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Title: Durability Aspects of the Ferricrete from the HVS Sections on Road P243/1			
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Abstract:

The ferricrete material from the HVS sections on road 243/1 was treated with various quantities of foamed bitumen or bitumen emulsion and also different percentages of cement and its erodibility and permeability determined by means of the erosion and the constant head permeability tests. Although there was no statistical difference between the test results of the various mixes, indications were that the permeability of the treated specimens was lower than that of the untreated material. The lowest permeability was that of the specimens treated with 1.8 % foamed bitumen and 1 % cement. These specimens also had the highest densities of the treated materials. Specimens with 3 % bitumen were more permeable and less dense, suggesting that density has a greater influence on the permeability of treated specimens than does bitumen content. Bitumen treatment does, however, reduce permeability as the untreated specimens had the highest density of all yet their permeability was approximately three times greater than that of the treated materials. The treated specimens could be considered practically impervious and therefore it is improbable that permeability will be the cause of any durability problems as the infiltration of air or water into the compacted layers will be minimal.

The erosion testing showed that the cement content had a greater effect on the specimens' erodibility than the quantity of bitumen added. Mixes containing 2 % cement were considered suitable for base and sub-base layers according to the test's acceptance/failure criteria. Mixes containing 1 % cement were considered unsuitable for use in either layer with exception of the material containing 3.0 % foamed bitumen and 1% cement, which was considered suitable for sub-base for all design traffic classes. The mixes containing foamed bitumen were somewhat less erodible than the corresponding emulsion treated mixes, suggesting that the foamed bitumen has more of a binding effect for the specific material that was tested. Statistically, however, there was no significant difference between the erosion test results of the two mixes at a given binder content.

It is thus recommended that no less than 2 per cent cement be used to stabilise the ferricrete as the material becomes potentially erodible when less cement is added and very likely to erode in its untreated form.

Keywords: deep in situ recycling, cement treated gravel, foamed bitumen treated gravel, emulsion treated gravel, durability, erosion, erodibility, permeability

Proposals for implementation: Report supplied to client for implementation.

Related documents: None

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1. INTRODUCTION

1.1 BACKGROUND

This project supports the objectives of the framework for the long-term assessment and implementation of Deep In Situ Recycling (DISR) technology using emulsion and foamed bitumen treatment processes. The main objective of the long-term assessment and implementation program is to produce guideline documents and design methods for DISR using the emulsion and foamed bitumen treatment processes for use by the road-building industry. These guideline documents and design methods will ensure more optimal designs, reducing the risk of premature failure and increasing the probability of optimal performance, thus increasing the confidence in the use of DISR as a potentially cost-effective rehabilitation method.

The assessment process is mainly based on the following assessment techniques:

- laboratory testing;
- Heavy Vehicle Simulator (HVS) testing; and
- field trials;

with the aim to assess the benefits of DISR combined with emulsion and foamed bitumen treatment and to create the knowledge base from which the guideline documents and design methods will be developed.

The main aspects that will be investigated include the following:

- the engineering properties (such as the bearing strength, permeability and erodibility) of the products from these processes;
- the mechanical properties (such as the stiffness, shear strength and strain at break) of the products from these processes;
- the material and pavement behaviour and performance of the products from these processes, and
- all aspects that impact on the above such as design, construction and maintenance strategies.

This report describes the testing of the durability of the ferricrete milled from the HVS test section on Road P243/1 when treated with various amounts of cement and foamed bitumen or bitumen emulsion. For reasons of expediency and cost only the erosion potential and permeability (ASTM method D2434) of the untreated and treated material have been tested to date. Strength testing of foamed bitumen and emulsion treated material are discussed in reports by Robroch[1] and Liebenberg[2] respectively.

1.2 PROBLEM STATEMENT AND MOTIVATION

Both the deep in-place recycling process and the emulsion and foamed bitumen treatments used in combination with this process have been applied successfully to the rehabilitation of roads. However, the benefits of rehabilitating roads in this manner have thus far not been quantified and the mix and structural design methods for these treatment processes are not well developed yet. Some research has been performed to determine the material properties and structural behaviour of these materials. Aspects such as the durability of materials treated in this manner also need to be investigated, particularly where cement or lime is added to the material either for improving the structural capacity of the layer or for assisting in the dispersion of the binder. The objective of this study is to gain an understanding of the durability behaviour of materials treated with cement and foamed bitumen or bitumen emulsion in order to develop comprehensive guidelines and design procedures for the optimal use of these materials.

1.3 DURABILITY

The Concise Oxford Dictionary defines durability as " lasting, resisting wear or decay". Road layers stabilised with pozzolanic stabilisers such as cement, lime, slagment etc. have sometimes failed due to durability problems, mostly caused by the ingress of water and/or air into the layer. It is therefore necessary to determine whether layers constructed by deep in situ recycling and stabilised with these products will exhibit durability problems and, if necessary, to determine ways of overcoming this.

