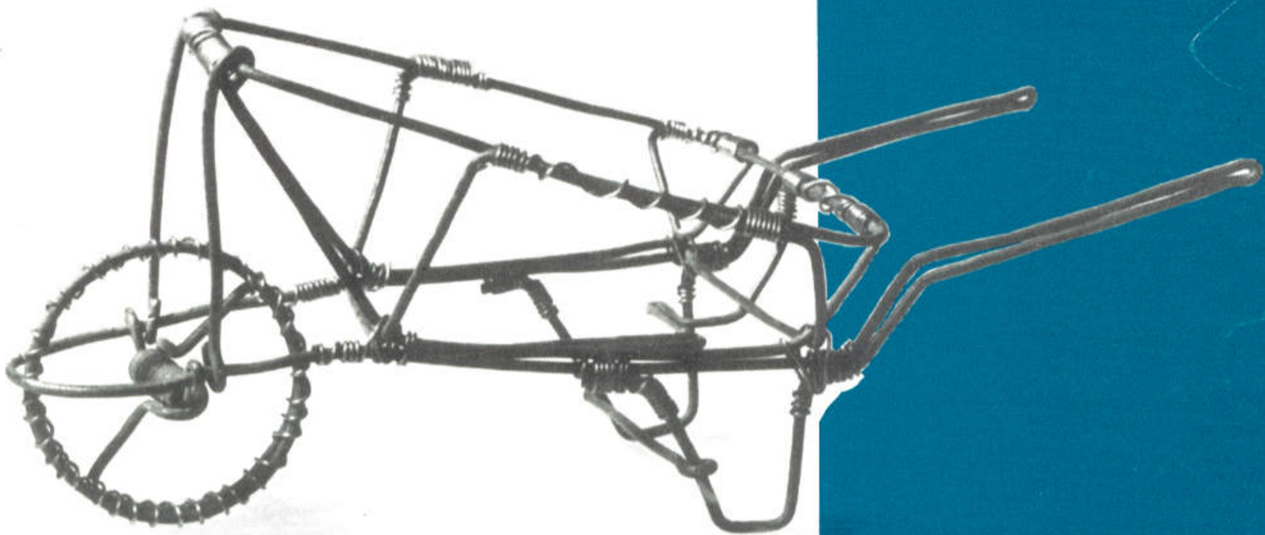
Construction and development

Concrete block paved roads: Experience gained on DBSA-funded projects

Donald MacLeod



Number 10

Concrete block paved roads: Experience gained on DBSA-funded projects

---

Construction and development series

Number 10

Development Bank of Southern Africa

Policy Working Paper No 73

Guideline Paper

ISSN 1022-0127

ISBN 1-874878-68-4

April 1995

Compiled by Donald MacLeod

Centre for Policy and Information

Development Bank of Southern Africa

Price: R10

Construction and development series

Titles in this series include

1	Socio-economic enhancement of development projects	R10
2	Interim guidelines for labour-based construction projects	R75
3	Guidelines for the identification of appropriate construction methods in developing areas	R10
4	Development and the application of building regulations	R10
5	Guidelines for emerging contractor development	R10
6	Labour based opportunities in construction	R10
7	Emerging Contractors: Estimating framework	R10
8	Concrete block paved roads; the developmental potential	R10
9	Small-scale contractors and the provision of housing	R10
10	**Concrete block paved roads: Experience gained on DBSA funded projects**	**R10**

These documents can be ordered from:

Development Bank of Southern Africa
P O Box 1234
Halfway House
1685
Tel (011) 313-3911
Fax (011) 313-3086

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. This 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 are executed in a way that also addresses communities' other needs. To achieve this, projects should be structured so that opportunities for employment and the development of skills and entrepreneurial abilities are maximised.

Construction and maintenance of resultant facilities are an essential part of any growing economy and in South Africa historically an important employer and an industry typifying 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, suggest 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

- 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
- entrepreneurial development.

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 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.

The Construction and development series of publications is produced by DBSA staff and consultants contracted to the Construction and development policy programme, whose advisory panel has recommended the widespread distribution of these publications to further the human development approach pursued by DBSA.

