_2- 68.3%)

Research by UK Road Research Laboratory showed there is a significant relationship between polishing of aggregate used in road surface and skid resistance. Factors affecting skid resistance are numerous and the concepts are based on the fact that pavement skid resistance is attributed mainly to the texture of the aggregates (A.G. Kokkalis et al., 2002) [1]. This friction is dependent on the microscopic and macroscopic roughness of the pavement surface, the polish-wear characteristics of the aggregates and the ability of the surface to drain (Beaton, 1976). In this study, a preliminary assessment on the relationship between skid resistance to quartz mineral and matrix material is carried out.

The first phase of this study examined the physical properties of the aggregates from these quarries to assess their suitability and that all aggregates conform to the standards for use as materials in road construction. Next, the polished stone value (PSV) of the samples of granite aggregates is subjected to a polishing machine using British Accelerated Wear and Polishing Device (BAWPD). The state of polish reached by each sample is then measured by a friction test and is expressed as a laboratory-determined PSV in accordance to BS 812 British Standards Institution 1989 [2]. Figures 2 and 3 showed a schematic diagram of the Accelerated Polishing Machine and Friction Tester apparatus used for the test.

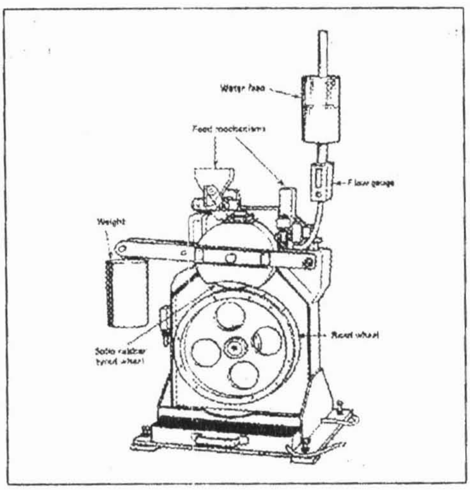

Figure 2: Accelerated Polishing Machine

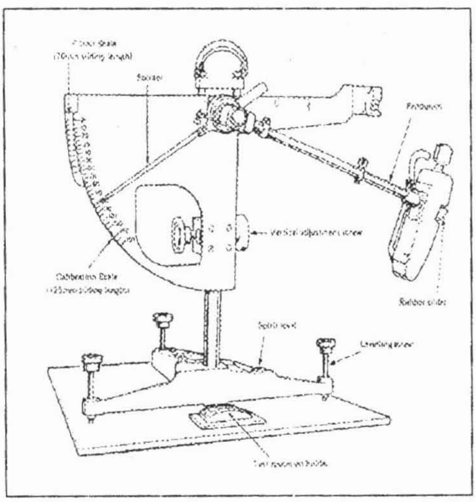

Figure 3: Friction Tester

A road stone specimen was first prepared using a specially designated mould with dimensions of 90.6mm x 44.5mm x 12.5mm (Figure 4). Aggregates passing through 10mm sieve size and retained on 14mm is used to make up the specimens. The aggregates are carefully selected and must be clean and free from dust. The flattest surfaces lying on the bottom of the mould which covers an area of 90.6mm x 44.5mm. Fine sand passing through 212 microns aperture is then filled up to three quarter of the depth of the mould. Finally, a hardener and resin is mixed together and filled into the mould. A metal cover is then clamped to prevent distortion during setting and hardening process which is approximately 30 minutes. The specimens are then clamp around the periphery of the road wheel of the polishing machine in Figure 2. A friction test is then performed using the friction tester to get the polished stone value of the aggregates (Figure 3).

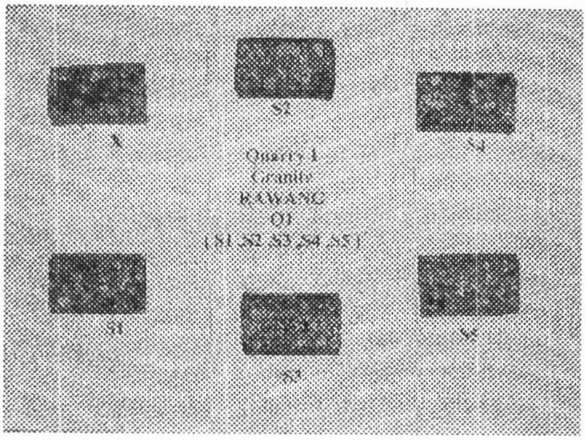

Figure 4: Road stone Specimen and Mould

RESULTS AND DISCUSSIONS

Results of various aggregate physical properties from all four quarries are tabulated in Table 3. Aggregates from all four sources are satisfactory and suitable for use as road aggregates which are within the limiting values. The aggregate property test is important because aggregates are the main ingredients in bituminous mix. The aggregate must withstand abrasion which can be determined from Los Angeles Abrasion test, sudden shock impact from Aggregate Impact Value test and also crushing under gradually applied compressive load from Aggregate Crushing Value test.