The existing requirements and specifications for materials treated with pozzolanic stabilisers are based almost entirely on strength requirements after 7 days of curing, with little attention being paid to the long-term durability of the material. Research has shown little correlation between durability and strength and has identified the potential for a stabilised material to lose strength under certain environmental conditions, namely, wetting/drying and carbonation. It is important that this strength reduction, in terms of the residual unconfined compressive strength, is not such that the structural capacity of the layer becomes inadequate for the applied loads. Many instances of distress or failure of pavements containing lime or cement stabilised layers have recently been attributed to unsatisfactory durability of the stabilised layers[3].

1.4 BENEFIT TO ROAD AUTHORITY

The laboratory work, combined with the HVS test results, contributes towards the development of methods for the rational assessment of the bearing capacity of roads rehabilitated with the deep in situ recycling method using a cold treatment process. In terms of practical benefit to the road authority, the combined laboratory and HVS testing improves the confidence in the bearing capacity estimates of roads rehabilitated in this way and reduces the risk of applying the process to wrong situations.

2. MATERIALS

2.1 MATERIALS USED

Much of the research to date has been performed on recycled cement treated base and sub-base materials obtained from the HVS site on Road P243/1. The durability testing is limited to this material for the current project but it is advisable to perform the suggested tests on other milled materials in future. The material used is a Ferricrete. The milled properties of this material are shown in Figure 1 and Table 1. More information on the material can be obtained from a report by Long and Theyse[4]. The original pavement consisted of a surfacing (multiple seals), a cement stabilised ferricrete base layer, an untreated ferricrete subbase layer and a natural subgrade layer. The pavement was recycled with a Wirtgen type, recycling machine to a nominal depth of 250 mm. The recycled material contained the milled surfacing and ferricrete from the base and subbase layers.

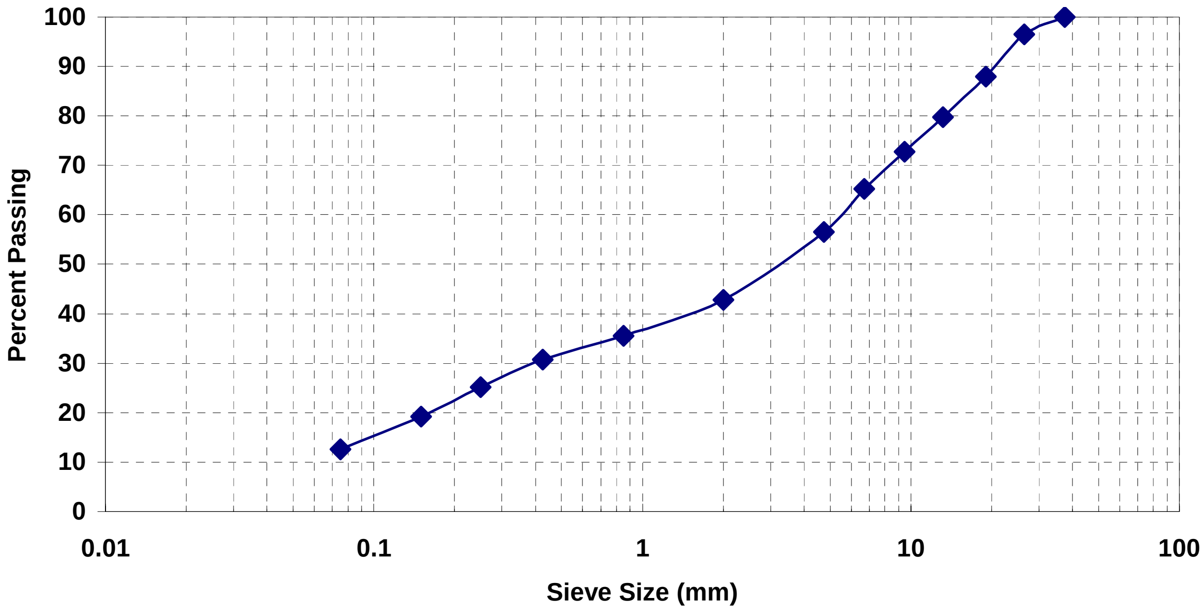

Figure 1. Grading of milled ferricrete

Table 1: Material Properties of the milled ferricrete

Test	Material Property	Value
Optimum moisture content (%)		11,2
Density results	Maximum dry density, Mod AASHTO (kg/m^3)	2013
	Apparent density (kg/m^3)	2777
	Bulk density (kg/m^3)	2436
Atterberg limits	Liquid limit (LL)	26,8
	Plastic limit (PL)	19,8
	Plasticity index (PI)	7,0
	Bar linear shrinkage (BLS)	2,6
California Bearing Ratio (CBR)	Swell (%)	0,6
	CBR at 98% compaction	56,0
	CBR at 95% compaction	23,0
	CBR at 93% compaction	17,5
	CBR at 90% compaction	5,8
Water absorption (%)		5
Initial consumption of lime (ICL) (%)		1.5

