ECONOMIC INVESTIGATION INTO LABOUR BASED SURFACING AND HOT MIX ASPHALT IN LOW VOLUME ROADS

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ABSTRACT

Smaller municipalities in rural towns have small budgets and it is difficult to tar the gravel roads due to budget constraints. It is however causing problems with gravel roads that need to be maintained on a regular basis, for dust control as in any other city. Hot Mix Asphalt plants are situated far from rural townships and transport costs are high to take this product to the rural townships. This requirement forms the basis of the research that was undertaken.

The research problem was to test Labour Based Surfacing (LBS) against Hot Mix Asphalt (HMA) to see which one is more economically viable. With the overall objectives being to provide employment and to tar the rural roads without compromising the specification standards. Cold Mix Asphalt (CMA) should be of similar standard as HMA to comply with all the engineering properties to standard specification on low volume roads.

INTRODUCTION

One of the greatest challenges for any rural municipality is poverty alleviation through job creation. The current unemployment rate in the Cape Agulhas area is 19.5% and increases annually. Thus, this burden falls on municipalities to think out of the box to create jobs through engineering innovation. We therefore have to explore every possibility and the various techniques to alleviate this problem, create sustainable jobs for economic viability, consequently decreasing indigents in the municipality.

Hence we as engineers are compelled to meet the needs of the people and provide service delivery through the above.

Roads are constructed annually due to backlogs, thus the opportunity was seen to do all the construction using labour intensive methods. Therefore the labour-based asphalt method would create more job opportunities. This product needed to be compared to HMA and all engineering properties had to be tested for our engineers to make educated decisions.

This paper deals with the description of LBS. It deals with the significance and applications in the civil engineering industry of the product. It further deals with the cost factor of surfacing, guidelines and specification applicable toHMA.

This project is in Napier, a rural town with 3 500 people, located approximately 180 km from Cape Town. The nearest HMA plant is about 150 km away and 300 km return.

The high cost of bitumen and transport in South Africa as well as the unemployment factor paved the way for optimising employment opportunities through labour intensive construction. Earth and gravel roads are susceptible to environmental damage, therefore the need to tar these roads and create jobs at the same time was of importance. Working with LBS decreases the volume of unemployment because of its high labour requirement of 20 people per team.

This can be realised through the adoptions where technically and economically visible of labour methods of construction, using light equipment, can be used. Labour based technologies that meet the requirements of conventional methods and products are a vital aspect. Engineering properties were evaluated to get decisive evidence on which way to go forward in these rural areas for HMA or LBS CMA.

HMA is proven conventional asphalt that is effective, but reduces the labour component by a huge margin. The equipment used for this asphalt is very expensive and needs to be carted with a low bed truck and for any given HMA at any given site or area, with at least two trips to cart the equipment, making this very expensive for smaller quantities. Experienced personnel are also needed for this asphalt.

Research problem

The transportation price of HMA plants to remote sites, reduction of quantity of surfaced roads in the remote areas. Maintenance problems arise as the small quantities are not cost effective. In the application of HMA mechanically where the labour component is significantly reduced.

OBJECTIVES

The objectives of this research are based on comparative analysis of costing and product performance, and are as follows:

- To quantify the cost effectiveness of the LBS mix versus HMA
- To measure the quality compliance of the mix versus HMA
- To measure social contribution via employment creation during construction of the mix
- To evaluate in service durability of the mix.

In order to determine which material option is economically viable, taking into account the applicable standards, the following approach was followed:

- Durability was compared through a comparative tests performed during the mix design phase by determination of binder content, binder film thickness, air voids, aggregate grading quality, etc.
- LBS CMA application designed as labour intensive road surfacing concept.
- Cost comparison and analysis of real life figures for direct and indirect costs as applicable to both products.

This research can empower municipalities in rural areas to use LBS asphalt as a standard for their roads and pavements that will be more cost effective than HMA. The research will contribute towards the overall objective of the Expanded Public Works Programme which aims to alleviate poverty and create sustainable employment, which is legislation.