GJ Richter
General Manager

JH de V Botha
Programme Manager

Mission of the Development Bank of Southern Africa

The Development Bank of Southern Africa is a regional development institution whose primary aim is to facilitate socio-economic development and empower people economically in the region.

Acknowledgments

The author gratefully acknowledges input to this document from Mike Kartsounis and the valuable and constructive comments given by colleagues Herbert Atkins, Peter Copley, Glen Havemann, Barry Jackson and Chris Milne. Thanks are also due to the CMA and the SABS for perusing the initial drafts of this document and to the consultants, contractors and communities whose experiences indicated the need for such a document. Finally, thanks to Sandra Calitz for her patient and meticulous typing.

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 compiler.

Copyright

Contents

Part III: Design and estimating for CBP roads projects

Introduction

Documents No 1 and 3 in the Construction and development series deal with development impact and design for development. These documents highlight the overriding principle of the DBSA, namely that the expenditure of development funds should be linked to the maximum use of local resources and making a maximum contribution to the community. The advent of the Reconstruction and Development Programme (RDP) expands this concept in as much as it demands that any construction being funded by government monies should provide employment, training and entrepreneurial opportunities for members of deprived communities.

Given the imbalances in South Africa and the need to create conditions that will enable all of the working population to become economically active, it is logical that this principle should apply to all construction projects. To ensure that this approach to development has an impact on the lives of a maximum number of people it is essential that

- projects are efficiently designed and priced
- the broader needs that a project must serve are identified and form part of the brief to the professional team charged with the design and construction of the project
- the project (design, documentation, method of construction and mode of management) must be the best and optimal solution to the identified problems
- the chosen technology not only satisfies the technological requirements of the project but is compatible with the developmental aims of the project.

This in turn requires that the design professionals must look beyond solutions that are merely conventional technological solutions. They must generate alternative designs and strategies, evaluate these and choose the most appropriate in terms of the paradigm described above. Given DBSA's recent experience of the job creation potential of concrete block paving (CBP) on roads, it is likely that this paving medium will be regarded as appropriate to many applications.

This document is a companion volume to *Concrete block paved roads: the development potential* (Document No 8). Since that document was published, DBSA has funded a large number of CBP roads projects, thereby adding to its experience of this paving medium. These projects have presented DBSA, the design consultants, supervising staff and contractors with a steep learning curve as all sought to familiarise themselves with the requirements and peculiarities of CBP.

DBSA is grateful to all who participated in these projects, who dealt with problems unforeseen and in the process created employment, training and entrepreneurial opportunities for the local communities. This document is based on the experience gained in negotiating the learning curve referred to above. It deals primarily with technical matters and is intended to assist design professionals and site supervisors to build CBP roads that are appropriate for their function and finished to an acceptable standard.

Document No 8, Part III, lists thirteen

technical references and ends with the following injunction: *'It is expected that consultants seeking to design and supervise DBSA-financed roads projects will ensure that their knowledge of CBP is as comprehensive as a study of these references will allow.'*

In retrospect it is now clear that many of the problems which were encountered came about because many of those involved did not have a comprehensive knowledge of CBP and were not familiar with the references. It is equally clear that the information contained in these references must be applied and interpreted. Hopefully the following pages will assist in this.

Part I: Lower standards on labour-based CBP projects?

1. Background

In the course of CBP projects the DBSA sometimes encountered the argument that technical standards must be lowered on labour-based work and when utilising local labour and small-scale contractors.

The developmental aim of each of these projects adhered to the RDP principle that the process of meeting a community's need for a road must provide employment, training and entrepreneurial opportunities for the local population. This, in many instances, meant that the design consultants, contractors and supervisory staff were dealing not only with a technology with which they were not completely familiar, but also with approaches to recruitment, training, construction methods and site supervision that they had not encountered or implemented before.

When problems inevitably arose in the course of these contracts, arguments were put forward by certain consultants and contractors to justify a reduction in the technical standards required 'because of the difficulties inherent in using local labour'.