2.2 MATERIAL TREATMENTS

The material was treated with bitumen emulsion, foamed bitumen, cement and combinations of the bituminous binders and cement. A 60 % anionic stable grade bitumen emulsion and an 80/100 NATREF foamed bitumen was used (also used in the foaming process at the HVS site). The cement was Alpha, Cem1 cement with a strength rating of 42.5 MPa.

In this exercise, the material tested was treated with 1 or 2 percent cement and with 1.8 or 3 per cent foamed bitumen or bitumen emulsion as shown in Table 2. These percentages were used in order to tie in with the results of previous testing and it is also unlikely that amounts of binder in excess of 3 per cent will be used in practice because of cost considerations. Untreated specimens were also tested for reference purposes.

Table 2: Percentages of bitumen and cement added to the ferricrete material

Bitumen treatment	Bitumen content (Residual) (%)	Cement content (%)
Foamed bitumen	1.8	2
	3.0	1
Emulsion	1.8	2
	3.0	1
None	None	None

2.3 SPECIMEN PREPARATION

The ferricrete was initially prepared according to the standard method described in TMH1[5] method A7 with the exception that the full grading of the material was used for testing. The +19.0 mm fraction was not crushed to pass this sieve as is recommended in the method.

2.3.1 Foamed bitumen treated specimens

The material preparation for the mix design and additional testing were all performed at the Transportek laboratories. The foaming was performed using a WIRTGEN laboratory foaming machine, shown in Figure 2 that was obtained from SIMLAB. A detailed description of the foaming and specimen preparation process is given in the companion report by Robroch[1].

2.3.2 Emulsion treated specimens

The emulsion treated material was prepared by adding the required quantities of emulsion to the compaction water, the volume of which had been adjusted to accommodate the emulsion water content, which was then added and mixed into the dried material.

Figure 2. Wirtgen Foaming Apparatus

3. TEST METHODS

The test methods used for testing both the untreated and treated materials were the Erosion test and the Constant Head Permeability test. The Erosion test developed by de Beer (1989)[6] simulates the grinding action occurring in pavement layers created by wheel loads and gives a good indication of the particles' tendency to erode (become loose) and pump in the presence of water pressure. For erosion and durability problems to occur in pavement layers, the ingress of water and air is necessary. Therefore, the more permeable the layer, the more susceptible it will be to both erosion and durability problems. Permeability tests (using water or air) give an indication of this possibility.

3.1 THE EROSION TEST

A schematic diagram of the erosion test is given in Figure 3 and the full test method given in Appendix A. Specimens for the erosion test are compacted in beam moulds (75x75x450mm) in three layers. Each layer is compacted with 56 blows of a standard Mod AASHTO hammer, after which the protruding material is pressed flush with the mould surface using a compression apparatus to attain the target density. The specimens were cured for a period of 28 days in sealed chambers, at room temperature, after which they were submerged in water for 24 hours and then tested using the Erosion machine to determine their Erosion Index (L). The Erosion Index (L) is the measurement of the average depth of erosion in millimeters averaged from 15 measurements on each erosion specimen after 5000 load repetitions.

The specimens are tested submerged and covered with a membrane on which a wheel loaded with 17.775 kg travels forwards and backwards (see Figure 3) simulating traffic action. The underside of the membrane, which rests on the specimens, is coated with an abrasive powder to promote abrasion.

3.2 THE PERMEABILITY TEST

Compaction of the material for permeability testing was done in three layers in Proctor moulds, which are approximately 101 mm in diameter and 116 mm deep. Three specimens were compacted per mix at different compaction efforts, namely 25, 55 and 75 blows of the compaction hammer per layer so as to achieve different densities. It was hoped that this would give an indication of how different densities would affect the permeability apart from the treatments' effect on the permeability of the material.

The specimens were cured in sealed plastic bags for 28 days at room temperature, after which the water permeability was measured according to ASTM D2434[7] using the constant head permeability apparatus with the water head set at 10 meters. The permeability is determined by measuring the amount of water flowing through the specimen over a given time period.

