THE USE OF PRECAST CONCRETE BLOCKS FOR THE CONSTRUCTION OF STRIP ROADS IN THIRD WORLD COUNTRIES

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SUMMARY

Cost-effective methods of providing adequate transportation facilities is a problem which many under-developed African Nations must address.

Due to the lack of available finance, roads in the more remote areas of these countries are often constructed with inferior natural materials which results in either costly maintenance programmes or, a road surface which quickly deteriorates through neglect and eventually becomes impassable.

Consequently, lines of communication are severed and commercial trading suffers due to the lack of infrastructural development.

Another major factor for sustaining growth in third world countries is that of creating employment schemes and an education system sufficient to train the local population in road-construction techniques, thereby eliminating the need for expensive expatriate services.

Namibia, a country situated on the West coast of Southern Africa, bordering on Angola, Botswana and South Africa, provides a classic example of these inherent problems and how, through the efforts of a major manufacturer of precast concrete products, a solution was found.

This paper describes a successful project where a unique type of precast concrete interlocking block was used to construct a strip road in the semi-desert surroundings of Ovamboland.

Some Practical and Economic Considerations of Road Construction in Third World Countries

In any developing country, adequate transportation facilities are vital to ensure successful socio-economic and industrial growth.

Therefore, most nations throughout Southern Africa are continually seeking cost effective and practical road construction methods for the more remote parts of their land.

Once built, maintenance programmes play a major role in keeping these low-cost roads to an acceptable standard, and this requires substantial financing which is not available to most African countries.

By definition [1], "a low cost road is one, which having regard to considerations of climate and traffic, has been located and built to geometrical standards commensurable with future requirements, but has been constructed with bases and surface to meet the present traffic requirements. It is, however, one which should be so designed, constructed and maintained that it allows for stage construction when traffic requires it and improvement in economic conditions permit".

Factors which require consideration [2] in the construction of low-cost roads are to;

(a) optimise socio-economic considerations in route selection, design standards and construction methods

(b) minimise construction and maintenance costs

(c) provide for stage construction where applicable

(d) provide for safe operations within the indicated and carefully planned prognosed traffic volume

(e) allow for labour-intensive construction techniques and the use of local human resources

(f) optimise the use of locally available, natural materials

(g) address environmental problems such as erosion, land slides, forest starvation and dust pollution

Finding solutions to these problems are certainly common to all African nations and none more so than Namibia.

In the northern parts of the country, namely Ovamboland, the devastating effects of a war which raged for more than 20 years meant that little or no maintenance had been undertaken on the many kilometres of unsurfaced sand roads in the region.

The Government of the newly independent country soon realised that the rehabilitation of feeder road networks would play a vital role in re-opening channels of communication, stimulating commercial trade and agricultural development in the most densely populated area of the country.

However, restricted finance, lack of quality road building materials and the vast distances meant that the Namibian Government were forced to consider alternative methods of road construction.

During April 1990, the Specialist Contracting Division of a

major manufacturer of precast concrete products was approached for assistance with a pilot project.

Following lengthy discussions with the manufacturer, the Namibian Department of Transport decided that a strip road configuration, using a unique design of interlocking concrete blocks could be a viable alternative to the more traditional surfacing materials.

Consequently, it was decided that a three kilometre test section be built to assess the overall performance in the harsh semi-desert surroundings of Ovamboland.

Although bitumen based strip roads have been built in other parts of the World and are well known to travellers in Zimbabwe and Zambia, it is believed that this project is the first in Africa to be constructed by using interlocking precast concrete blocks.

The Suitability of Locally Available Road Building Materials

As previously mentioned in this paper, Ovamboland does not possess many deposits of quality gravels and generally the available in-situ materials consist of a fine to very fine clayey sand.

In order to finalise the design of the precast concrete strip road, a full soils investigation was required so that actual material properties could be analysed and assessed for their suitability in layerwork construction.

Insitu materials were sampled from the existing road and also from available "shona" deposits adjacent to the test site.

Typical test results are indicated in Table 1.

TYPE	IN-SITU ROAD	SILCRETE DEPOSIT	SHONA DEPOSIT
DEPTH	0 - 350 mm	—	—
IN-SITU M.C.	4,4%	—	—
IN-SITU DENSITY	91,2%	—	—
MOD. AASHTO	2008	1827	2026
< 0,075mm	17%	6%	21%
G.M.	1,2	1,7	1,1
P.I.	13	7	16
CBR AT 90%	6	18	4
93%	13	31	9
95%	22	46	17

TABLE 1

The on-site testing established gradings and in-situ densities of the existing road material at varying depths. Further laboratory tests were subsequently undertaken on samples of the same material, various "shona" deposits and silcrete from a borrow pit in order to analyse CBR values at relative densities, moisture contents, plasticity indices and modified AASHTO values.

