Petrographic assessment of re-textured road surface aggregates

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Abstract

Since the costs of structural maintenance of slippery road surfaces are very high, re-texturing offers the potential for economically increasing a road's surface life without the addition of new material. Correctly using mechanical re-texturing techniques improves mechanical properties of the road stones. These techniques can be used in more sensitive areas to provide adequate surface skidding resistance.

The main objective of the present research is to investigate material properties and performance in the laboratory of aggregates subjected to mechanical treatments (sand blasting) with a view to establish the cause of some aggregate material to benefit in terms of their Polished Stone Value (PSV) enhancement.

Samples of aggregate from 35 quarries have been assembled and in the first stage a thin section of each aggregate was prepared (from at least six rock fragments of each individual aggregate) and their petrological properties determined. In the second stage, test specimens were made in accordance with the procedures described in BS812 Part 114 1989. Initially, the PSV of each aggregate sample was measured in a program of standard tests. The test specimen was subjected to a program of sand blasting treatments.

The type of mechanical processes involved in re-texturing suggest the relevance of geological structure and properties in determining their degree of enhancement of surface texture for each specific aggregate. It was found that the surface texture resulting from erosion of the aggregates during re-texturing not only depends on their mineralogy, petrographic properties, differential wear, but, above all, mainly depends on the percentage of the soft mineral distribution over the whole matrix of the rock mass. The relationship between different surface

WIT Transactions on The Built Environment, Vol 111, © 2010 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/UT100261

texture (natural and re-textured) and their new PSV (after treatment) of aggregates is also evaluated.

Keywords: aggregates, re-texturing, thin section, polished stone value, sand blasting, road maintenance.

1 Introduction

Since the costs of structural maintenance of slippery road surfaces are very high, re-texturing offers the potential for economically increasing a road's surface life without the addition of new material. Sand blasting technique is basically a method which strikes the surface of aggregate with abrasive particles. The sand blasting method attacks the softer minerals and plucks them out leaving the harder minerals projecting (if the air pressure, amount of sand, distance of the nozzle from the specimen and angle of nozzle is set accurately) Soleymani Kermani [1].

It is often found that some aggregate material even from the same petrographic groups benefit more from mechanical treatments than others. It must be kept in mind that in all questions of rock-nomenclature, rock masses are seldom homogeneous; several varieties of distinct appearance and slightly different composition often appear together and may be found in the same quarry. Naturally occurring rocks are an aggregation of mineral particles. The properties of the individual minerals and their relative proportions are to some extent related to the mechanical characteristics of any aggregate with regard to re-texturing. The geological factors affecting the performance of aggregate materials are mainly petrographic and related to the mineral content of the rocks and the petrofabric texture. It may be anticipated that an aggregate's grain size, bonding and mineralogy will influence the manner in which it responds to mechanical re-texturing treatments Soleymani Kermani [1]. Petrographic analysis enables such characteristics to be assessed. Therefore, before any treatment takes place, it is advantageous that a thin section analysis be carried out in order to identify mineral constituents and other geological properties of aggregate.

Taking into account the different hardness of each individual rock material, aggressiveness of the method used directly relates to the hardness of each individual material. The variables (air pressure, amount of sand, distance of the nozzle from the specimen and angle of nozzle) have to be established correctly in the laboratory first, and then calibrate the sand blasting machines in real situation according to laboratory findings. In this case the quality of treated surface will be guaranteed and surface disintegration will not happen.

Hartley [2] considered that a qualitative but detailed knowledge of the effect of petrological characteristics upon the mechanical properties of aggregates was required. He reviewed the qualitative relationship between petrography and the polishing of both natural and artificial aggregates. Verhoef [3] considered the quantitative relationship between petrographic evaluation of the rock and selected properties such as their tensile and compressive strengths and their abrasion resistance. The present research takes into account the relationship between petrographic properties and mechanical behavior of aggregates during re-texturing treatment.

2 Petrographic procedures

This research describes petrographic assessment of the geological factors affecting the performance of aggregate materials with regard to mechanical re-texturing treatment. In the study of rocks in thin sections, a petrographic study for road stone evaluation including measurement of the volume proportions of the main mineral constituents of the rock, the average grain chord (GS) and the degree of weathering and hydrothermal alteration have been evaluated of aggregates before it is tested using mechanical and physical treatments. This will allow selection of material on a quantitative basis that likely to fall within a given specification. Therefore, it would be advantageous to study the use of quantitative petrographic procedures for aggregate screening and selection before conventional tests are undertaken.