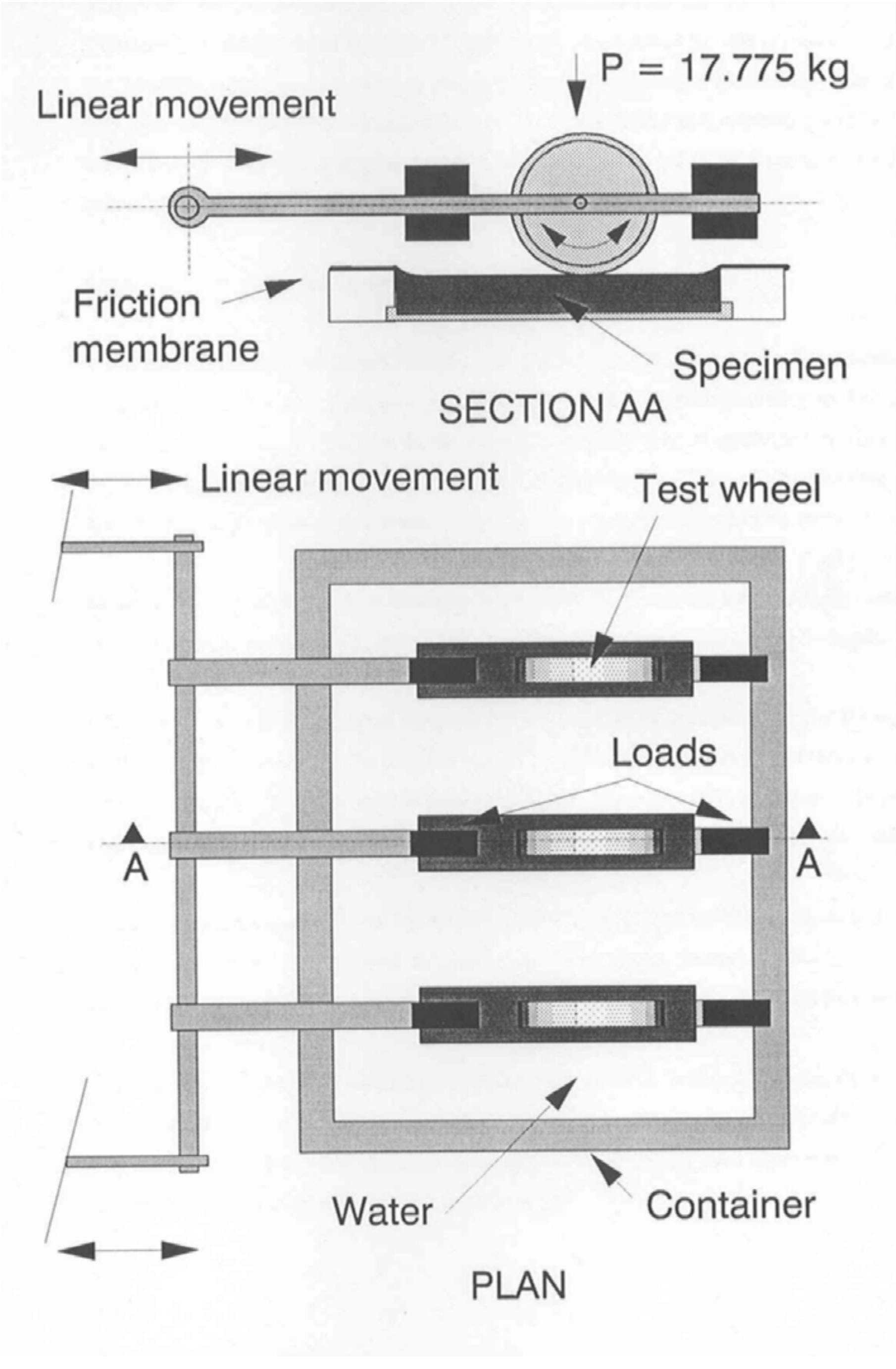

Figure 3. The Erosion Test Device

4. LABORATORY TEST RESULTS

4.1 PROBLEMS WITH SPECIMEN PREPARATION AND LABORATORY TESTS

Several problems were experienced with the laboratory testing. The target density and moisture contents were not always as accurately achieved as in previous similar laboratory studies, i.e. Theyse[4]. Unless otherwise stated, all values reported in the figures and associated discussion are the actual values that were obtained, and not the target values.

4.2 PERMEABILITY TEST RESULTS

The test results are summarized in Table 3.

Of interest is the fact that in most cases the density did not increase after 55 blows, and in some instances did not increase after 25 blows (1.8 % foamed bitumen / 2 % cement and the untreated specimens). The densities obtained for the treated specimens varied between 94 and 97 per cent of Mod AASHTO density, whereas the untreated specimen densities were virtually the same as those obtained by Mod AASHTO compaction.

