REHABILITATION OF DAMAGED ASPHALT PAVING USING CONCRETE BLOCK PAVING ON A NATIONAL ROAD IN SOUTH AFRICA.

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ABSTRACT

National Route 3 is one of the busiest and most heavily trafficked roads in South Africa. Up to 10 000 vehicles per day use the slow (crawler) lanes with 30% of these being heavy long distance haulage vehicles. In addition, at least 25% of these are overloaded, which is currently a serious, widespread problem on the South African roads, leading to a rapid deterioration of the road system. With cut backs in Government spending, good economical solutions were being sought to rehabilitate the severely damaged sections. A trial section of Concrete Block Paving (CBP) was installed as part of a study programme testing various concrete solutions to rehabilitate the slow lanes where severe rutting had occurred. The existing asphalt surface was badly deformed with shoving and moulding of the premix layer.
The programme was part of a R21,2 million contract to rehabilitate approximately 17 kilometres of slow lanes with 180mm thick Continuously Reinforced Concrete Pavement. The remedial work was restricted to working sections of 2 kilometres with 2 of the 3 lanes open at all times. Two thin concrete test sections (100mm) were installed with the CBP during November /December 1998 and opened to traffic mid December 1998.

1. INTRODUCTION

This paper details the design and construction of the Concrete Block Pavement installed on National Route N3 north of Pietermaritzburg, Natal, South Africa in 1998. Following a site inspection in 1997, Professor Brian Shackel of the University of New South Wales, Australia, was commissioned to carry out the analysis and design of the proposed block pavement. Details below on the design are extracts from his original report of June 1998. Construction of the trial section was undertaken on behalf of the Concrete Manufacturers Association using a local contractor under the supervision of the author.

2. EXISTING PAVEMENT

Test pits and transverse slots taken along the route showed that the structure of the existing pavement varied greatly. Also, the road was constructed over a number of years with the slow climbing lanes added later. Photo 1 clearly shows the extent of rutting and shoving of the asphalt surface.

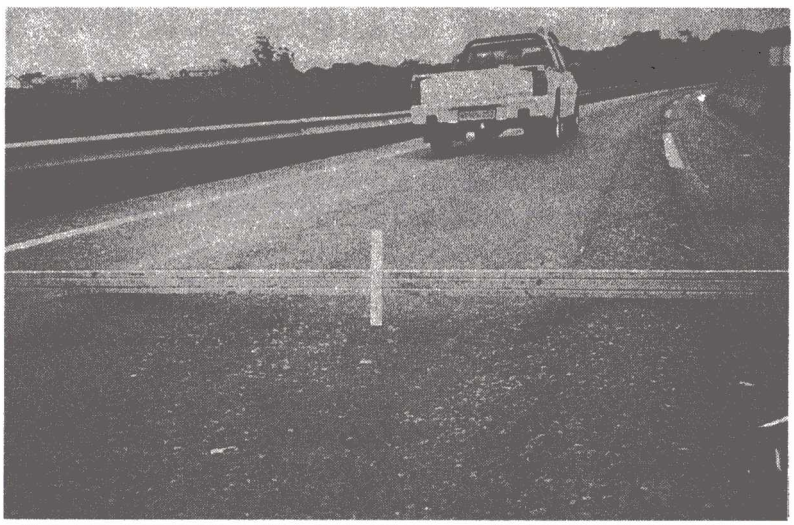


Photo 1 - Asphalt rutting

Conclusions from the site investigation undertaken showed that the asphalt surfacing was in poor shape with low residual voids. There was no evidence of sub-base/ sub-grade deep seated failure. The support to the asphalt was generally a crushed rock (Dolerite) which was sometimes stabilised. Due to this varying support it was decided not to disturb the underlying layers. In addition, further treatment to the base would prolong the disruption to one of the busiest routes in South Africa.