2. DBSA's view

DBSA considers that such a relaxation of standards would be a mistake that would confirm the perception held by many that roadworks carried out in a labour-intensive manner must inevitably be inferior to these produced by conventional contracting arrangements.

This in turn would be harmful to the government's Reconstruction and Development programme.

In addition, both DBSA and the South African Bureau of Standards (SABS) consider that the standards outlined in the SABS specifications are not onerous or particularly difficult to achieve. However, if CBP roads that comply with SABS standards are to be produced using local contractors, locally recruited labour and the developmental approaches advocated by the DBSA, it is essential that

- all concerned in the process are, or make themselves, familiar with the technology involved in CBP construction
- road layers and the surface that is to receive the paving and bedding sand are constructed to a standard that simplifies the task of block laying
- relevant specifications relating to concrete block paving are acknowledged and complied with
- it is understood that the specifications are there
  - to assist in achieving the required quality
  - not to be pored over and interpreted, with a view to declaring acceptable that which is unacceptable
- developing contractors and locally recruited labour are provided with a suitable level of training.

3. Training

The last requirement mentioned above is one of the vital developmental aims of the DBSA and the RDP to be achieved in CBP roads projects. Consideration must be given at the outset of the project to

- funding for the training
- who will provide the training
- scope of the training, for example technical and entrepreneurial.

On many projects funded by DBSA, the National Economic Forum (NEF), Independent Development Trust (IDT) and the National Public Works Programme (NPWP), training has been funded by the Department of Labour. However, the department's budget has not allowed it to fund training on every project. In these cases the client has either

- funded the necessary training separately from the cost of the project, or
- included a condition in the contract stating that training must take place and accepted that the tenders submitted to carry out the works include the cost of the training specified.

Training is a 'growth industry' in South Africa. A variety of organisations offer training and, depending on the organisation, the training can be good or bad. It is essential therefore that the quality of training provided be evaluated.

In the case of concrete block paving the Portland Cement Institute (PCI) offers help in the establishment of suitable concrete mixes and in the technique of casting concrete of a consistent quality. Some members of the Concrete Masonry Association (CMA) offer courses in block laying and provide certificates of competency.

Certification or proof that a worker has undergone training in a specific discipline is very important. In some projects being carried out under the NEF programme of community-based projects the workers opted to work on projects that offered lower wages but where they would receive training and certificates that proved they had undergone such training.

Part II: Comments on SABS specifications relating to CBP

4. Background

The relevant SABS specifications are described below and those clauses that were ignored, became the subject of debate or argument, or were interpreted in a manner that reduced the quality of the project are commented on. Consultants need to take cognisance of these comments and take steps to avoid similar problems on their projects, by dealing with the matters raised in the following ways:

- address the issue in the design considerations
- cover it in the project specification
- include special conditions in the contract
- emphasise it as a consideration during construction.

It is essential that the following sections be read in conjunction with Document No 8 and the SABS specifications that are referred to.

5. SABS specifications

The relevant specifications are *SABS 1058-1985* and *SABS 1200 MJ-1984*. These give the parameters within which the blocks and the finished road surface are acceptable.

5.1 SABS 1058: Concrete paving blocks

Clauses 4.3 and 4.5 list dimensions and compressive strength.

It is the supplier's responsibility to ensure compliance. To do so it is necessary for the supplier to establish and implement basic quality control procedures to ensure that

- the plan dimensions of any block do not vary from the original by more than ±2 mm
- the thickness of any block does not vary from the stated thickness by more than ±3 mm
- the compressive strength is acceptable.

Any block with dimensions outside the limits given must be rejected for purposes of road paving.

The tolerance on thickness allows a block specified as 80 mm thick to be 77 mm or 83 mm, or any dimension in between. This tolerance is allowed to accommodate the difficulty of setting machines and casting concrete to exact dimensions. This does not mean that a difference of 6 mm in the thickness of blocks in the same production run displays an acceptable level of quality control. It is not good practice to have a 6 mm difference in the thickness of blocks that will be adjacent to each other in a road. Producers should strive to produce blocks that are as uniform in thickness as possible within the parameters given.