Mean values for density and permeability were calculated and are shown in Table 3. Although this procedure is not strictly correct, it does give an indication of these values for a particular mix, especially as neither density nor permeability seem to follow a particular pattern with regards to compaction effort or percentage bitumen added. The exception being the mix to which 1.8 % net bitumen (emulsion) and 2 % cement was added, where the density increased as the compaction effort increased (number of blows) and the permeability decreased with increasing density. The reason for permeability not always increasing with increased density is possibly because the mixes were not homogenous. The structures created within the specimens on compaction are formed randomly and no two specimens would have the same number or configuration of routes through which water could flow. This is especially true for materials that have large percentages of coarse particles, as it is more difficult to prepare consistent specimens from a coarse material than from a fine material.

The treated specimens with the lowest permeability were those to which 1.8 % foamed bitumen, and 2 % cement had been added. The highest densities for the treated materials were also obtained from these specimens, suggesting that density has a greater effect on the permeability of the treated material than the amount of bitumen added. The permeability values obtained for the other treated mixes were higher and of the same order. The addition of bitumen, however, does reduce permeability as the specimens containing no bitumen or cement had the highest density, yet their permeability was approximately three times greater than that of the treated mixes. The cement content had no effect on density or permeability, as would be expected, as the addition of such small quantities of fine material would not significantly change the grading of the material.

To determine whether the permeability for the various mixes were statistically different, the "t" test was performed on the means of the test results. No significant differences were found for the mean permeability of the different mixes. The "t" test statistically determines significant differences between the means of small groups of samples.

Table 3: Permeability Values for Foamed Bitumen and Emulsion Treated Specimens

Bitumen Type	Residual Bitumen content (%)	Cement content (%)	Compaction effort (blows)	Mod AASHTO Compaction (%)	Density (kg/m^3)	Permeability (cm/sec)
Foamed bitumen	1.8	2	25	97.0	1952	8.2×10^{-6}
			55	97.2	1956	0.21×10^{-6}
			75	97.3	1958	0.52×10^{-6}
Mean				**97.2**	**1955**	$\mathbf{3.0 \times 10^{-6}}$
Foamed bitumen	3.0	1	25	94.1	1895	3.5×10^{-6}
			55	95.8	1929	58×10^{-6}
			75	95.5	1922	10×10^{-6}
Mean				**95.1**	**1915**	$\mathbf{24 \times 10^{-6}}$
Emulsion	1.8	2	25	92.5	1862	82×10^{-6}
			55	95.9	1931	6.0×10^{-6}
			75	97.4	1960	0.1×10^{-6}
Mean				**95.3**	**1918**	$\mathbf{29 \times 10^{-6}}$
Emulsion	3.0	1	25	94.5	1902	9.3×10^{-6}
			55	97.4	1960	50×10^{-6}
			75	96.9	1951	4.6×10^{-6}
Mean				**96.3**	**1938**	$\mathbf{21 \times 10^{-6}}$
None	0	0	25	100.1	2015	19×10^{-6}
			55	99.5	2003	4.8×10^{-6}
			75	99.8	2008	200×10^{-6}
Mean				**99.8**	**2009**	$\mathbf{75 \times 10^{-6}}$

Compaction energy per blow = 7.5 Joules

Table 4 shows typical permeability values for some soil types for reference purposes. According to Table 4 (adapted from Rosenak[8]) most of the results obtained for the material are indicative of very low permeability and poor drainage characteristics. Of the treated materials, eight of the specimens (different percentages bitumen and/or cement contents) would be considered "practically impervious" (10^{-6} range), whereas the other 4 would be considered to have low permeability (10^{-5} range). Even the specimens of the untreated materials showed low permeability. Van der Merwe[9] reported permeability values between $1x10^{-6}$ and $25x10^{-6}$ cm/s for a crushed stone material compacted to different densities. The average results reported for the foamed bitumen and emulsion treated specimens (Table 3) are comparable to the results for the crushed stone material compacted to 85 - 86 % apparent density.

It is thus improbable that the permeability of this material, untreated or when treated with foamed bitumen or bitumen emulsion will be the cause of any durability problems as the infiltration of air or water into compacted layers will be minimal.

Table 4: Typical permeability values for soils[8]

Soil type	Coefficient of permeability (cm/sec)	Permeability	Drainage
Gravel	$10^{2} – 1$	High	Good
Sandy gravel, Sand	$1- 10^{-3}$	Fair	Fair
Very fine sand, Silt	$10^{-3} – 10^{-6}$	Low	Poor
Clay below zone of weathering	$10^{-6} – 10^{-9}$	Practically impervious	Practically impervious

4.3 EROSION TEST RESULTS

The results of the erosion testing are shown in Table 5.