There is no standard specification for CMA and engineers as well as clients are very sceptical of this Cold Mix. Economically it is also perceived that the costs of CMA are greater than HMA.

METHODOLOGY

This research mainly focused on the engineering properties of LBS CMA and HMA and their economically viability in rural townships. To achieve this both asphalts needed to be placed on one road 100 metres apart to have the same volume of traffic on both hot and cold mix.

The cost of HMA and the labour component was measured and the Marshall Test was done in the laboratory. LBS CMA was mixed and placed on site with the labour content. The results of the test were plotted on graphs to show the most economical as well as the specification of both products

The following comparative tests were done on HMA and CMA:

- Binder content
- Marshal Stability
- I.T.S. (Indirect Tensile Strength)
- Permeability

Cost comparison of real life figures were also done for direct and indirect cost, to plot and analyse both products.

The test was done in Roos Street, Napier for the Labour Based Asphalt (30mm layer) and HMA in Dirkie Uys Street, Bredasdorp (30mm layer).

Research Design

The mix design and extensive testing of LBS were created by Road Materials Stabilisers to create employment.

Real life examples of LBS asphalt and HMA are used to give an accurate indication of the most viable benefit of the products. Both products were done on the same road and visual testing was to establish the deformation of the road. The section was 100 m in length and 5 m in width for both the LBS and HMA. The laboratory tests were done by the laboratory in Brackenfell and permeability tests were also done for water resistance (TRH 8). Traffic counts were done for two weeks to determine if it conforms to low volume traffic. From this, a proper evaluation could be done and both products compared for economic viability.

Research Methodology

LBS and HMA were done by hand and machine irrespectively during the same week under similar weather conditions. Nuclear gauge on site-testing was done on the HMA to give an indication if the densities pass the test. Samples were taken to the lab and cores were drilled for Marshall engineering testing according to TRH 8. Permeability tests were done on both products on-site and sent to the laboratory for analyses.

Cores were drilled on-site according to TMH1 standards and sent to the laboratory for analyses. The tests which were performed were binder content, BRD, rice test, voids in the mix, stability, flow, stability flow and indirect tensile stress. The tests were undertaken to evaluate the strength and durability of the material.

Permeability tests were conducted on site by the TMH6 method for water resistance and sent to the laboratory. This data was presented in a graphical format.

The mixing procedure for LBS cold mix (shown in figure 3.1) has been achieved using the following sequence of activities:

- Load and place bags of LBS filler at regular intervals.
- Then place the desired quantity of road stone and crusher sand next to each bag of LBS.
- Mix the materials together with the LBS thoroughly and then add the required quantity of bitumen emulsion to each stockpile.
- Mix again thoroughly and if necessary to improve workability add some water to the LBS asphalt mix until the required consistency is achieved.
- Close the mix with empty bags if it is going to be placed at a later stage of the day.
- Make sure no water can ingress the mix.

Figure1: The laying procedure.

The laying procedure can be described as follows:

- Thickness guides need to be placed (30mm loose placed material for a nominal 25mm compacted seal).
- Lightly water the base and sweep off any standing water.
- The mix need to be spread and levelled to the desired thickness and apply water lightly to the already levelled surface if so needed.
- Screed the mix and level and compact with roller 2-4 passes using vibration.
- Without vibration compact again 2-3 roller passes and the drums must be watered to prevent the material of sticking and picking up on the drums.
- When the asphalt surface becomes saturated with a brownish liquid, this is an indication that enough water and compaction have been applied.
- Now a visual inspection is done and if needed the surface is rolled again 2-4 times without vibration.

The levelling procedure can be described as follows as shown in Figure 2

- When LBS are placed about 8mm higher than the required finish, 5mm for compaction and three mm for the levelling process.
- A straight edge was used consists of 3.5 m in length because the road is done in half widths (2.5 m at a time).
- Drag the straight edge on the kerb and on the thickness guide on the other side.
- When done with this operation pour more LBS where needed and rake it close with a normal premix rake.
- If required pour water on top for the compaction procedure.

