THE CHOICE OF PRECAST CONCRETE BLOCK PAVING FOR LARGE INDUSTRIAL PROJECTS IN REMOTE REGIONS OF SOUTH AFRICA

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SUMMARY

The use of segmental concrete blocks in South Africa has, over the past ten years, enjoyed increasing popularity as an acceptable method of industrial pavement construction. As time progresses and more experience is gained, local design engineers and clients have become more comfortable with this type of pavement and its capabilities which has resulted in an increase in the size of projects being con structed with concrete blocks. It has further resulted in the consideration of block pavements for use on large projects which are situated in regions remote from the main metropolitan areas of South Africa, a country of 1 200 000 km2 and only 10 major cities.

This paper presents a discussion of two of the largest industrial block paving projects to have been constructed in South Africs, each being situated more than 350km from Johannesburg.

Both of these projects have characteristics which ultimately resulted in different reasons being responsible for the choice of block paving as the surfacing. In the one case, economic and climatic reasons were important while in the other inferior subsoil materials, maintenance and construction programme advantages were more relevant.

The paper discusses the economic, structural and practical investigations that were undertaken prior to the final selection of surfacing, it discusses the planning and co-ordination required during construction and illustrates that, although logistical and practical problems are associated with construction, a block pavement can nevertheless be competitive in remote regions.



Geographical Locations in S.Africa

1. CEMENT FACTORY. N.CAPE.

1.1 Introduction.

In June of 1984, a new cement factory at ULCO in the Northern Cape was nearing completion and a final decision was required as to the type of surfacing to be used on the 50000m2 of roads and storage areas on the project.

The paving specification for the project allowed for the use of either precast concrete blocks or the more traditional insitu concrete slab. The client, being a cement producer, decided against the use of any surfacing material which did not contain cement.

One of the contractors in the joint venture construction team is a major manufacturer of precast concrete blocks in South Africa and although the project is situated over 300km from their nearest production plant, they were keen to investigate the possibility of using blocks rather than the slab alternative.

The client did not have any preference for either type of surface as long as the pavement ultimately provided him with the service that he required.

The Civil Engineer on the project requested a proposal from the contractor which he could consider before making his final recommendation to the client. This proposal had to deal with structural, economic and climatic considerations and also had to ensure that the project programme would not be extended.

1.2 Structural Considerations.

Cross-sections through the various proposed pavement designs are shown in Figure 1.

At the time when the final decision as to the type of pavement to be adopted was required, the majority of the sublayers had already been constructed to the top of the Selected Subgrade

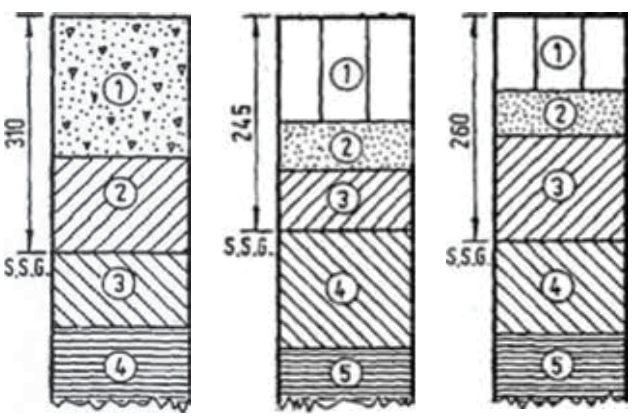
Gravel (SSG). Although it was recognised that there would be differing thicknesses of pave ment above this level depending on the final pavement choice the finished levels on the project were not considered critical enough to influence the final design.

The loading on the pavement was estimated as follows :-
Access Roads - 20 fully laden 50t cement haulers and 20 empty cement haulers per day.

Storage/Service Areas — Solid wheel fork-lift activity of a moderate nature.

Design Life - 40 years

In addition, on certain access roads, there could be light vehicles and infrequent maintenance vehicles.