Table 3: Aggregate Properties of Granite

Quarry Source	Rawang (Q1)	Puchong (Q2)	Cheras (Q3)	Hulu Selangor (Q4)	Standards	Limiting Value (Thomson et al., 1993)
Los Angeles Abrasion (LA)	20.56%	18.79%	16.96%	14.38%	ASTM C131	<45%
Aggregate Impact Value (AIV)	14.08%	10.92%	11.93%	9.49%	BS 812 Part.3	<30
Aggregate Crushing Value (ACV)	15.7%	17.01%	16.53%	12.55%	BS 812 Part.3	<35
Flakiness Index	15.53	15.03	16.43	14.87	BS 812	<35

Relationship between PSV and Petrography of Aggregates

Aggregate fragmentation and wear depend on the toughness and hardness of the aggregate minerals and the aggregate itself. Polishing depends on the difference in hardness of the different minerals present in the aggregate (Tremblay et al., 1995). This petrography test result shows percentage quartz, percentage matrix and grain size for limited data set of 20 samples of granites from 4 quarries. From the analysis, a relationship between grain size, material matrix and quartz against the skidding resistance of the granite samples can be determined. The samples were taken at random from different spots at each location with aggregates ranging from 50 mm to 70 mm for petrography analysis and 20mm to 10 mm for testing of PSV of the aggregates. Thin sections of every granite sample from different quarries were prepared and examined under the electron microscope with 33X magnification. A summary of the petrography description of the aggregates and Polished Stone Value (PSV) is tabulated in Table 4.

Granite aggregates from all quarries are of medium grain size except for aggregates from Hulu Selangor which are mostly of coarse grains. Results analyzed from the petrography and PSV of the aggregates revealed that coarse grain size aggregates have less % of matrix material which generally means that materials of size less than 0.06mm held together present within the grain size. The study also showed that coarse aggregates gave higher PSV values in dry condition but is generally more or less the same percentage of reduction in Polished Stone Value in wet condition. The difference in percentage of all the aggregates from all four sources showed an average reduction of 33.7% PSV from dry to wet condition.

Table 4: Polished Stone Value and Petrography Tests Results

RAWANG QUARRY	Sample R1	Sample R2	Sample R3	Sample R4	Sample R5	Average
% Mineral (Quartz)	25	25	20	25	30	25
Grain Size	Medium	Medium	Fine	Medium	Medium	Fine/ Medium
% Matrix Material <0.06mm	20	15	25	20	20	20
Polished Stone Value (dry)	49.6	49.4	48	49.2	49.4	49.1
Polished Stone Value (wet)	33.5	31.9	30.0	31	32.2	31.7
PUCHONG QUARRY	Sample P1	Sample P2	Sample P3	Sample P4	Sample P5	Average
% Mineral (Quartz)	30	30	35	30	35	32
Grain Size	Medium	Medium	Medium	Medium	Medium	Medium
% Matrix Material <0.06mm	15	10	15	15	10	13
Polished Stone Value (dry)	51	52	52.8	52.2	52.7	52.1
Polished Stone Value (wet)	34.7	35.7	36.3	35.6	36	35.7
CHERAS QUARRY	Sample C1	Sample C2	Sample C3	Sample C4	Sample C5	Average
% Mineral (Quartz)	35	35	35	30	30	33
Grain Size	Medium	Medium	Medium	Medium	Medium	Medium
% Matrix Material <0.06mm	10	10	10	10	15	11
Polished Stone Value (dry)	52.1	52.3	52.7	52.5	52.7	52.5
Polished Stone Value (wet)	35	33.8	34.1	34.8	34.2	34.4
HULU SELANGOR QUARRY	Sample HS1	Sample HS2	Sample HS3	Sample HS4	Sample HS5	Average
% Mineral (Quartz)	35	35	45	40	35	38
Grain Size	Coarse	Medium	Coarse	Medium	Medium	Medium /Coarse
% Matrix Material <0.06mm	5	10	5	10	10	8
Polished Stone Value (dry)	54.4	54.7	55.4	54.8	54.7	54.8
Polished Stone Value (wet)	35.6	36.9	37.4	36.6	36.2	36.5

For Rawang Quarry, the surface texture of these aggregates consists of fine to medium grain and results showed that these aggregates have low level of skid resistance with an average value of 49.1. Since the limiting value is ≤58 (Table 1), the skid resistance of these aggregates is acceptable as minimum requirement for High Specification Aggregate (HSA). However, aggregates from Cheras and Puchong which consists mainly of medium grain size aggregates showed that the skid resistance level is intermediate. This increment may be due to larger grain size of the aggregates. This phenomenon of increasing level of skid resistance is also true to Hulu Selangor aggregates which consists mostly of coarse aggregates and showed high level of skid resistance compared to the other aggregate sources.

