ESTABLISHMENT OF APPROPRIATE SLURRY SEAL DESIGN METHODS FOR SOUTH AFRICA

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Abstract

Slurry is used widely in southern Africa as surfacing seals, texture treatments and as part of Cape Seals in the rural and urban environments. Several concerns were raised by industry regarding the appropriateness of the modified Marshal method for the design of slurries, as published in TRH3 (SANRAL,2007) and resulted in the publishing of SABITA Manual 28 (Design and Construction of Slurry Seals and Microsurfacings).

This paper provides the background to and results of investigations leading to the recommended design processes, as published in Manual 28. These included evaluation of different design methods, a synthesis on Cape Seals in southern Africa, testing the effect of aggregate with different fines content and testing the effect of twenty two different cement types on slurry consistency.

1 INTRODUCTION

Slurry is used widely in southern Africa as surfacing seals, texture treatments and as part of Cape Seals in the rural and urban environments. Several concerns were raised by industry regarding the appropriateness of the modified Marshal method for the design of slurries, as published in TRH3 (SANRAL, 2007) and resulted in the publishing of SABITA Manual 28 (Design and Construction of Slurry Seals and Microsurfacings).

Following investigation into the current practice of slurry design and publishing of a first draft document, seminars were held across South Africa to obtain feedback from practitioners. Feedback from these seminars were incorporated into the final document and concerns further investigated.

This paper provides the background to and results of investigations leading to recommendations as published in SABITA Manual 28. These included evaluation of different design methods, testing the effect of aggregate with different fines contents, a synthesis on Cape Seals in southern Africa and testing the effect of twenty two different cement types on slurry consistency.

2 SLURRY TYPES AND USES IN SOUTH AFRICA

2.1 Composition

Slurry is a homogenous mixture consisting of:

- Fine aggregate (Normally crusher dust) , or where required to satisfy grading requirements and permitted, a blend of crusher dust and a limited percentage approved sand)
- Stable grade bitumen emulsion (anionic or cationic) or a modified emulsion
- Filler (usually cement or lime)
- Water
- Additive (to facilitate more rapid curing in case of rapid setting slurry)
- Polymer (in case of Microsurfacings)

2.2 Slurry types and uses

Slurries are typically used for:

- Initial and reseals
    - Coarse slurry seals or Microsurfacings, normally with thickness of 6 mm – 15 mm
    - Cape seals, with the slurry filling the voids in a single seal matrix
- Pre-treatment and routine maintenance actions
    - Texture treatments to obtain a uniform texture depth before reseal with single sized stone
    - Rut filling using Microsurfacing

  - Edgebreak repair
  - Covering new structural patches
  - Seal damage repair
  - Holding actions

3 HISTORICAL DESIGN APPROACHES

Different methods of slurry design have developed in South Africa to determine the appropriate binder content for specific materials and purposes. The methods used are as follows:

- Modified Marshal method 1 as described in TRH3 (SANRAL, 2007)
- Variation to the TRH3 described method in terms of preparation of the briquettes – not officially documented
- Western Cape Provincial Government Method (WCPA, 2010)
- Gautrans Design Method (Gautrans, 1992)
- Colas Method (Not previously officially documented)
- Binder film thickness selection (ISSA approach)
- Wet track abrasion test (ASTM 3910)

Where as some methods required compaction of briquettes at different bitumen contents, others merely required a grading analysis and selection of an “appropriate” binder content.

For the Modified Marshall methods, the key to the appropriate binder content was not only in the numeric results obtained, but also in detailed visual evaluation of the specimens.

Although the recommendations from the experienced practitioners seldom resulted in less than optimum surfacings, it was felt that the art of interpretation was too complex for general practitioners.

Following several discussions on this topic, consensus was reached that:

- The Wet Track Abrasion Test should be used to obtain a minimum binder content
- The Colas method is a simple, but appropriate method that could also be done by site laboratories to determine an appropriate binder content
- For low traffic volumes and aggregate gradings within the standard envelopes, the Gautrans binder selection graphs are appropriate. These graphs were developed by a team of practitioners based on trials and experience.

  Notes:

  The graphs have been adjusted according to standard TRH3 traffic parameter “Equivalent Light Vehicles per lane per day” and the “Gautrans” climatic areas converted to the Weinert N climatic areas (Weinert, 1985)

  Current practitioners were of the opinion that the recommended “appropriate” binder contents are unnecessary high. These areas on the graphs are now shaded in red as shown in Figure 1.