1a. CONCRETE ROAD	1b. 100mm BLOCKS	1c. 80mm BLOCKS
1. 210 mm CONCRETE SLAB	1. 100mm INTERLOCKING BLOCKS	1. 80mm INTERLOCKING BLOCKS
2. 100 mm SUB-BASE CRUSHED STONE 95% MOD AASHTO	2. 20 mm BEDDING SAND	2. 20 mm BEDDING SAND
3. 150mm S.S.G 95% MOD. AASHTO C.B.R. « 15	3. 125 mm SUB-BASE CRUSHED STONE	3. 160 mm SUB-BASE CRUSHED STONE
4. SUBGRADE TO 93% MOD. AASHTO C.B.R. « 7	4. 150mm S.S.G C.B.R. S 15	4. 150mm S.S.G C.B.R. S 15
	5. SUBGRADE C.B.R. S 7	5. SUBGRADE C.B.R. S 7

Figure 1. Pavement Cross-sections

From reference to the catalogue of designs in "Structural Design of Segmental Block Pavements for Southern Africa" (1) it was ascertained that a traffic design condition of Type 1c was applicable and that the pavement design based on using 80mm thick interlocking blocks would be adequate.

On this project, a separate contract had been awarded to produce crushed aggregates for concrete and crushed rock subbase material. This contract, having been completed earlier, have produced enough material to satisfy the requirements of the concrete road design. However, in order to construct the block pavement, substantially more crushed stone subbase would have been required. Two 125mm thick subbase layers stabilised with 3% cement were specified to be used in place of the 160mm crushed stone layer once the crushed stone material was finished.

Consideration was also given to the applicability of using either 80mm or 100mm blocks on the main access road to the factory from the provincial road where traffic speeds of up to 60 km/hr could be expected. It was decided that as long as joint widths were maintained at between 2 and 5mm, the 80mm thick blocks would be adequate and there would be no risk of blocks being "plucked out" due to the vehicle speed. A polishing effect to the surface of the blocks, which could result in reduced wheelgrip, was also believed not to be a pro blem provided that crushed aggregates were used in block manufacture (as was the case).

The original specification required that 40 MPa blocks be supplied to the project. In South Africa, it is not normal for blocks of such a high compressive strength to be manufactured. In normal industrial applications, blocks of 25 MPa are common with strengths of 35 MPa being required only in areas of extremely harsh conditions . In this case, it was recommended that blocks with a 28 day strength of 25 MPa would be adequate.

The original concrete road proposal did not call for edge restraints other than compacted subbase material. It was necessary for heavy duty industrial kerbs to be included as horizontal restraints for the blocks in the alternative proposal. Figure 2 shows the two alternative solutions.

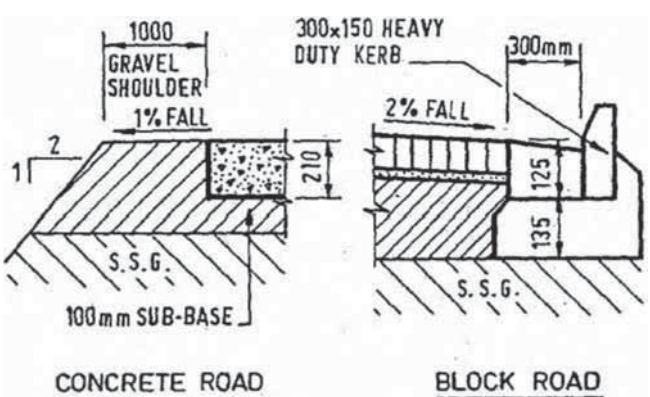


Figure 2. Edge Restraints.

Yet a further consideration was one ok drainiage. The concrete road proposal required a crossfall of only 1% against the block pavement which required a 2% crossfall. Consequently there was a further slight increase in subbase material necessary to make up this slope difference .

All of these differences became pertinent in the economic comparisons discussed in Section 1.5.

