

TECHNOLOGY TRANSFER OF LARGE AGGREGATE MIX BASE
[LAMB] ON JOHANNESBURG ROADS

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Abstract

Research on Heavy Duty Asphalt Pavements [HDAPs] was conducted by the CSIR Division of Roads and Transport Technology on behalf of the South African Bitumen and Tar Association [SABITA]. This research soon focused on Large Aggregate Mixes for Bases [LAMBS] for which new mix design procedures had been developed. An early focus of this research was the constructibility issues associated with this road building material. The superior performance of LAMBS was validated by means of accelerated road tests done by the Department of Transport. The need for structural strengthening of the M2-Motorway in Johannesburg during its rehabilitation afforded opportunity of transferring the technology to the road construction industry. LAMBS was selected as it was cost-effective and had proven bearing capacity under high traffic volumes and heavy axle loads. LAMBS was exposed to very heavy traffic on the M2-Motorway without any problems before it was overlaid with a final surfacing.

1. INTRODUCTION

The development of Large Aggregate Mixes for Bases [LAMBS] is the direct result of a research project on Heavy Duty Asphalt Pavements [HDAPs] conducted by the CSIR Division for Roads and Transport Technology. This project started in 1988 and was funded by the South African Bitumen and Tar Association [SABITA].

This research project can be viewed as a model of focused and successful research and development. The need was clearly client driven and from the outset the project was directed towards the attainment of a practical and useful output [SABITA, 1993]. Specific and well planned management and funding were also committed to technology transfer, a phase which has often been neglected.

LAMBS were developed for high traffic volume or for the highest category road. The aim was to develop a superior asphalt mix product which could withstand the stresses imposed by such aggressive high traffic loading, specifically by heavy axle loads and high tyre pressures. They were specifically designed to overcome deformation and creep associated problems.

The technology transfer of LAMBS had already commenced when it was decided to use LAMBS as part of the rehabilitation on the M2-Motorway in Johannesburg. This decision significantly accelerated the transfer of this new technology to the road industry at large. This successful transfer of knowledge and expertise, as experienced in Johannesburg, is described in this paper.

2. TECHNOLOGY TRANSFER APPROACH

The total spectrum of research and development is illustrated in Figure 1 [Oujian and Carne, 1987]. This spectrum of technical activity starts from basic research and passes through the development and engineering phases to produce products, services, processes or policies as the final output. Basic research is shown as consisting of mainly discrete events without any specific practical focus, while applied research progressively couples research outputs in a focused manner to result in products or processes with greater practical significance. Technology is conceptually transferred between tasks of increasing size and technology-coupling events to result in user-orientated outputs. Strictly speaking, the initial research involvement on LAMBS started in the development phase and not in the research area as defined in Figure 1. No basic research was done as the client, SABITA, had a clear user- or product-related focus from the start and was an active partner throughout in the project management process. The focus of the technology transfer was therefore a movement from the development phase to the engineering phase.

One of the stated goals of the Roads Directorate of the Johannesburg City Council [JCC] is to pursue new and appropriate technology so as to confirm its leadership role as a metropolitan road authority. As a client body with this attitude, the Roads Directorate is also aware of the greater risks associated with the implementation of such new technology. The risk management approach followed starts with a partnership with the other role players, in which the Roads Directorate as a technology transfer partner in development and research. The various stake holders involved were:

- | | |
|---------------------------|--|
| • Research funding/client | : SABITA |
| • Research organisation | : CSIR Roads and Transport Technology |
| • Road authority/client | : Roads Directorate, Johannesburg City Council |
| • Contractor | : Road Surfacing Division, Roads Directorate |
| • Supplier | : Asphalt Plant, Roads Directorate, Protea Asphalt |
| • Consultant | : Steward Scott Inc. |

