Concrete block paved roads: the development potential

Construction and development

Number 8

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Concrete block paved roads: the development potential

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Donald Macleod
Centre for Policy Analysis
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Construction and Development Series

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Series preface

Policies and strategies for promoting development in South Africa are arguably as important a product of the Development Bank of Southern Africa as its loan finance and technical assistance programmes. The series of publications on 'Construction and development' illustrates this point.

Development projects in South Africa have traditionally been undertaken to meet only the physical needs of the recipient community. South Africa's changing social and economic environment demands that such projects be executed in a manner that ensures that the community's other needs are also addressed. To achieve this, projects should be structured so that opportunities for employment and the development of skills and entrepreneurial abilities are maximised.

Construction is an essential sector in any growing economy. In South Africa it has historically been both an important employer and an industry typical of the overcapitalisation which has bedevilled the economy. These considerations, together with the fact that a large part of DBSA's lending goes to construction projects, suggested that it would be helpful to make practical proposals to assist the industry to adapt and contribute to development in the new circumstances.

The publications in this series present an approach to development that focuses on:

— the identification of the broad economic and social needs of communities

— optimal use of resources available to them

— ways in which communities can exploit the opportunities presented by development projects

— approaches to making best use of labour — an abundant but underutilised resource

— appropriate design and methods of building and construction

— the use of, and misconceptions about, building regulations.

The publications are thus designed to help alleviate the constraints which have inhibited poorer communities from developing the skills at both individual and community level that can lead to the development of entrepreneurship and genuine empowerment. This is perhaps the most important message of the series. It is above all through active participation in the process of development that individuals and communities can improve their quality of life. And it is to this end that the series is dedicated.

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Modification and additions

Users and readers are requested to share their comments, recommendations and own experiences. Readers who wish to contribute to further editions should contact the author.

For further information contact:

D Macleod
Development Bank of Southern Africa
P O Box 1234, Halfway House, 1685
Tel: (011) 313-3911
Fax: (011) 313-3086/3072

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Preface

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Part I: Introduction

In document 3 of the Construction and development series, *Guidelines for the identification of appropriate construction methods in developing areas*, the criteria given for supporting the construction component of any development project are that it should:

- be affordable
- be acceptable to the end user
- be appropriate to the brief
- address the needs of the community
- make maximum use of local resources
- contribute to the community in economic terms
- be such that the community's resources are sufficient to operate and maintain the facility provided.

That document emphasised that a development project that is implemented to satisfy a need of the community should satisfy as many of the community's other needs as possible. In document 1 in this series, *Socio-economic enhancement of development projects,* the additional needs that should be satisfied by a development project are further identified as employment, wages, training, entrepreneurial opportunities, etc.

Given the housing backlog in South Africa and the resultant need for new settlements supplied with roads and services, the upgrading that is necessary to almost all of the roads in townships that were conceived and developed with only rudimentary roads and services, and the poor condition of many rural roads, there is an obvious demand throughout the country for roads of an adequate and acceptable quality. The satisfaction of this demand represents an opportunity for the upliftment and development of the communities that need these roads.

Support for the policy that all construction projects should, as far as is practical, aim to maximise employment and other opportunities comes also from the recent announcements by the Government regarding steps to alleviate unemployment, the initiatives taken by the National Economic Forum and by Cosatu and the National Committee for Labour-Intensive Construction.

This paper deals with the use of concrete block paving (CBP) and seeks to show that this paving medium can provide extremely durable, structurally adequate roads that are aesthetically pleasing and that its use can considerably increase the labour content of the surfacing of any road that would normally be finished using double seal or asphalt. It also seeks to show that the use of CBP can provide opportunities for local entrepreneurs and small contractors, and that this can be achieved at a cost that is comparable with that of conventional road construction or at a premium that is acceptable in view of the contribution that the use of CBP can make to the community.

This paper should prove useful to anyone concerned with development within South Africa, including local and regional authorities, development agencies, the consultants and planners who advise them, and non-governmental organisations concerned with job creation and with improvement of the environment.

This is not intended as a labour-intensive roads manual[1] or a technical manual on CBP. The technical aspects of this paving medium that are dealt with serve to highlight the properties of

CBP that make it unique and that, in DBSA's experience, are not fully understood by many who are engaged in development in South Africa. This paper is intended to provide in a readily available form:

— pertinent information regarding the technical performance of CBP

— important points of design and detail that are likely to affect that performance

— information that will allow the reader to evaluate the advantages and disadvantages of CBP compared to conventionally surfaced roads.

To achieve these goals, it is inevitable that reference be made to conventional asphalt surfacing. However, no attempt is made to provide a comparative analysis of CBP and conventional road construction. It is hoped that the information provided will stimulate development practitioners to acquire a better understanding of the situations in which the use of CBP, with its attendant employment and entrepreneurial opportunities, should be considered.

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[1] Labour-intensive road construction is covered in detail in the documents listed in the bibliography given on pages 108 - 114 of *Interim guidelines for labour-based construction projects*, document 2 in this series.

Part II: Background information on concrete block paving

1. Development

For centuries urban roads have been paved using segmental paving in the form of stone blocks (known as setts), wooden blocks and bricks bedded and jointed with materials such as sand, cement mortar, lime mortar and bitumen. The modern interlocking concrete block paver can be regarded as the successor of these materials. Much of the work on the development of CBP was carried out in Germany between the end of the nineteenth century and the First World War. Experiments in 1930 produced blocks with a compressive strength of up to 100 MPa, and tests in 1936 showed that CBP could stand up to very heavy traffic. However, until the end of the Second World War block pavers produced in concrete were regarded as simply a cheaper, more accurately sized version of the stone sett.

It was in the reconstruction of war-damaged Europe that the modern concrete block paver finally evolved. In the Netherlands at that time all brick production was required for building purposes and the paving industry started producing rectangular concrete pavers as a substitute for the traditional brick pavers that had been used in the Netherlands for centuries. These concrete pavers were used successfully, and as their use increased designers began to refine the block shapes so that each unit could key into its neighbour. The dentated and accurately dimensioned shapes that evolved had the following advantages:

- The pavers were self-locating.
- The joint width could be accurately controlled.
- The bedding and jointing medium was simply sand.

A consequence of this was that it became possible to lay high-quality CBP road surfaces using a labour force that was predominantly unskilled. As the use of this paving spread in Europe, production costs decreased and the variety of proprietary units that came on the market made CBP cheaper and more versatile than any previous form of segmental paving. In the 1960s and early 1970s this paving medium became established and accepted in many countries outside of Europe. CBP was introduced to South Africa in the 1960s.

In most of the countries which adopted CBP there had been little or no experience in the use of small-element paving. Consequently there was a perceived need to establish a sound technological basis for the design and construction of CBP pavements. This led to a sustained world-wide research effort, to which the CSIR of South Africa made a major contribution through work carried out by the National Institute for Transport and Road Research (now Transportek). The results of this research effort served both to distinguish CBP from earlier forms of segmental pavement and to establish it as a modern alternative to other forms of pavement construction.

2. Use today

2.1 General

CBP has been used in ever-increasing quantities over the past 40 years. Initially the popularity of this paving medium was due to its wearing qualities, versatility, low maintenance requirements and its aesthetic appeal. The fact that CBP used more labour than conventional surfacing was regarded as a penalty in Europe's labour-scarce economy. Years of recession have changed this perception, and the opportunities for job creation presented by the use of CBP are now appreciated. This potential has been realised in Australia and in New Zealand where CBP is used extensively in new roads and in the rehabilitation of existing streets, roads, quays and public areas under the banner of Community Employment Programmes. Some years ago the government of Ecuador decided that henceforth all roads surfaced or constructed under its National Roads Building Programme would use CBP to provide the maximum number of jobs in the construction process.

2.2 South Africa

In South Africa many CBP projects have been carried out over the years. The DBSA has studied several of these, for example roads in Goodwood (1966), Chatsworth (1972), Aggeneys (1978/9) and a container terminal in Durban harbour (1978). The DBSA has also monitored CBP projects at Belabela and at Vosloorus. Both were undertaken with the express purpose of providing maximum employment for the local people. As a result of this work and other research the DBSA is confident that where it is correctly designed and constructed, such surfacing will provide adequate technical performance and that its use can dramatically increase employment and entrepreneurial opportunities in the construction process.

In view of the urgent need for employment and entrepreneurial opportunities in South Africa, the DBSA is now encouraging the use of CBP together with labour-intensive approaches on DBSA-funded road projects and recommends that the use of CBP be considered wherever its technical performance and cost render it appropriate to the project under consideration.