Figure 2: The in-situ levelling procedure

The compaction procedure can be described as follows:

- Once levelled the prepared LBS area can lightly watered and compacted with a Bomag 76 roller taking 2 to 3 passes with vibration.
- Now again lightly water the compacted LBS and compact without vibration using 2 to four roller passes.
- Do a visual check to monitor if the LBS surface becomes saturated with a brown liquid.
- If this has occurred, then sufficient water and compaction has been applied.
- The only mechanised equipment that is required is the vibratory pedestrian asphalt roller.

Figure 3: The compaction procedure

A gravel road with low volume traffic, experiences the same problems as gravel roads with medium volume traffic. These gravel roads need to be maintained every three months and dust is a problem especially during windy seasons.

With kerbs and prime, the road already makes a huge difference to the community and also because the job creation poverty alleviation criteria was met. About 20 people were on site for six months with a total budget of R500 000. There is an edge strip on the one side and a concrete lined side drain on the lower side of the road. This is due to the fact that there are no storm water pipes and therefore storm water needs to run-off the road to the nearest storm water system.

Figure 4: The Napier roads before LBS

Figure 5: Napier road primed and ready for LBS

During this procedure which was done by hand, from mixing to laying and compacting, the specifications were closely followed, making this a good cold mix product. Quality control needs to be very strict as this product is mixed by hand and the design mix must be exactly the same throughout. As can be seen the road was done in half widths for better control on the straight edge, workability and little to no sagging in the middle.

Figure 6: Napier road during LBS

Figure 7: Napier road completed with LBS

The end result looks like a HMA road, which was the reason for testing the product on the same basis as Hot Mix to prove that LBS Asphalt meets both the visual and the engineering requirements to make this the preferred product in rural townships.

Research equipment

Most of the equipment used for construction was labour based. A Bomag 76 roller was used for compaction purposes.

The laboratory that was used was the Cet Lab in Brackenfell with a SANAS accreditation and calibration equipment. Tests were done in accordance with TRH8 and TMH6 method ST4.

The list below shows the suggested plant and equipment requirements for the production and placing of approximately 350m2 to 500m2 of LBS Asphalt surfacing per day.

Suggested plant and tools requirements for a team of 20 people are:

- 5 x wheel barrows
- 10 x shovels
- 8 x (25l) containers
- 2 x brooms
- 2 x hammer (plus 10nails and gut line)
- 4 x thickness guides (30 mm angle iron x 30 m long)
- 4 x metal rakes
- 4 x watering cans
- 2 x 4 m level
- 1 x pedestrian roller
- 2 x 500 -1000ℓ water tank
- 1 x drum stand
- 1 x drum tap

Table 1: Shows the tasks of a mixing team required to perform each task.

Task	No of persons	Activity
Supervision	2	Check quality and maintain production rate
Materials supply and mixing	10	Mix the measured aggregate, LBS filler and bitumen emulsion
Thickness guides and setting out	2	Setting out of road and the thickness guides
Spreading and levelling of final mix	4	Place and roughly level LBS asphalt
Compaction	2	Compact the asphalt road surface and water

RESULTS

Material grading

The LBS asphalt mixture utilises a combination of 9.5 mm and 6.7 mm road stone and crusher sand. The selection of an aggregate material for use in Asphalt depends on the availability, cost and quality of the material, as well as the type of construction for which it is intended. To determine if an aggregate material is suitable for use in asphalt construction, it needs to be evaluated in terms of size and grading. The maximum size of an aggregate is the smallest sieve through which 100 percent of the material will pass.

The grading of the material in Figure 8 shows that it conforms well according to the TRH8 specifications. Therefore the materials are continuously graded throughout the mixing process.