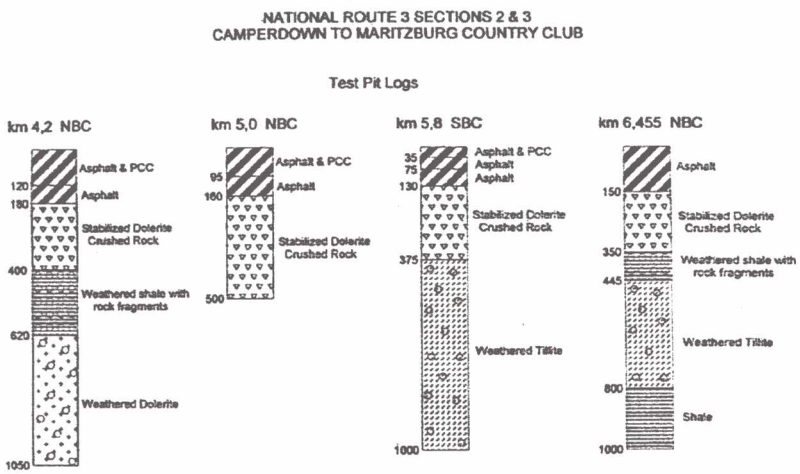


Figure 1 - Test pits

3. CONCRETE PAVEMENT INLAY

Following the investigations it was decided to use a 180 mm Continuously Reinforced Concrete in the slow lanes. This was heavily reinforced as can be seen in photo 2 with the steel alone costing 25% of the value of the concrete section. The placing of the concrete was done by hand and the ridability of the final surface achieved was to the outer limits of that required.

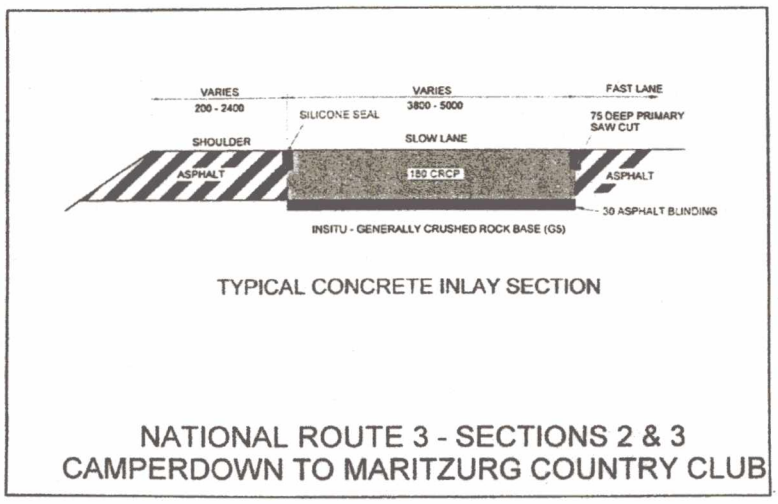


Figure 2 - Concrete Inlay

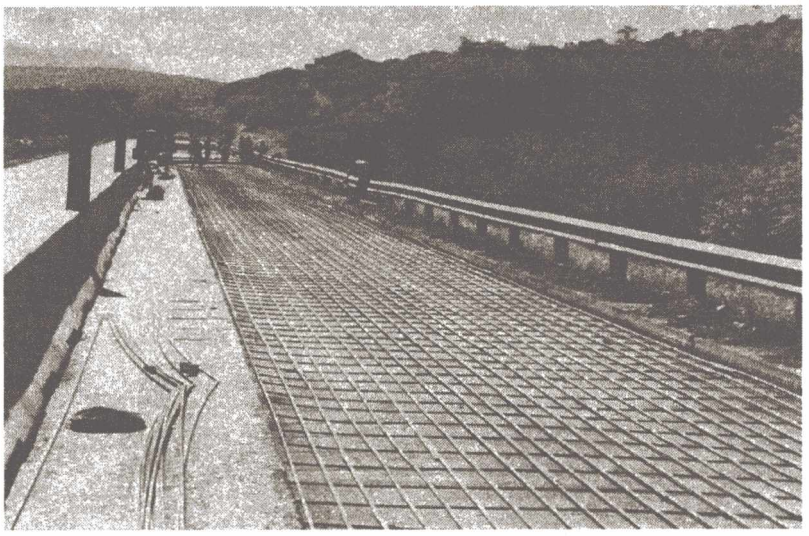


Photo 2 - Steel to Concrete

4. CONCRETE BLOCK DESIGN AND ANALYSIS

4.1 Existing Pavement - Proposed Test Site

Cores and trenching at the proposed site established that the existing pavement comprised the following;