The tolerance on plan dimensions allows for the fact that in the casting process, the moulds will wear, causing the plan dimensions of the blocks to increase.

While the most economic use of a mould will be obtained from one that initially produces blocks that are 2 mm undersize and that is discarded when the blocks reach the specified size limit, it should be realised that it will prove difficult to maintain the pattern and the joint widths in the paving if the plan dimensions vary by as much as 4 mm. Again, the blocks should be as uniform as possible within the parameters given. In view of the variation that can occur it is essential that the blocks are laid in the same order in which they were cast.

On the question of tolerances there is nothing to stop any consultant demanding much tighter tolerances than these specified by the SABS. However, the increased cost of producing such blocks can only be justified in exceptional cases.

The compressive strength test requires that 12 representative blocks be chosen from a sample batch. (The comments under Clause 6.1 and the content of Clause 6.2 discuss how the number of blocks that the sample batch can represent is determined.)

When tested their average strength should be that specified, that is 25 MPa or 35 MPa. None should be less than 20 MPa in the case of the 25 MPa block, or 30 MPa for the 35 MPa block.

If the strength of any of the 12 blocks is less than the minimum specified, the blocks that are represented by the sample are rejected. There is no provision anywhere for the acceptance of blocks that do not comply with this simple rule.

Clause 1.2d points out that in the case of a block specified as 25 MPa, *'even with good manufacturing control, a compressive strength exceeding 30 MPa is necessary in order to achieve the required minimum individual strength'.* (20 MPa)

Attempts to economise by using a concrete mix with a strength closer to that specified have resulted in large numbers of rejected blocks.

Later in the same clause it is stated 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'.*

This comment is there to guard against the temptation to specify unnecessarily high concrete strengths. It is not a justification for ignoring the results of the compressive strength tests. However, there is justification for the use of higher strength (35 MPa) blocks at the junction of CBP roads and gravel roads wherever the gravel will be deposited on the surface of the CBP and increase the abrasive effect of the traffic.

Clause 6.1 refers to the inspection of all the blocks in a sample batch.

The number of blocks from which a sample is drawn will vary depending on the consistency of the quality of the blocks being produced. If the quality control is good and there are no wild fluctuations in dimensions and strength, the sample can be taken from a large number of blocks – say a day's or even several days' production. Where quality control is lax a sample will be taken from a relatively small number of blocks.

Clause 6.2 defines test specimens and cautions that while the test on these can be used as a guide *'a sampling plan agreed upon between the purchaser and the manufacturer should be used to select the required number of samples in the case where a decision is to be made on the acceptance or rejection of a consignment* (see Appendix C).'

Appendix C discusses both quality control at manufacturing stage and sampling plans for fully manufactured blocks.

Clause 6.4 describes the compressive strength test.

The compressive strength given is the strength of the individual block when it is tested. It is not the cube strength of the concrete that the block is made from. Neither is it the strength achieved at 28 days (see comments on 1200 MJ, Clause 2.3 below).

It must be emphasised that the compressive strength test described in SABS 1058 is not a quality control mechanism. It is simply a test to determine whether or not the quality control procedures that were implemented during the manufacturing process were adequate.

As stated earlier, the supplier must institute, monitor and implement the quality control procedures that are necessary to ensure compliance. The engineer should be party to the measures adopted and be confident of the product, or he should institute the necessary test procedures to ensure that the paving that will be laid in place is of an acceptable standard.

No engineer should allow the circumstances that occurred on one contract where the supervising engineer had to resort to removing blocks from a section of ostensibly finished roadway to ascertain their compliance or otherwise. The appearance of the road indicated that many of the blocks did not comply. Tests confirmed this, but almost a kilometre of CBP road was laid and more than 350 000 blocks had been cast and stockpiled in the manufacturer's yard before this confirmation was obtained.[1]

5.2 SABS 1200 MJ: Segmented paving

Clause 2.1.1 lists other specifications that *'... inter alia, shall form part of the contract document'*. These are the project specification and:

