

COMPACTION

An innovative solution for township roads in sandy areas

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This paper describes the design and construction process of an innovative road pavement structure for a township in an area which has a total lack of traditional road construction materials. The project is in the Dukuduku area of KwaZulu-Natal north of Mtubatuba.

The road network consisted of 12km of tracks in thick, loose white aeolian *in situ* sand over which a thin layer (150mm) of Berea Formation sand (Berea Red with some plasticity) had been placed about four years previously. Most of this had since been assimilated in the loose aeolian sand. These tracks served about 960 agriplots, each being between 2 500 and 3 500m² in area.

The brief for the project was to provide a passable, all-weather, durable road network with a black surface, with a very limited budget. As local materials had to be used exclusively, a highly cost-effective design was required.

Historical background

The Dukuduku Forest in KwaZulu-Natal is considered to be one of South Africa's most valuable indigenous forests. Historically, however, local inhabitants have sought temporary shelter in this area since the days of Shaka and, in fact, have a historical claim to parts of Dukuduku. During the late 1980's large-scale settlement of squatters in the area occurred. Many of these squatters were removed to the nearby New Dukuduku in 1993. A basic system of roads (tracks) and water reticulation was provided, but the roads were impassable for much of the year. The Department of Local Government and Housing investigated the situation and identified the unsuitability of the road system in the area as a priority for attention. This paper discusses the upgrading of these roads in the approximately 2 000ha comprising New Dukuduku carried out to improve the quality of life of many of the squatters resettled from the Dukuduku Forest.

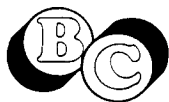
Geology and environment

The geological materials occurring in the area consist solely of sands of Quaternary age including the Berea Formation and other more recent deposits, mostly aeolian and lacustrine in origin. These materials extend to considerable depths (>70m) in the area and the closest potential gravel pits are in excess of 25km distant and consist of weathered basalt. Weathered basalt is a high risk gravel material (weathered basic crystalline rocks contain smectite clays and are typically non-durable in wet areas) likely to decompose rapidly in pavement layers.

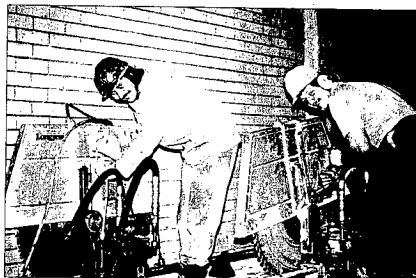
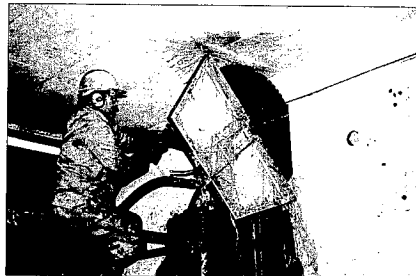
The area can be considered to have a lightly rolling topography, with a number of vleis and even ponded areas in which hippopotami reside. The vegetation consists mostly of grassland replacing the planted coniferous forest which has been removed as well as of rem-

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nants of the indigenous forest. The climate in the area is classified as humid and mesothermal with an annual moisture surplus. The annual average rainfall is about 900mm and the Weinert N-value is less than 2, the area thus being classified as wet for pavement design purposes.

Material testing

Testing of the existing sand tracks with a Dynamic Cone Penetrometer (DCP) indicated that the *in situ* CBR strengths varied between 5 and 8 to depths of in excess of 1.5m. Limited laboratory testing of the sands gave the results summarised in Table 1.

Property	Aeolian sand	Berea Red Sand
Per cent passing 2mm	100	100
Per cent passing 0.075mm	3 - 6	39
Grading modulus	0.95 - 0.99	0.69
Liquid limit	NP	24
Plasticity index	NP	11
Linear shrinkage	0	5.4

Table 1: Summary of test results.

Pavement design

Various pavement design options, including various pozzolanic and ionic soil stabilisers were evaluated. The factors considered in the structural design of the pavement were:

- design life – a design life of ten years was assumed;
- traffic – essentially no heavy vehicles use the road, which will mostly be trafficked by mini-bus taxis and cars. The predicted cumulative E80's over the design life were thus taken as less than 3 000.

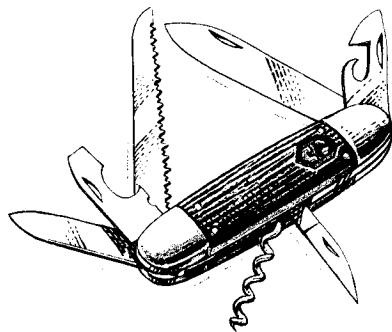
Based on the catalogue of designs for light pavement structures with granular bases in wet areas (draft TRH 4, 1997) a typical pavement structure would require 100mm of G7 gravel (minimum CBR of 15% at 93% Mod AASHTO density) under 100mm of G5 gravel (minimum CBR of 45% at 95% Mod AASHTO density) with a single surface treatment. The recommended foundation for this structure is G9 quality (minimum CBR = 7% at 93% Mod AASHTO density).

