IMPROVING THE DURABILITY OF SEAL AGGREGATE BY PRECOATING

T. Thothela*, G. Robertson*, K. Jenkins**

*Aurecon, PO BOX 494, Cape Town, 8000

**Stellenbosh University, Private Bag X1, Matieland, 7602

Abstract

It is essential that the durability requirements applied to surface seal aggregates are relevant in order to deal with the scarcity of high quality aggregates. There has been a general increase in cases where a local source of adequate quality seal aggregate is overlooked, or rejected, on the grounds that it is not satisfying published durability specifications. Alternative sources are then identified and aggregates hauled over long distances at great cost to the economy and environment. By conducting a series of 10% FACT and ACV laboratory tests on pre-coated seal aggregates it is shown that the pre-coat is capable of increasing the crushing strength of aggregates as well as limiting the water absorption of aggregates. It is suggested that this measured effect of pre-coating an aggregate should be considered during the aggregate selection process.

1. INTRODUCTION

The increasing scarcity of high quality rock and aggregates as well as the heightened pressure on the construction industry to seek more environmentally friendly alternatives, has brought to the forefront the need to question the relevance of durability/hardness requirements being applied to surface seal aggregates.

There has been a general increase in cases where good quality aggregate, with proven historical performance, is rejected on the basis of not satisfying the stone durability test requirements. This often leads to an onerous process of identifying a new source and aggregates being hauled over long distances at great costs to the client (and/or contractor) and the environment. The current 10% FACT specification for surfacing aggregates durability is a minimum 75% ratio for aggregates tested under wet and dry conditions, and for the ACV test the specification is a maximum ranging from 21 to 29% depending on the rock type. Problems may arise, for instance, when an aggregate has a dry 10% FACT of 330 kN and a wet value of 215 kN, giving a wet/dry ratio of 65%. In this instance, what is often overlooked is the fact that the wet value of 215 kN exceeds the required minimum dry value of 210 kN, as well as the fact that seal aggregates are usually coated with bitumen which, theoretically, should prevent the ingress of water/moisture that leads to the loss of strength in the wet test.

The purpose of this paper is to report on the investigation of the effect of moisture on the crushing strength of pre-coated seal aggregates. By conducting a series of 10% FACT and ACV tests on pre-coated and un-coated aggregates, this paper will show that the pre-coat fluid is capable of limiting the water absorption of aggregates and thus play an influential role in improving the wet strength of aggregates.

2. BACKGROUND

This research subject came about as a result of a recent experience on a reseal project on the N12 in the Northern Cape between Kimberley and Hopetown. A local quarry, situated on the project road, was earmarked for the supply of aggregates, however, at the time of preliminary testing it emerged that the seal aggregates did not meet the required 10% FACT wet/dry ratio specification of 75%. Typical dry 10%FACT values of the dolerite rock ranged between 380 and 420kN, and the wet 10%FACT values between 220 and 280kN, producing an average ratio of 68%. As a consequence, an alternative aggregate source was identified 300km away from the project site with an additional haul cost of R500 000 to the client, upon more detailed investigation the dolerite aggregate at this new source also proved to be inadequate producing wet/dry ratios ranging from 65 to 71%.

Ultimately, after numerous repeat tests at different laboratories, consultation with industry experts and literature, the recommendation to the client was for the local quarry to be accepted on condition that the dolerite rock would be blasted from selected un-weathered faces in the quarry to counter the possible detrimental effects of traces of the secondary mineral smectite, found during the petrographic analysis, as well as conducting regular tests and monitoring the wet 10% FACT value and ensuring that it is always above the dry 10%FACT specification of 210kN.

In terms of seal aggregates, the questions that need to be asked are, how likely is it that the surfacing aggregates will become soaked? Is the fact that the aggregate is pre-coated, embedded in a bituminous layer to at least a third of its depth, used in a dry area, and has no historical evidence of poor performance, easily disregarded?

There have been attempts to address some of these concerns. A study[1], in 1991, to evaluate weak aggregates on low-volume roads was done in Botswana, as part of a research program with the aim of making best use of locally available materials for road construction. A study of duricrusts (a group of materials which comprises calcretes and silcretes of Botswana), from four different sources for use as surfacing seals was conducted; the investigation included a series of chemical and mechanical tests as well as an assessment of performance in full-scale road trials.