3. When is CPB the appropriate paving medium?

Shackel (7 - see technical references in part III, section 2) states:'As broad generalisations it can be said that concrete block paving excels in terms of either cost or performance in the following circumstances:

- Where heavy or concentrated wheel loads are to be carried and especially where large numbers of turning or slewing movements are expected.
- Where traffic intensities are high.
- Where subgrade conditions are poor.
- Where the pavement must withstand severe operational conditions such as widely varying temperatures, frequent fuel, oil or lubricant spillages or large ongoing deep settlements.
- Where ready access to underground services is needed.
- Where the appearance and aesthetic qualities of the pavement are major design considerations.
- Where planning exigencies may require changes in the pavement layout within the effective service life of the blocks, base or sub-base.'

In addition, experience has shown CBP to be particularly suitable at intersections, where braking forces are high and a sustainable level of good skid resistance is required of the road surface. This is especially applicable to environments experiencing high ambient temperatures (>30°C).

4. Acceptability of CBP

4.1 In general

The appeal of CBP to the general public is high. The variety of shapes and the different colours that are available have made concrete block pavers an attractive paving medium for upmarket housing developments, driveways, patios, etc.

For both aesthetic and practical reasons CBP is a popular paving medium in industrial applications and in container depots, garage forecourts, car parking areas and lorry parks. It has been used for years to provide strong and durable parking aprons for planes at European airports and at the time of writing similar CBP aprons are being laid in place at Jan Smuts International Airport in South Africa.

Local authorities and others concerned with the maintenance of roads appreciate

- the long-term durability of CBP
- that maintenance requirements are low
- that where maintenance must be carried out, it can be done with a minimum of equipment
- that services can be accessed or installed with relative ease by removal and replacement of pavers
- that reinstatement of the pavement does not leave obvious patches.

Johannesburg City Council successfully resurfaced deteriorated asphalt roads in the suburb of Brixton with CBP and provided CBP pavements. More recently the resurfacing of Maude Street in Sandton was carried out using CBP in a variety of shapes and colours. From the above it appears that CBP is an established and popular paving medium in South Africa. However, this is not universally the case, as the following section will show.

4.2 To developing communities

It is not unusual for developing communities to regard with suspicion any proposal that materials other than conventional bitumen be used on their roads and these suspicions and reservations must be attended to before embarking on CBP projects. Experience has shown that, if the community is dissatisfied with the road provided for them, no amount of information regarding its technical performance or economy of operation will change the community's perception that the road is deficient in some way.

Two recent incidents illustrate the seriousness of this problem. In May 1993 a consultant engineer reacted to DBSA's suggestion that CBP be used in a roads project in KwaZulu by stating that: 'CBP has been a failure in Chatsworth and is so unpopular with the local community that Durban City Council are tarring it over.'

Enquiries revealed that:

- Far from being a failure the CBP surfacing had performed well with virtually no maintenance since it was laid in the late 1960s and early 1970s.
- The concrete blocks that were laid had no edge chamfers, the kerb detailing was rudimentary and no surfaced footpaths were provided. The roads had a 'utility' appearance that had not been improved by 25 years of constant use and by the use of inappropriate remedial measures, eg tarmac filling of services trenches.

- Poor appearance coupled to the local people's perception that CBP roads were the roads supplied by a white local authority to a subeconomic housing development for another race group had stigmatised the roads and made the community leaders determined that they be 'upgraded' to conventional asphalt.
- Durban City Council was now bowing to the community's demands for 'black' roads, which it could do at bargain rates as the original CBP and its base layers were so structurally sound that asphalt could be laid directly on the surface of the blocks.

The question of perceptions and the influence that these can have on decisions taken by a community arose again this year when the engineer of a township near Uitenhage proposed that the finance available to upgrade the township's roads be spent on CBP surfacing and that the community take advantage of the employment and entrepreneurial opportunities presented. The local civic association rejected this proposal, saying that 'The white communities get black roads, why should we settle for less?'

The members of the civic association were not aware of the widespread and increasing use of CBP in prestigious projects and upmarket developments; their perception that CBP was an 'inferior surfacing to what whites got' was so strong that they were prepared to forgo the employment and other opportunities that the use of CBP offered the community.

These examples illustrate how essential it is that the structures of developing communities be fully informed so that their decisions can be based on facts and not on perceptions. In most instances this can only be achieved by intensive dialogue and possibly by showing the community suitable examples of all the alternatives under consideration. It is hoped that this document will prove helpful in such circumstances.

Part III: Technical information on concrete block paving

Technical references

A great deal of information is available on CBP, the quality of the pavers, the bedding sand, the jointing sand, the design of the base and sub-base, the treatment of the subgrade and the techniques required for successful laying. The following documents were consulted in the preparation of this paper and are extensively quoted from. No attempt is made to repeat the detailed information contained in the references. Anyone wishing to obtain a comprehensive knowledge of CBP would be well advised to study the documents listed.

1) SABS 1058-1985 *Standard specification of concrete paving blocks.* South African Bureau of Standards.
2) SABS 1200 MJ-1984 *Standardised specifications for civil engineering construction, MJ: Segmented paving.* South African Bureau of Standards.
3) Draft UTG 2 *Structural design of segmental block pavements for southern Africa.* Committee of Urban Transport Authorities.
4) BS 7533-1992 *Guide for design of pavements constructed with clay or concrete block pavers.* British Standards Institute (available from the South African Bureau of Standards).
5) *Paving block manual.* Concrete Masonry Association.
6) *Precast concrete paving blocks: Laying manual.* Concrete Masonry Association.
7) *Design and construction of interlocking concrete block pavements,* by B Shackel. Elsevier Applied Science Publishers (available from the Concrete Masonry Association).
8) LOCKPAVE software package for the design of interlocking concrete block pavements, available under licence from the Concrete Masonry Association.

In addition to the above sources of information that concern themselves exclusively with CBP, the following references are quoted from or referred to:

9) TRH 4 1985 *Structural design of inter-urban and rural road pavements.* Committee of State Road Authorities.
10) Research Report DPVT-187 'Use of the dynamic cone penetrometer (DCP) in the design of road structures' by M de Beer. Roads and Transport Technology, CSIR.
11) Computer software version 3 'DCP analysis and classification of DCP survey data' by Citran. Obtainable from Roads and Transport Technology, CSIR.
12) CSIR Research Report 644 'The prediction of moisture content in untreated pavement layers and an application to design in southern Africa' by SL Emery.
13) Concrete block paving for highways, *Highways and Transportation,* December 1991, by Dr O'Grady.

2. Definitions

Definitions differ locally and overseas. This document follows international practice exemplified by documents 4 and 7 and the computer program (8), where the blocks are referred to as *blocks* or *pavers,* the layer immediately under the bedding sand is referred to as the base, the layer intervened between the base and the natural ground as the *sub-base* and the natural ground as the *subgrade.*

In the South African documents (1,2,3,5 and 6) the block layer is referred to as the *base.* The layer immediately under the bedding sand is defined as the *sub-base.* The layers, if any, that are intervened between the natural ground and the sub-base are defined as *selected subgrade* if singular or as *upper selected* and *lower selected* where two layers are used. The natural ground is defined as *subgrade.*

These differences in definition have the potential to confuse designers and layman alike. This problem is discussed in part IV, section 3.

The terms *bitumen* and *bituminous surface* are used in this document to describe conventional bitumen-based, double seal and asphalt road surfacings. The term *road* covers urban and rural roads and streets.

3. The concrete block paver

3.1 General

Concrete paving blocks are produced from high-strength concrete to close dimensional tolerances in machines that are capable of providing mechanical vibration. The blocks are about the size of a standard brick and are manufactured in thicknesses of 50 mm to 120 mm. The top edges of the blocks are normally chamfered. The blocks need to have good abrasion resistance and durability. The compressive strength values of blocks commonly manufactured in South Africa are 25 MPa and 35 MPa.

Block paving is laid on a prepared sand bedding layer on a compacted and prepared base. The dimensional accuracy of the blocks allows them to be laid accurately with very fine joints. The blocks are compacted into the bedding layer by means of a plate vibrator which is passed over the surface of the paving. During the compaction process the bedding sand infills the lower portion of the joints between the blocks. The upper portion of the joints is filled by sand swept and vibrated into these gaps during compaction. *The initial interlock provided in this way between the mating faces of the blocks allows the blocks to share concentrated loads over a wide area of pavement, transforming the block layer into a structural element of the pavement* and differentiating it from previous forms of segmental paving and from bituminous surfacings.

Block pavements can be opened to traffic immediately after the compaction and joint filling have been completed. The block layer tends to stiffen (gain strength) under traffic as the blocks settle down and wedge together until a condition of equilibrium known as lockup is achieved. This is dealt with in 5.1 below.