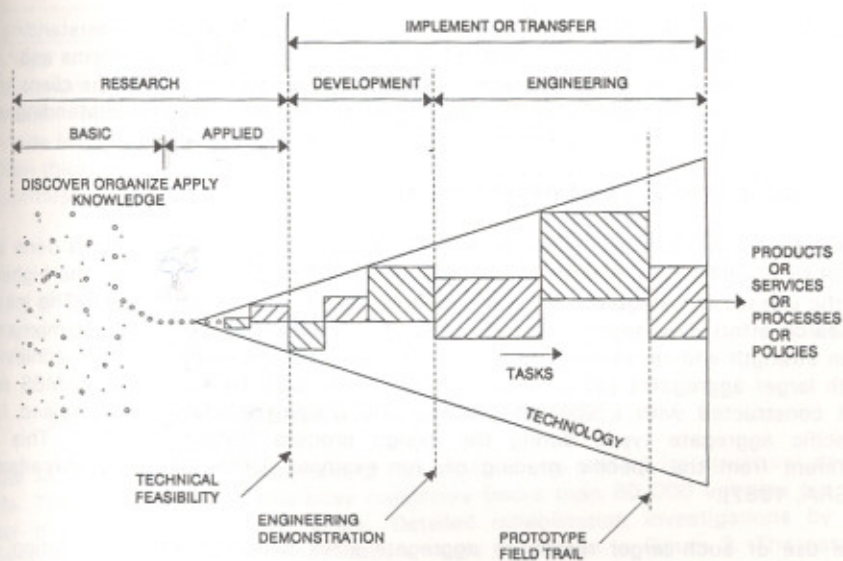


FIGURE 1

MODEL OF DEVELOPMENT OF TECHNOLOGY

(Ujjan and Carne, 1987)

The management and co-ordination of these stake holders was done along the lines of the following three axioms of truth [Oujian and Carne, 1987].

- Axiom 1. Utilisation is inversely proportional to the distance between researcher and users of research. [A close working relationship was established with the project steering team between the various parties].
- Axiom 2. The utilisation is inversely proportional to the degree of formality in the communication between the researcher and the user. [The above-mentioned steering team were highly task oriented and informal in its communication, with the minimum of formal documentation].
- Axiom 3. The utilisation of research increases with the degree of understanding that the researcher and the user have of each other's problems and motivations. [The phased approach and leadership role of the client and his needs and the research client ensured shared understanding in this hands-on direct inter-action on a project level].

3. OVERVIEW ON LAMB DEVELOPMENT

LAMBS evolved from the Heavy Duty Asphalt Pavements [HDAPs] project done by CSIR for SABITA in an effort to prove that asphalt pavements can carry the highest traffic classes or categories without undue distress over their design life. The initial research effort very soon focused on the need for such superior asphalt mixes to gain strength and resistance to deformation from the aggregate interlock achieved with larger aggregates [37.5 to 53 mm maximum size]. By definition, LAMBS are not constructed with a specific grading. The grading available is optimised for specific aggregate types during the design process [SABITA, 1993]. This is different from the specific grading of, for example, Dense Bitumen Macadams [CSRA, 1987].

The use of such larger maximum aggregate sizes necessitated the adoption of laboratory procedures in which a larger [150 mm diameter] mould could be used. The Marshall mix design method was found to be lacking in its sample preparation procedures and to give unrealistic test results. The indented-head Hugo hammer was developed further for this 150 mm diameter mould and successfully calibrated against the results of performance tests [Grobler et al, 1992]. Apart from improvements to standard test procedures, this research project proved the value of upgraded engineering test, such as Indirect Tensile Strength [ITS], Repeated Indirect Tensile Test [RITT] and the Dynamic Creep Test [DCT], [SABITA, 1993].

Constructibility was identified as an area in need of detailed investigation and a number of trial sections near Cape Town were constructed and carefully monitored. [Grobler et al, 1992]. Hereafter full scale sections were constructed near Dundee, Natal before the first technology transfer was effected, by means of an actual rehabilitation project on one of the taxiways at Jan Smuts Airport. [Grobler et al, 1992]. The Dundee trial sections were tested with the Heavy Vehicle

Simulator [HVS] of the Department of Transport. These accelerated tests on performance proved that the new engineering tests mentioned above are very useful for predicting structural performance behaviour of LAMBS. They also proved that LAMBS can carry the highest traffic class [more than 50 million equivalent standard axles] without structural failure [Grobler et al, 1992].

These research and development efforts led in an evolutionary manner to the establishment of the following design criteria for LAMBS, summarised in Table 1. [SABITA, 1993].