The results of the mechanical tests (on the basis of the 10%FACT) showed that, if the specifications (adopted from the South African specifications) of the Botswana Road Design Manual are applied, then only one of the four materials would meet the requirement and the rest would be below the requirement. The road trials involved subjecting the materials to the normal traffic volumes on trans-Kalahari routes (100 to 150 vehicles per day) in Botswana as well as up to 700 vehicles per lane per day traffic in the United Kingdom. The road trials showed that these ‘marginal’ materials performed very well under both traffic conditions, with the exception of one aggregate which performed less well, but there was sufficient evidence to indicate that all the materials would be satisfactory as surfacing aggregates for lightly trafficked roads. The study led to the proposal of new interim specifications for seal aggregates, shown in table 1, and the suggestion to relax the 75% wet/dry ratio for roads constructed in the drier regions of the Kalahari provided that the minimum soaked test value is satisfied.

Table 1 Interim 10%FACT Specification proposed in Botswana[1]

Minimum 10% FACT Values (kN)		Pavement Design Category (equivalent standard axles)
Dry Test	**Soaked Test**	
180	135	> 3 million
150	115	0,8 – 3 million
130	100	< 0,8 million

Similar studies have been done in South Africa. Recommendations to relax the specifications for aggregate hardness are contained in a 1996 Department of Transport research report RR93/263[2] and, in 2004 a paper presented at the CAPSA conference by Dr Phil Paige-Green[3] made a case for the use of aggregates softer than specified, in surfacing seals and to propose possible relaxations in the currently specified strength requirements. The study focused on a number of possible surfacing aggregate materials with dry 10%FACT strengths ranging between 42 and 145 kN and testing the seals under the Heavy Vehicle Simulator and overall results indicated that materials with surprisingly low strengths performed relatively well. It was also noted that, pre-coating of the aggregate increased the soaked strength of the materials significantly.

This paper looks at the seemingly overlooked impact of pre-coating aggregates on the wet crushing strength and the resultant impact on material selection, with the intention of reducing unnecessary haul and the depletion of the best quality aggregates.

3. LABORATORY EXPERIMENTS

Testing was carried out on four different types of commonly used seal aggregates, from five different quarries. Three samples were obtained from quarries in the Western Cape and two from the Northern Cape. The sample number, location and material type are listed:

Sample	**Location**	**Material Type**
A1	Malmesbury, Western Cape	Granite
A2	Durbanville, Western Cape	Greywacke Hornfels
A3	Worcester, Western Cape	Eucrite
A4	Kimberley, Northern Cape	Dolerite
A5	De Aar, Northern Cape	Dolerite

The pre-coat that was used is a bitumen based cutback blended from selected petroleum derivatives and a chemical adhesion agent, and is one of the most commonly used pre-coats for seal aggregate. It can be used with all local seal aggregates, including aggregates which are known to have poor affinity for bitumen.

Samples were collected from the respective quarries, sieved into the correct size fraction for the tests, and split into two for the pre-coated and un-coated tests. The pre-coating of aggregates was done with minimal amount of fluid and were left to dry for four to five days until completely dry in order to eliminate the possibility of generated fines being bound together by bitumen. The wet test samples were soaked for 24 hours before testing. The number of tests completed for each sample was 36; eighteen tests for the uncoated and eighteen for the pre-coated aggregates.

4. TEST RESULTS

The 10%FACT and ACV average results are summarised in Tables 2 and 3, and illustrated in Figures 1 and 2.

The ACV test is essentially similar to the 10%FACT test. The basic difference between the tests is the use of a constant force of 400 kN applied over ten minutes and measuring the percentage of fines passing the 2,36 mm sieve, while in the 10%FACT the force is varied so that only 10% fines passing the 2,36 mm sieve are produced

Table 2 Summary of 10%FACT results

Aggregate Tests		Source Quarry				
		A1	A2	A3	A4	A5
Not Pre-coated	Dry-10%FACT (kN)	416	387	364	342	301
	Wet-10%FACT (kN)	305	333	323	324	297
	Wet/Dry ratio (%)	73%	86%	89%	95%	99%
	Water absorption (%)	0.26	0.34	0.31	0.07	0.16
Pre-coated	Dry-10%FACT (kN)	386	386	354	367	359
	Wet-10%FACT (kN)	379	368	424	380	370
	Wet/Dry ratio (%)	98%	95%	120%	103%	103%
	Water absorption (%)	0.17	0.21	0.16	0.04	0.11