1.3 CLIMATIC CONSIDERATIONS.

The relevant climatic factors which were used in the assessment of the two pavement types are summarised below :-

Temperature

Min.	-8 Deg C
Max.	40 Deg C
Average Min.	10,8 Deg C
Average Max.	26 Deg C
Average Variation	15,2 Deg C

Rainfall

Annual Average	419 mm
Winter Average	7 mm
Summer Monthly Average	65 mm
Extreme 24 hour period	70 mm

The possibility of intense 24 hour rainfalls which occur regularly in this region during Summer was considered not to be a problem for block paving, provided that -
(i) the 2% crossfall was maintained
(ii) the jointing sand complied with the specification
(iii) the joint widths were between 2 and 5 mm
(iv) adequate attention was paid to the discharge of the stormwater from the pavement edges

Due to the large temperature differentials and the particularly high daily temperatures in Summer, it was considered that the flexibility and infinitely jointed nature of the block pavement would provide better resistance against stresses caused by thermal movement which can be particularly problematic with cast insitu concrete slabs.

1.4 PRACTICAL CONSIDERATIONS.

Whereas the construction of an insitu concrete road would be relatively straight forward, it was realised that the practicalities of importing concrete blocks from as far as 300-400 kms away would require careful planning and coordination.

It was proposed that manufacturing of the blocks would have to start early enough to allow a stock level of at least 6000m2 to be established on site before the commencement of laying operations. This was considered the minimum requirement in order to ensure a continuous supply of blocks to the laying subcontractor in the event of there being either manufacturing or transport disruptions.

The transportation of the blocks, which was in the order of 9000t of material, was considered to be large enough to warrant the letting of a separate sub-contract for the delivery and offloading of the precast units.

As there was only one supplier of river sand within a 200 km radius of the site, concern was expressed about the quality of bedding sand and the likelihood of its standard being maintained within the required grading specifications. However, discussions with the supplier ensured that a stockpile of sand meeting the required specifications would be made available for the project.

Although the grading of the locally available sand did not totally fall within the NITRR RP/9/84 (1) recommended envelope, it was found that it was close enough not to be a problem. Figure 3 shows the average grading of the bedding sand which was used on the project. The sifted river sand from the same source was proposed for the jointing sand.

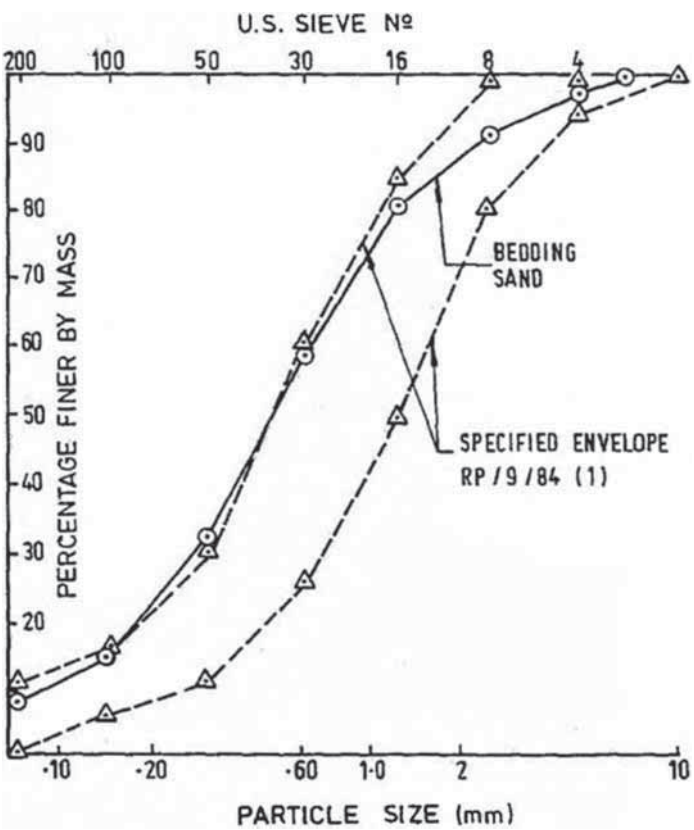


Figure 3. Bedding Sand Grading.