3.2 Size and shape

The minimum size of a concrete block paver is generally that of a standard brick. SABS 1058-1985 (i) lists the following thicknesses (in mm): 50, 60, 80, 100 and 120. The most readily available thicknesses are 60, 80 and 100 mm. Various block shapes are available. Figure 1 below illustrates some of these. The shape determines the block's classification as follows (the prefix S is used in South Africa; elsewhere blocks are simply classified as A, B or C):

S-A: blocks that interlock along all vertical faces

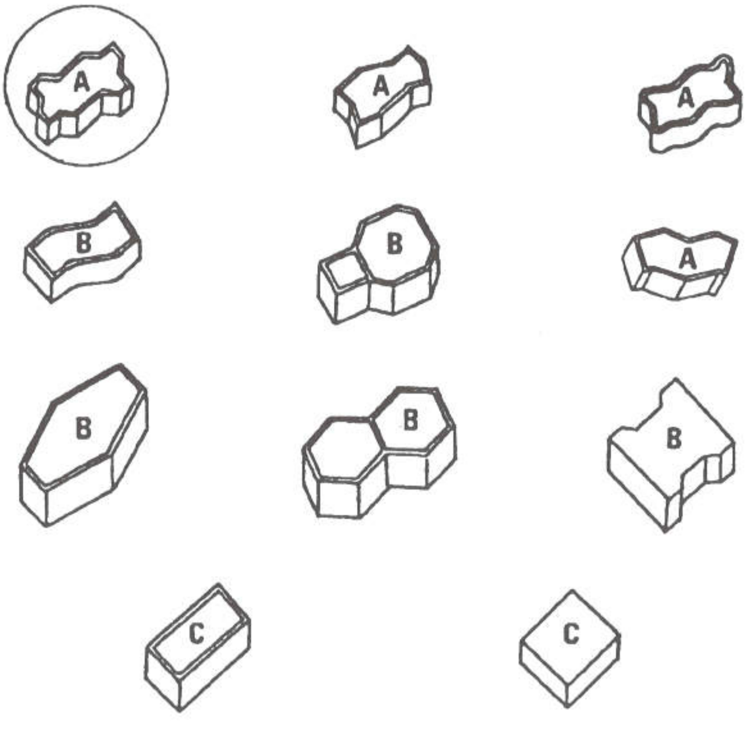
S-B: blocks that interlock along some vertical faces

S-C: blocks that fail to interlock along the vertical faces.

Thus an 80/S-A block is 80 mm thick and will develop full interlock.

The German-designed Uni pave block (circled in figure 1) is manufactured all over the world and its performance has been taken as the standard against which the other block designs are judged. The best performance is generally obtained from S-A blocks. The others are less resistant to high loads and to wheels slewing and screwing but are obviously suitable for lighter loadings or for predominantly pedestrian traffic.

Figure 1: Paving block shapes



3.3 Mix design

The mix design will to a large extent be determined by the quality of the local materials. In many circumstances, where local materials are not suitable they can be rendered suitable by mixing them with a proportion of imported sand and/or aggregate. Once the mix design is established, all materials should be checked for consistency on delivery. The mix should be redesigned if inconsistencies are evident or if the source of the materials is changed.

The following information is quoted for general guidance: Shackel (7), p 162:

The appropriate mix design of the concrete depends on the production techniques adopted. Most paving block machines require a very dry, low-slump mix with the following characteristics:

- Water/cement ratio is normally less than 0,4 and typically within the range 0,34 to 0,38.
- Water content is usually between 5% and 7% of total mix.
- Cement content can be as low as 300 kg/m³ but for adequate durability should not fall below 380 kg/m³.
- Aggregate(ie sand and stone)/cement ratio is typically 3:1 to 6:1. However, experience suggests that 6,2:1 is appropriate for 60 mm thick blocks and 5,5:1 is suitable for 80 mm thick blocks.
- Sand/aggregate ratio is typically 60:40.
- Aggregate size is 6 to 12 mm.
- To ensure durability, the aggregate should be sound and free of soft or honeycombed particles.

3.4 Compressive strength

While blocks with compressive strengths of 40 MPa and 60 MPa are still used in some countries overseas, South Africa has settled on two strengths of block, namely 25 MPa for normal use and 35 MPa for heavy-duty use (in container terminals or in severe environmental conditions where blocks will be exposed to freeze/thaw cycles or frequent washing with sea water).

Only these two strengths of block are covered in SABS 1058 - 1985 (1) and SABS 1200 MJ 1984 (2). The reason for this is set out on p 5 of SABS 1058-1985: 'Research conducted by the National Institute for Transport and Road Research (see NITRR Document RP/9/84) indicates that the structural performance of a pavement is largely dependent on the degree of interlock of the paving blocks, and is virtually unaffected by the compressive strength of the blocks. *The specifying of an unnecessarily high minimum strength will therefore only increase the cost of the paving without improving its performance*' (emphasis added).

This statement assumes of course that the support to the paving is properly designed and constructed.

The compressive strengths specified have only been achieved consistently and economically by casting the concrete paving blocks in machines that provide mechanical vibration. Hand moulding of concrete block pavers is not an option.

The compressive strengths specified are those of the blocks determined in accordance with SABS 1085-1985 (1). The strength given is not the cube strength of the concrete that the blocks are made of.

3.5 The edge chamfer

The chamfer to the upper edges of the paver is a feature that is vital to the satisfactory performance of CBP. The chamfered groove formed between adjacent pavers

- minimises the visual effect of any small discrepancies between the pavers
- directs jointing sand and detritus into the joints
- prevents tyre suction acting on the joint

— allows water to follow the slope of the paving without a build-up of water on the running surface

— reduces the likelihood of a car aquaplaning on a rain-covered CBP surface.

The advantages conferred by the use of chamfered units more than compensate for the better ride quality of unchamfered units (see 4.2 below).

3.6 Durability

The surface of all concrete block pavers must be durable. As is the case with all cement-based products, the durability of the finished article will be enhanced by proper curing. It is recommended that within 24 hours of casting, the blocks be stacked, soaked with water and covered with plastic sheeting to seal in the moisture for a period of 7 days.

4. Surface characteristics of CBP

4.1 Light-reflecting qualities

Tests conducted in 1982 at the University of New South Wales showed that CBP has much higher luminance factors than bituminous surfaces both in daylight and artificial light. The luminance factor for bitumen is approximately 0,07. For blocks it ranges from 0,14 to 0,27 in daylight. The values in artificial light are 0,14 to 0,33.

4.2 Ride quality

Surveys of road users indicate that at speeds below 70 kph CBP is perceived to provide a ride quality equal to that of a bitumen surface. Above this speed, ride quality is perceived to be inferior to that of bitumen. However, the riding quality of a properly constructed CBP road tends to improve under traffic. This fact was taken into consideration when the British Standards Institute prepared BS 7533-1992(4), which gives guidance on the design of CBP roads where traffic speeds will exceed 30 mph (50 kph). See 9 below.

UTG 2 (3), section 9.6, emphasises that 'suitable riding quality requires strict adherence to the surface levels especially between individual blocks' and goes on to say that non-chamfered units generally provide a better ride quality than chamfered units.

It has been suggested that the fact that CBP roads are rougher than bituminous road surfaces could affect the cost benefit analysis of any CBP road that will be subjected to high- speed traffic. The roughness of CBP can be quantified in terms of the Q-car index if this is required.

4.3 Skid resistance

Tests conducted in Denmark by the Danish State Road Laboratory and by Shackel (7) in Australia and in Durban, South Africa, show that the skid resistance of CBP is equal to or exceeds that of bituminous surfaces and is generally the equivalent of that of a grooved rigid pavement. According to Shackel (7) the skid resistance values of CBP decrease in the early stages of traffic and thereafter maintain a satisfactory level.

UTG 2 (3), section 9.6, states: 'For segmental blocks to be used for higher speed roads some degree of surface roughness is necessary. The results of an extensive investigation showed that some bricks and some of the concrete units with smooth surfaces which were evaluated did not provide adequate skid resistance. The normally available 25 MPa wet compressive strength units made with angular particles are suitable.'

4.4 Traffic noise

Studies referred to by Shackel (7) show that at speeds up to 60 kph in dry conditions the traffic noise of CBP is similar to that of a bituminous pavement. In wet conditions CBP has been reported to be quieter than bituminous surfaces. At speeds above 60 kph the noise level on CBP has been measured as 5 to 8 dB higher than on bitumen at similar speeds. A point noted by O'Grady (13) is that the noise generated by traffic on CBP is perceived to be 'different' and this difference appears to inhibit speeding by motorists travelling on CBP surfaces.

4.5 Resistance to water penetration

In the long term CBP becomes effectively impermeable. In the early life of the pavement some water penetration may occur. This is discussed in detail in 6.9 below.