Each aggregate (at least six rock fragments of each individual aggregate) was compressed and cemented into a briquette using an epoxy resin. The briquette was ground, mounted, cut and polished to make a thin section measuring about 50 by 70 mm. The resin used to mount the rocks carries a fluorescent dye. The fluorescence is used to assess the micro porosity of the rocks under the polarizing microscope. Mineralogy, the variation in hardness of the constituents, the texture and the amount of alteration that appear to be connected with the degree of polish which the rock acquires during the test have been assessed, and the factors affecting the re-texturing treatment of aggregate have been analyzed. Volume proportions: the thin section was used to obtain the volumetric composition of the rock by point counting. For most uniform aggregates the number of points counted need not be large, providing the area is covered fully, since the modal composition need be known only approximately Allman and Lawrence [4]. A total of 200 points has been found to be adequate. Only the major phases such as the epidotic, chlorite and calcite of hydrothermal origin have been assessed.

Grain size: the mean particle size of the rock was obtained by counting grain boundaries along a line of traverse of measured length. This gives an average chord length for the grains in the rock which relates to the actual grain size distribution. For most purposes a traverse of approximately 120 mm provides a sufficiently reliable estimate of this average chord by 1.75. This gives a close approach to the true grain size. The measurement is simple to make if only the mean particle size is to be determined. Sometimes it may be necessary to establish the grading curve of particles in the rock and in this case it is necessary to record the individual measurements made for each grain, either using image analysis procedures or direct measurement on thin sections following the procedures used by sedimentologists (e.g. Textoris [5]). For the present work the grain size was recorded as that conventionally understood in describing coarse, medium and fine grained rocks, but represented by the mean chord length instead of the actual particle size (Table 1). Table 1 also shows the degree of

Table 1: Shows grain size and degree of alteration of each aggregate.

Aggregate no.	Petrographic name	Degree of alteration (1-5)	Grain size large	Standard deviation	Grain size small	Standard deviation
1	Dolerite	1	1.0		0.1	0.05
2	Spilitic basalt	4	0.15			
3	Trachyandesite	4			0.09	0.03
4	Dolerite					
5	Altered dolerite	4			0.21	0.1
6	Dolerite					
7	Dolerite	1			0.2	0.1
8	Altered dolerite	2	0.3	00.1	0.03	0.1
9	Grandiorite	3			0.5	0.15
10	Porphyritic microgranite	2	0.3	00.1	0.03	0.02
11	Coarse granite	1	0.75	00.2		
12	Coarse granite	4	1.0	00.3		
13	Coarse granite	3	1.0	00.43		
14	Grandiorite	3			0.46	0.2
15	Granite					
16	Porphyritic microgranite	4	0.6	00.2	0.05	0.02
17	Recrystallized sandstone	1	0.3	00.4	0.03	0.05
18	sandstone Calcareous	3	0.33	00.3		
19	Greywake	-	0.3	002	0.05	0.01
20	Greywacke	2			0.26	0.05
21	Greywake	-			0.2	0.07
22	Limestone	-	0.5		0.01	
23	Limestone					
24	Marble	-			0.06	0.05
25	Granophyre	1			0.19	0.2
26	Altered mica-gabbro	4			0.43	0.1
27	Hydrothermally altered dolerite	4			0.6	0.2
28	Leucodiorite	4			0.6	0.2
29	Altered dolerite	3	0.3	00.2	0.03	0.03
30	Altered trachyte	3	0.3	00.3	0.08	0.02
31	Grandiorite	4			0.6	0.05

alteration of each aggregate. The test was not carried out for aggregates 4, 6, 15 and 23 because there was not sufficient material to make thin section of those particular aggregates but, other test (sand blasting) has been carried out (Table 3 and Figure 3). The percentage of mineral content of each aggregate is evaluated (Table 2). In practice, the chord length is measured for every grain along a given traverse, including matrix phases, alteration, and weathering products. The result obtained is typically measurable in micrometers even where the rock is conventionally regarded as coarse grained.

This actual grain size was measured for all the rocks and it was found to relate most often to the occurrence and size of secondary products and inclusions of accessory phases. To avoid this problem rules for measurement of grain size were defined as follows.

1- Grains are counted that represent the primary texture. For example, an altered feldspar crystals counted as one grain and so is a feldspar containing apatite neediest.