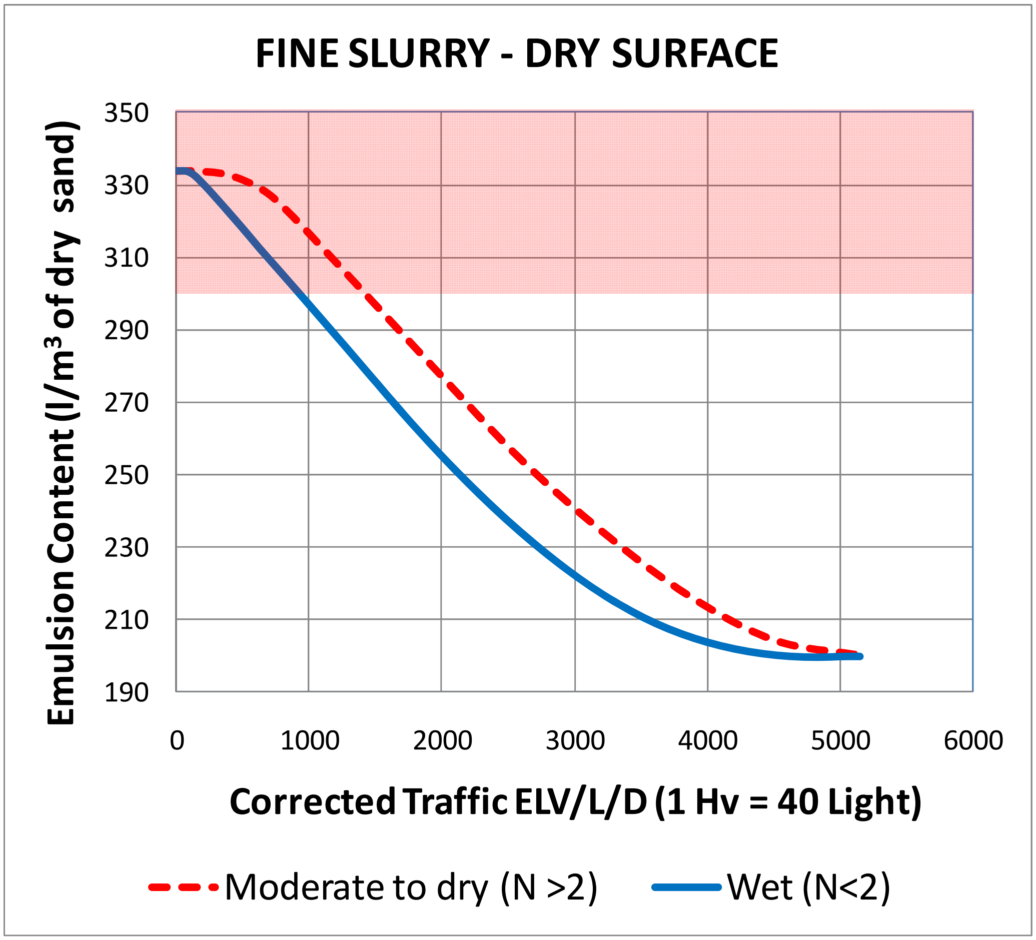

Figure 1 Adjusted Gautrans Design Graph (Example)

4 SPECIAL INVESTIGATIONS

4.1 Effect of fines content

During final discussions with practitioners, concerns were raised that much time is spent, prior to aggregate delivery and construction, to sample materials, to transport these samples to specific laboratories and to do testing and interpretation of results. The grading of materials delivered to site, within the COLTO specification, often varies greatly from the samples used for design. Uncertainty regarding the applicability of the design then results in a need for re-design and additional time.

In order to evaluate the impact of grading changes for on-site adjustment, a study was carried out, varying the percentage of fines (minus 0.075mm) in the mix from 5% to 12% and the binder content from 5% to 12%.