5. Structural characteristics of concrete block paving

5.1 Load-bearing capability

The block layer is not merely a decorative wearing surface but often represents the principal load-bearing course. Typically no more than 50% of the stress applied to the pavers is transmitted to the top of the base. CBP tends to stiffen under traffic and may rapidly gain an equilibrium condition known as *lockup*. Once this is achieved, the stresses reaching the top of the base can diminish to as little as 35% and the pavement has a greatly reduced sensitivity to changes in either the magnitude or the number of repetitions of traffic loadings.

Lockup can be induced by rolling the surface of the paving with a pneumatic-tyred roller immediately after filling the joints. Lockup should be induced where wheel loads in excess of 30 kN will be experienced or where low traffic volumes will delay the achievement of lockup in the paved surface.

5.2 Resistance to deformation

For a given thickness of pavement and a given number of axle loads CBP usually exhibits smaller deformations than bituminous pavements. It is desirable to design block pavements so that, before lockup, they do not accumulate terminal deformations of more than 5-10 mm in urban applications and 15-20 mm in rural or industrial applications.

5.3 Deflections under load

CBP can routinely tolerate much greater recoverable deflections than bituminous pavements. See part IV, section 2.

5.4 Choice of base-course material

The choice of base-course material has a large influence on the performance of CBP under traffic. See part IV, section 3.

6. Practical details

6.1 Laying pattern

The herring-bone pattern has been proved to be the most efficient. The basket weave pattern is less so and the plain stretcher bond pattern has the poorest performance. Highly decorative patterns can be achieved by the use of coloured paving blocks.

6.2 Joint widths

Joint width is critical to the performance of CBP. According to SABS 1200 MJ - 1984 (2), joint widths of 2 mm to 6 mm are acceptable. However, experience has shown that the Concrete Masonry Association's rule of the thumb should be used to judge whether a joint is acceptable or not (*Paving block manual* (5), p 19): 'Joint widths should be as uniform as possible and average 3 mm over 20 pavers.' Uniform joints will not be achieved unless the pavers are of a uniform shape and their dimensions are within the tolerance specified.

6.3 Edge restraints

Edge restraints consisting of precast concrete or cast *in situ* concrete edging strips, kerbs or channels are an essential part of CBP. Their function is to retain the sand bedding and to contain the horizontal thrust that allows load sharing between neighbouring block pavers. The edge restraints ensure that the blocks at the edges of the pavement do not creep outwards or rotate under load with consequent opening of the joints and loss of interlock. Several different approaches to the provision of this essential element are given in *Paving block manual* (5).

6.4 Thickness of paver

The performance of CBP is influenced by the thickness of both the pavers and the base course. An increase in paver thickness is generally more beneficial to pavement performance than a corresponding increase in base thickness. However, increasing the thickness of the paver is likely to be more expensive than increasing the base thickness. In table 1 the LOCKPAVE program (8) was used to calculate base thicknesses for given paver thicknesses on two roads on a weak sub-grade. In both roads a 20 mm increase in the thickness of high strength concrete block will save 50 mm of crushed stone base course.

Table 1: Base thickness versus paver thickness

Road	1			2		
Paver thickness (mm)	100	80	60	60	80	100
Calculated base thickness (mm)	600	645	685	505	460	415
Practical thickness of base (mm)	600	650	700	525	475	425

1 heavily trafficked (in terms of axle loads).

2 approximately half the number of axle loads calculated for 1.

UTG 2 (3), section 9.5, deals with this subject and should be studied for a better understanding of the relationship between the thickness of the paver and that of the base.

6.5 Sand for bedding and jointing

Concrete block pavers should be laid in a bed of sand with a uniform depth of 30 to 50 mm that should compress to 20 to 30 mm when the surface of the CBP is vibrated. BS 7533-1992 (4) recommends that 50 mm of sand be laid on an unbound base and that a lesser thickness be laid on a bound base. However, it is recommended that the procedure set out in section 5.3 of the *Paving block manual* (5) be followed when laying and compacting bedding sand.

Experience has shown that the more sand that is used, the more likely it is that the paving will deform. It is essential therefore that bedding sand is not used to make good discrepancies in the base profile: the finished surface of the base, ie the layer immediately under the bedding sand, should accurately reflect the desired profile of the finished road surface to ensure that a uniform thickness of sand is used.

The quality of sand is all-important. It should not have a significant quantity of plastic fines. Ideally, the sand specified in SABS 1200 MJ-1984 (2), section 3.3, should be used. However, South Africa has plentiful supplies of mine sand and this has been used successfully on many projects in this country.

Shackel (7) cautions that 'Particular care should be given to filling the joints with sand. Ideally, dry jointing sand should be brushed into the joints using hand or mechanical brooms. Excess sand should then be broomed off the pavement before final compaction. The widespread practice of seeking to vibrate the jointing sand into place whilst maintaining a cover of sand on the pavement must be treated with caution as there is a tendency to compact the pavement in a non-uniform manner because of variations in the thickness of the cover of excess sand. This can lead to a rougher riding quality in the pavement than might otherwise be achieved.'

6.6 Plastic sheeting under the bedding sand

The mistaken practice of laying plastic sheeting under the bedding sand of a CBP pavement in the belief that it will discourage the germination of wind-blown seeds or prevent the ingress of moisture to the base and sub-base has led to the premature failure of several CBP projects. The presence of this material produces a slip layer that allows all the lateral forces applied to the paving blocks to concentrate in the layers above the plastic. In no circumstances should plastic sheeting be incorporated in CBP construction.

6.7 Control of weeds

Wind-blown seeds germinate in the sand between the blocks and can be controlled by applying herbicides at suitable intervals of time.

6.8 Drainage and storm-water control

As is the case with other roads, the layers under the CBP should be protected from inundation and consequent lessening of performance by the provision of appropriate drainage and storm-water control measures and possibly by stabilisation of the base layer. S Phillips suggests that an exception to this rule can be made in the case of roads where the layers under the CBP consist of water-bound macadam. In those developments where the roads must double as storm-water channels, CBP is a more durable paving medium than bitumen.

6.9 Moisture control

At construction stage. During the first two to three months after completion some infiltration of water may occur through the joints between the block pavers. If rainfall could be a problem, when the layer of material that will receive the bedding sand is compacted, levelled and trimmed, it should be primed by a light application of a cut-back bitumen or a bituminous emulsion at a rate not exceeding 0,6 litres of residual bitumen per square metre. This seal should immediately be blinded with a light application of the sand chosen for the bedding layer.

In use. It has been shown that in new pavements the jointing sand becomes more compressed, the blocks settle and the joints fill with detritus with the result that the pavement becomes effectively impermeable. Nevertheless it is important that water does not lie or pond on the surface of the paving. To avoid this the minimum cross fall in CBP should be 2% and the minimum longitudinal fall 1%.

7. Rural roads

Interlocking concrete block pavements have been widely used in rural roads in Europe, especially the Netherlands and Germany, and in Central America. Although block paving in rural situations has been used mostly in flat terrain, it has also found application in mountainous areas.

8. Inclined roads

CBP has found application in mountainous areas, for example the Austrian Alps, where the steepness of the grade may make the use of paving machines impractical and where conventional surfacings are apt to creep under traffic. In Chatsworth, Durban, steeply inclined roads were paved with CBP before 1972. A recent inspection showed that these roads were structurally adequate after more than 20 years with little or no maintenance.

9. Traffic speed

It was conventional wisdom that CBP was only suitable for traffic travelling at not more than 60 kph. This view emanated from Europe, where ride comfort and noise levels are possibly more important considerations than need be the case in a developing country. Some years ago the government of Ecuador grasped this fact and decided that henceforth all roads surfaced or constructed under its National Roads Building Programme would use CBP to provide the maximum number of jobs in the construction process.

In 1992 the British Standards Institute issued BS 7533-1992 (4), which gives guidance on the design of minor (50 kph) and major (110 kph) roads constructed with CBP. The recommendations contained in BS 7533-1992 are based on experience with CBP on heavily trafficked sections of British highways over a number of years. In view of this, DBSA considers that where CBP is properly designed, it is a suitable paving medium for roads where traffic will travel at speeds in excess of 60 km (see Part IV Section 7).

10. Maintenance and rehabilitation

CBP roads cost less to maintain than bitumen-surfaced roads and CBP has a higher salvage value than bitumen.

According to Shackel (7), 'Most engineers agree that maintenance costs are lower for block pavements than for bituminous surfaces. A study made in 1969 of 87 block pavements with a total area of 421 000 m^2 constructed between 1957 and 1969 showed clearly that less maintenance was required for the block roads than for conventional pavements. The annual maintenance costs, averaged over a thirty-year period, were estimated to be just 20% of those associated with bituminous surfaces. For industrial block pavements somewhat higher maintenance costs have been reported. For example, in the Europe Container Terminus, Rotterdam, it has been reported that block paving requires about a third of the maintenance expenditures associated with bituminous pavements or concrete rafts.'