Surface Course	:	155 to 180 mm Asphaltic Concrete
Base Course	:	170 mm Cement Stabilised Crushed Rock (Dolerite)
Sub-base	:	150 mm Granular Material (med to hard weathered shale)

Soil reports classified the base as A-1-a and the sub-base as A-2-6 material according to AASHTO Classification.The cement stabilised base was reported to have yielded intact cores with the stabilisation still active. Dynamic Cone Penetrometer (DCP) tests indicated the subgrade had CBR values of 20% or better to a depth of 700 mm below the pavement with moduli better than 100 MPa.

4.2 Design Requirements

For design purposes the trial pavement was required to make maximum effective utilisation of the existing pavement structure and to withstand 12 million E80's as the design traffic over a design life of 7 years. For analysis purposes the following elastic moduli E and Poisson's Ratios, v, have been assumed.

Pavers	3200 MPa	with v = 0,3
Bedding Sand	200 MPa	with v = 0,35
Asphaltic Concrete	1500 MPa	with v = 0,3
Cement Treated Base	2300 MPa	with v = 0,35
Granular Sub-Base	230 MPa(Max)	with v = 0,35
Subgrade	100 MPa	with v = 0,4

These values were chosen to be both conservative and in conformity with the materials data available for the test site, or in the case of the pavers, with published test data.

4.3 Proposed Block Pavement Structure

80 mm	Pavers Shaped Interlocking	
20 mm	Sand Bedding	
55 - 80 mm	Asphaltic Concrete (Existing)	
170 mm	Cement Treated Base (Existing)	CTB
150 mm	Granular Sub-Base (Existing)	GSB
	Sub-grade	

The structure was analysed using the LOCKPAVE - PRO computer programme (version 11) which includes design methodology based on the AASHTO pavement design method in addition to full mechanistic analyses. This allowed three independent approaches to be adopted:

1. Mechanistic analyses of the thickness of CTB and GSB needed directly beneath the pavers and bedding sand if the structural contribution of the existing asphalt surface is neglected.
2. Mechanistic analysis of the pavers and bedding sand applied as an overlay on a pavement excavated to give asphalt thicknesses between 55 and 80 mm.
3. An AASHTO analysis of the pavers and bedding sand applied as an overlay on a pavement having asphalt thicknesses between 55 and 80 mm.

It has been assumed that the drainage conditions are characterised as "fair" implying the pavement substructure would be expected to drain in one week or less and would be saturated between 5% and 25% of the time. To model these conditions the maximum moduli of all unbound materials was reduced to 70% of maximum values given above.

4.4 Analysis Neglecting Asphalt Layer

For traffic of 12×10^6 E 80's the LOCKPAVE mechanistic analyses indicate that for a sub-grade modulus of 100 MPa or more, the required structure would comprise just 100 mm of CTB on 150 mm of Granular Sub-base. The existing thickness of CTB is greater than that required and the sub-base corresponds to that in place. Therefore it can be

concluded that even neglecting any structural contribution by the 50 to 80 mm asphalt, the proposed inlay design is structurally adequate.

4.5 Overlay Analysis

In analysing the test pavement as an overlay it was necessary to combine the structural contributions of the Sub-base and Sub-grade because the LOCKPAVE programme can only model the existing pavement as only 3 layers including the sub-grade. This has been done by assuming that the combined effects of the sub-base and sub-grade can be modelled as a semi-infinite layer having a modulus of 150 to 200 MPa.
A full mechanistic analysis shows that the required thickness of asphalt ranges from approximately 70 to 80 mm. The available thickness expected on the N3 site would be adequate, however quite possible in places to be as low as 55 mm. In view of the analysis presented having no asphalt layer, it is concluded that the test pavement would still have adequate structural capacity. The reason for this apparent anomaly is that the overlay analysis assumes a 70% diminution of the sub-base structural capacity for the selected overlay condition factor. This is an extremely conservative assumption.
Using AASHTO design methodology for analysing an overlay of concrete block paving on asphalt overlaying CTB, shows that theoretically, the minimum thickness of asphalt required for a sub-grade CBR of 15 or more, would be 55 mm. This corresponds to the minimum thickness of asphalt expected on the site. The AASHTO analysis confirms the feasibility of constructing the trial block pavement as an overlay.