Table 1. Design criteria for LAMBS [SABITA, 1993]

Property	Criterion
Voids	Minimum 2%; Maximum 6%
Maximum binder content	Dry side of minimum VMA vs binder content
Voids in Mineral Aggregate [VMA]	
Voids filled with bitumen [Vbe]	Minimum 12%
Film thickness	Minimum of 75% and Maximum 85%
Stiffness @ 25° C/10 Hz	Minimum of 8 microns
	1. Minimum 2000 MPa for stiff layer
	2. Minimum 1500 MPa, Maximum 2500 MPa for flexible layer
ITS @ 25° C	Minimum 899 KPa
Dynamic Creep Modulus @ 40° C	Minimum 10 MPa

4. M2-MOTORWAY REHABILITATION REQUIREMENTS

The M2-Motorway in Johannesburg has reached the end of its structural design life. The average age of this busy motorway [more than 60 000 vehicles per day per direction] is 15 to 20 years. Detailed rehabilitation investigations by the consultants identified the rehabilitation needs as shown in Figure 2. The eastern sections of the M2 in particular were in dire need of structural strengthening due to the high percentage of heavy vehicle usage and overloading in these areas.

The structural strengthening was to include the milling out of structurally failed sections and the repair of localised failed areas in a phased process. The high traffic volumes necessitated that the work be done at off-peak hours, mainly at night time and over weekends. Detailed and innovative traffic flow arrangements had to be made to ensure that at least 2 lanes would be open in both directions during construction. This included a period of contra-flow on certain sections of the Motorway. The first phase of the rehabilitation concentrated on the first 3 km of the westbound carriageway [from the Cleveland bridge to the Denver off ramp]. The final structural strengthening design requirement was changed to a new asphalt base of 100 mm with a 40 mm surfacing on top.

5. LAMBS IMPLEMENTATION

The rehabilitation project described earlier is a greater risk than normal procedures because of the specific circumstances and construction procedures followed and described earlier. This in itself requires very effective project co-ordination. It was decided to use 75 mm LAMBS followed by 25 mm of fine continuously graded premix as a levelling /sealing layer, making up the required 100 mm bitumen base. The wearing course consisted of 40 mm of porous asphalt [Horak et al, 1993].

As mentioned earlier, LAMBS were constructed with success elsewhere [Grobler et al, 1992], However, the specific circumstances on the M2-West required additional procedures to manage the associated risk. The mix design and material selection was done jointly by the CSIR, the consultants, the Roads Directorate laboratory and their Asphalt Plant. It was also decided to lay at least 1000 tonnes of LAMBS on Heidelberg road as part of the planned rehabilitation of this road before construction started on the M2-West. The main aim of this was to familiarise the Road Surfacing Division of the Roads Directorate with the constructability issues.

The design of the LAMBS was in line with the specifications listed in Table 1. The grading was a smooth continuous curve without kinks, with a maximum aggregate size of 37.5 mm. The percentages passing the crucial 4.75 mm and 0.075 mm sieves were 40 per cent and 3 to 4 per cent respectively. A 60/70 penetration grade bitumen was used and a binder content of 3.5 per cent was specified. An average density of 98 per cent was achieved, a minimum of 97 per cent being specified. The total void content was 4 per cent.

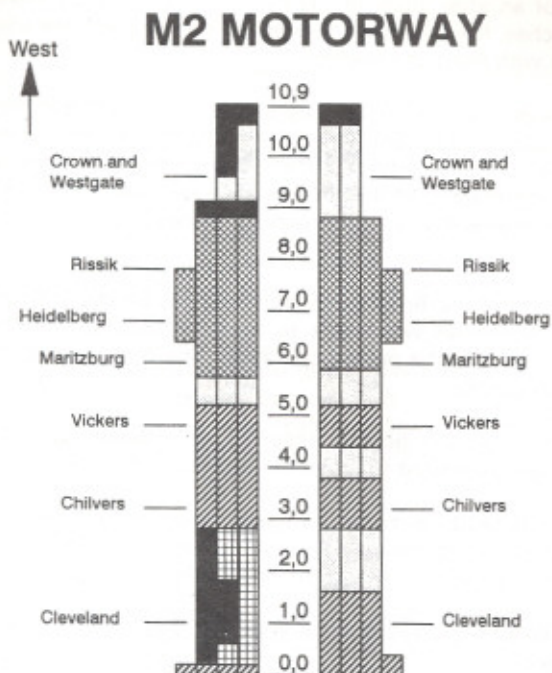
The average values of resilient modulus and dynamic creep modulus of the LAMBS used on the M2-Motorway are given in Table 2. These were determined on cores extracted from Heidelberg Road, which served as a trial section for the then approved mix design. The results indicate that the LAMBS had high stiffness and that the road mix would have excellent resistance to permanent deformation.