The time available in the programme for the construction of the roads and service also dictated an average laying rate of 600m2/day for 4 months starting in February 1985. It is

not anticipated that this would present a pro blem, especially if the on site stock of blocks was established before laying commenced.

1.5 ECONOMIC CONSIDERATIONS.

In carrying out an accurate economic comparison between the two alternative proposals, it was necessary to include all additional items that would make up the final block pavement con struction. This included the following :-

(a) kerb edge restraints

(b) additional crushed stone subbase

(c) additional earthworks due to increased crossfall

(d) initial inclusion of 80mm and 100mm blocks

(e) initial inclusion of 25 MPa and 30 MPa strengths

In order to facilitate the exercise, all rates were reduced to project tender rates initially and only escalated once the total costs were calculated.

The following assumptions were made for the purpose of the comparison :-

(a) 50 600m2 paving

(b) 6 000m kerbing

(c) Concrete Road
Original road 19 000m2 - 275mm thick
Additional road 31 600m2 - 210mm thick

(d) Tender rates:

Blocks - supplied and laid/m2

80/25	R23,36
80/25	R24,17
100/25	R28,39
100/35	R29,28

Earthworks/m3

S.S.G.	R 4,44
Crushed Stone	R21,76
Stabilised Subbase	Rll,75

Kerbs/m R17,33

Concrete Road/m2

275mm thick	R33,42
210mm thick	R28,61

PROPOSAL	TOTAL PRICE AT TENDER RATES	TOTAL PRICE AT ESCALATED RATES (+22%)
1. Concrete Road	R1539100	R1877700
2. Block Pavin crushed stone subbase		
2a. 80/25	R1363416	R1663370
2b. 80/35	R1404402	R1713370
2c. 100/25	R1582634	R1930810
2d. 100/35	R1627668	R1985750
3. Block Pavin stabilised subbase		
3a. 80/25	R1357016	R1655560
3b. 80/35	R1398002	R1705560
3c. 100/25	R1575834	R1922520
3d. 100/35	R1620868	R1977460

Table: Total Price Comparisons.

1.6 PAVEMENT CHOICE.

Having completed the investigations as out lined above, the contractor presented his pro posals to the Engineer for consideration. The main factors in favour of the proposal were as follows :-

1. Interlocking blocks laid on a suitably de signed foundation were technically adequate for the particular application.

2. The provision of 80mm thick blocks of 25 MPa compressive strength (28 days, wet) would be sufficient.

3. The foundation design contained in Figure 1, or as amended for stabilised subbase was an adequate design.

4. When taking into account the loading and climatic conditions, a flexible pavement would be a superior solution.

5. The block pavement would offer the client a financial saving in the order of R214 000.

After due consideration, the Engineer recom mended to the client that the block paving solution be accepted. The contractor was in strutted to commence manufacture of the 80/20 blocks in November 1984 and construction in February 1985.

1.7 PAVEMENT CONSTRUCTION.

The manufacture of the blocks was ultimately carried out at two different factories in order to satisfy the tight programme requirements of the project. These factories were situated in the Carltonville and Welkom areas at distances of 425km and 325km respectively from the site.

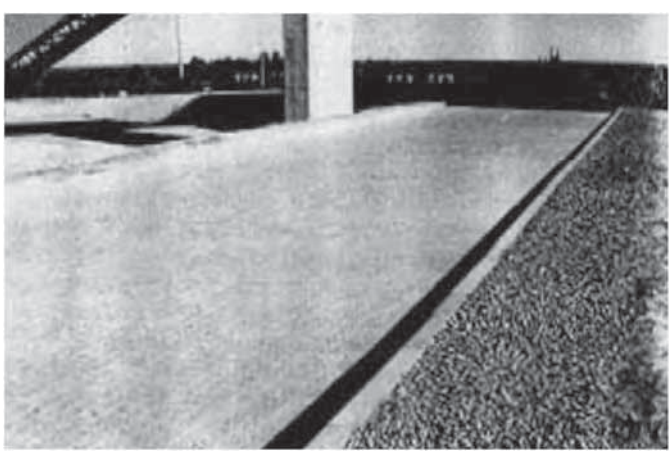
Tenders were called for the transportation of

the blocks and a sub-contract ultimately signed with one operator. The transporter was to ensure that 6000m2 of blocks were on site prior to the start of construction and then to maintain a rate of 150t or 850m2 per day thereafter. The provision of the stockpile on site proved invaluable on a number of occasions due to transport breakdowns and the increase in block laying production.