The mix containing no cement or bitumen was, as would be expected, the most erodible (Erosion index (L) = 11.77) as there was no stabiliser or binding agent holding the particles together. The best performing mix was the one with 1.8 % foamed bitumen and 2 % cement (L = 0.71) followed by the mix containing 1.8 % residual bitumen and 2 % cement (L = 0.98). The failure criteria for the erosion test for materials used in flexible pavements specified by Gass, Ventura and de Beer[10] is given in Table 6. The traffic classification, on which the criteria is based, given in TRH4 (1985)[11] (figures available when the test was developed), as well as the revised figures given in the later version of TRH4 (1996)[12], are also shown. According to the given criteria these mixes are considered suitable materials for base layers where the traffic is classified as E0-E4 (1985), ES0.1-ES30 (1996). They would naturally also be suitable for sub-base layers. The mix containing 3 % foamed bitumen and 1 % cement would be suitable as a sub-base material where the traffic is classified as E0-E2 (1985), ES0.1-ES3 (1996) (L = 4.35), whereas the mix having 3 % residual bitumen and 1 % cement would be considered unsuitable for either base or sub-base for any of the traffic classes mentioned. The untreated material is very likely to erode under trafficking.

A statistical analysis of the erosion index results indicated no significant difference between the mean erosion index for the foamed bitumen and emulsion treated mixes having 1.8 % residual binder and 2 % cement. There was also no significant difference between the erosion index of the foamed bitumen and emulsion treated mixes with 3 % bitumen and 1 % cement. There were, however, statistically significant differences between the mean erosion indices of the untreated material, material treated with 3 % residual binder (foamed bitumen and emulsion) and 1 % cement and the material treated with 1.8 % residual binder (foamed bitumen and emulsion) and 2 % cement with the erosion index decreasing as the cement content increased. The cement content therefore has a significant effect on the erosion index for the levels at which these tests were done.

Table 5: Erosion Index Values for Foamed Bitumen and Emulsion Treated Specimens

Bitumen Type	Bitumen content (%)	Cement content (%)	Density (kg/m^3)	Erosion Index (mm)
Foamed bitumen	1.8	2	2076	0.73
			2075	0.52
			2076	0.89
Mean			**2076**	**0.71**
Foamed bitumen	3.0	1	2043	4.03
			2058	2.67
			2049	6.35
Mean			**2050**	**4.35**
Emulsion	1.8	2	2066	0.55
			2069	1.33
			2073	1.05
Mean			**2069**	**0.98**
Emulsion	3.0	1	2060	5.56
			2048	6.16
			2062	7.66
Mean			**2057**	**6.46**
None	0	0	2041	13.74
			2051	10.58
			2061	10.99
Mean			**2051**	**11.77**

Table 6: Failure Criteria for C3/C4 materials in Flexible Pavements[10]

Layer	**Traffic class TRH4(1985)[11]**	**Traffic class TRH4(1996)[12]**	**Erosion Index (L)** (mm)
Bases	E0 - E4	ES0.1 – ES30	≤ 1
Sub-bases	E0 - E2	ES0.1 – ES3	≤ 5
Sub-bases	E3 - E4	ES10 – ES30	≤ 3

The cement content has a significant effect on the mixes' erodibility but not the residual bitumen content. This is possibly because at 1 % cement the materials' natural demand for cement (ICC) has not been satisfied and also there were more bonds formed at the higher cement content resulting in a more durable, stronger material. The mixes containing foamed bitumen appear somewhat less erodible than the corresponding emulsion treated mixes, suggesting that the foamed bitumen had more of a binding effect for this specific material. As was previously stated, however, there is no statistically significant difference between the test results of the two treatments, at the same residual binder content.

Figure 4 is a photograph of the foamed bitumen treated erosion specimens after testing in the erosion machine. The three specimens on the right are of the untreated material, those in the centre contain 3 % bitumen (note the darker colour) and 1 % cement and those on the left were treated with 1.8 % bitumen and 2 % cement. In terms of erosion, the best performing specimens were those with the higher cement content (on the left in Figure 4) and the worst were those without any treatment (on the right in Figure 4).

Figure 4. Erosion Specimens Treated with Foamed Bitumen

5. CONCLUSIONS AND RECOMMENDATIONS

The ferricrete material from the HVS sections on road P243/1 was treated with various quantities of foamed bitumen or bitumen emulsion and also different percentages of cement and its erodibility and permeability determined.

The lowest permeability values were those of specimens treated with 1.8 % foamed bitumen and 2 % cement. These specimens also had the highest compacted density of all the treated specimens, suggesting that density plays a significant role in determining permeability more so than bitumen content, as increases in bitumen content did not necessarily reduce permeability. The untreated specimens, however, had the highest densities yet their permeability was approximately three times that of the specimens to which bitumen and cement had been added. This indicates that although the binder content does not significantly reduce the permeability of treated specimens, the mere presence of bitumen reduces the permeability of the material. The specimens of the treated materials could be considered practically impervious. It is thus improbable that the permeability of this material, untreated or when treated with foamed bitumen or bitumen emulsion will be the cause of any durability problems as the infiltration of air or water into compacted layers will be minimal.