2- Grains wintergreen or otherwise combined to make a unit of a fine grained matrix are counted as a single unit along the lines of traverse. An area of granophyres texture for example, counts as one grain and so does a collection of intercultural quartz grains making a sand particle in sandstone.

3- Grains occurring as small inclusions, accessory minerals, or alteration products are not counted.

From a study of the thin section one could uncover other valuable information in understanding the structure and the behavior of any material aggregate used for a particular purpose, namely the minerals, bonding, alteration, grain size and percentage of the mineral which in this research have been used to analyze the re-textured specimens.

Table 2: Percentage of minerals within each aggregate.

Ag. No.	Petrographic name	Quartz	Feldspar	Maca	Chlorite	Opaque	Clcite	Clino pyroxene	Others
1	Dolerite		61					39	
2	Spilitic basalt		70		8	5		17	
3	Trachyandesite		78		10	2	1	10	
4	Dolerite								
5	Altered dolerite		60	10	13	2		15	
6	Dolerite								
7	Dolerite		70			TRACE		30	
8	Altered dolerite		66	2	2			30	
9	Grandiorite	15	67	2	15	1			
10	Porphyritic microgrranite	30	67	3	TRACE				
11	Coarse granite	20	55	25					
12	Coarse granite	25	65	8	2				
13	Coarse granite	30	60	10					
14	Grandiorite	12	70	8	8	2			
15	Granite								
16	Porphyritic microgrranite	27	50	15		2	1		Epidotes
17	Recrystallized sandstone	95	4	1					
18	sandstone Calcareous	25	50	10	10		5		
19	Greywake	70		27		3			
20	Greywacke	63	30	2			5		
21	Greywake	83		10		2	5		
22	Limestone						100		
23	Limestone-								
24	Marble						100		
25	Granophyre	50	58	10	10	2			Amphib5
26	Altered mica-gabbro	50			28	2		20	
27	Hydrothermally altered dolerite	50			5	2		43	
28	Leucodiorite	20	56	4	3	2		15	
29	Altered dolerite	60	15	25			25		
30	Altered trachyte		70	5			25		
31	Grandiorite	5	60	15	8	1			

3 Sand blasting treatment

A piece of apparatus has been designed and developed (by the author) to carry out the re-texturing treatment (Soleymani Kermani [1]). The apparatus is of a simple design consisting of a table to the side of which the road wheel is mounted, exposing one specimen at a time for the use of pendulum for PSV determination and sand blasting treatments (Figures 1 and 2). A hole is positioned at the centre of the table in order to hold the shaft which is connected to a movable arm so that the sand blasting nozzle can be fixed in position (Figure 2). The road wheel can be retained in:

1- Fixed position (by tightening the bolted wheel to the shaft using a spanner) for the purpose of taking the pendulum value.

2- Rotating position (by placing a washer between the shaft and the wheel) for re- texturing treatments.

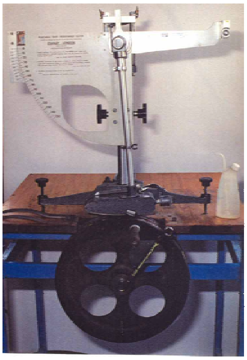

Figure 1: Fixing British pendulum to the apparatus to measure PSV.

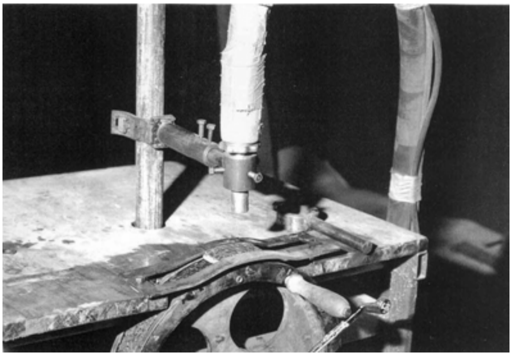

Figure 2: Fixing the sand blasting nozzle to carry out the re-texturing treatment.

3.1 Methodology

In order to ensure accuracy and repeatability, to make sure that in all stages of re-texturing the condition for the test stays the same for every sample of aggregate, and that all aggregates receive the same treatment, verification was needed to control if the output result from the apparatus is standardized. Two sets of specimens (each set consisting of 4 samples) of each aggregate allocated for each treatment.