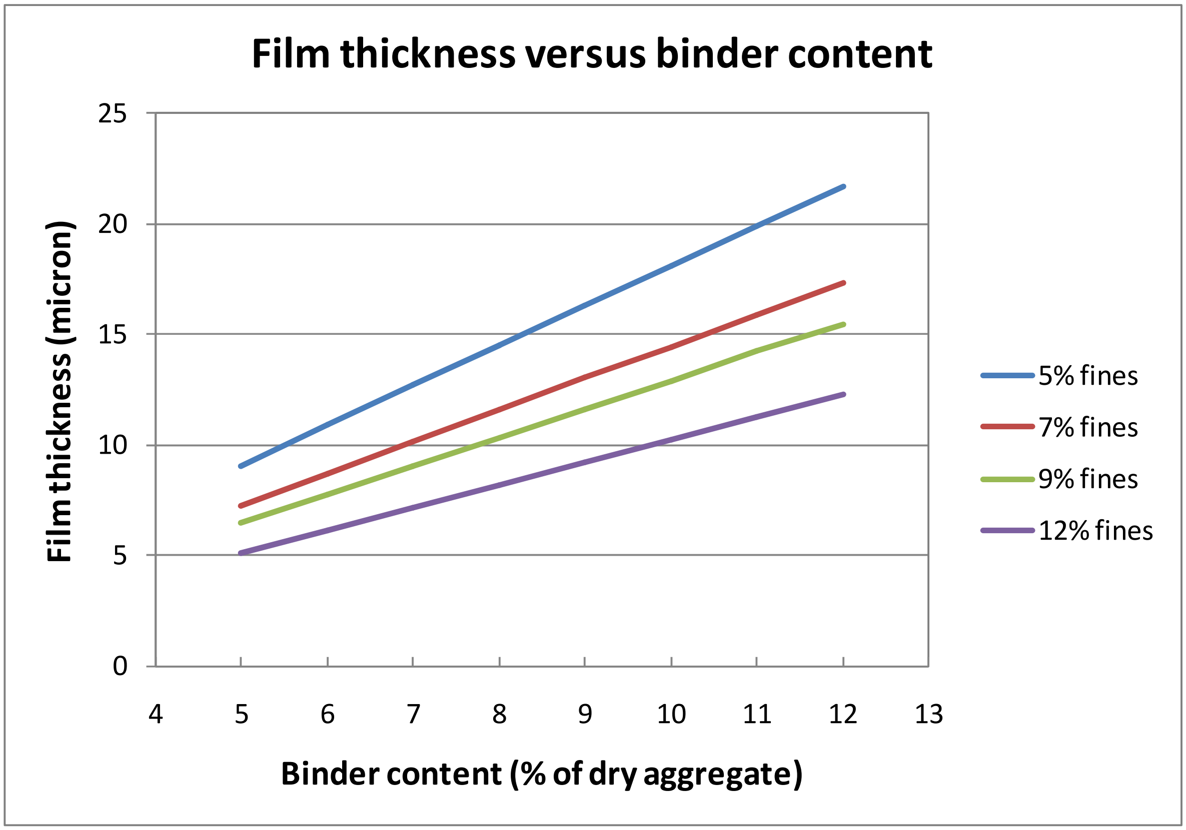

Figure 2 Film thickness versus binder content

Results obtained indicated that significant adjustments could be required to obtain a target film thickness when the fines content of delivered materials vary from the design samples.

Using the Colas method of compacting briquettes with the different fines content and bitumen content at 60 ^{o}C and evaluating the visual appearance, zones of expected good and poor performance were identified, as shown in Figure 4