SABS 1200 A	Civil engineering construction: General
SABS 1200 AA	Civil engineering construction: General (small works)
SABS 1200 D	Civil engineering construction: Earthworks
SABS 1200 DA	Civil engineering construction: Earthworks (small works)
SABS 1200 DM	Civil engineering construction: Earthworks (roads, subgrade)
SABS 1200 G	Civil engineering construction: Concrete (structural)
SABS 1200 GA	Civil engineering construction: Concrete (small works)
SABS 1200 M	Civil engineering construction: Roads (general)
SABS 1200 ME	Civil engineering construction: Subbase
SABS 1200 MK	Civil engineering construction: Kerbing and channeling

[1] In April 1995 DBSA had a case where a million bricks were manufactured for a roads contract under the guidance of a professional engineer. No one can say whether or not these blocks comply with the strength requirements of SABS 1058. Batching, sampling and testing must now be carried out to determine compliance or otherwise.

It is important to remember that the content of all of these documents must be considered when one is constructing a CBP road in accordance with SABS 1200 MJ. Where there are contradictions between SABS 1200 MJ and other SABS specifications relating to pavement layer works, SABS 1200 MJ will dominate except in the case of Clause 5.1.1.1 (see comments on this clause below) and in the following case.

Clause 2.3 defines wet strength as *'the strength at 28 days of a test block ... tested in accordance with the relevant method given in SABS 1058'*.

SABS 1058 Clause 6.4 makes it clear that the compressive strength of the blocks is **not** the 28-day strength. This particular anomaly is explained by the fact that when in the year following the issue of SABS 1200 MJ, SABS 1058 was prepared, the drafting committee decided that a block is acceptable **when it reaches the required strength**. Thus the definition dealt with under Clause 6.4 of SABS 1058 above, supersedes this definition. However, until the SABS revises SABS 1200 MJ the conflict between the specifications will continue to cause confusion.

It is recommended that since adequate wet curing of concrete is essential to its long-term durability, no blocks should be transported or laid in place until they are 14 days old. no matter how early the date at which they attain the required strength.

Clause 3.1.2 deals with the class, type and strength of blocks.

It is essential for long-term durability that the manufacture of the paving blocks be programmed to ensure that they are properly cured and have attained their design strength before they are transported and laid in place – hence DBSA's recommendation in Clause 2.3.

Clause 3.2 lists suitable kerbs and channels.

In designing the appropriate kerbs or edges for block paving, it should be noted that the transverse loading on CBP is significantly greater than on conventional paving. This is primarily due to the build-up of residual forces in CBP layers during the compaction process and during trafficking in the early life of the pavement. Edge restraints – whether precast or cast – *in situ* must have sufficient mass and be robust enough to carry out their function. Consequently, care should be taken to ensure that the design strength of the kerbing is achieved before final compaction is conducted. This is facilitated by Clause 7.6, which requires that kerbs, channels and the like *'be tested in accordance with SABS 1200 MK'*.

Experience has shown that the kerbing defined in Figures 5 and 6 of SABS 927 (see Appendix I) is so light that extra support must be provided in places where the CBP will be subjected to vehicular traffic.

Clause 3.3 specifies the grading of bedding and jointing sand, and contains the very sensible proviso that *'...where evidence satisfactory to the engineer has been provided of the successful previous use of sand having another grading, sand of such other grading may be used'*.

The SABS considers that control of the grading will provide the necessary limitation on the plastic content of the sands. However, on one site where both the engineer and the contractor were adamant that the bedding sand complied with the specified grading, tests showed that its plastic index was generally 2-4 and in one case 6.

In general, bedding sand should be non-plastic, as per SABS 1200 M. (A non-plastic material has no discernible plastic index, as defined on page 17 of TMH 1: *Standard testing procedures for materials.*) Wherever possible, angular quartz-based sands should be used, as the harder the sand particle and more angular it is, the greater the internal angle of friction of the sand layer. Consequently, the higher the internal angle of friction of the sand layer the greater is its resistance to shearing. Shearing failure in the sand layer normally manifests itself as 'deep basin' rutting in the CBP.

If suitable sand is not available locally or within economic transporting distance, then CBP may not be the most appropriate paving medium for a particular contract.