3.2 Method of testing

The first stage consists of the following:
1- Specimen prepared according to BS 812:
2- Polished using accelerated polishing machine as specified in BS812 [6].
3- PSV of each specimen was determined (from fresh aggregates).
4- Specimen assembled on apparatus for treatment, and
5- The pendulum value taken.
6- Polished using accelerated polishing machine as specified in BS812 [6].
7- PSV of each specimen was determined (from re-textured aggregates).

3.3 Sandblast testing

The term "sand" has been used in this research instead of copper slag (j blast supa) particles (0.2-1.5 mm dia grain size.). A specified amount of sand (j blast supa) is fed into a pressurized air stream and blasted perpendicularly onto the surface of the test specimen from a distance of 130 mm (Soleymani Kermani [1]). Specimens are assembled on the road wheel which is slowly rotated to enable the sand blasting to have a uniform effect on the samples with minimum damage (in terms of weight reduction) (Figure 2).

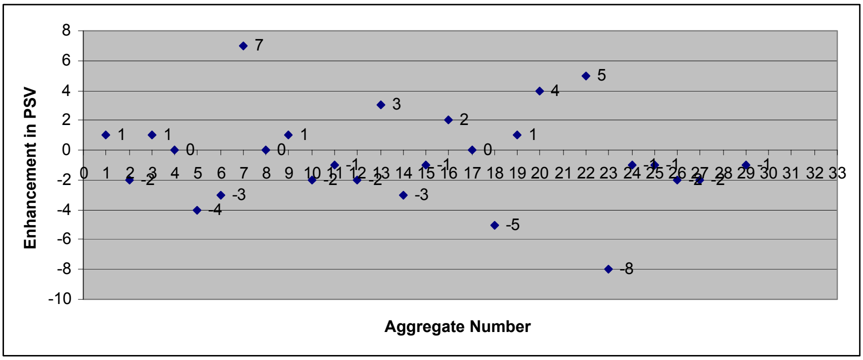

Figure 3: Performance of each aggregate in terms enhancement of PSV after the sand blasting treatment.

Table 3: Performance of aggregates in terms of the PSV before and after treatment.

Aggregate type	Aggregate No.	PSV (Before treatment)	PSV (after treatment)	Enhancement
Basalt				
	1	50	51	1
	2	51	49	-2
	3	53	54	1
	4	60	60	0
	5	51	47	-4
	6	49	46	-3
	7	53	60	7
	8	53	53	0
Granite				
	9	56	57	1
	10	53	51	-2
	11	52	51	-1
	12	50	48	-2
	13	53	56	3
	14	48	45	-3
	15	53	52	-1
	16	54	56	2
Gritstone				
	17	44	44	0
	18	56	52	-3
	19	61	62	1
	20	53	57	4
	21			
Limestone				
	22	35	40	5
	23	59	51	-8
	24	40	39	-1
Gabbro				
	25	55	54	-1
	26	55	52	-3
	27	61	59	-2
	28			
	29	49	48	-1

Since making specimens is a time consuming and expensive process, several parameters have been checked before the experiment started. Normally a sample is clipped on top of the road wheel (Figure 2) and sand blasted first. This is to establish that there is no blockage in the air stream, a uniform flow of blasting material, produce even texture and, generally speaking, to ensure that the apparatus is in working order (Soleymani Kermani [7]). Since a wide range of rock and mineral types were tested, blasting conditions (i.e. air pressure, amount of abrasive, diameter of blasted surface) had to be standardized. Therefore tests have been carried out on a number of samples with different values of air pressure, flow of abrasive and diameter of blast nozzle, in an attempt to optimize the simulated treatments. Table 3 and Figure 3 show enhancement of the PSV of some aggregates in different petrological groups. The test was not carried out for aggregates 21 and 28 because there was insufficient material to make samples to perform sandblasting treatment.

4 Conclusions and recommendations

From the thin section analysis, some characteristics of the aggregates which it is not possible to determine by physical tests in the laboratory (e.g. alteration, cleavage, grain size, mineral arrangements and their differential wear resistance, percentage of soft and hard minerals etc.) can be easily studied therefore it is recommended that petrographic assessment of the surface aggregate be carried out before any treatment takes place (Table 1).

The results indicated that different rock types respond in varying ways when subjected to retexturing treatment (Figure 3). Since, petrographic properties of each individual aggregate are very much different from one another even those from the same petrographic group, therefore, each aggregate should be considered on its own merits, not in relation to others.