The erodibility testing showed that the cement content had a significant effect on the specimens' erodibility. The quantity of bitumen added did not have a significant effect on the erodibility. Mixes containing 2 % cement were considered suitable for base and sub-base layers according to the criteria specified by in Gass, Ventura and de Beer[10], whereas those containing 1 % cement were considered unsuitable for use in either layer with exception of the material containing 3.0 % foamed bitumen and 1 % cement, which was considered suitable for sub-base where the design traffic is classified as E0-E4 (TRH4 1985), ES0.1-ES30 (TRH4 1996). The mixes containing foamed bitumen were somewhat less erodible than the corresponding emulsion treated mixes, suggesting that the foamed bitumen has more of a binding effect. Statistically, however, there is no significant difference between the test results of the two mixes.

In terms of durability considerations it is therefore recommended that no less than 2 % cement be used to stabilise the ferricrete as this material is potentially erodible when less cement is added and very likely to erode in its untreated form. This level of cement may vary for different materials depending on the ICC of the material. This aspect requires further investigation using a wide range of materials.

6. REFERENCES

1. ROBROCH, S. **Laboratory testing on foamed bitumen and cement treated material from HVS test section on road P243/1**, Transportek, CSIR, Contract Report CR- 2001/69, 2001.

2. LIEBENBERG, J.J.E. **The influence of various emulsion and cement contents on an emulsion treated ferricrete from the HVS test sections on Road P243/1**, Transportek, CSIR, Contract Report CR – 2001/77, 2001.

3. SAMPSON, L.R. and PAIGE-GREEN, P. **Recommendation for suitable durability limits for lime and cement stabilised materials.** Transportek, CSIR, Research Report DPVT 130, 1990.

4. LONG, F.M. and H.L. THEYSE, **Laboratory Testing for the HVS Sections on Road P243/1**, Transportek, CSIR, Contract Report CR-2001/032, 2001.

5. **Standard methods of testing road construction materials.** 1986. Pretoria: Department of Transport. (Technical Methods for Highways (TMH 1), No1).

6. DE BEER, M. **Aspects of erodibility of lightly cementitious materials.** Transportek, CSIR, Research Report DPVT 39, 1989.

7. American Society for Testing and Materials. **Annual book of ASTM standards**, ASTM, Philadelphia, 1982.

8. ROSENAK, S. **Soil Mechanics.** Batsford Ltd, London, 1968.

9. VAN DER MERWE, C. J. **Some aspects of subsurface drainage in South Africa.** Ph D thesis, University of Pretoria, 1988.

10. GASS, B.,VENTURA, D.F.C. and DE BEER, M. **Erodibility of cemented materials.** Transportek, CSIR, Research Report RR 91/167/1, 1992.

11. **Structural design of flexible pavements for interurban and rural roads.** 1985. Pretoria: Committee of Land Transport Officials (COLTO). (Technical Recommendations for Highways (TRH4).
12. **Structural design of flexible pavements for interurban and rural roads.** 1996. Pretoria: Committee of Land Transport Officials (COLTO). (Technical Recommendations for Highways (TRH4).

APPENDIX A: EROSION TEST

APPENDIX B: WORK PROPOSAL

Transportek, CSIR
DRAFT PROJECT PROPOSAL
June 2001
Guidelines on the Durability of a Previously Cement-treated material, Recycled with Foamed Bitumen and Emulsion

BACKGROUND

This project proposal is in support of the objectives of a framework that has been created for the long-term assessment and implementation of Deep In Situ Recycling (DISR) technology using emulsion and foamed bitumen treatment processes. The objective of the long-term assessment and implementation program is to produce guideline documents and design methods for DISR using the emulsion and foamed bitumen treatment processes for use by the road-building industry. These guideline documents and design methods will ensure more optimal designs reducing the risk of premature failure and increasing the probability of optimal performance.

The assessment process will mainly use the following assessment techniques

- laboratory testing,
- Heavy Vehicle Simulator (HVS) testing and
- field trials

to assess the benefits of DISR combined with emulsion and foamed bitumen treatment and to create the knowledge base from which the guideline documents and design methods will be developed. The main aspects that will be investigated include

- the engineering properties (such as the bearing strength, permeability and erodibility) of the products from these processes and ,
- the mechanical properties (such as the stiffness, shear strength and strain at break) of the products from these processes,
- the material and pavement behaviour and performance of the products from these processes and
- all aspects that impact on the above such as design, construction and maintenance.