Maintenance of CBP surfaces is easily carried out using a minimum of equipment. If services are to be installed or accessed below the paving, the blocks can be removed and replaced. This can be carried out with relative ease by the method described in *Paving block manual* (5) (pp 25 and 26). No patches are obvious in the reinstated surface.

BS 7533-1992 (4) has the following to say on maintenance:

'It may be necessary to reset the pavers during the life of a pavement if the rut depth exceeds 10 mm. This may be a result of displacement of the laying course sand and is not necessarily an indication of pavement failure. An inspection of the roadbase should be carried out prior to the relaying of pavers to ensure that no structural deterioration has occurred.

'Displacement of laying course materials can occur in pavements for a variety of reasons. For example, pavements subjected to channelized trafficking, or particularly severe localized braking or turning movements, may require resetting of the surfacing materials from time to time. Also, areas where sustained heavy rainfall is common may develop surface undulations due to laying course sand movement well before the end of the pavement's structural design life.'

11. Service life of concrete block paving

If properly constructed, CBP roads can have a long life (40 years). Service life is determined primarily by the performance of the base, sub-base and subgrade rather than by any change or deterioration in the blocks themselves. Full-scale repairs are likely to be needed after 20 years, and in reconstruction one may normally expect to reuse 90% to 95% of the blocks.

12. Cost of concrete block paving

12.1 United Kingdom

In the United Kingdom CBP is gaining in use on bituminous surfacings because of its aesthetic appeal and because of the fact that in the UK, CBP roads are now cheaper to build and maintain than conventional roads.

12.2 South Africa

In South Africa it has generally been considered that CBP roads would cost 20% more than bitumen-surfaced roads. In a study of recent CBP projects, consideration of the contract sums submitted in open tender for DBSA-financed road projects and of consultants' estimates for projects shows that this is correct where the anticipated traffic load is a light one and the subgrade conditions are good; but that as the anticipated traffic load gets higher and the subgrade conditions get poorer, the premium for CBP is reduced until the cost of the two alternatives is very similar.

This reduction in the cost of CBP compared with conventional roads depends on various factors, such as:

- The engineer's approach to the design of the CBP road:
    - Does the design of the base layers and treatment of the subgrade reflect the structural capabilities of CBP?
    - Is the cost saving potential of the simpler treatment of these items reflected in the estimates?
- The contractual arrangements:
    - Is the contract such that only a large contractor with adequate resources can price it?
    - Does it encourage the use of labour?
    - Is the contract split into portions that can be priced by small contractors and local entrepreneurs?
- The source of the concrete block pavers:
    - a commercial producer
    - a small subcontractor
    - produced on site using local labour
- The method of laying CBP:
    - main contractor
    - specialist subcontractors
    - local labour.

12.3 Training costs

Depending on the approach taken, allowance may need to be made for the cost of training unskilled labour or providing technical or entrepreneurial support for the establishment of small contractors (see part V, section 2.2). These costs may in many instances be borne by the training budgets of the regional development corporations or recovered from funds supplied by central government.

12.4 Cost-benefit analyses

Capital cost is not the only thing to take into account when deciding between CBP and bituminous surfacing; other considerations are the reduced maintenance cost of CBP over the life of the road, the high salvage value in the block pavers and the potential of this paving medium for providing more employment and entrepreneurial opportunities than conventionally constructed roads.

In a recent roads contract designed for light traffic the estimates for CBP were 22% above those for a Cape Seal surfaced road. However, the cost-benefit analysis showed identical internal rates of return over the life of the road.

In April 1993, when six contractors tendered for a heavily trafficked bitumen surfaced road with alternative prices for CBP, the four lowest tenders priced the CBP marginally lower than the bituminous road. The cost-benefit analysis showed the internal rate of return for CBP to be superior to that for bitumen.

13. Job creation potential of concrete block paving

Any road construction project has the potential for providing employment and entrepreneurial opportunities to members of the community. The extent to which this potential is realised depends on the effort that is made to assign to labour those tasks that can be completed in a labour-intensive manner and to restrict as far as is practical the use of mechanical plant.

The job creation potential unique to CBP lies in the additional labour required to lay concrete block paving and the edge restraints on a prepared base. Also, concrete block pavers of an acceptable quality can be made on site using relatively inexpensive mechanical equipment and locally recruited labour.

Below the surface the labour requirement is the same for CBP and bitumen-surfaced roads — accepting that construction of a CBP road beneath the paving will involve fewer layers or a smaller overall thickness than a bitumen-surfaced road. The two methods also provide the same opportunities to labour in the formation and stabilisation of embankments, the digging and lining of storm-water control measures, the construction of culverts, the erection of fencing, landscaping and grass sowing.

Early in 1993 a consultant engineer made the following comparison for a DBSA-funded roads project in Bophuthatswana. The road was approximately 10 km long and the surfaced width was 12 m:

Person-months required to surface road with double seal	3,25
Person-months required to form kerbs and lay CBP	307,00
Person-months added if the concrete paving blocks were made on site by local entrepreneurs	133,00

The calculation for double-seal surfacing assumed normal bituminous surfacing procedures. If Sabita's recently unveiled proposals for labour-enhanced construction of bituminous surfacing[1] had been applied and this had resulted in a tenfold increase in employment, CBP would still have been more labour-intensive.

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[1] Manual 11: *Labour enhanced construction for bituminous surfacing* and Manual 12: *Methods and procedures*, South African Bitumen and Tar Association, March 1993.

Part IV: Design of concrete block paved roads

1. Background

Most of the designs of bituminous roads submitted to the DBSA for funding have been based on the catalogue designs contained in TRH 4 (9). Where the Bank has requested that alternative designs be presented for the roads using CBP, these designs have apparently been achieved by the simple expedient of removing the wearing course and the base layer from the bituminous road design and substituting a block layer on bedding sand on what was the sub-base of the bituminous road. This design convenience apparently stems from a belief fostered by UTG 2 (3) that the concrete pavers and the bedding sand of a CBP road perform the same function as the wearing course and base course of a bituminous road and that these two are equivalent and interchangeable.

According to Shackel (7) this approach can result in overdesign of the subgrade cover of the CBP road with the consequence that the cost of the CBP alternative will be higher than necessary. Paradoxically this simple conversion of a bituminous road to a CBP road carries with it the possibility that the layer immediately below the bedding sand may be overstressed.

It is reasonable for a funding authority to expect that the design finally chosen for a road should be the most economical and appropriate of several designs generated for the anticipated traffic loading, the bearing capacity of the subgrade, the climatic conditions and the quality of the road-base materials that are available locally.

Some time ago the Federal Highways Administration (FHWA) of the United States of America found that these expectations were not being met by proposals for roads projects submitted to it by individual states for funding. Enquiries showed that the designs for these roads were derived predominantly from catalogues. The FHWA reacted by announcing that after 1995 no road-building proposal submitted to it would be considered unless it was

- — the product of a mechanistic design process
- — accompanied by a life-cycle costing analysis
- — the subject of a structured maintenance programme.

In view of this, DBSA considers it advisable to offer the following information concerning the design of CBP roads with apologies to those professionals for whom this section merely states the obvious.

2. Design method

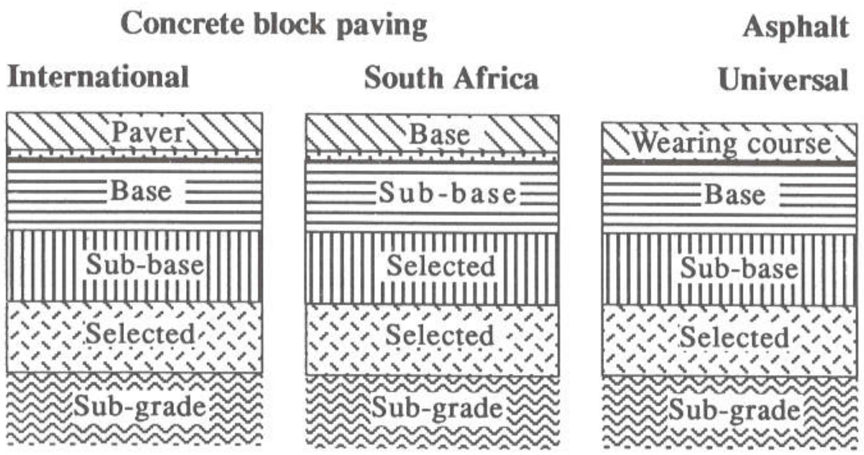
Shackel (7) states that 'It is not appropriate to adapt design methods developed for asphalt pavements to CBP because such procedures are normally predicated on maintaining much smaller pavement deflections than can, in practice, be accepted by a block pavement.' Elsewhere he expands this statement as follows: 'CBP can routinely tolerate much larger deflections than conventional pavements without becoming unserviceable. For this reason the overall stiffness of CBP can often be much less than for a conventional pavement. *Accordingly the thickness of the base and sub-base needed in CBP is normally less than for alternative forms of construction*' (emphasis added).