From this research a general conclusion that can be drawn as follows:

- Some aggregates from the same petrological groups have ended up to be significantly higher in performance in terms of their re-textured pendulum value (Figure 3).
- After treatment, the PSV of some aggregates increased significantly, aggregates No. 7, 13, 20, 26, 29 and 30 (Figure 3 and Table 3).
- Thin section analysis has shown that aggregates having their soft mineral placed in hard matrix and also those with small alteration within the harder minerals or along the grain boundaries experience more enhancement in the PSV, whereas many of the changes are within the repeatability of the apparatus (+/-5 units) (Figures 4 and 5).

  From 18 samples of aggregates which had a sufficient amount of soft minerals, thin section analysis revealed that these aggregates which have a distribution of hard and soft minerals over their matrix, are more amenable to sand blasting than others (Figure 4). From 17 aggregates which were chosen as such to represent different petrological groups indicates the tendency of harder material aggregates to perform better with sand blasting treatment (Figure 5).
- This investigation indicates that: (i) one mineral or combination of hard minerals like quartz, feldspar and pyroxene or small amount of constant alteration throughout the aggregate. (ii) Presence of (less than 13%) of soft minerals of hardness (2-3) (i.e. Mica, Chlorite and Calcite) which have been distributed evenly throughout the rock matrix benefits more from treatment (Figure: 4).
- It has been revealed that aggregates with hardness of more than 6 receive quality treatment using this method (Figure 5).
- Petrographical group classification seems to have little to no effect regarding the enhancement of the PSV by re-texturing the aggregates (Figure 3).

Re-texturing gives diverse results for aggregates with different grain size aggregates from the limestone group.

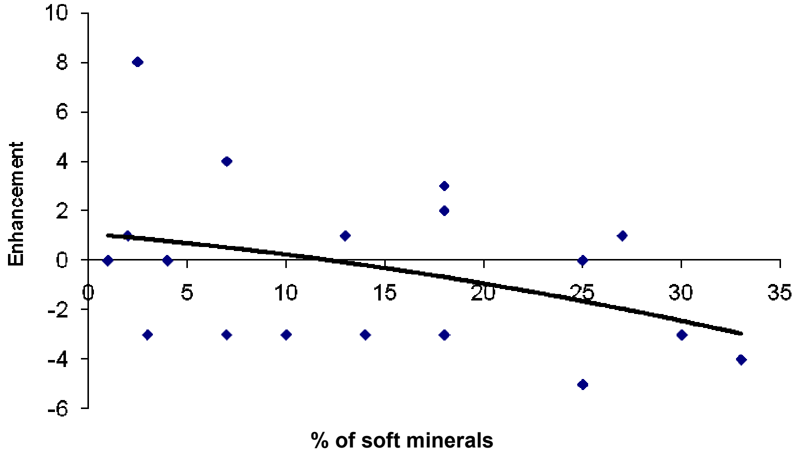

Figure 4: Percentage of soft minerals V enhancement in terms of the PSV.

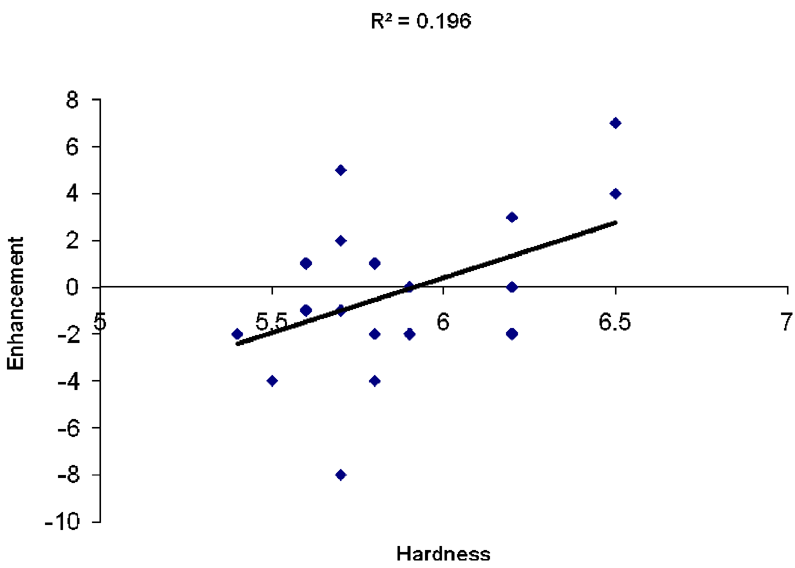

Figure 5: Hardness V enhancement in terms of the PSV.

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