4.6 Existing Pavement - Final Test Site

Before construction of the CBP the location of the proposed test site was moved 5 kilometres north. Cores and Dynamic Cone Penetrometer tests taken at the site showed a different pavement structure to that of the original test site. In addition, the slow lane was added later than the original two lanes resulting in a stepped asphalt layer across the test site as shown in figure 3:

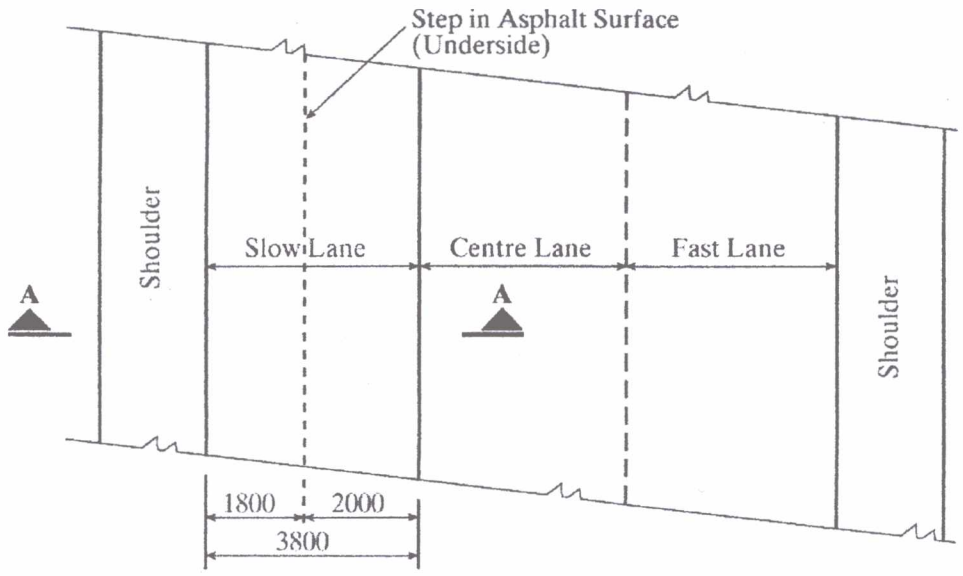
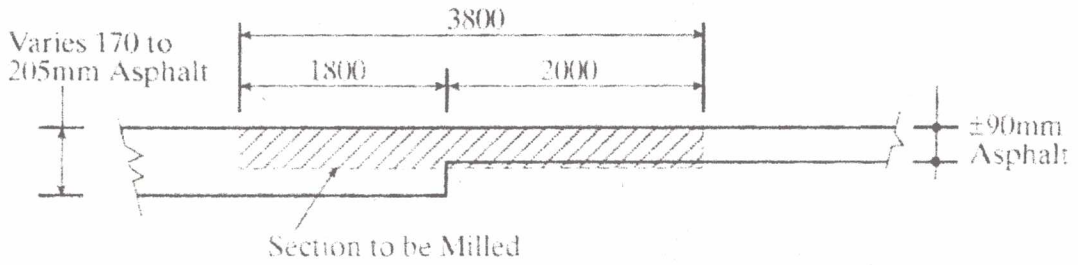


Figure 3 - Plan on Test Area



Section A - A

The slow lane had an asphalt layer of between 170 to 205 mm over a 1,8 meter width and only 90 mm over the remaining 2 meters. Tests done at the site revealed the following structure:-

Surface course	:	90 to 205 mm asphaltic concrete
Base course	:	260 mm crushed dolerite rock
Sub-base	:	220 mm weathered sandstone
Formation	:	320 mm clayey weathered sandstone

Soil reports classified the base as A - 1 - a and the sub-base as A - 1 - b material according to AASHTO classification. The base-course at this site was not stabilised but was thicker than the original site (260 mm vs 170 mm). DCP tests indicated the sub-grade had CBR values of +40% at a depth 800 mm below the pavement with moduli better than 160 MPa. Although the sub-structure was not the same as used on the original design and analysis, it was decided to proceed with the trial CBP. Where the asphalt layer was only 90 mm thick, the base-course was milled out a further 80 mm and replaced with asphalt.