PROBLEM STATEMENT AND MOTIVATION

Both the deep in-place recycling process and the treatments used in combination with this process (emulsion and foamed bitumen treatment) have been applied successfully to the rehabilitation of roads. However, the benefits of rehabilitating roads in this manner have thus far not been assessed. Some research has been performed to determine the material properties and structural behaviour of these materials. Aspects such as the durability of materials treated in this manner, however, also need to be investigated and this is especially important where cement or lime has been added to the material either for improving the structural capacity of the layer or for assisting in the bituminous binding process. The objective of this study is to gain an understanding of the behaviour of materials treated with cement, foamed bitumen or bitumen emulsion in terms of durability in order to develop comprehensive guidelines and design procedures for the optimal use of these materials.

The Concise Oxford Dictionary defines durability as “lasting, resisting wear or decay”. Road layers stabilised with pozzolanic stabilisers such as cement, lime, slagment etc. have sometimes failed due to durability problems, mostly caused by the ingress of water and/or air into the layer. It is therefore necessary to determine whether layers constructed by deep in situ recycling and stabilised with these products will exhibit durability problems and, if necessary, ways of overcoming this.

The existing requirements and specifications for materials treated with pozzolanic stabilisers are based almost entirely on strength requirements after 7 day curing, with little attention being paid to the long-term durability of the material. Research has shown little correlation between durability and strength and has identified the ability of a stabilised material to lose strength under certain environmental conditions, namely, wetting/drying and carbonation. It is important that this strength reduction, in terms of the residual unconfined compressive strength, is not such that the structural capacity of the layer becomes inadequate for the applied loads. Many instances of distress or failure of pavements containing lime or cement stabilised layers have recently been attributed to unsatisfactory durability of the stabilised layers.

METHODOLOGY

This proposal describes testing to determine the durability of materials treated with various amounts of cement and foamed bitumen or bitumen emulsion and combinations of these for deep in situ recycling. This information will ultimately form part of a design guidelines and a material design method for these materials.

The testing required for determining the durability of emulsion/cement and foamed bitumen/cement treated materials is outlined below.

<u>Materials</u>

Much of the research to date has been performed on the recycled cement treated base and subbase materials from the HVS site on Road 243-1and testing will be limited to this material at this point. It will be advisable to perform the suggested tests on various material types found in South Africa and commonly used in road construction, at a later stage.

Durability tests

The commonly used test method for determining durability is the mechanical wet/dry brush test, as modified by Sampson and Ventura. The erodibility test developed by De Beer also gives a good indication of the particles tendency to erode (become loose) and pump. The mechanical wet/dry brush test simulates the loss of cementation due to continued wet/dry cycles in the pavement whereas the erosion test simulates the grinding action of pavement layers in the presence of water pressure. For erosion and durability problems to occur in pavement layers the ingress of water and air is also necessary, therefore the more permeable the layer the more susceptible it will be both to erosion and durability. Permeability tests (using water or air) give an indication of this possibility. A residual unconfined compressive strength (RUCS) test is also suggested as this gives an indication of the structural capacity of the treated layers after the material has been subjected to carbonation, a failure mechanism identified by Netterberg, Sampson and Paige-Green in their investigations of various stabilized base course failures. For reasons of expediency and cost only the erosion potential and permeability of the untreated and treated material will be tested at this point.

Testing

It is suggested that both the Erosion Test and the Constant Head permeability test be done on the treated and untreated materials as given in the Table below, which means that five tests of each will be carried out.

Chemical agents

Mainly three types of chemical agents are to be considered. These are bitumen emulsion, foamed bitumen, cement and combinations of these. The bitumen emulsion will be a 60 % anionic stable grade. The cement will be normal ordinary Portland cement (OPC) and the foamed bitumen will be that used in the foaming process at the HVS site.

Compaction

Compaction of the mixed material will be done at 100% Mod AASHTO.

Curing and Testing

The standard curing time of seven days as prescribed by the test methods will be used.

PROJECT COST

Table 1: Type and costs of testing

OPC content (%)	Foamed Bitumen content (residual) (%)	Emulsion content (residual) (%)	Erosion potential tests	Permeability tests	Costs (R)	
					Eros	Perm
0	0	0	1(3reps)	1	2130	250
2	1.8	0	1(3reps)	1	2130	250
2	0	1.8	1(3reps)	1	2130	250
1	3	0	1(3reps)	1	2130	250
1	0	3	1(3reps)	1	2130	250
Total test costs					10650	1250
Running Costs					2800	
Total testing costs					**14700**	

Human resource costs

The human resource costs are set out in the Table below.

Table 2: Human resource costs

Task/ Activity	Person Responsible	Cost (R)
Project planning and supervision	D Ventura	8 400
Data processing and interpretation	D Ventura	5 600
Report	D Ventura	14 000
Review	H Theyse	3 392
Total costs (human resources)		**31392**

Total project cost:

Testing	R 14 700
Human Resources	R 31 392
Total	R 46 092
VAT	R 6 453
TOTAL	**R 52 545**