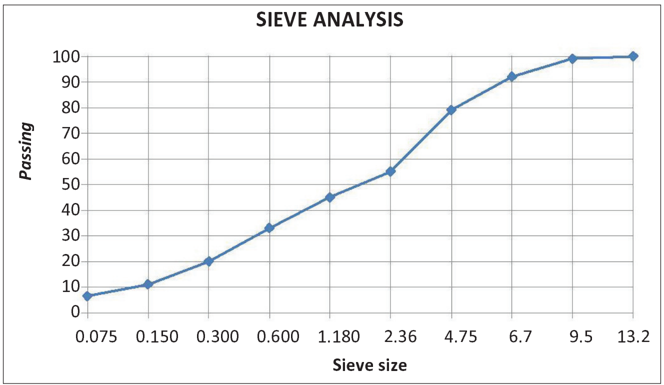

Figure 8: Shows graphically LBS asphalt Grading at Napier

Permeability tests

Permeability can be defined as the ability of a medium to allow the flow of liquid or gas through it. South African pavements usually have a 40 mm asphalt surfacing layer on top of a granular base layer. The performance of granular base layers are highly dependent on the moisture regime in these in these layers and granular layers tend to fail quickly when the moisture content of these layers become too high. An important feature of any thin asphalt surfacing layer would be to prevent the ingress of water into the granular base layers. That will cause granular base failure and fatigue cracking and deformation of the asphalt will come into existence.

Table 2: Summary of Permeability Results for Napier Road research project

NAPIER PERMEABILITY			
Chainage km	**Final Reading**	**Time min**	**Per Ltr/h**
90 Roos Street	50	10.00	0.3
39 Roos Street	50	10.00	0.31
18 Leeubekkie Street	50	10.00	0.32
4 Leeubekkie Street	50	10.00	0.33

As per Figure 9 it has been demonstrated that LBS is very dense and the ingress of water is very low. Thus making it a good surface for a granular base design as no water can damage the base from the top of the surface.

Low permeability of a surface promotes log-term durability and protects the supporting layers form the ingress of water. Low permeability also limits the rate of transfer of oxygen, micro-organisms and volatile constituents through the asphalt layer. Thus the LBS conforms to these specifications.

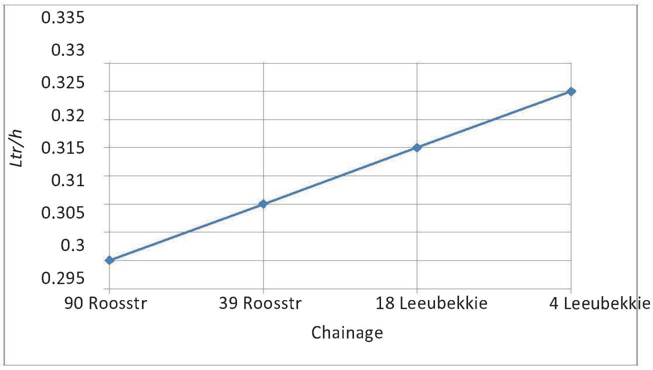

Figure 9 : Illustration of LBS Permeability for the different test samples.

The most important factors adversely affecting durability (usually in combination) are high surface temperatures and the action of water, sunlight and traffic. Poor durability normally results in pitting, sanding or ravelling of the surface; brittleness and early cracking; loss or displacement of the binder film and potholes.

The results shown prove that this product is durable with regards to all of the above criteria.

Marshall engineering properties (Voids in the mix/Binder content)

As LBS Asphalt is cold mixed by hand, the binder content needs to be optimum for workability of the mixture. The binder content that is more than 5.5% creates a durable asphalt layer. This will help to ensure that no bleeding is visible. Table 4.2 shows the voids in the mix and BRD, MTRD and the binder content. The bulk relative density is calculated from the mass and bulk volume of a briquette in saturated dry surface condition.

Durability

Testing results for LBS in Napier	Sample1	Sample2	Sample3
BINDER CONTENT % (C7b)	5.1	5.5	4.6
B.R.D (C3) MARSHALL	2.511	2.455	2.483
M.T.R.D. (C4)	2.629	2.634	2.641
MARSHALL VOIDS %	4.5	5.4	6
STABILITY kN	8.3	8.5	9.1
FLOW mm	2.7	3.2	2.8
STAB/FLOW RATIO	3.1	2.7	3.3
ITS (kPa)	756	1074	860

Table 3: Summary of test results for LBS Marshall Properties done in Napier

The most important factors adversely affecting durability (usually in combination) are high surface temperatures and the action of water, sunlight and traffic. Poor durability normally results in pitting, sanding or ravelling of the surface; brittleness and early cracking; loss or displacement of the binder film and potholes.

