South African Experience with In situ Recycling with Bitumen Emulsion and Foamed Bitumen

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Summary

The bulk of the South African road network was constructed in the 1960s and 1970s. At present, only a small percentage of available funds is allocated to the construction of new roads, the majority of funds being spent on rehabilitation of the existing road network. New strict environmental laws, together with depletion of natural resources for road building materials, forced road managers and pavement designers to seriously consider the use of recycling techniques.

South Africa has more than 20 years' of experience in the use of bitumen emulsion for the rehabilitation of granular layers. The arrival of new, sophisticated deep in situ recycling machines, offering high speeds of reconstruction and thus minimizing disruption to traffic, made this technique, as well as the use of foamed bitumen, very attractive. In recent years, quite a number of deep in situ recycling projects have been undertaken using small amounts of bitumen (about 2 %) and cement, either in the form of foam (FTB) or emulsion (ETB). The majority of them were successful but some were not. It has been realized that deep in situ recycling process is not as simple as it first appeared; it is not a "quick fix". However, it is an effective technique when carefully controlled.

In South Africa, due to the high unemployment rate, job creation and the development of small, micro and medium entrepreneurs (SMMES) receive high priority. The road authorities and construction industry help to fulfill these objectives by using labour-intensive construction (LIC) methods. It has been proven that the LIC can be used successfully on recycling projects using either emulsion or foamed bitumen.

This paper addresses problems encountered in the design and construction of recycled flexible pavements using both machine and labour-intensive construction methods, and offers solutions.

1. INTRODUCTION

The bulk of the South African road network was constructed in the 1960s and 1970s. At present, only a small percentage of available funds is allocated to the construction of new roads, the majority of funds being spent on rehabilitation of the existing road network. New strict environmental laws, together with depletion of natural resources for road building materials, has forced road managers and pavement designers to seriously consider the use of recycling techniques.

South Africa has more than 20 years' of experience in the use of bitumen emulsion for the rehabilitation of granular layers. The arrival of new, sophisticated deep in situ recycling machines, offering high speeds of reconstruction and thus minimizing disruption to traffic, made this technique, as well as the use of foamed bitumen, very attractive. The majority of roads in South Africa consists of either lightly cemented or crushed stone base layers covered with thin surfacing (chip seal or asphalt concrete overlay). These types of pavement can easily be recycled. In recent years, quite a number of deep in situ recycling projects have been undertaken using small amounts of bitumen (about 2 %) and cement, either in the form of foam (FTB) or emulsion (ETB). The majority of them were successful, but some were not. It has been realized that the deep in situ recycling is not as simple as it first appeared; it is not a "quick fix". However, it is an effective technique when carefully controlled.

This paper addresses problems encountered in the design and construction of recycled flexible pavements using both machine and labour-intensive construction methods, and offers some solutions.

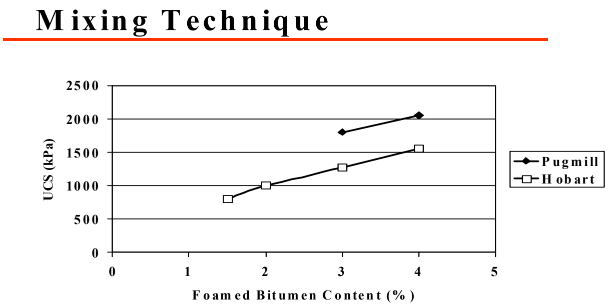
This paper is based mainly on an investigation and research on foamed bitumen treated layers funded by the Gauteng Department of Public Transport, Roads and Works and the South African Bitumen Association (SABITA). I would like to acknowledge the project team: Dr. Fenella Long and Hechter Theyse from CSIR, Transportek, Prof. Kim Jenkins from University of Stellenbosch and Dave Collings from Loudon International. The investigation resulted in **Interim Technical Guidelines: The Design and Use of Foamed Bitumen Treated Materials**, published by the Asphalt Academy, Technical Guideline 2, September 2002. This paper is based on this work.

2. ISSUES RELATED TO THE DESIGN

The majority of recycling projects constructed recently with foamed bitumen were designed for the use of bitumen emulsion. Economic factors forced the designers to use foamed bitumen. Foamed bitumen has an advantage over emulsion because of the lower transport cost. In situations where contractors offered a lower price for recycling with foamed bitumen, the question was raised if the same design method can be used for foamed bitumen and emulsion. As industry moved into the use of foamed bitumen with the high speed recyclers, many other questions were raised. Some of them are listed below.