3. Quality of the layer immediately below the bedding sand

Shackel (7) states: 'Where the term sub-base has been used to describe the layer lying immediately below the bedding sand, this has led inexperienced designers to adapt existing highway sub-base specifications to characterise this layer.' He goes on to say: 'It cannot be overemphasised that it is crucial to specify materials that are of base-course quality for this layer.'

UTG 2 (3) defines the layer under the bedding sand as the sub-base on the premise that 'whereas the blocks themselves form the surfacing of the road, their structural properties are similar to those of a road base — hence they are known as the base layer'.

Figure 2: Comparison of terms used in road construction



It is possible that this premise, together with the South African documentation on CBP roads that reflects it (see part III, section 2), has caused the confusion of which Shackel warned. However, it is suggested that the differences in the names of the layers that make up the different types of road need not be a problem provided that

- The roads are built to a balanced design.
- This design is based on the properties exhibited by the materials used in each layer irrespective of what the layer is called.

It is further suggested that designers cannot achieve balanced designs for CBP roads simply by amending catalogue designs that have been produced for bituminous roads. Indeed it is possible that designers will not achieve balanced designs even if they use the catalogue designs provided specifically for CBP and set out in UTG 2 (3) (see below).

4. Limitations of draft UTG 2

Shackel (7) comments that the catalogue designs that were included in this draft document 'appear to be conservative'. Mechanistic design analysis shows that this indeed so. Most of the designs are very similar to TRH 4 (9) designs for bituminous roads modified in accordance with the premise described in 3 above. Mechanistic analysis was used in conjunction with RSA failure criteria in deriving the TRH 4 (9) design catalogue. It is understood that the UTG 2 (3) catalogue designs were not derived from such detailed analyses. The UTG 2 designs do not appear to take advantage of the intrinsic structural strength of CBP or address the failure modes that are specific to CBP.

5. Differrent design philosophies for treatment of the subgrade

UTG 2 (3) presents a limited menu of predesigned road sections for different loading conditions. The menu can be as limited as it is because an integral design assumption is that the subgrade will have a CBR of 15% (see 7.2 below) or, if it does not, then the subgrade will be modified or a suitable cover in the form of selected layers will be added to achieve a CBR of 15%.

By contrast the LOCKPAVE program (8) designs the road for the CBR of the subgrade whatever that may be. Where the subgrade CBR is 4% or less, the options given by the program are:

- Stabilise the subgrade to provide a working platform for construction and consolidation of the base.
- Construct a suitable sub-base as a working platform on top of the *in situ* subgrade and construct the base on this.

In either case the design produced is such that the compressive stress on the layer immediately under the platform is that dictated by the original *in situ* CBR value of the subgrade.

Another approach where the CBR value of the subgrade is less than 5% is to do the minimum improvement necessary to the subgrade to allow work to proceed on the construction of a base (or a base and sub-base combination) that is designed so that the induced strains in the minimally modified subgrade are within the range of tolerance of the unmodified subgrade.

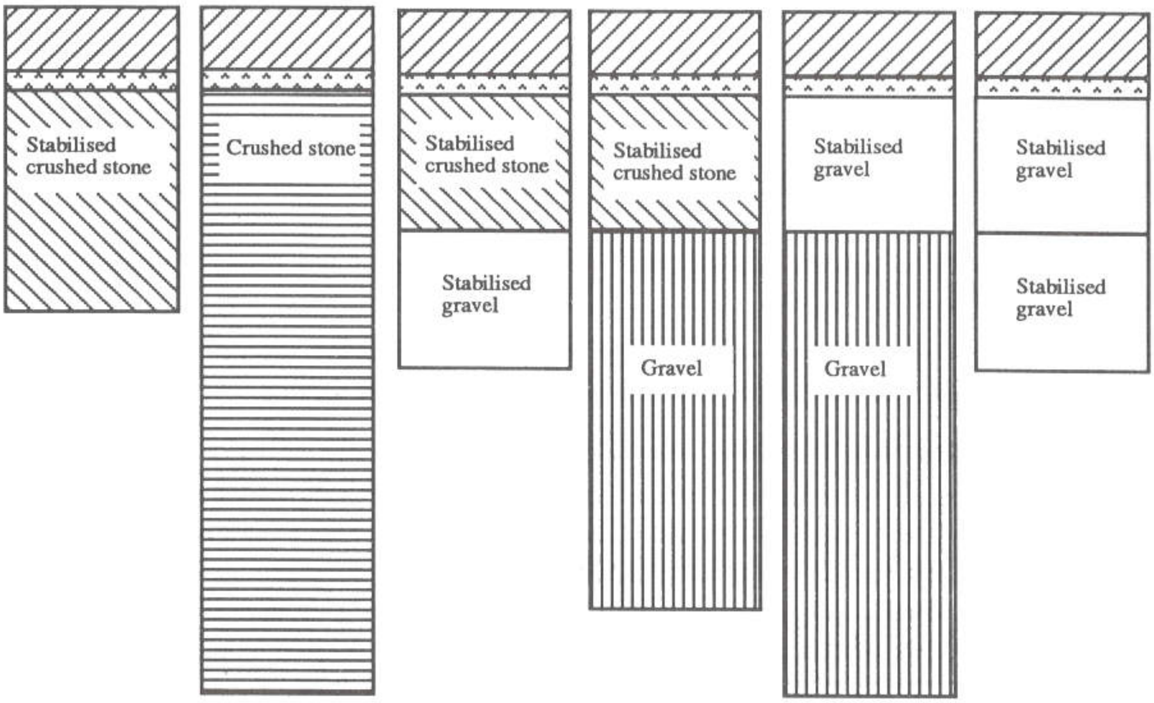
It is felt that these design approaches could profitably be explored by designers and that the result could be cheaper roads. However, to properly explore these approaches they will have to design CBP roads by mechanistic means.

6. Mechanistic design of concrete block paved roads

The LOCKPAVE program and others like it can, for a given set of circumstances, generate many alternative road designs for consideration by a designer. Computer programs like this make it possible to test the effect of using different materials with widely differing characteristics and to examine the cost implications of their use. In addition the mechanistic design method allows one to identify circumstances in which the required thickness of a gravel or crushed stone base is actually less than that required for the stabilised version of the same materials. These circumstances are not covered in the average catalogue design.

Figure 3 below shows six alternative designs produced by the LOCKPAVE program for a road to be constructed on a subgrade with a CBR of 5%. Identical traffic loadings and anticipated life spans were applied in every case.

Figure 3: Road designs



The advantages of the LOCKPAVE program are that it is menu-driven and easy to use; it does not require an extensive knowledge of mechanistic design philosophies; and multiple pavement profiles and loading scenarios can be designed and analysed in a short space of time. However, users of the program should note the following limitations (Kartsounis):

- The program does not use failure criteria for the crushed stone layer (referred to as crushed rock in LOCKPAVE). Therefore, it does not take the overstressing of this layer into account. Overstressing of the crushed stone layer can be a problem if the layer directly below it does not provide adequate support. It is strongly recommended that the crushed stone layer is checked for overstressing in pavement profiles where the supporting layers are not stabilised.
- The program uses cement-stabilised failure criteria for the stabilised layer. These overestimate the tensile strength of lime-stabilised layers by a factor of three.
- The failure criteria for stabilised layers assume failure of the layer at crack initiation. No account is taken of the still useful life of the stabilised layers between crack initiation and their degradation to the equivalent of granular layers.

Another approach to mechanistic design is to use a generic linear elastic program and defined RSA failure criteria instead of a specific CBP program. The generic approach is more flexible than LOCKPAVE but it is more time-consuming and requires a background knowledge of mechanistic design procedures.

With the calculating power of the average PC and computer programs such as LOCKPAVE at their disposal it is inappropriate for designers to resort to 'catalogue' designs for a CBP road — particularly when the catalogue design chosen is that of a bitumen road which is then 'modified' to become a CBP road.

7. Important considerations in road design

7.1 Adjustment of cumulative traffic load (total E80s)

BS 7533-1992 suggests that in certain circumstances adjustments should be made to the cumulative traffic figures for CBP roads as follows:

'Where channelized traffic is expected, the traffic figures should be multiplied by three before carrying out the design, to allow for the increase in the concentrated application of loads at a particularly point on the pavement. Normal lane widths in a highway do not generally constitute channelized traffic but channelized traffic can develop on any road, eg on steep hills or approaches to traffic signals.

'Where speeds in excess of 60 kph are expected, the cumulative traffic should be multiplied by two before carrying out the design to allow for dynamic loading effects.'