Clause 5.1.1.1 states that the subbase layer,[2] that is the layer immediately under the bedding sand, *'shall be constructed in accordance with the requirements of SABS 1200 ME'.*

This specification allows a maximum aggregate size not exceeding two thirds of the layer thickness. Since in almost every case the layer thickness is 150 mm, this means that the maximum aggregate size allowed will normally be 100 mm. This conflicts directly with the catalogue designs given in *UTG 2: Structural design of segmental block pavements for South Africa*, which specify a maximum aggregate size of 63 mm. (C3 and C4 for cemented subbase layers and either G4 and G5 for granular subbase layers, compacted to 95% MOD AASHTO.)

On several projects it proved difficult to achieve the required final level tolerance (*Degree of accuracy I*, as detailed in Clause 6.2) on the subbase owing to the use of the aggregate size allowed by SABS 1200 ME and in one instance, to the presence of oversized material. In view of this, the maximum size of aggregate used in the subbase should not exceed 63 mm and should preferably be less. If such material is not available locally or cannot be made available economically, then consideration should be given to the appropriateness of CBP in that area.

Provision should be made for the removal or breaking up of oversized material. This material should not be discarded. It can be used to protect storm water outlets and drains against erosion prior to the re-establishment of vegetation.

Clause 5.1.1.2 forbids the use of the bedding sand to fill depressions in the subbase.

This condition should not be relaxed even in areas where small depressions are caused by the removal of oversized material.

Clause 5.1.1.3 states that *'the level after compaction shall be the designated level of the top of the subbase ±10 mm ...'.*

[2] Refer to Document No 8, Part IV, Section 3 for a discussion on the problems created by the South African practice of calling this layer the subbase. Refer also to Appendix II below, where Figure 2 of Document No 8 is reproduced and clarification given regarding the purpose of the illustration.

A literal interpretation of this requirement led to the acceptance of a subbase with irregularly spaced corrugations and a pock-marked profile on the grounds that the difference between the high points and the low points did not exceed 20 mm. This resulted in the thickness of the bedding sand varying by 20 mm at intervals as close as 150 mm, which gave rise to problems in achieving the required finished block levels.

In order to facilitate the laying of the paving and to achieve a satisfactory ride quality, it is essential that the surface of the subbase presents a regular and smooth appearance and reflects as accurately as possible the finished profile of the block surface. This is not emphasised in SABS 1200 MJ and it is suggested that a clause to this end should be added to the project specification by the engineer.

No traffic other than unavoidable construction traffic should be allowed on the subbase and any damage should be made good before the bedding sand is spread.

Clause 5.1.2.2 deals with unstabilised subbases.

It has been shown that CBP joints are permeable in the first two to three months of the life of the pavement. Therefore, where a subbase material is used that is susceptible to weakening on saturation and where rain is likely to be a problem in the early life of the pavement, the surface of the subbase should be sealed using a cut-back bitumen, as described in Part III, Section 6.9 of Document No 8.

Clause 5.2 requires that *'edge restraint ... shall be constructed ... before any units are laid'*.

The comments relating to Clause 3.2 above make it clear that this requirement is important in ensuring the structural integrity of the CBP. To ensure uniform joint spacing and to induce 'lock up' of the CBP it is important that the blocks are laid and fitted to the edge restraints, and not the other way round.

It is a source of concern that so many engineers involved in DBSA and NEF projects regard the requirements of SABS 1058 as sacrosanct but are quite happy to ignore this clause and other crucial requirements of SABS 1200 MJ. Well-made blocks cannot compensate for bad engineering practice.

Clause 5.3 specifies that the compacted thickness of the bedding sand should be *'25 mm ±10 mm'*, gives the moisture content of the sand and cautions that it should not be laid too far in advance of the paving.

The thickness specified is the **compacted thickness**. Obviously a thicker layer of uncompacted sand must be laid to achieve this, yet on one project where the engineer's drawings showed 20 mm thick sand under the blocks, the profiles used to control the sand thickness were just 20 mm deep. When this was queried the supervising engineer stated that 'the subbase surface is so irregular that we must be getting the required average'.