5. CONSTRUCTION OF TEST PAVEMENT

The area was saw cut to a depth of 100 mm and milled out. Over the stepped area where the asphalt was thinner, a further 80 mm of the crushed Dolerite base course was removed and replaced by 80 mm asphalt. (See fig. 3) All debris was removed and surface ground and cracks patched up with a rubberised bitumen to an even surface. A 500 mm wide x 300 mm deep concrete edge beam was constructed at the exit end of the section. No beam was required at the approach end as the 100 mm insitu concrete section formed the edge restraint. Three drainage slots were cut into the lower end shoulder to allow for drainage of the sand bedding layer. 50 mm diameter PVC pipes were installed into the slots and sealed with cold asphalt.

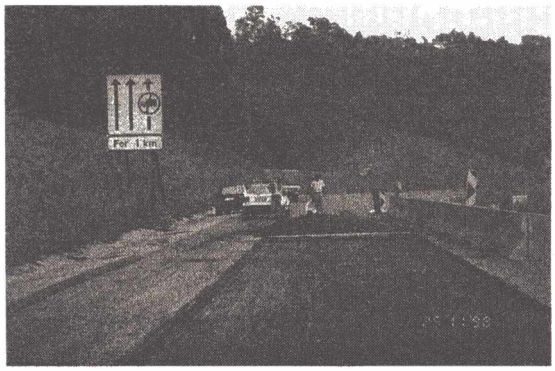


Photo 3 - Milled out section



Photo 4 - Drainage slot

Wickdrains were laid along the outer edges of the paved area plus two diagonals. The wickdrains comprised a tubular polyethelene drainage core wrapped in a filter jacket of non-woven continuous filament polyester. Overall thickness was approximately 5 mm with a discharge capacity of $1,4 \times 10^{-2}$ liters per second. Bedding sand was spread over the wickdrains and entire area and then screeded to receive pavers.



Photo 5 - Wickdrains

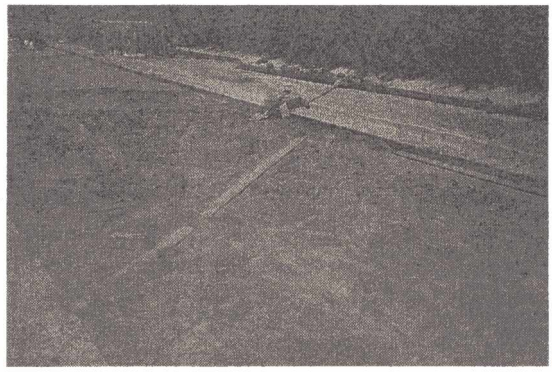


Photo 6 - Diagonal wickdrain

80 mm thick grey shaped pavers of 35 MPa strength were laid in herringbone pattern. Edge blocks were used up against the centre lane edge and blocks cut to fit at the shoulder. Originally hot rubberised bitumen was used in the joint between pavers and asphalt. However, this proved to be impractical and messy and was removed. The joint was filled with a polysulphide around the entire periphery of the paved surface.
After filling the joints with sand and final plate compaction, the entire area was sprayed with a solvent based joint sealer. The actual construction time was two working days, but was carried out over a number of days due to bad weather and on site delays. The section was opened to traffic the following day after completion.