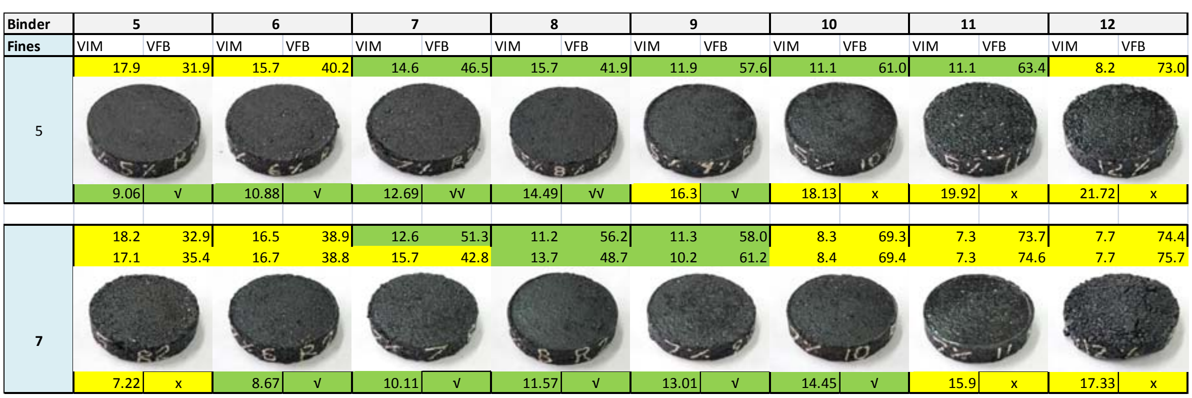

Figure 3 Assessment of compacted samples

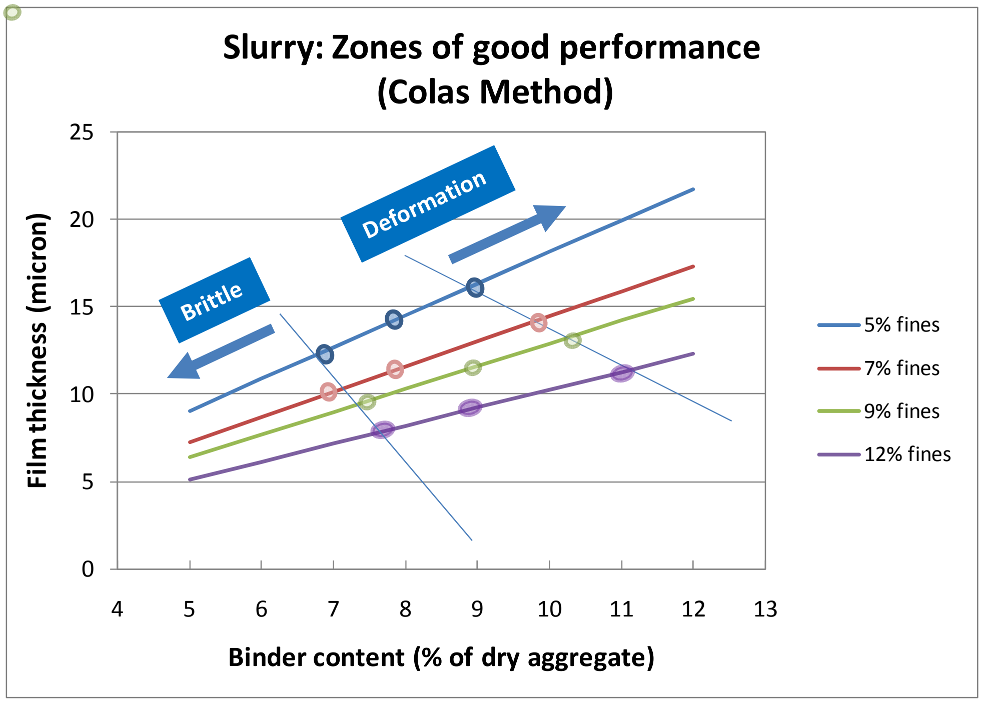

Figure 4 Zones of expected performance

Wet Track Abrasion Tests were performed on all the samples. The border between the "Brittle" and "Good" performance zones, coincided well with the start of the stable mass loss binder contents (refer Figure 5).

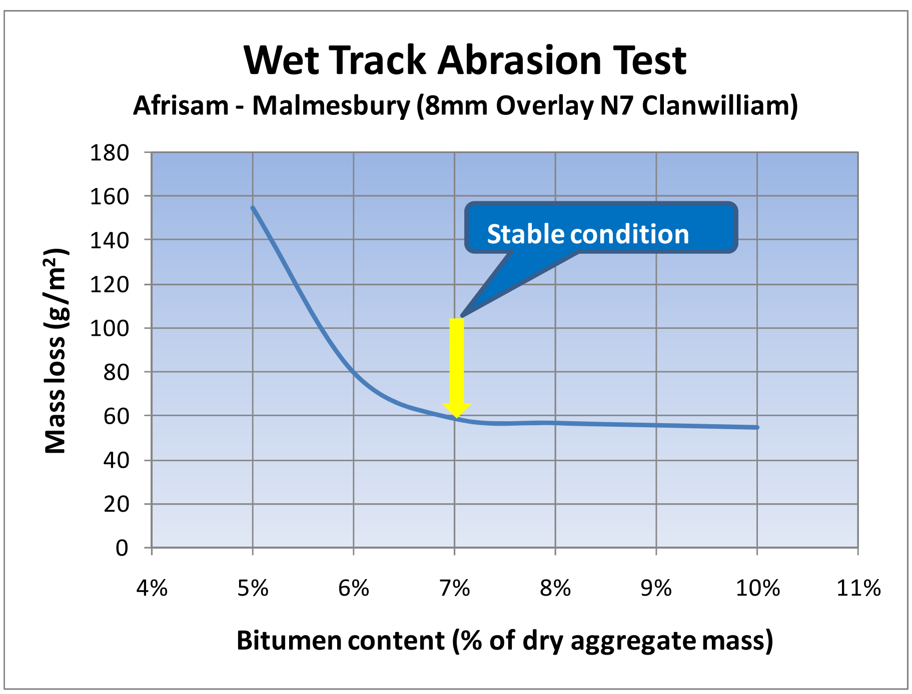

Figure 5 Wet track abrasion test

The conclusion drawn from this study is that the fines content makes a significant change to the appropriate binder content but, that “Colas test method” is a sufficiently reliable method to make adjustments on site.

4.2 Synthesis on Cape Seals

The Cape Seal was originally developed in the Cape Province of South Africa and is still used with great success, mainly as an initial construction seal but often now also as a reseal, specifically where heavy vehicle turning actions are expected or where the maintenance capability of the responsible road authority is suspect. Due to several reasons, variations to the original Cape Seal have been applied and are in the majority of cases, considered to be successful.