No problems were experienced with the quality of the bedding and jointing sands and no delays occurred in the block laying other than those due to earthworks preparation and weather conditions . It should be remembered that the months between February and June are Summer months and the period of highest rainfall.

The block laying contractors were based on site while the manufacturer's Contracts Manager co-ordinated all delivery activities as well as all liaison with the Engineers and other contractors involved. Rates of laying at times peaked over 1000m2 per day for a team of 4 skilled layers and 18 unskilled labourers.

Ultimately, 45 000m2 of blocks and 6 200m of kerbs were constructed within a period of 4 months. The Engineer and client were extremely satisfied with the entire construction phase of the pavement and the project was handed over within programme and budget. Therefore fully justifying the Engineer's decision to select the precast concrete block alternative.



A Section of the Completed Block Pavement at Ulco

1.8 PAVEMENT PERFORMANCE.

At the time of writing, the pavement has been in service for approximately 2-1/2 years and is performing is predicted.

The only sign of a possible problem is in one area of particularly heavy slewing by the heavy trucks where there are indications of the block ourface wearing. This ranId also be a function of the colder temperatures in Winter.

There is some evidence of colour variation on the pavement resulting from the manufacture of the blocks at two different factories. However, the variation is not severe enough to be aesthetically displeasing.

The client is satisfied with the performance of the pavement and has had to carry out little maintenance work on it.

Stormwater management has been excellent and structural distress is neither evident at this stage nor expected to be a problem in the future.

2. NEW GOLD PLANT. ORANGE FUEL STATE.

2.1 INTRODUCTION.

In November 1985, a contract was awarded to a large manufacturer of precast concrete blocks to supply and lay approximately 100 000m2 of 80mm and 60mm thick interlocking blocks for roads, storage areas and general open spaces at a new Gold Plant in Welkom in the Orange Free State, 350km South of Johannesburg.

The client used their own in-house civil engineering design department to carry out the design and supervision of the pavement contract .

While the construction phase provided some unusual logistical and co-ordination problems, the more interesting aspect of this project is the discussion of the initial reasons for the choice of block paving and the assessment of how the pavement has satisfied these original conceptions.

2.2 SUB-SOIL CONDITIONS.

A comprehensive soils investigation for the whole project was carried out for the designers by a firm of Consulting Engineers specialising in Geotechnical Engineering. In total, forty-three 760mm diameter test holes were examined on the site which indicated the following soil conditions :-

(a) the site bedrock is mainly a yellowish and greenish grey silt stone present at depths varying from 2,7m to 8,2m below natural ground level. At these levels it is of very soft rock consistency, becoming more competent with depth.

(b) the soils overlaying the bedrock are generally as follows : -
(i) Windblown sands which extend to a maximum depth of 1,6m have been shown to become very compressible when saturated and can be classified as "collapsing" sands.

(ii) Stiff fissured sandy clays and highly fissured and slickensided very stiff shales extending to the top of the bedrock. Sandy clays have swell potentials ranging from medium to very high, are very desiccated and can un-

dergo significant swell, up to 150mm, if their moisture content is increased. These clays have P.I's of up to 32 and CBR's less than 7%.

It is clear that the major factors controlling the design of the pavement was the expansive clays underlying most of the site and to a lesser extent the potentially "collapsing" windblown sands present near the surface. Figure 4 shows a typical profile for the site.