7.2 California bearing ratio (CBR)

One of the most common tests for soil for road-making is the CBR test, which was developed in the early 1940s by the United States Army Corps of Engineers. This is essentially a small-scale loading test which measures the force needed to cause a 50 mm diameter disc to penetrate 2,5 mm in about 2,5 minutes into either an *in situ* or a laboratory soil sample. The measured force is expressed as a percentage of 13,2 kN, the force needed to achieve the required penetration into the original sample of crushed California rock.

The same material can produce very different CBR readings at different densities (levels of compaction) and at different moisture contents. While *in situ* CBR tests reproduce the current soil structure, moisture and density, they do not necessarily reproduce the appropriate post-construction conditions. The appropriate density is that achieved by the compaction process. The appropriate moisture content is the equilibrium value.

7.3 Soaked CBR as basis of design

A study of the designs of roads submitted to the DBSA for funding shows that they are invariably done on the basis of the soaked CBR, ie with the subgrade and road-bed materials in their weakest state.

The soaked CBR is appropriate for materials that will be saturated in service. The soaked CBR may not be the appropriate CBR in certain climatic zones or in those circumstances where the base materials and subgrade are unlikely to become saturated.

UTG 2 (3), section 7.2, contains the following suggestion regarding the choice of the CBR value in certain climatic areas of South Africa: 'A proper preliminary soil survey should always be conducted. In the design it is current practice to use soaked CBR values and the use of these soaked values, especially in dry regions, is overconservative. It is therefore suggested that the design CBR of a material be increased from soaked CBR to approach the *in situ* CBR, for example in the large dry areas of southern Africa.' Figure 10 in UTG 2 shows the dry areas referred to.

Emery (12) has the following to say on this subject: 'In South Africa, materials classification of unstabilised and modified soils and gravels is carried out using the soaked CBR test to measure strength. Most pavement design methods use subgrade resilient modulus or CBR determined in the soaked condition. However, it is known that the moisture regime of many pavements in South Africa is drier than this. In other countries, considerable savings are made in the road industry by design using subgrade strength at expected field moisture condition (such as NAASRA, 1979). Such savings should be possible in South Africa once the pavement moisture regime is understood and can be predicted.' He goes on to describe the moisture regime of existing pavements in South Africa, presents methods for predicting moisture content in pavements and integrates predicted moisture content with the pavement design process. The cost savings of designing on the basis of the unsoaked CBR are quantified.

7.4 Properties indicated by the CBR

The CBR test can be a measure of the vertical stress and the shear strength of the material being tested. Uzan *et al* [1]report that

Cohesion of soil (kPa) = 25 x CBR%

Shear strength of soil (kPa) = 6 x CBR%

E (MPa) = 10 x CBR%

While these values are considered appropriate for granular materials, it is suggested that where clay is encountered tests should be done to check the correlation.

7.5 Rapid determination of CBR using a dynamic cone penetrometer

The conventional test for determining the *in situ* CBR of soil samples at various depths is time-consuming or requires the use of expensive equipment that may not be readily available at the level of development discussed in this paper.

Since 1962, when Gawith & Perrin[2] produced a correlation between the *in situ* CBR displayed by a soil and the number of blows required to drive the tip of a dynamic cone penetrometer (DCP) 25 mm into the subject material, it has been possible to use DCP as a rapid means of determining the CBR of soil or base material at many different levels.

Table 2 gives a correlation between CBR and the penetration per blow that is achieved by a DCP capable of delivering 140,3 kN m/m^2.

The DCP is a simple, convenient and inexpensive device which can provide a useful check at all stages of road construction from the preliminary investigation to the final compaction of the base layer. DCP-CBR calibrations are more consistent for granular than cohesive materials because of the moisture sensitivity of cohesive materials. It is recommended that in the case of cohesive materials the CBR values determined using the DCP be calibrated for site conditions by comparing the results with laboratory CBRs (under *in situ* moisture conditions).

Attention is drawn to the advances in DCP technology in reference 10 (information on the use of DCP in the design of road structures) and to the computer software for DCP analysis and classification of DCP survey data (reference 11).

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[1] Uzan, J, Livneh, M & Ishai, I, 1980. 'Thickness design of flexible pavements with different layer structures'. *Australian Road Research* 10(1): 8 - 20.

[2] Gawith, AH & Perrin, CC, 1962. *Development in the design and construction of bituminous surfaced pavements in the state of Victoria, Australia.* Proc Int Conf on Structural Design of Asphalt Pavements. Ann Arbor.

Table 2: Calibration of dynamic cone penetrometer

mm/blow	BR	mm/blow	CBR	mm/blow	CBR
≤4	50+	12	18	23	9
5	50	13	17	25	8
6	40	14	16	28	7
7	33	15	14	33	6
8	28	16	13	38	5
9	25	18	12	45	4
10	22	19	11	60-70	3
11	20	20	10	80-90	2
				≥100	1

Source: Van Vuuren, DJ, 1969. 'Rapid determination of CBR with a portable dynamic cone penetrometer'. *The Rhodesian Engineer*, September.

Part V: DBSA's experience

1. Comparison of three roads projects

1.1 Background

Three roads projects funded by other agencies have had a particular influence on DBSA's policy on the use of CBP together with labour-intensive approaches on Bank-funded roads projects:

- a road constructed between Zwide and Kwazakhele in Port Elizabeth
- a road upgrading project at Belabela Township near Warmbaths
- an IDT-funded site and services scheme with paved roads at Vosloorus Ext 28.

1.2 Port Elizabeth

Here the local authority constructed a conventional bituminous road and pavements to a high standard. The surrounding population has a 70% unemployment rate yet that same population sat and watched an out-of-town contractor build the road in record time using sophisticated machinery. While the community's need for a road was satisfied, no other need was addressed.

1.3 Belabela

In this case R650 000 per annum was made available to upgrade the gravel roads in the Belabela Township. The consultants opted to use CBP and organised the contract in such a way that the community manufactured the pavers, cast concrete kerbs *in situ* and laid the CBP. The pace of the contract was dictated by the need to provide work for each year budgeted for. The community earned 50% of the budgeted amount each year.

This approach met the need of the community for improved roads and also provided work, wages and training. The training created entrepreneurs who were able to continue making paving blocks and bricks for sale to the local community after the roads contract was prematurely ended by lack of funds.

1.4 Vosloorus

The consultants engaged on the Vosloorus site and services scheme followed the approach used at Belabela with the following differences:

- The contract was carried out by a main contractor.
- The contractor won the contract in open tender against more conventional approaches.
- A definite contract period operated with penalties to be imposed if this was exceeded.

Against this background the contract was run with the emphasis on production. The main contractor set up a pan mixer and a block-making machine on site and employed local labour to make, stack, cure and deliver the block pavers. Local subcontractors were appointed to lay the pavers at an agreed rate per square metre. Kerbs were cast *in situ* and storm-water drains were dug by hand and lined with reject block pavers. The contract was completed one month ahead of schedule.

In this case the community decided that quality roads were a priority over other items normally supplied in an IDT-funded site and services scheme. The approach taken not only satisfied this requirement but provided jobs, wages, training and entrepreneurial opportunities. The resultant roads were appropriate, answered a need and would not impose a maintenance burden on the community. It is significant that all this was achieved at a price that was less than that put forward by other contractors for building the roads by conventional means.

1.5 Wages and output

1.5.1 Belabela

As the township roads were to be upgraded with a fixed amount of cash made available each year for five years, there was no scope for providing production incentives in either block production or rate of laying. The work was organised so that it lasted a year and cost exactly the year's allocation of cash. Wage rates were fixed at R8 — R15 a day. With such low wages and no incentive scheme, how was production maintained and quality assured? Was it simply by the threat of dismissal in an economic depression? The consultants claim that this proposition is too simplistic as:

— The work teams were drawn directly from the community that stood to benefit from the upgrading.

— The teams developed their skills and developed a pride in their work.

— Peer pressure had a lot to do with maintenance of quality: local residents were quick to point out a fault if it occurred near their dwelling.

1.5.2 Vosloorus

As the roads and services were part of a large contract with definite contract price and contract period, the blocks had to be produced and laid as quickly as possible. It was therefore possible to structure the contract to provide incentives for increased production and laying rates. The blocks were produced by men paid R20 a day plus a bonus sum that varied with increased rates of production. The blocks were stacked and moved by women who originally earned R10 a day and who, when offered a bonus that would obviously depend on the men's production rate, opted for a fixed rate of R12 a day. Laying was done by self-employed subcontractors paid R4 a square metre if the blocks were delivered to the roadside for them or R4,75 if the subcontractors loaded the blocks in the yard and off-loaded them at the roadside. The transport was supplied by the main contractor.