Due to the variation currently applied, it was considered necessary to compile best practice for design and construction, as obtained from the experience of several practitioners in southern Africa. A paper on this topic was published at the 2nd Sprayed Seal Conference in Melbourne, Australia, 2010 (Van Zyl and Van Niekerk, 2010)

The initial Cape seal consisted of a single-sized 19.0 mm aggregate, openly spaced to allow two hand applications of a fine slurry.
The binder application for the coarse aggregate (19.0 mm) is split into a tack coat using either hot binder e.g. 80/100 Pen Bitumen or bitumen emulsion and a cover spray consisting usually of a diluted emulsion. The recommended application rates are determined from documented design methods taking into account the size of the aggregate, traffic and geometry of the road.
The binder content of the slurry as originally specified by the Cape Province is considered by many practitioners to be on the high side e.g.:

- First layer – 14% Emulsion by mass of the dry aggregate (60% Anionic Stable grade emulsion)
- Second layer – 20% Emulsion by mass of dry aggregate

The typical total slurry application is 125 m^2/m^3 with approximately 66% of the volume applied in the first layer

Variations on the typical Cape Seal in southern Africa include:

- Use of other aggregate sizes - from 9,5 mm up to 37,5 mm
- Aggregate spread rate to obtain an open or dense shoulder to shoulder matrix
- Application of one, two or three (in case of large aggregate) applications of slurry
- Use of different slurry aggregate gradings
- Use of different binder types, including modified binder, in the tack coat
- Use of unprecoated or precoated stone with or without a cover spray

- Replacing conventional slurry with rapid setting slurry
- Application of slurry by hand or with a spreader box

Almost all binders available in South Africa have been used for tack coat application and include:

- 80/100 pen
- 150/200* (not currently available in South Africa)
- MC 3000** (not recommended by experienced practitioners due to high cutter content)
- Cationic 65 Spray grade
- Stable grade emulsions, both anionic and cationic
- Homogeneous hot polymer modified binders S-E1 and S-E2
- Non-homogeneous polymer modified binders S-R1 (Bitumen Rubber)
- Polymer modified emulsions - SC-E1 and SC-E2 (typically 5% polymer 70% emulsion)

The most common defects occurring on Cape Seals are:

- Cracking due to oxidation and hardening
- Raveling due to low slurry binder content or high proportions of natural/ rounded sand
- Fattiness with main reasons recorded being:
    - Embedment of the coarse aggregate as with chip seals
    - Too high binder content in the slurry either through design/ construction or not taking account of the bulking due to moisture
    - Too high binder application in the tack coat
    - Cutters in the prime coat, tack coat, or slurry emulsion
    - Wet precoating
    - Application of the slurry before the emulsion tack coat has cured
    - Segregation of the slurry due to movement over too long distance or too coarse grading for the available voids
    - Combination of factors increasing the eventual binder content in the slurry and upward migration to the surface
    - Too high tack coat application rate and wrong binder type
    - Aggregate spread too open for high traffic volumes

The conclusions drawn from this study is that Cape seals could perform well in both high and low traffic environments provided that the design and construction method is adapted for the expected circumstances. Factors to be taken into consideration are:

- Method of slurry application (By hand or spreader box)

In case of base irregularities the possibility exists that the slurry will cover the aggregate if applied with a spreader box. In such a case the binder content should be lower to prevent fattiness. (Refer Figure 6)

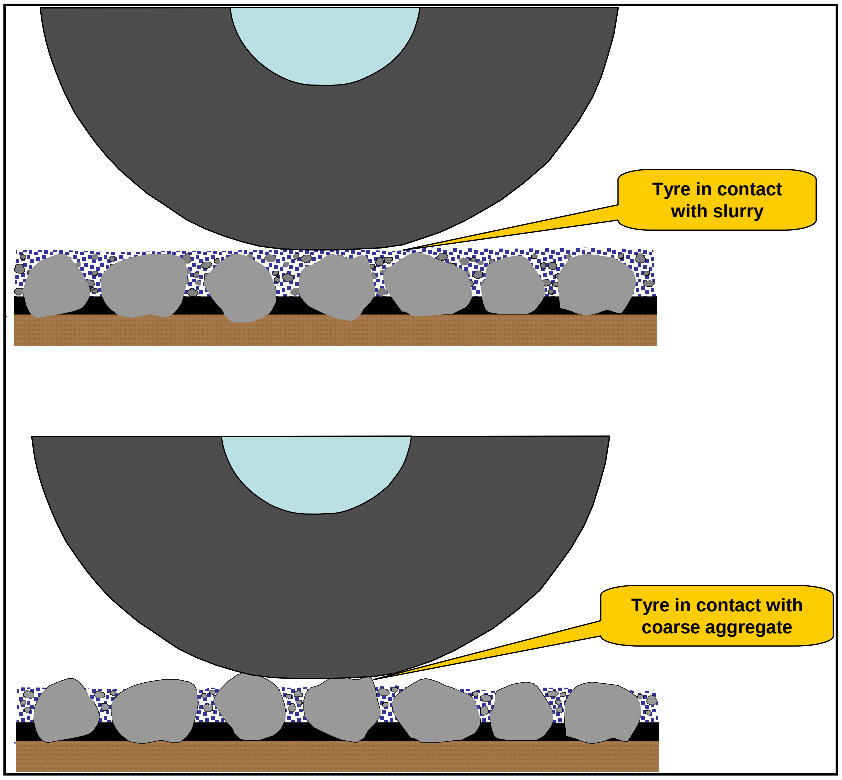

Figure 6 Impact of spreader box and hand application

- Contact of the slurry with the tack coat, cover spray, precoating and wheel load