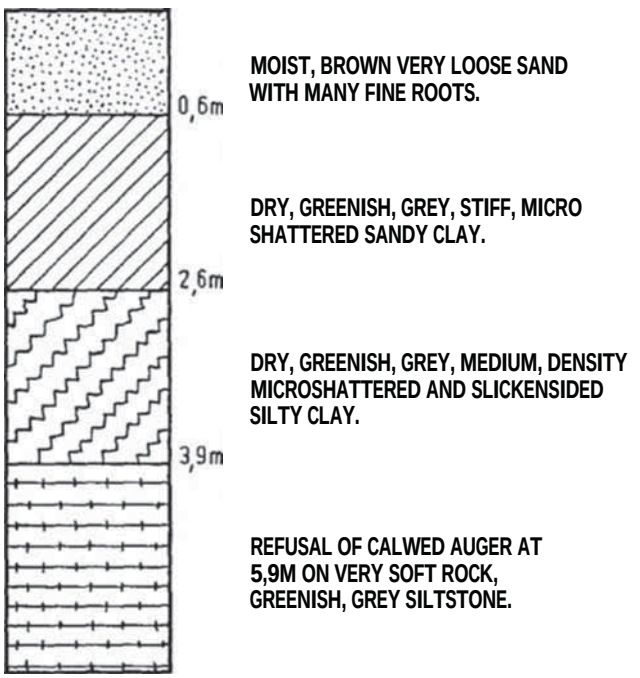


Figure 4. Sub-Soil Profile.

2.3 DESIGN CONSIDERATIONS.

The gold bearing ore is delivered from the Gold Mine to the Gold Plant by rail or conveyors and consequently there are only moderate loading conditions required of the pavement. In fact, the most severe loading was expected to occur during the construction phase of the plant to complete the structural steel erection simultaneously with the laying of the pavement.

The nature of the sub-soil conditions were such as to persuade the designers that a flexible pavement would be preferable to a rigid pavement . This was further backed up by the poor performance of a reinforced concrete road which had been constructed nearby at an earlier date.

The use of an asphalt surface was precluded for the following main reasons :-

1. the high summer temperatures

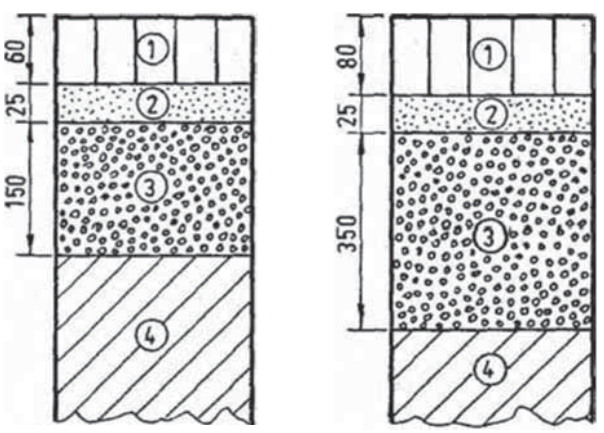
2. the transportation and use of corrosive chemicals

3. the need for the pavement to sustain several construction activities prior to the opening of the plant.

It was therefore concluded by the designers that precast concrete blocks offered the best solution.

As the depth of potentially heaving clay was in some areas considerable, the design philosophy adopted maintained that the excessive removal of the clays was neither desirable economically nor necessary structurally. It therefore remained to design the pavement such that the structural depth would be sufficient to satisfy the loading imposed vertically on the insitu material.

Dump rock which was available in abundance from the nearby mine shafts was specified as the sub-base material. 20 000m2 of 80mm thick interlocking blocks were specified on the roadways and 80 000m2 of 60mm thick blocks in the storage and other general purpose areas. Figure 5 shows sections through the pavements.



5a LIGHT TRAFFIC AREA

1. 60/25 INTERLOCKING BLOCKS.
2. 25mm BEDDING SAND.
3. 150mm SELECTED DUMP ROCK. PARTICLE SIZE ≥75MM. COMPACTED WITH 10 PASSES OF 8t VIBRATORY ROLLER.
4. IN-SITU MATERIAL RIPPED 150mm AND COMPACTED TO 95% MOD. AASHTO.