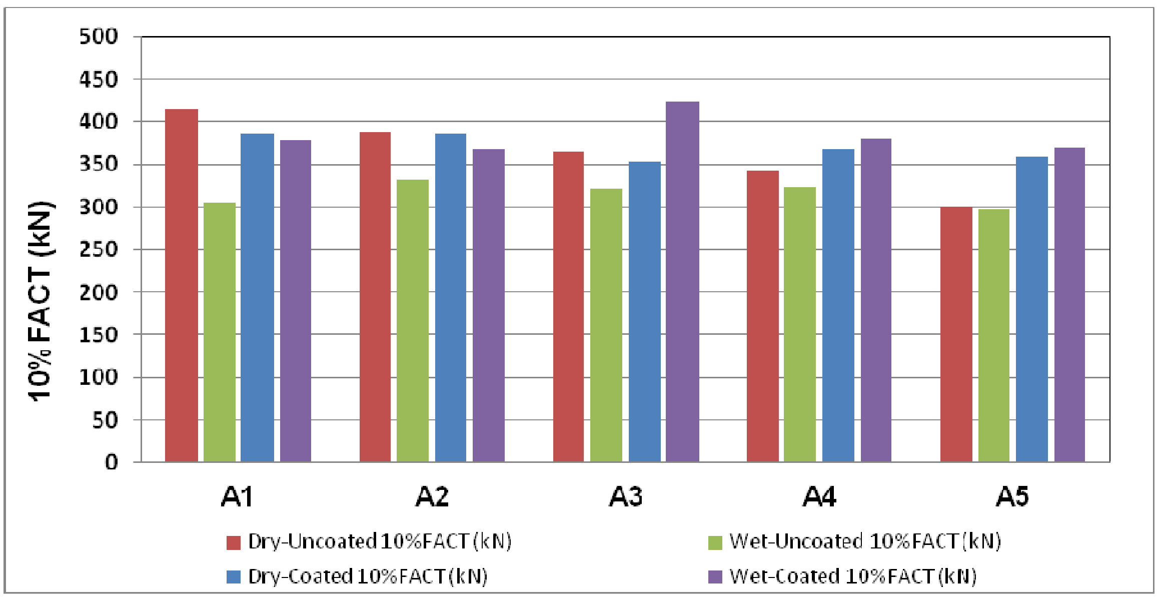

Figure 1 Graphical representation of 10%FACT results

Table 3 Summary of ACV test results

Aggregate Tests		Source Quarry				
		A1	A2	A3	A4	A5
Not Pre-coated	**Dry ACV (%)**	9.8	10.4	11.9	12.2	14.0
	Wet ACV (%)	12.9	12.4	14.1	12.8	14.4
	Water absorption (%)	0.26	0.34	0.31	0.07	0.16
Pre-coated	**Dry ACV (%)**	10.5	10.7	11.6	11.1	11.7
	Wet ACV (%)	10.6	11.1	9.1	10.7	11.1
	Water absorption (%)	0.17	0.21	0.16	0.04	0.11

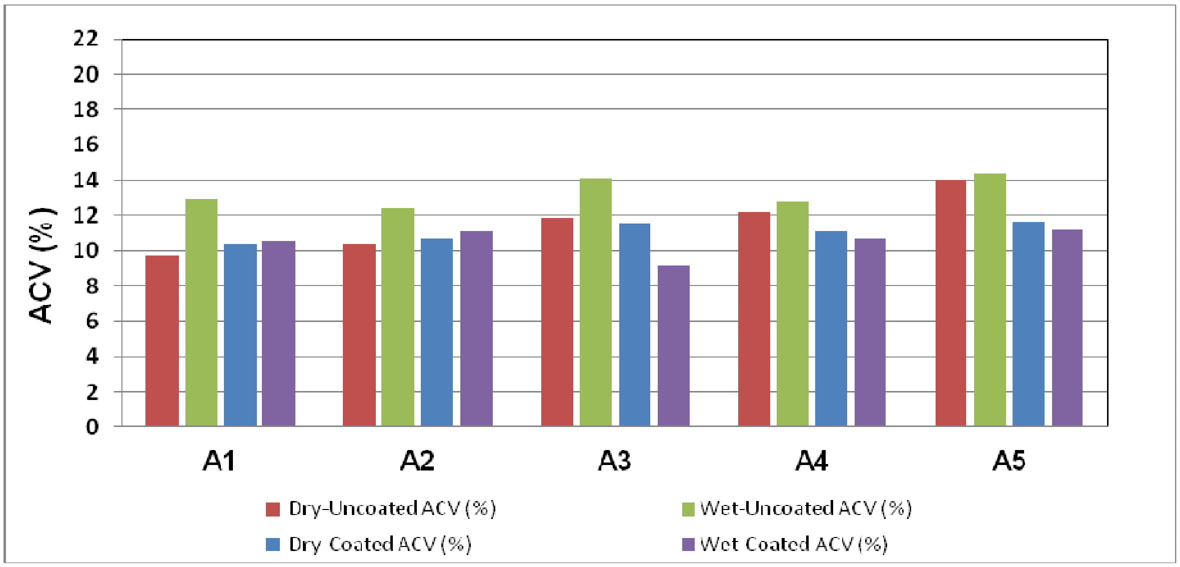

Figure 2 Graphical representation of ACV test results

5. DISCUSSION OF RESULTS

5.1 Water Absorption

It is clear that pre-coating does limit the water absorption of aggregates. The water absorption reduction ranges from 30% for the dolerite (sample A5) to 47% on the eucrite. The microscopic analysis of surface voids and the mineralogical content of each rock type were incomplete at the time of writing, however, it is envisaged that the low viscosity of pre-coating fluid allows it to penetrate the surface voids and the bitumen that gets trapped in the voids is able to limit the absorption of water.