Figure 7 shows a situation where the single sized aggregate is openly spread, a cover spray is applied and the slurry is in direct contact with the wheel. The kneading action forces the tack coat binder into the slurry mix resulting in excess binder on the surface. The situation is aggravated when cutters are present in the tack coat, cover spray or precoating.

Figure 8 displays a situation where a hot binder, without a cover spray, is used with dry precoated stone, densely spread (shoulder to shoulder) with the slurry not in direct contact with the wheel load. The internal friction between the stone particles also assists to minimize movement and hence, less kneading of the slurry.

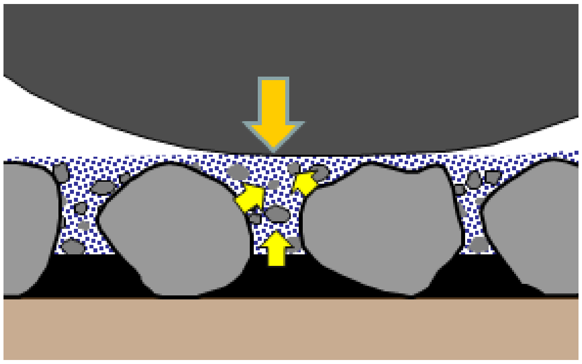

Figure 7 High slurry interaction

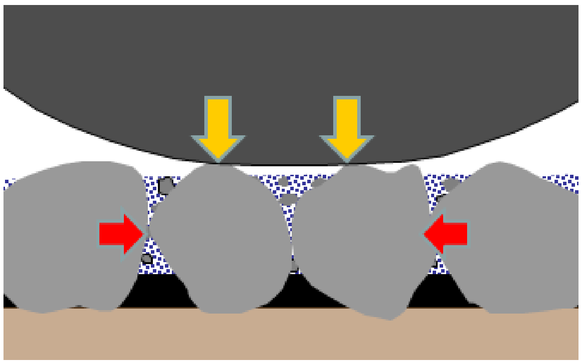

Figure 8 Low slurry interaction

- Quality and availability of equipment

  Although it is preferred and often specified to use self-propelled chip spreaders, these are not always available resulting in the need to adjust designs for the conditions at hand. Over chipping of the single sized aggregate as shown in *Figure 9* makes it impossible to obtain an open matrix to accommodate two layers of slurry or, even one layer of medium graded slurry on a 13,2 mm Cape Seal.

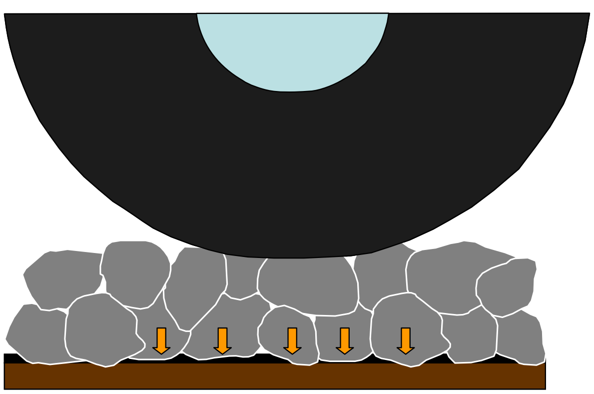

Figure 9 Poor compaction due to over-chipping

- Traffic volume and load

Initial 19 mm Cape Seal were designed for relatively low traffic volumes (500 – 100 vehicles per day) with an open texture and high binder slurry (14 – 20 parts of emulsion per 100 parts of dry aggregate). The slurry was worked into the voids by hand, using a squeegee resulting in no or little direct contact with the wheel loads. The high binder slurry also assisted in low permeability and durable surfacing.

Designing for high traffic volumes requires a different approach to select a Cape Seal structure and slurry system that would minimize fattiness but prevent aggregate loss/ ravelling. Although limited work was done using aggregate sizes larger than 19 mm, several 19 mm Cape Seals have been constructed with success carrying in the order of a 1000 heavy vehicles per lane per day. The key lies in minimizing embedment and minimizing free binder to interact with the "Dry slurry".

4.3 Effect of cement type

4.3.1 Background

Concerns were raised by some practitioners regarding the effectiveness of different cement types.