1.6 Road widths

1.6.1 Belabela

Here the gravel roads were in existence and in use. The widths were fixed as:

Bus routes	7,5 to 8 m
Others	5,5 to 6 m

These widths are excessive if we consider the volume and type of traffic that actually uses the roads. If it had been decided to make the paved roads narrower than the original gravel roads, the yearly grant of money would have produced more lineal metres of usable road. As it is, 25% of the roads remain unpaved after the yearly grant was withdrawn.

1.6.2 Vosloorus

Here the roads were designed as follows:

Bus routes	6,0 m
Main service	5,5 m
Lesser service	3,5 to 4,5 m
Access	2,7 m
Surface water run-off	1,5 to 2,0 m

The bus route is convex (shedding water to the side) and all other roads are concave, acting as a water channel. The narrow roads are widened to 5,5 m at the junctions to facilitate turning for vehicles.

1.7 Conclusion

The insensitivity to the people's needs shown in Port Elizabeth is in contrast to the benefits conferred on the community by the approaches taken at Belabela and Vosloorus. This, coupled with the commercial success of Vosloorus, helped to convince the DBSA that use of CBP would enhance the probability of a roads project's meeting the criteria for development set out in part I of this document.

2. Procurement of concrete pavers

2.1 Suppliers

In DBSA's experience the developmental potential of CBP can only be realised if there is an adequate supply of paving blocks of an acceptable quality at an economical cost. The arrangements that are made to procure the paving blocks are therefore crucial to the success of a CBP project. DBSA has experience of projects where the blocks were procured from:

(a) an established commercial manufacturer making blocks bearing the SABS mark

(b) a casting yard set up on site by the main contractor to serve the contract

(c) a locally established casting yard supervised and organised by the project's consulting engineer

(d) a small established local block-maker with the necessary expertise and business acumen to successfully convert his production to CBP

(e) a newly established block-maker taking advantage of the opportunities presented by the roads contract to enter the CBP business.

The following observations can be made about these suppliers:

Employment. Supplier (a) will generally have employed less labour than any of the others and this labour would not necessarily be from the area to be served by the project. Suppliers (b), (c), (d) and e created many more employment opportunities for the local people.

Cost. The pavers supplied by supplier a will generally be the most expensive and those by (d) and (e) the cheapest.

Quality. Blocks supplied by supplier (a), are of an assured quality. In the case of (b) and (c) the contractor or consultant has direct and informed control of quality. Supplier d has generally required guidance and e has required extensive technical support.

Quantity. Supplier a generally has no difficulty in supplying the contract requirements. Suppliers b and c have the freedom to supply all the required blocks or to obtain additional supplies from suppliers (a), (d) and (e). Suppliers d and e may not individually be able to supply the whole contract but can contribute a suitable part.

Support. Supplier (d) may need entrepreneurial support in the form of bridging loans. Supplier (e) has required extensive entrepreneurial support.

2.2 Choice of supplier

While it is desirable from a developmental point of view to obtain the paving blocks from suppliers d and e, it is only possible to do this if sufficient support mechanisms are in place for these suppliers or emerging entrepreneurs to be given the technical and entrepreneurial assistance required for sustaining their businesses while they become established in this new field. The necessary support can be provided by the regional development authority or can be built into the contract. Document 5 in this series, *Guidelines for emerging contractor development,* sets out a framework for programmes that are designed to provide this support.

2.3 Case study

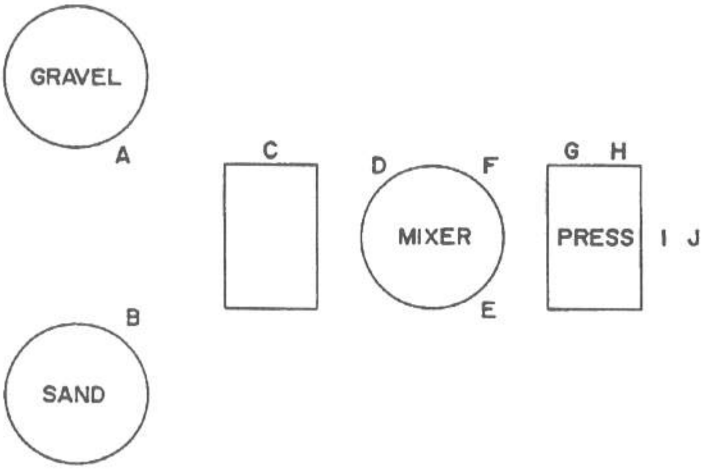
The following is quoted from the consultants' report on a contract in which the supply of blocks was split between a type-a supplier and two type-e suppliers who were established with the assistance of loans from the local development corporation but without, as it emerged, sufficient support mechanisms in place. The recommendations given in the following report represent one approach to solving the problem of support for emerging contractors.

> **Problems encountered during manufacturing of interlocking blocks**
>
> The following are problems encountered by supplier 2 and supplier 3. They are both new small subcontractors:
>
> - Lack of continuing funds for cement, maintenance of plant, etc. Initially they were helped with financing but that seems inadequate.
> - Both subcontractors have other permanent positions and spend little time at the plant, with resultant lack of supervision.
> - The subcontractors do not understand the contract documents. (For example supplier 2 expects to be paid before his concrete blocks are accepted.)
> - The cement mixer is often overloaded.
> - The blades of the mixer are not set correctly.
> - The blades are not kept clean of hardened cement.
> - Cement/sand mix varies considerably.
> - New blocks are not cured by keeping moist or covered by canvas.
>
> It seems that the above-mentioned points occur mainly owing to lack of regard for importance of the points mentioned and not owing to negligence.
>
> The initial crusher sand proposed by PCI consisted of mostly 'rounded river-bed stones' and although a mix was prescribed by PCI, variations soon occurred. Subsequently PCI have prescribed a new source of crusher sand. To date no blocks have been produced to standard, all failing to reach the required crushing strength, probably owing to lack of cement or using wrong or soiled sand.
>
> **Problems encountered during laying of interlocking blocks**
>
> The laying seems to be less of a problem as there is more supervision on site by the consulting engineer or the main contractor.
>
> Supplier 2 had to lay 276 m^2 per day from beginning of August. Supplier 3 had to lay 500 m^2 per day but has now gone bankrupt.
>
> **Conclusion and recommendations**
>
> It seems clear that the manufacturing process poses many problems for the new entrepreneur.

> For assistance with financing we propose that an adequate loan to bridge the period up to payment for the first load of blocks be provided. A typical press and mixer cost approximately R65 000 and R20 000 respectively.
>
> Because of possible claims from the subcontractor or main contractor in case of failure it has always been a problem for the supervising consultant to get involved in the manufacturing process. A better method would be to help select and train staff beforehand. A sufficient lead time for training is essential otherwise production would soon fall behind.
>
> Training should be done by the main contractor and all management should be done by him for an initial period of three months. In this period he shall have all authority over the staff of the subcontractor to ensure that the hiring and training programme runs smoothly. The main contractor should be allowed to tender a lump sum for this training period.
>
> The design mix and testing of the resultant interlocking blocks should be done by the consulting engineer during the design stage using materials available on site. PCI can assist with the design mix.

The consultant goes on to describe a small and efficient block-making yard:

> There is a small, successful contractor near Vryburg using the same plant as supplier 3 and producing 8 000 - 10 000 blocks per day. There is however always good supervision at the mixing and manufacturing plant. Each worker has a specific task and therefore becomes a specialist in this field.
>
> The following sketch indicates how a typical successful layout would function using 10 persons:



Production staff

A: Provides gravel
B: Provides sand
C: Prepares mix
D: Operates mixer
E & F: Feed mixed material into press
G & H: Operate block press
I & J: Stack blocks

Part VI: Conclusion

It is hoped that this document will increase readers' awareness of the contribution that concrete block paving can make to development, labour-intensive construction, opportunities for emerging contractors and entrepreneurial development.

It is also hoped that it will now be easier to identify projects in which CBP is the appropriate surfacing medium, acquaint developing communities with the fact that CBP is not a cheap substitute for 'black' roads and assist development authorities to weigh up the advantages in using CBP against the premium in cost (if any) over bituminous roads.

Designers of roads projects are requested to pay particular attention to part IV. The DBSA is concerned that

— The structural advantages of CBP should be reflected in the designs that are presented for funding.

— The economies which result from mechanistic design of these roads should be reflected in the estimates and in the tender figures.

— Designers should not use the soaked CBR as a basis of design in those circumstances where this has been shown to be inappropriate.

Finally it must be repeated that this document is not intended as a technical manual on CBP. Professionals practising in the fields of development and road construction are recommended to study the references listed in part III, section I. It is expected that consultants seeking to design and supervise DBSA-financed roads projects will ensure that their knowledge of CBP is comprehensive as a study of these references will allow.

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Published by Development Bank of Southern Africa
P O Box 1234 Halfway House 1685
Telephone (011) 313-3911
Telefax (011) 313-3086