In Figure 5, it is noticeable that samples from each quarry tend to plot within different tracts. A strong positive relationship can be seen when PSV increases as percentage of quartz content increase, and this is also true in wet condition although the PSV is obviously lower than dry condition.

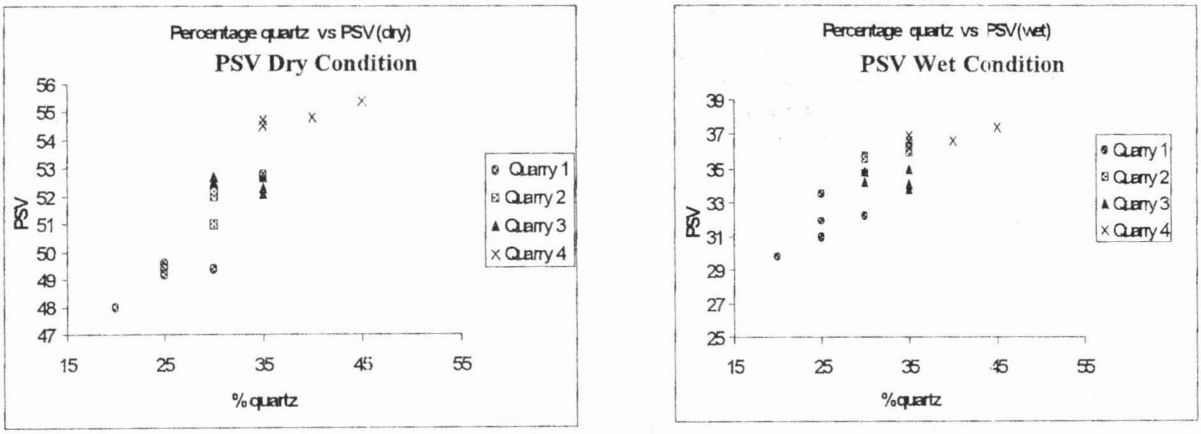

Figure 5: Percentage of Quartz versus PSV

However, the relationship between percentage of material matrix and PSV showed a negative sign as % matrix material is higher within the aggregates. The % matrix material is the material with <0.06mm held together within the aggregates. The relationship pattern is also similar to aggregates in wet condition PSV test (Figure 6). This trend showed that as the % of materials < 0.06mm increases the PSV decreases.

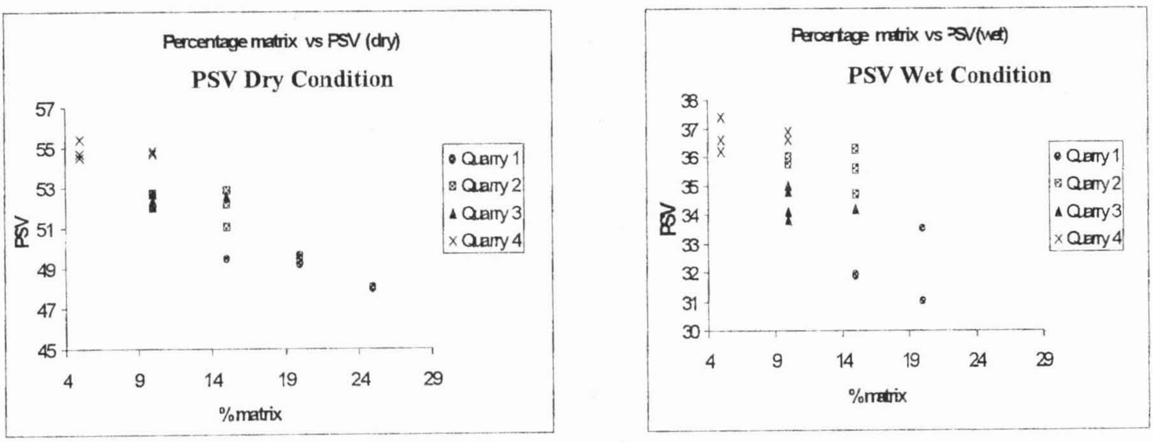

Figure 6: Percentage of Matrix Material versus PSV

CONCLUSION

Granite rocks are volcanic aggregates which normally show low but stable resistance to skidding, but their resistance to wear is high and pavement surfaces with these types of aggregates tend to maintain their macrotexture over time. The properties of granite aggregates in this study are satisfactory and conform to the standards which indicate that the aggregates are suitable for use in bituminous mix. It is apparent from the analysis that the petrography of aggregates is important and readily affect resistance to polishing, especially so with variation in hardness and proportion of soft minerals present in the aggregate. An in-depth study on the macro and micro texture of the aggregates must be carried out in future which is not covered in this study. However, a preliminary investigation of the PSV of aggregates with varying quartz content and percentage of matrix material gave good indication of the skidding resistance of the aggregates in this study.

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