The test site in Namibia was some 3000 kilometres from the manufacturers headquarters and, therefore, presented unusual logistical problems in the implementation of this portion of the project.

The Structural and Geometric Design of the Road

In line with the overall concept of low volume road construction, the concrete manufacturer proposed that local materials should be used for construction with differing structural designs incorporated along the 3km test section so that behavioural patterns could be monitored under loading.

Eventually, four distinct foundation designs were utilised and are described in Table 2.

TEST SECTION	NO. 1	NO. 2	NO. 3	NO. 4
CHAINAGE KM 0	1,4	2,0	2,5	3,0
BLOCK LAYING	INTO EXCAVATED TRENCHES	INTO EXCAVATED TRENCHES	INTO EXCAVATED TRENCHES	LAID ONTO SUBGRADE
BEDDING LAYER	25mm SAND	25mm SAND	25mm SAND	25mm SAND ON 25mm GRAVEL
GAP FILLER	SAND / CEMENT MORTAR	SAND / CEMENT MORTAR	SAND / CEMENT MORTAR	NOT REQUIRED
WEARING COURSE 150mm	NATURAL SILCRETE FROM BORROW PIT	EXISTING ROADWAY MATERIAL FROM CHAINAGE 2,0 - 2,5	NATURAL CLAYEY SAND FROM SHONA DEPOSIT	50% CLAY MIXED WITH 50% SAND FROM NATURAL DEPOSIT
DESIGN CBR / DENSITY	45 AT 95%	45 AT 95%	30 AT 95%	30 AT 95%
SUBBASE 150mm	EXISTING ROADWAY MATERIAL	EXISTING ROADWAY MATERIAL	NATURAL CLAYEY SAND FROM SHONA DEPOSIT	EXISTING ROADWAY MATERIAL
DESIGN CBR / DENSITY	15 AT 93%	15 AT 93%	15 AT 93%	15 AT 93%

TYPICAL STRUCTURAL DESIGN TABLE 2

Ovamboland is a predominantly flat region with only slight, undulating natural land contours and sporadic rainfall through the summer months. It was therefore considered necessary to design the test section with a 3% double camber graded to both sides to allow surface water to run off into the adjacent veld.

Consequently, an additional wearing course layer was required over the existing sub-grade, not only to provide the structural bearing capacity but also to raise the road levels so that adequate drainage would be provided.

Being a low volume road, it was established that the designs should cater for approximately 100 light duty vehicles per day with maybe one, or two delivery trucks.

From the results of the tests undertaken on the existing road materials, it was found that they would be adequate as a sub-grade layer. However, material selection for the wearing course or sub-base layer required special consideration.

Silcrete located at a borrow pit some 15km from the site was specified for use along the first section, but it was realised that haulage costs would not meet the ultimate objective of providing a low cost road. Thereafter, the wearing course layer of the remaining three sections were all constructed of a clayey "shona" sand material which was readily available.

A typical section through the precast concrete strip road and in-situ approach slab are shown in Figs. 1 and 2 respectively.