Normally 1 to 2% cement by mass of aggregate is added to the slurry to improve the workability of the mix and enhance the ease of application. There are 4 cement manufacturers in South Africa who supply cement from 11 different factories. Portland cement samples were obtained from all the sources to evaluate the degree of interaction between the different general purpose (CEM) cements and the general slurry grade emulsions available in the South African market. The general interaction between cement and the three slurry systems being used in South Africa is discussed below, as well as the outcome of the tests performed with the Portland cement sourced from the various suppliers.

Due to the varying Calcium Oxide contents of the various Portland cements available, a study was initiated to evaluate the thickening effect of the different types of CEM cements with anionic and cationic stable grade emulsions. The medium graded crusher dust used for the evaluation was of quartzitic origin and 1% cement by mass of aggregate was used to prepare the slurries. All the slurries contained 15% emulsion and 11% water by mass of aggregate. No tests were performed with microsurfacing emulsions. The following parameters were evaluated for slurries prepared with both anionic and cationic stable grade emulsions:

4.3.2 Consistency

The consistency test was performed using the method prescribed in ASTM D 3910.
The prepared slurry is placed in a small cone on a plate with graduated concentric circles. The slurry is allowed to flow out of the cone and the degree of slump, measured in millimetres, is an indication of the consistency of the mixture.

4.3.3 Viscosity

The viscosity was measured using a Stormer viscometer (ASTM D562), which is a rotational viscometer used for determining the viscosity of paint and other heavy-bodied compounds. It consists of a paddle type rotor that is spun by an internal motor. The rotor speed can be adjusted by changing the amount of load supplied onto the rotor. A fixed load was applied for all the slurry samples evaluated and the time required to rotate the rotor for a fixed number of rotations was established. A higher viscosity slurry would thus require a longer period to complete the fixed number of rotations.

A comparison of the consistency (flow) and viscosity results appear in the graphs below:

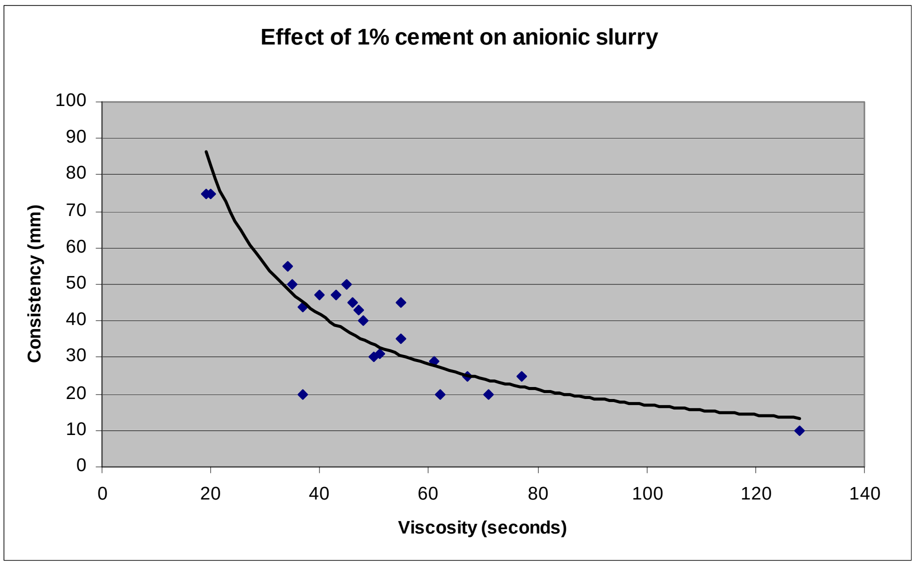

Figure 10 Anionic Slurry (Consistency versus Viscosity)

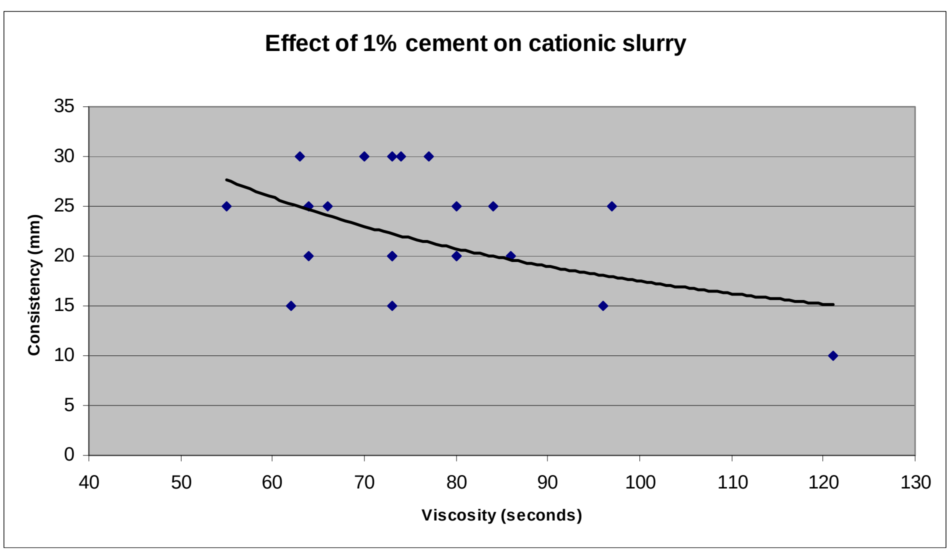

Figure 11 Cationic Slurry (Consistency versus Viscosity)