5.2 10% FACT

The two samples (A4, A5) from the Northern Cape were specifically chosen to investigate their performance in light of the relaxation of the specifications on the reseal project on the N12 between Hopetown and Kimberley. Unexpectedly

Unexpectedly, the results observed on these two samples (A4, A5) taken in 2010 did not reflect the original durability concerns experienced during construction in September 2009 where the wet/dry ratios 10%FACT ranged between 64 and 71%. Subsequent site laboratory test results have also shown that the wet/dry ratios from source A5 have improved to 87% and as high as 94%. This can be attributed to blasting of a much younger rock face in the quarry, where the onset of weathering has not taken place because it was discovered that the previously low wet/dry ratios were caused by traces of smectite found in the rock.

The chart illustrates that the dry crushing strength of samples A1, A2 and A3 is relatively similar for pre-coated and un-coated aggregates; the crushing strength of pre-coated aggregates is between 0 and 7% less than un-coated aggregates. Samples A4 and A5 show a strength improvement of 7% and 19% respectively. It is possible that the small amount of residual bitumen on these pre-coated aggregates affects the generation of measurable fines that forms the basis of the 10%FACT test. Also, the possibility of aggregates being able to absorb residual bitumen from the pre-coating fluid is still to be investigated by petrographic analysis.

The results of the wet 10%FACT clearly shows that pre-coating of aggregates plays a significant role in the wet crushing strength of aggregates. The strength improvement of wet-coated aggregates to wet-uncoated aggregates ranges between 11% for sample A2 and 31% for sample A3, with an overall average of 22%. The associated wet/dry ratio is improved by an average of 18% and surprisingly, the wet crushing strength of samples A3, A4 and A5 surpass that of the dry samples, thus showing wet/dry ratios of more than 100%. All the samples show a similar pattern of strength gain from the wet-uncoated aggregates to the wet-pre-coated aggregates. The likelihood that this improvement in strength is attributed to the pre-coat is high.

5.3 ACV

For the un-coated aggregates, the typical trend of the wet test producing higher ACV values was established, i.e. soaked aggregates are weaker than dry aggregates. In the case of the pre-coated aggregates, the differential between wet results and dry results is much smaller and in certain cases, particularly on sample A3, is reversed, i.e. soaked aggregates appear stronger than dry in this test. Other than these observed trends between dry and soaked ACV results, the more pertinent trend is that observed through the comparison between the soaked tests for un-coated and pre-coated aggregates, where the ACV of pre-coated aggregates is improved by an average of 20%, ranging from 10% (sample A2) and up to 35% (sample A3).

6. CONCLUSIONS

The intention of this study was to investigate the effect of aggregate pre-coating on durability of the aggregates. While it has been shown that pre-coating has a positive impact on aggregate durability and in some cases, improving the dry strength, the challenge lies with industry to assimilate these findings and take them into consideration when designing seals and preparing project specifications for seal aggregates. Specifications must always be prepared in the context of their application in order to be relevant and meaningful.

7. ACKNOWLEDGEMENT

The laboratory test results presented in this paper form part of an on-going research project in partial fulfilment of the requirements for the degree of Master of Engineering at the Stellenbosch University.

8. REFERENCES

1. Woodbridge, ME, Greening, PAK, and Newill, D., 1991. **Evaluation of weak aggregates for surface dressing on low-volume roads**. Fifth International Conference on Low Volume Roads, Raleigh, North Carolina 19-23 May, 1991.

2. Paige Green, P., Coetzer K., Lea, J., and Semmelink, C., 1996. **Appropriate use of locally available materials in concrete, bituminous surfacings and layer works for roads in rural areas**. Research report RR93/263. Department of Transport, Pretoria.

3. Paige-Green, P. 2004. **Aggregate strength for bituminous surfacings for low volume roads: A heavy vehicle simulator experience**. Proceedings of the 8th Conference on Asphalt Pavements for Southern Africa (CAPSA '04). Sun City, South Africa, 12 – 16 September 2004.