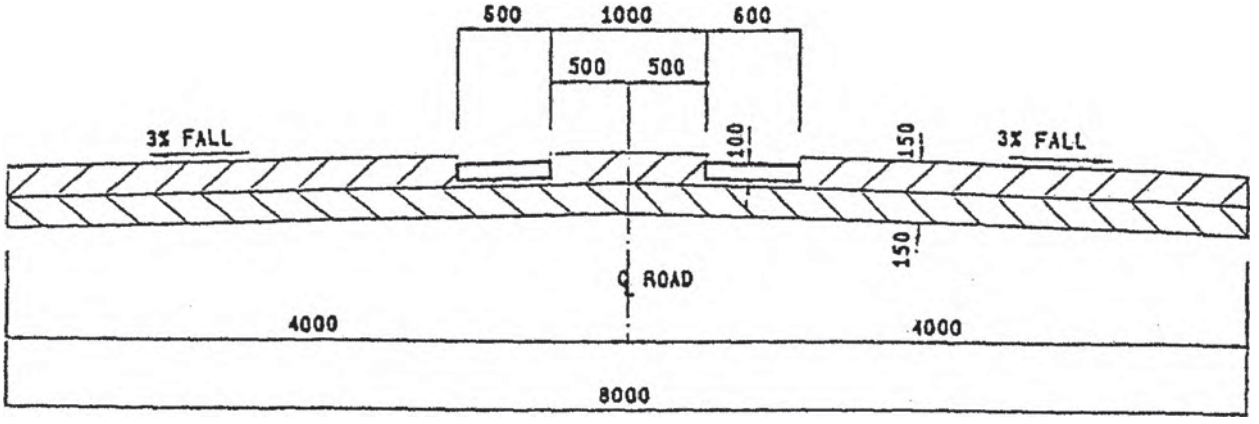


FIGURE 1

TYPICAL SECTION THRU ROADWAY SCALE 1:50

To cater for the majority of vehicles likely to use the strip road, the blocks were spaced 1000mm apart, so that both sets of tyres would be comfortably placed upon the precast concrete strips. The full road width was 8000mm to allow for the passing mode when oncoming or overtaking vehicles would have to move off the strips and eventually return after safe passing.

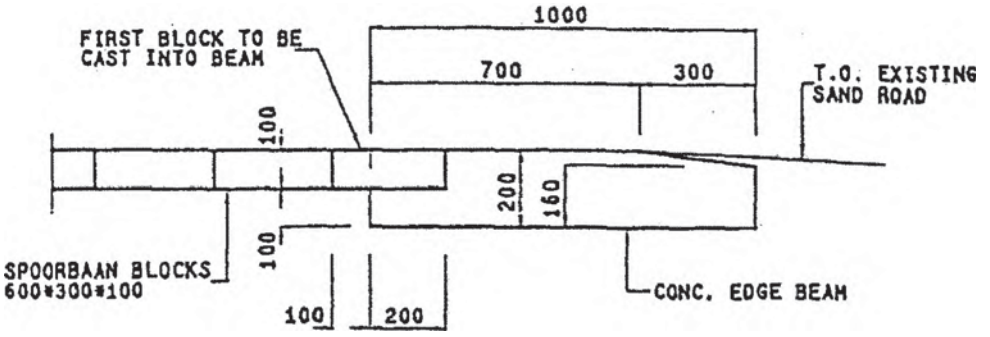


FIGURE 2

TYP. SECTION THRU APPROACH RAMP SCALE 1:20

An in-situ concrete slab was designed at each end of the trial section to provide restraint to the blocks from the horizontal forces caused by traffic moving from the existing sand road onto the strips.

Block Production

The precast concrete units were produced at a manufacturing operation located in Grootfontein, which was the closest facility available to the test site.

The existing VB2 blockmaking machine was specially adapted to accept the prefabricated block mould and also a steel draw sheet technique to form the unusual shaped block which is illustrated below in Figure 3.

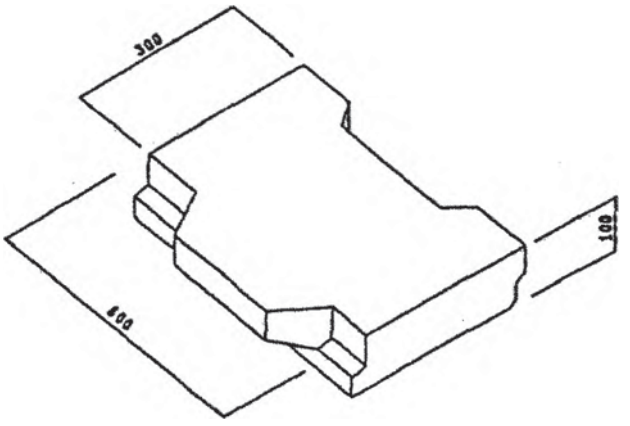


FIGURE 3

Under wheel loading, the tongue and groove configuration along both sides of the 600mm block dimension provides an interlock

to disperse the positive shear transfer from one block to the next and also the mechanical joint between each block offers resistance to any vertical forces which may arise.

A wet compressive strength of 25 MPa at 28 days was specified using the following concrete mix design which yields a cement aggregate ratio of 1:6.

120 kg 9,5mm crushed aggregate
420 kg crushed sand
 90 kg cement

A total of 20 000 No. blocks were manufactured over a period of 17 days and fully cured prior to despatch. The blocks were then transported in 36 tonne trucks over a distance of 350 kilometres to the test site in Oshakati.

The Advantages of Using Precast Concrete Blocks

For many years precast concrete blocks have offered strength, durability and aesthetic appeal to projects built worldwide and this strip road was no exception. However, the following advantages became apparent to the client not only at proposal stage but also as the contract progressed.