From the above results it is clear that there is a reasonably good correlation between the consistency and viscosity results obtained on slurries prepared with anionic emulsion. The correlation obtained on the cationic slurries, was not so good. The most important information gleaned from these results is that the consistency of slurries prepared with cationic emulsion, is considerably higher than the equivalent anionic slurries.

4.3.4 Relationship between calcium oxide content and consistency

The CaO content of the cement used in the evaluations was obtained from the suppliers.

Due to the ASTM D 3910 Consistency test (Flow) being a standard test done on site, the relationship between CaO content and flow was determined. The results are shown in Figure 12, with the effect of CEM I cements on anionic emulsions highlighted in yellow.

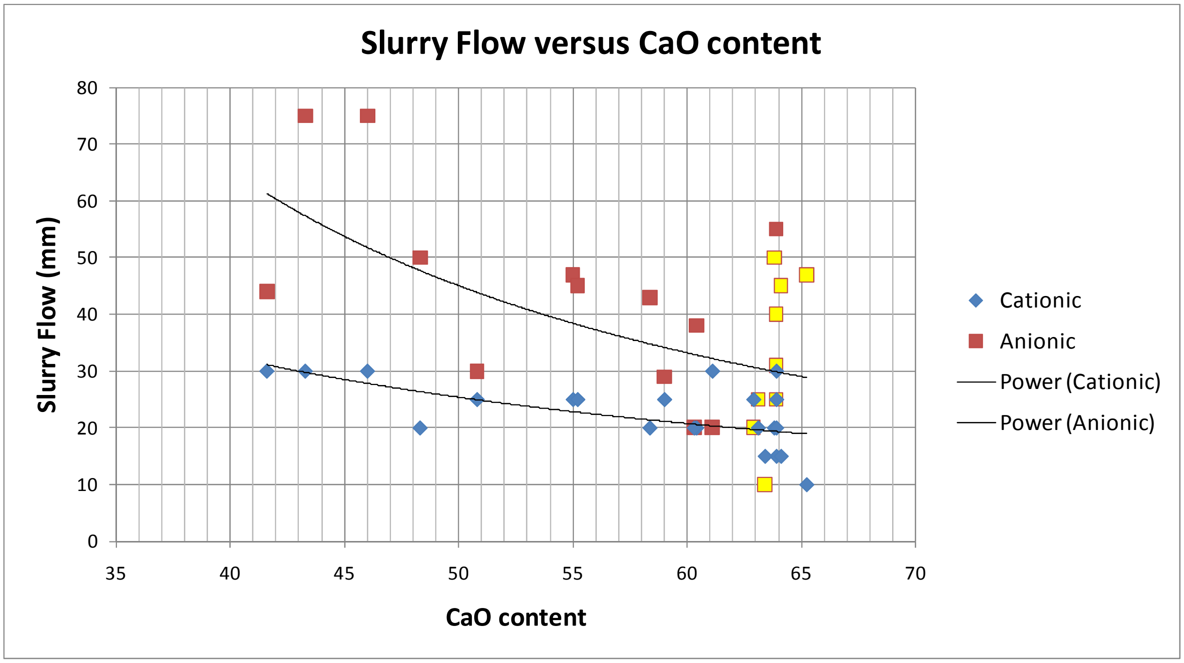

Figure 12 Consistency (Flow) versus CaO content

Important conclusions drawn from these results are that:

- Cationic emulsion slurries have a higher water demand to obtain a specific flow, resulting in potential higher permeability of the slurry
- The flow obtained with CEM I cements from different sources react differently, specifically with anionic emulsions, resulting in the recommendation that re-evaluation of the water demand is required when cement is obtained from a different source

No real evidence could be found during this particular study that the CEM V cements are not effective. Mixing tests indicated that it still reacts with the emulsion to obtain a creamy mix. However, as shown on Figure 12, the CEM V cements could produce a very high flow with anionic emulsion, which could result in a sensitivity to segregation.

5 CONCLUSIONS

This paper provides some background to the selection of appropriate design procedures for slurry surfacings in South Africa as well additional information regarding the effect of different fines contents in mixes, a synthesis on Cape Seals in southern Africa and the effect of different types of cement on slurry mixes.

6 REFERENCES

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KEY WORDS

Slurry, Microsurfacing, SABITA manual 28