Photo 7 - Centre lane edge

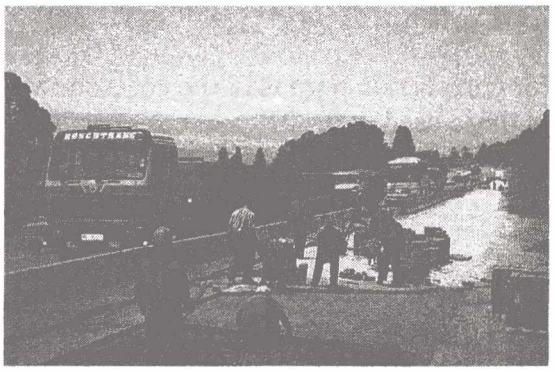


Photo 8 - Laying blocks



Photo 9 - Applying joint sealer



Photo 10 - Completion of pavement

6. EVALUATION

6.1 Performance

The test section was opened to traffic during the first week of December 1998. After 18 months the pavement is performing extremely well with no visual signs of rutting or deformation. The test site is on a gradient of 6% and as a result the traffic is moving at speeds of between 15 to 35 kph. In addition, they tend to track on the same line over the pavement offering a more severe loading. Light vehicles using the slow lane are travelling at speeds in excess of 60 kph and the road is noticeably smoother than the concrete test sections immediately before the block pavement.

6.2 Problems

To date, the only problems experienced are related to the drainage of the sand bed which becomes an important factor. Sealing off the interface between the pavers and asphalt is critical as rainfall runoff from the remaining lanes discharges over the block pavement and saturates the sand bed. Due to this the wickdrains were unable to cope with the volume of flow following exceptionally heavy rains soon after completion. Bedding sand washed out along the length of the diagonal drains causing some settlement of blocks. This did not affect the performance of the area but it was decided to remove the diagonal wickdrains which was done in March 2000. This was done under traffic with minimum disruption. In view of this, adequate drainage of the sand bed is essential.

6.3 Costs

For comparison purposes, the costs shown below for the concrete and asphalt are based on those used in the original contract. The block pavement costs were based on prices at time of tender in 1998.

Table 1 Cost Comparisons

CONCRETE INLAY (180 mm)		ASPHALT INLAY (180 mm)		80 mm CONCRETE BLOCK PAVING	
Concrete	R 60,48	Base	R 75,50	Blocks laid	R 56,65
Texture	0,82	Surfacing	16,43	Wickdrain	1,90
Curing	3,00	Chipping	1,89	Joint sealer	3,80
Steel	33,65	Edge treatment	1,10		
Milling	16,56	Milling	27,18		
Saw cutting	2,18			Saw cut	2,18
Joint seal	5,47			Poly joint	5,47
Mill 30 mm	2,76				
Asphalt blinding	11,95				
Compaction	0,32	Compaction	0,32		
TOTALS	**R 137,19**		**R 122,42**		**R 66,20**

The CBP alternative shows a saving of between 46% to 52% over the asphalt and insitu concrete solutions respectively. Added to this there is no lengthy curing period required as with the concrete solution, so accommodation of traffic is easier and the total contract period is reduced resulting in further savings.

7. CONCLUSION

The CBP has performed very well with no signs of rutting after nearly 18 months of service. Considering that the heavy trucks tend to track along the same line, the performance is more noteworthy. With the restrictions placed on the construction sequence due to the volume of traffic, Concrete Block Paving offers far more flexibility in the accommodation of this traffic during construction. In addition, the curing period required by the reinforced concrete more than doubles the contract period required compared to CBP.

Taking the cost into consideration, CBP becomes a viable alternative solution for the rehabilitation of rutted lanes with savings of up to 50% over concrete or asphalt. However, there still exists a mindset with authorities and engineers in South Africa regarding the engineering integrity on Concrete Block Paving. We believe that full scale testing as done above will help change the misconception regarding the performance of CBP.

We wish to thank Mr Mervyn Williams, Senior Partner of A.A. Loudon and Partners, Consulting Engineers responsible for the design and supervision of the contract, for his efforts in obtaining approval from The Department of Transport for the CBP trial section.

REFERENCES

1. Shackel, B. "Design of Concrete Block Pavement Inlay Test Section to National Route 3 , South Africa." Report June 1998.

2. Williams, M. "Rutting on Steep Climbing Lanes" in Proceedings, 2nd Cementitious Pavements Forum South Africa, May 1999.