(a) The system proved to be labour intensive and would provide employment for the local population.

(b) The blocks are all pre-manufactured and cured prior to delivery thereby offering easy and clean handling.

(c) No expensive construction equipment would be required for block installation.

(d) Should any material consolidation occur under the blocks, the very nature of the strip road concept would still keep its structural integrity.

(e) In the harsh climatic conditions, expansion joints are not necessary as the blocks are infinitely jointed.

(f) The use of precast concrete blocks would increase the skid resistance properties under braking/slewing forces.

(g) Any maintenance required could be carried out cheaply and easily by local labour crews.

(h) The dust hazard is considerably reduced thereby making for safer driving conditions and future environmental control.

(i) The strip road configuration is ideally suited to stage construction where finance permits.

(j) Should the strip road be subjected to exceptional damage through, say an Act of God, the blocks offer considerable salvage value and would be re-used elsewhere.

(k) Mobile production plants could be used to manufacture the blocks directly on site and then moved from time to time as construction progresses.

The Construction Phase

The sub-grade and wearing course layers were built to the design parameters as indicated in Table 2 and this operation took approximately 3 weeks to complete.

One week prior to the first block delivery, the construction crew commenced trench excavation for both strips from the start of the test section.



The trenches were cut by hand, 1000mm apart, to a depth of 125mm and trimmed accurately with small hand tools. As the wearing course layer was designed to provide stability against any lateral block movement, it was important to ensure that any overbreak was kept to a minimum. A local sand was used for bedding purposes and screeded to a thickness of +/- 25mm across the full trench width.

The approach slab at chainage 0,00km was then cast with the first two blocks incorporated into the pour to provide initial stability for both strips. Thereafter, the excavation crew continued along the test section always keeping well ahead of the block laying team.



The blocks were easily manhandled into position and then placed so that the full interlock was achieved. Fine sand was brushed into the joints and a sand/cement mortar was used to till any material overbreak between the block edge and wearing course layer. Pneumatic compaction was used to ensure the blocks were bedded correctly and that all the joints were completely filled with sand. The block laying process was identical for Sections 1, 2 and 3 but was purposely altered for Section 4.

Along this final section, the blocks were laid directly onto the sub-grade and local shona material spread around the blocks to provide the wearing course layer. Small rollers and hand stampers were then used to compact this material to form both the shoulders and median section. The intention here was to experiment, with a different technique for constructing the strip road. Another in-situ slab was cast at the end uf the 3km test section to finish the process and this portion of construction took approximately two months to complete.

The Performance of the Strip Road

During a period of ten months after completion, the performance of the road was critically evaluated [3], specifically during the summer rainfall season between November and February. Re gular visits were made so that a full record could be kept on the performance of each section of the roadway and an as-built soils survey was compiled for reference purposes.

Soon after the trial section had been opened, it was observed

that traffic volumes had increased to an average of 300 vehicles per day which is substantially more than allowed for in the original design parameters. However, the roadway is still performing as expected and offers a very comfortable driving surface, specifically when compared to the badly corrugated sand roads in the surrounding areas.

From a total of 20 000 blocks originally laid, no more than 150 No. or 0,75% show signs of distress and the cracking in no way impairs the serviceability of the strip road. In the passing mode, more than 80% of the road users are using the strip road correctly and the generation of dust has reduced to a minimum. In isolated areas, some consolidation has occurred under the blocks but again, due to the flexible nature of interlock, the riding surface is not impaired.



Minor maintenance has been undertaken on the test section mainly along the median between the two block strips and along both road shoulders where limited settlement of the wearing course occurred, to depths of approximately 25mm. Where necessary, local material from a nearby deposit was spread over the full road width and compacted so that the wearing course would again be flush with the block surface.

Although the evaluation period has produced one or two minor modifications which would be incorporated into any future low-volume strip roads, the experimental test section using precast concrete blocks in this type of configuration has proved a success.

In conclusion, there is little doubt that this method of con struction could be used to provide secondary and tertiary roads in many of the under developed countries around the World.

REFERENCES

[1] Tanzania Government : Quoted : Second Five Year Development Plan, 10th International Road Congress, Dar-es-Salaam, 1969, Vo. 1, p.53.

[2] Dierks, K. ’A General Decision Making Model for the Development of Appropriate, Low-Volume Rural Roads in Namibia with Special Reference to Labour-Intensive Building Methods', Windhoek, 1990.

[3] Michau, P.St.C. 'Spoorbaan Trial Road on DR3613 from Oshakati to Okahao - Ovamboland’, Johannesburg, 1991.