Table 2: Engineering properties of LAMBS

Property	Measured Average value
Resilient modulus	3 300 MPa
Dynamic Creep modulus	21 MPa

6. CONSTRUCTIBILITY OF LAMBS

Constructibility issues concentrated mainly on the prevention of segregation during mixing, transportation and laying operations. As the mix consists of large aggregate in a low fines matrix, it is prone to segregation. The basic procedure followed was to control segregation at the mixing plant and not during paving. This is normally



LEGEND:

- Patch & Crackseal (P & C)
- P & C + 2 x 40mm Asphalt
- P & C + 140mm Asphalt
- Mill & Replace Asphalt Surfacing (M & R)
- M & R + 100mm new Asphalt
- M & R + 140mm new Asphalt

FIGURE 2

M2 Proposed Rehabilitation Measures
(15 Year Design Period)

achieved by means of an after mixer at the plant. In cases where mixes appeared segregated [last batches from hoppers tended to do this] on the trucks, it was dumped and remixed with front end loaders.

Larger trucks were favoured as their use facilitated the use of loading procedures which minimised segregation. Smaller trucks displayed the worst kind of segregation and usually on one side of a truck due to the aforementioned loading deficiencies. It was acknowledged that the distance travelled from the plant to the paver increases the probability of segregation. Plants closest to paving were therefore used.

Two pavers were used by the Road Surfacing Division; An ABG Titan 355 and a HOES 12000. No modification was made to these. It was acknowledged that a paver cannot remix premix in the paving operation. The following techniques were used to minimise segregation :

- When segregation in the hopper occurred on edges, due to tipping, the hopper bat wings were used to move the premix to the middle of the hopper.
- Paving was restricted to a maximum width of 4m to lay a finished depth of 75 mm. This was to maintain traction on the drive wheels and to keep the material as close as possible to the end of the augers.
- The augers and screed screens were kept full, which minimised segregation under the screed.
- The screed was kept hot which minimised "tearing" of the paved mix.
- A tendency towards surface segregation was noticed on the joints. This was however usually flushed up with the pneumatic rollers.

Both pavers were used on the M2-Motorway; One paving to the rear of the other in adjacent lanes [in tandem]. This reduced the number of longitudinal joints on the four lanes from three to one.

The rollers used were 1 x 3 steel wheel , 1 x tandem double vibrating drum and 2 x 22 tonne pneumatic rollers. Irrespective of rolling sequence, the required density was achieved. However the sequence to obtain a well closed surface was:

steel roller x 1 pass
 Vibration x 2 passes
 pneumatic 4 passes with a final steel roller pass.

Good riding quality was achieved and at times sections were opened to traffic within 30 minutes of final roll. When segregation of the finished surface did occur it was treated in one of the three ways.

- i. Where possible, the large aggregate was raked off and fine material raked in. This could only be done before rolling commenced.
- ii. Fine cold premix was raked into the surface after compaction and rolled in with a pneumatic roller.
- iii. Slurry was applied to the segregated surface after it had been open to traffic for one day.

Application of the slurry gave the best results. However there was little stone loss from the surface regardless of the treatment. In the approximately 15 days of open LAMBS remained unsurfaced on the M2 no claims were received for damage to vehicles due to lifting stones.

On the trial sections it was necessary to lay ramps over obstructions. These were laid by hand and rolled immediately because, due to the depth of mix being laid, the paver could not cope with the extra load and lost all traction. By limiting the layer thickness to the range of 75 mm to 100 mm, LAMBS were easy to pave and level control was very good.

7. CONCLUSIONS

The development of the LAMBS technology and subsequent implementation activities is an excellent example of a well-managed technological development. The fact that the research and development work addressed a real need in the roads industry and that the implementation programme was rigorously driven, involving a receptive client body, ensured successful implementation.

The risks associated with the project were managed well by ensuring direct communication between researchers, road authority and consultants and by taking precautions such as the construction of adequate trial sections.

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