2.1 Lack of laboratory mixers simulating field conditions

The mixing of bitumen mixes is a very dynamic process. The foamed bitumen collapses rapidly once in contact with cold aggregate. Different laboratory mixers can produce material samples with up to 25% difference in strength properties as shown in the graph. Therefore, it is very important to use a laboratory foaming plant and mixer that simulate the field conditions.

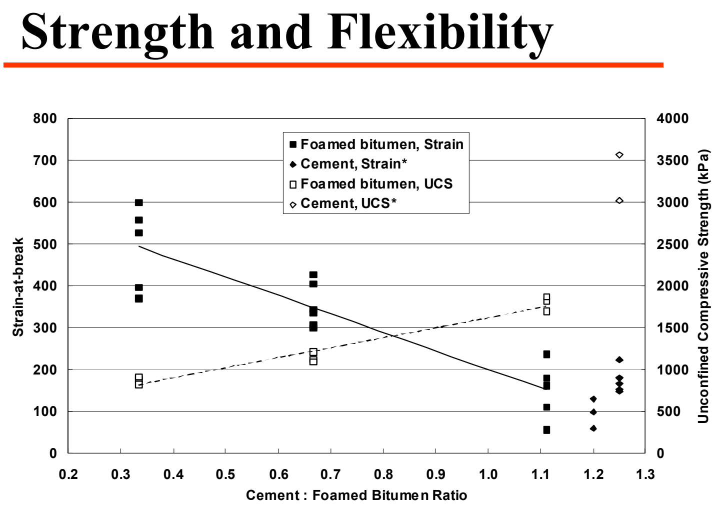


The rotary mixing motion of the blenders used in the laboratory mixers (see the photos below) is not ideal to simulate site mixing and is often causes segregation of the aggregate. The field mixing process includes twin-shaft pugmills, drum-mixers, free-fall mixers and milling-drum mixers. These devices all provide sufficient volume in the mixing chamber and energy of agitation to ensure that the aggregate is airborne when it makes contact with the foamed bitumen.

A mixing time of 30 seconds is generally used in the laboratory, which is longer than in situ mixing. Due to the lack of appropriate laboratory mixers in South Africa, CSIR Transportek is designing and manufacturing a new type of mixer, shown below, to enable better simulation of field conditions.

2.2 Determination of optimum ratio of bitumen and cementitious binders

The type of recycled material and design traffic volume influence the amount of bitumen and active filler, such as cement or lime required in the mix. The end product can be a granular, cemented or visco-elastic material. Granular type mixes contain a small (< 2%) of bitumen and little (<1%) or no active filler. Cemented type foam bitumen mixes contain a moderate amount of an active filler (1% to 2%) and a small (<2%) amount of bitumen. Visco-elastic mixes are produced by adding moderate to high (>2%) amounts of bitumen with little (<1%) active filler. The strength of the material (UCS) will increase by adding active filler but flexibility will decrease (see the graph). Flexibility will increase by adding bitumen but then the strength may decrease. It is very important to find the optimum active filler to bitumen ratio for each specific design.



2.3 Appropriate performance tests

The shear strength parameters and tensile properties of foamed bitumen treated materials play an important role in the long-term performance of these materials because of the interaction between the resistance to permanent deformation and flexibility of those mixes. The permanent deformation is measured with trialaxial test and the flexibility with a flexural beam test. In practice these tests are seldom feasible due to time and financial constrains. Therefore, the Unconfined Compressive Strength (UCS) and Indirect Tensile Strength (ITS) tests are accepted as cost-effective alternatives and are used during mix design. The table provides criteria for the foamed bitumen treated material classification system, used in South Africa, in terms of the UCS and ITS values. This approach is an attempt to capture the complex behavioural characteristics of foamed bitumen treated materials.

Foamed bitumen mix classification

Material Code		ITS (kPa)	
		100-300	300-500
UCS (kPa)	700 -1400	FB4	FB3
	1400-2000	FB2	FB1

2.4 Pre-design pavement investigation to assess variability of material properties

The fact that modern recyclers can move very quickly has also disadvantages. There is no time for corrections to the design to be made during construction. Therefore, the pre-design investigation should be very thorough. Possible changes in the type of material, and its properties such as moisture content, grading and previous maintenance (patching) should be taken into consideration during the design. Often the frequency of material sampling should be higher for construction with recyclers than for conventional construction.