5B HEAVY TRAFFIC AREA

1. 80/25 INTERLOCKING BLOCKS.
2. 25mm BEDDING SAND.
3. 550mm SELECTED DUMP ROCK. PARTICLE SIZE ≥100MM. COMPACTED WITH 10 PASSES OF 8t VIBRATORY ROLLER.
4. SUB-GRADE MATERIAL TO BE COMPACTED TO ACHIEVE C.B.R. ≤ 7%.

Figure 5. Pavement Cross Sections.

2.4 MAINTENANCE AND OTHER CONSIDERATIONS.

A striking aspect of this project was the existence of large areas which would have little or

no vehicular loading. The need for these areas to be surfaced and the high priority placed on the minimisation of maintenance further reinforced the dscision to use precast concrete blocks.

The most important points taken into consideration were as follows :-

1. the lower cost of maintenance should the pavement move due to the sub-soil heaving

2. grass and trees would not survive in areas subject to chemical pollution or process spillage, therefore untrafficked areas would require Surfacing to reduce dust

3. in order to minimise the ingress of moisture into the sub-soils, grassed areas were not recommended

4. the need for the reduction of maintenance contractors for security reasons (e.g. garden services)

5. large open areas would be required as storage space for maintenance equipment to the main plant

6. the need for the future installation of additional services below pavement level due to expansion programmes



A Typical Open Area of Paying.

2.5 CONSTRUCTION PHASE.

The blocks were manufactured at two different factories in order to meet the required produc tion programme. The 60mm blocks were delivered from a factory close-by while the 80mm blocks were delivered from a factory more than 350km away.

The majority of the block laying was carried out in 8 months by a contractor utilizing 4 skilled layers and 16 unskilled labourers.

No particular construction problems were expe rienced as a great deal of attention was paid to the planning of work areas and the co ordination with other contractors through the Site Managers. The efficient co-ordination of the block deliveries to the site was of particular importance due to the distance involved in the case of the one factory and due to the lack of space on site.

The normal sequence of events for the construction of n typical area was as follows :-

1. steel fabrication contractors vacate area

2. earthworks contractor constructs foundation layers

3. paving contractor installs kerbs and lays blocks

4. area inspected by cliest's representative and accepted

5. steel fabrication contractors move back into area with mobile cranes etc.

The time lapse between steps 3 and 5 would sometimes be only a matter of one day. It is very obvious that there was a tremendous advantage in having blocks which were capable of immediate use as the pavement surfacing. During this critical fast track construction period on the project, the high intensity of other construction disciplines and activities would have caused considerable programme problems due to curing periods if insltu concrete slabs had been specified and would have caused considerable damage if asphalt had been specified.

2.6 PAVEMENT PERFORMANCE.

At the time of writing, the pavement has been in service for more than 18 months and has been performing as required in all areas.

There are a few areas where sub-soil movement has taken place which has resulted in slight surface deflections. However, these are minimal and do not affect the serviceability of the pavement.

There are also one or two areas where the blocks show signs of surface deterioration which appear to have been caused during the particularly harsh construction phase. Again these areas form a very small percentage of the total and have not affected serviceability.

In general, the client is extremely satisfied with the pavement which has certainly performed as expected in the various areas of initial concern. In fact, the same client has since had several other projects paved using cone blocks.

CONCLUSION.

In South Africa, concrete block pavements for large industrial developments are rapidly becoming a viable alternative to the more conv-

tional asphalt and insitu concrete hards landings.

Their structural capabilities, together with their practical and maintenance benefits are acknowledged as important and relevant attributes and these are automatically being considered in the initial feasibility study for any particular project.

It has been illustrated that in order to arrive at the most economic long term solution to a pavement design, it is necessary to undertake extensive investigations. This is even more critical in the case of concrete block paving in remote areas of South Africa where it is not only a relatively new pavement type, but where large distances from production units may initially cause a specifier to exclude it from his options on the basis of economy.

The foregoing discussion also illustrates the important point that "value" is certainly not measured by cost alone.

Logistical and construction organisational factors can have as important an influence on the ultimate choice of paving to be used as can technical and economic considerations.

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