The *in situ* materials were considered to be suitable for subgrades provided appropriate compaction was obtained. They could even be used as the G7 sub-base if compacted adequately. The base, however, was a problem and various alternatives for granular base were evaluated. None of these was considered cost-effective and the use of a foamed bitumen treated mixture of the Beréa Red sand and the white aeolian sand was considered to be the most effective solution.

The road was 'surfaced' only with a light spray of dilute (1:1) 60% cationic bitumen emulsion to completely bind the upper layer of the foamed bitumen base and any loose sand which may have accumulated during rolling and finishing. The aim was to apply a slurry seal after the road has been in service for some time. Subsequent performance has shown that the application of a light seal is essential for good performance.

Construction

As the foamed bitumen layer would typically fail by fatigue through tensile stresses at the bottom of the layer it was necessary to minimise deflections as far as possible by stiffening the subgrade through deep rolling. In addition, the subgrade needed to be as stiff as possible to



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provide a suitable reaction for a high degree of compaction of the foamed bitumen. After considering various alternatives, heavy impact compaction was proposed.

The contract was awarded to Shire Construction with Landpac and Colas East being appointed as sub-contractors for the subgrade preparation and foamed bitumen base supply respectively.

Impact compaction

Compaction was carried out with a three-sided Landpac 25kj impact compactor. Twenty five passes of the compactor were applied and the *in situ* strengths before and after rolling were monitored with a 2m DCP, together with the settlement which is determined by comparing the average level of the rolled surface with a predetermined datum.

The results of this monitoring are summarised in Table 2.

Density testing was carried out at a

Property	Range (number of samples)	Mean
Density (kg/m ³)	before rolling	81.8
	after rolling	94.4
		64
Settlement (mm)		
DCP penetration rate (mm/blow)*	before rolling	26.6
	after rolling	10.6
DCP strength (CBR equivalent)	before rolling	7
	after rolling	24
Plate Bearing Value (kPa/mm)	before rolling	
	after rolling	299

*Over the full depth of 1.8 to 1.9m

Table 3. Summary results from monitoring the effect of impact compaction.

depth of 300mm and significant compaction was recorded. Densities were not determined at greater depths. The densification resulted in a settlement of 38mm in 750mm of imported fill overlying a swampy area and of 90mm in the *in situ* material. Cut and fill materials were treated with the

impact compactor with similar end-results.

It is clear from the results that a significant improvement in strength was achieved under the impact compaction. The DCP results (total penetration between 1.85 and 1.9m) showed that the increase occurred over the full

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depth of nearly 2m. The material effectively increased from G9 to G7 quality (at a relatively high *in situ* moisture content). This is supported by a back analysis of the plate bearing value which results in a calculated Elastic Modulus (E) of 140MPa which is typical of G7 materials in the moist state.

The impact compaction process resulted in disturbance of the upper 50 to 200mm of the non-cohesive sand surface due to the horizontal shear forces developed during the impact compaction process.

This was rectified by rolling with a 10t vibrating roller after the addition of 25mm of Berea Red sand to the upper 150mm of the layer, scarification, mixing and levelling prior to placement of the foamed-bitumen layer.

It should be noted that, as the energy applied to the subgrade during impact compaction was significantly higher than will ever be applied by traffic, the possibility of traffic-induced rutting in the subgrade is essentially eliminated.

Foamed bitumen

The foamed bitumen was produced off-site using a Colas plant, the product being trucked in, dumped, spread and rolled. Various mixes of the available sands were tested with different cement and bitumen contents to arrive at the optimum mix design for the foamed bitumen. The *in situ* materials were very moist during construction, necessitating the addition of an extra 1% cement.



The 25kJ Landpac impact compactor used in the project. The compactor is hauled by a 250kW four-wheel-drive tractor.

Some localised problems were encountered with the high plasticity in certain pockets within the Berea Red sand which had not broken down during processing and which disintegrated during rolling and in service in the road. The final mix consisted of 89% white sand, 5% Berea Red sand, 2% cement and 4% 150/200 pen bitumen.

Drainage

As the township is in a wet area, drainage was considered to be important. The drainage relies on the natural gradient in the area with flat side slopes on the formation to move water away from the road. These flat side-slopes also help to minimise erosion.

In the areas where the vleis are crossed, the road was raised on fill constructed from the local sand and

compacted with the impact compactor. The silty nature of the fill material resulted in high capillary suctions which necessitated the fill being raised to provide at least 750mm of pavement above the capillary water height.

Costs

The total cost of the project was R220 000/km. This represented an effective saving of R60 000/km over conventional methods. This was considered to be very cost-effective in terms of the paucity of construction materials in the region.

Performance

At the time of preparation of this paper, the roads were less than six months old. Apart from localised holes resulting from disintegration of the plastic 'nodules' of Berea Red sand the performance of the road has been good. The performance of the road will be closely monitored over the next few years.

Conclusions

This project has shown that, in an area where no traditional construction materials occur, it is economically possible to construct light pavement structures with only one imported layer of material by ensuring suitable subgrade preparation.

Heavy impact compaction has been shown to be a rapid, cost-effective means of obtaining appropriate compaction in the subgrade to a depth outside the influence of normal traffic.

It is thus unlikely that significant rutting resulting from further compaction of the subgrade will occur during the design life of the road.