2.5 Sampling of material

In the design phase, unless a large recycler is used for sampling, the grading of the recycled product can only be estimated from samples of the existing pavement. Mix designs are usually carried out on material broken down in a mini laboratory crusher and the resultant grading is invariably coarser than that achieved when recycling, and therefore the design phase laboratory test results are conservative. Recycled cement treated materials and RAP seldom generate a sufficient amount of fines (<0.075mm) during recycling, which are very important for foamed bitumen treatment. It is a good practice to recycle a section of road without any additives for the laboratory mix design.

2.6 Differences between the resultant products using emulsion and foam bitumen

Research consisting of comprehensive laboratory and accelerated pavement testing carried out in South Africa shown that there are no significant differences between the end products of material recycled with the use of emulsion and foamed bitumen. The use of foamed bitumen is preferred in the following cases:

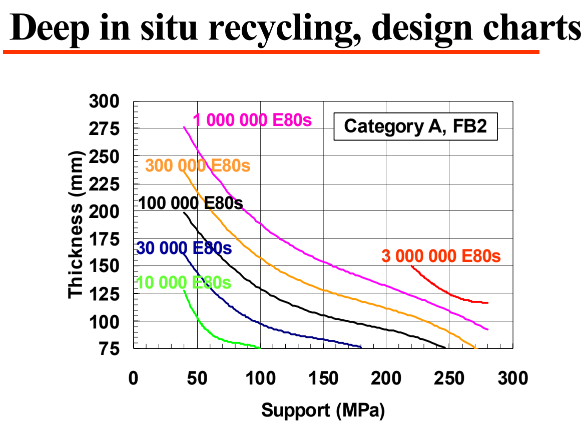
- early opening to traffic
- high initial moisture content

The use of emulsion is preferred in the following cases:

- local bitumen has inadequate foaming properties and use of foaming agents is required
- material temperature is lower than 15 C
- inadequate fines in the material

2.7 Mechanistic empirical design method

In South Africa (SA) a mechanistic empirical method is used to design pavements. Until recently this method could not be used for emulsion or foamed bitumen treated layers, as the mechanistic-empirical models for these materials were not available. This year, data generated from advanced laboratory tests and accelerated pavement tests using the Heavy Vehicle Simulator (HVS) were used to develop the mechanistic-empirical models for foamed bitumen treated materials. Design charts were developed for four road categories (different design reliability), and for FB2 and FB3 class of material. An example of a design chart is shown. The equivalent mechanistic-empirical models for emulsion treated materials are currently being developed.



3. ISSUES RELATED TO CONSTRUCTION

Treating a material with foamed bitumen can be achieved either “in-plant” by feeding the material components through a mixing unit or “in-place” using a recycler. In-plant mixing is normally considered for new roads or upgrading projects that require additional structural layers and for labour intensive construction.

In place recycling became popular due to the advent of modern powerful recycling machines, which allow quick pavement rehabilitation and thus minimum disruption to traffic. Unfortunately sometimes these recyclers are seen as “magic boxes” and quality control is neglected. In certain cases a lack of experience and understanding of the recycling process resulted in premature pavement failures. Some of the problems encountered during construction of foamed bitumen treated layers in South Africa are discussed below.

3.1 Awareness of the differences between conventional recycling with the use of graders and in situ recyclers

The recyclers do not “cross- or forward-blend” (less than 200mm cross blending is expected) therefore material variability, which occurs across the width of the road must be corrected prior to recycling. For the same reason the accurate spreading of cement is a very important consideration. The application rate of cement (or lime) normally applied with foamed bitumen is relatively low (1% to 1.5% by mass). Such low application rates are difficult to achieve accurately when using bulk spreaders. Alternative methods, such as hand spreading should be employed.

3.2 Limited time for corrections due to high speed of recycling

The daily production of the recycling process is relatively high compared to other road construction processes with correspondingly high consumptions of stabilising agents. For the output potential to be realised without compromising quality, detailed planning is essential. The planning should include the recycling work, equipment, logistics and trial sections. For example, the planning should include a detailed cut plan. Important consideration when working with foamed bitumen is the location of the outer wheel-path relative to longitudinal joints (overlaps) between adjacent cuts. Such overlaps often fall in the outer wheel-path when recycling a single carriageway. Standard practice when dealing with overlaps is to reduce the width of application of foamed bitumen by closing off nozzles preferably in the second cut only. Failure to ensure that the outer wheel-path receives the required treatment will result in an under-application of foamed bitumen and premature failure.

3.3 Adequate compaction

The performance of any material depends largely on the density achieved through compaction. Compacting a thick layer of foam treated granular material requires special attention to prevent the top horizon from bridging as shown on the photo.