The LBS and HMA comply to all the required specifications and therefore the roads will be durable to all physical conditions.

The results shown in this chapter prove that this product is durable in terms of the above criteria.

Financial comparison

This Cold Mix was only compared to HMA and not Double Seal and Cape Seal for the following reasons:

- Double Seals are also done with machinery and the labour component is bit higher than HMA but lower than LBS.
- For both seals machinery are required, i.e. sophisticated slurry truck and a team of six workers.
- For the Double Seal you need a chip spreader and and at least 2 x10m3 trucks with a team of 10 workers.

LBS UNIT COSTS

Table 4: Summary of Costs for LBS Construction

Project Costs Aggregate	Kg	R/kg	Cost
LBS	9.68	R3.10	29.99
SS60%	4.40	R7.80	34.32
C/Sand	24.43	R0.45	10.99
6.7 mm	3.45	R0.45	1.55
9.5 mm	8.05	R0.45	3.62
Labour			6.67
	50.00 kg/m^2		87.15 R/m^2

If 10 000 square meter area is laid, the unit cost amounts to R95.21 per square.

If a 1 000 square meter area is laid, the unit cost amounts to R140.21 per square.

If no transport is considered, the unit cost amounts to R75.27 per square.

Labour component for 10 000 squares of LBS amounts to 33 days for 20 people or 66 days for 10 people.

HMA UNIT COSTS

Material	R1 293.92 per ton
Placing of Hot Mix per ton	R185.00 per ton
Establishment	R50 000.00

For HMA 10 000 squares can be laid in 2 days with 10 people.

It is clear from the above, that for HMA the labour component is a minute cost contributor, whereas for LBS job creation is evident.

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This project focused on the evaluation of HMA and LBS CMA in smaller rural municipalities. Real life projects were done to create the best viable and economical recommendation of these products.

Reducing of unemployment was the basis that LBS was used and the criteria had to meet the requirement of HMA on low volume roads for Cape Agulhas Municipality to meet the needs of their people through job creation.

After 18 months the Cold Mix is still water tight and no sagging occurs. Visually the ride ability and overall quality is still very good.

Conclusions

From the above this research has proven that the need to build low volume roads for maintenance purposes, dust control and an adequate transport medium for the community, is effective and a cost benefit in the long term.

Residential roads with low volume traffic and in the rural parts of the country needed to be upgraded and by labour intensive basis to alleviate poverty as per government legislation.

This product can only be done in dry weather conditions in order for the properties to remain the same and no extra water is added while mixing, placing or compacting.

The permeability tests have shown that LBS Asphalt is dense and the ingress of water is merely impossible from above thus the granular base material will be durable.

The capital layout for this product will be more cost effective in the longer term than gravel roads, i.e. gravel roads need to be maintained three times per year and re-gravelling to take place every seven to ten years.

Because of the high labour involvement, LBS Asphalt will reduce unemployment and thus sustain the community and alleviate poverty. Hence the people's needs were met by creating jobs.

Recommendations

Following the research and analysis, LBS Asphalt is recommended for the following projects:

- Upgrading of low volume rural access roads, from gravel to surfacing standard.
- Upgrading of low volume residential streets, gravel to surfacing standard.
- Constructions of side walk surfacing in rural or urban environments.

This product successful implementation will depend on rigorous pavement and materials investigations during the design of the project. Quality control and supervision during construction must be of a high standard because of the hand mixing of this product.

It is also important to note that the long term performance of any bituminous surfacing is dependent on adequate drainage and the removal of moisture from the pavement. The installation of kerbs and storm water systems will be required in many instances, which will add to the labour intensive nature of the project.

It is also recommended that riding quality will not be that good for high speed traffic because of the fact that surfacing is applied by hand generally has an inferior riding quality than surfacing done by a paver. The recommended speed is therefore below 60 km/h.

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