The material exits the recycler in a relatively loose state and is immediately driven over by rear wheels of the recycler and compacted. It is important that the material lying between the wheel paths is first compacted before being levelled with a grader. Failure to do that will result in a permanent density differential between the material in the wheel-paths and that between the wheel paths.

3.4 Potential lamination caused by pre-compaction under the wheels of recycler

When an additional layer of material is spread over the pre-compacted wheel paths of recycler, lamination may occur due to the lack of cohesion between the pre-compacted material and the loose material. To avoid this, the pre-compacted wheel-paths can be spayed with a diluted bitumen emulsion prior to adding the new material.

3.5 Adjustments to varying moisture

Varying moisture in the in situ pavement must be expected and anticipated when the following conditions are encountered:

- Cracks in the surfacing that allow water to penetrate the pavement
- Where the road has unsurfaced shoulders
- At the bottom of sag vertical curves

It is impossible to accurately predict the moisture content of a pavement before recycling, at the design stage. The only method is to vary the addition of water whilst recycling and to constantly measure and test. This requires a supervisor with sufficient experience.

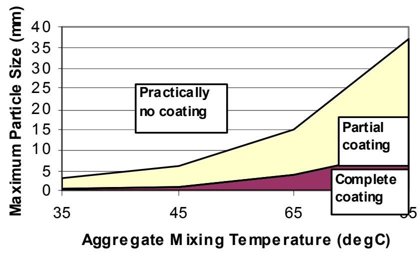
3.6 Control of recycled layer thickness

Although the recycler is equipped with an automatic sensor, the depth of recycling is critical and should therefore be checked on both sides of the cut every 100 metres and any necessary adjustments made. Cognisance must be taken of the increase in surface elevations on the side overlapping the previously recycled material.

3.7 Construction in ambient temperatures below 10° C

The temperature of the aggregate at the time of treatment with foamed bitumen has a significant influence on the degree of coating and the properties of the mix produced. Jenkins showed that an increase in aggregate temperature from 20°C to 65°C results in an increase coating of particles as shown in the graph.

Influence of aggregate temperature on particle coating



Laboratory mixes should be produced at temperatures similar to that expected during field recycling. It is suggested that recycling with foamed bitumen should not take place when the aggregate temperature is lower than 10°C. The quality of the foamed bitumen can compensate for low aggregate temperatures within certain limits, as shown in the table. The foam index is a measure of the combined expansion ratio and half-life.

Foam suitability

Foam Index (sec)	Aggregate 15°C	Aggregate 25°C
<75	Unsuitable	Unsuitable
75 – 100	Very poor	Poor
100 – 125	Poor	Moderate
125 – 175	Moderate	Good
75 – 200	Good	Very good
>200	Very good	Very good

10°C to 15°C aggregate needs FI>500

4. POLITICAL AND SOCIAL ISSUES

In South Africa, due to the high unemployment rate, job creation and the development of small, micro and medium entrepreneurs (SMMES) receive high priority. The road authorities and construction industry help to fulfill these objectives by using labour-intensive construction (LIC) methods. It is a policy in South Africa that on the LIC projects, communities living in the vicinity of the construction site are directly involved in the construction. The labourers have to be selected and trained prior to the commencement of their tasks. The LIC projects should, from the beginning, be designed and planned as such because of vast differences between machine and labour construction.

It has been proven that the LIC can be used successfully for recycling or upgrading of low volume and access roads. A short discussion of LIC related issues follows.

4.1 Quality of road surface finish / riding quality

The riding quality of roads constructed with LIC methods is rather poor due to the simple equipment used for the level control and the use of small compactors.

4.2 Compaction

It is very important not to compromise on the compaction specification as it influences the pavement performance. The required density is difficult to achieve with the use of small compactors.

4.3 Quality control

LIC projects require more frequent quality control and supervision than machine construction due to the employment of inexperienced workers.

4.4 Construction duration

LIC projects take longer to complete.

4.5 Construction cost

The cost of LIC is higher (up to 50%) than machine construction. Contributing factors are the cost of additional supervision, the prolonged safety risk and the cost of traffic delay during the longer construction time.

4.6 Social benefits

The social benefits are very difficult to quantify. The benefits include money paid to the community in form of wages, training given to labourers: experiential and general, development of entrepreneurs (potential future contractors). Till now there is no monetary value attached to the gain of knowledge and experience, as it is difficult to ensure job sustainability.

5. CONCLUSIONS

The recycling, using both in–place recyclers and labor-intensive construction, has been successfully used in South Africa. However, the design and construction of such projects are not as simple as perceived, and therefore need to be carefully executed. This paper discussed some of the problems associated with these projects and presented solutions to these problems, where applicable.