The uncompacted thickness required to arrive at a compacted thickness of 25 mm must be ascertained for each site and for each sand. The engineer should check and approve the profile depth before allowing bedding sand to be spread to receive the paving.

The tolerance of ±10 mm on the sand thickness is given to facilitate the achievement of a smooth surface to bedding sand that is laid over the variations allowed in the surface of the subbase (Clause 5.1.1.3). However, if the subbase presents a regular and smooth appearance and accurately reflects the finished surface of the road, as advocated in the comments on Clause 5.1.1.3 above, the bedding sand can be of a uniform thickness and it should be possible to reduce the compacted average thickness to 20 mm.

In practice it has been found practically impossible to maintain the **specified** moisture content in the sand. This is not a problem provided that the sand has a moisture content and that this is kept as uniform as possible throughout the course of the day's production. The temptation to spread the sand too far in advance of the pavers should be resisted as, depending on the weather conditions, prolonged exposure of such a thin layer of sand will cause its moisture content to change radically.

Where there is doubt about the suitability of the sand, its plastic index should be checked before rather than after the blocks are laid, otherwise it may be necessary to lift and relay the blocks on suitable sand.

Clause 5.4 deals with the pattern of the units to be laid, the joint widths and the fact that whole units should be laid first, then the gaps infilled with special blocks or with cut blocks.

While all paving to DBSA-funded roads has been laid in a herringbone pattern, the orientation of the blocks has caused some debate. Some consultants aver that the joints must be parallel to the kerb ' to reduce the need for cutting' and others that the block pattern should be an overall continuous one and that the edges should be 'cut to fit'. Both approaches have been used. In practice it has become obvious that

- blocks must be cut and fitted at the edge restraints in either case
- it is difficult to maintain the same block pattern orientation undisturbed over a long length of road
- provision must be made for joints across the road between areas with differently orientated block patterns
- these joints must be carefully formed.

Observation of numerous CBP roads has led to the conclusion that the joints need not be laid parallel to the kerbs. It is virtually impossible to keep these entities parallel and in a dead straight line. A preferable solution could be to orientate the joints at 45 degrees to the kerbs on straight sections of road, and allow the angle to vary considerably before reorienting the paving in relation to the kerbs.

The joint between the blocks and the kerb or edge restraint is just as important to the structural integrity of the road as the joints between the individual blocks. This means that the cutting and fitting of infill blocks must be carefully and accurately carried out. This is an essential exercise and the writer is not in favour of some of the practices employed in certain projects in an attempt to reduce cutting. It is recommended that the cutting involved be detailed, priced for, and properly carried out.

It is recommended that the blocks be cut at the edge restraints, using a block splitter (guillotine). A contractor should only be allowed to use the hammer and bolster method of cutting if the quality of the cut edge is as good as that achieved by the block splitter.

Where a joint must be formed across the road, this should take the form of a simple, straight, accurately sawn joint between areas of differently orientated block patterns. This is a better solution than two other jointing techniques examined, namely

- fitting the blocks to a cast *in situ* reinforced concrete beam which disturbs the ride pattern
- attempting to fill the irregular gap between the perimeters of the different areas with cast *in situ* concrete (see comments on Clause 5.5 below).

The sawn joint should not occur on a bend where lateral wheel loading will be applied to it.

While it is stated that joint widths of 2-6 mm are acceptable, experience has shown that the joint widths should be as uniform as possible and average 3 mm when measured over 20 pavers.

Clause 5.5 allows '*each gap where a closure unit cannot be used*' to be filled '*with concrete ...* '. It specifies the cube strength, maximum aggregate size to be used and how the concrete should be cured; it gives guidance on block compaction in the vicinity of *in situ* concrete infilling, and most importantly, it states ***'filling shall be kept to the absolute minimum'.***

Despite the last injunction it has been observed that block layers and supervising engineers are tempted to use *in situ* concrete infill to reduce the amount of block cutting at the edge restraints and to use this material to rectify deficiencies.

The comments on Clause 5.4 above stress the importance of the junction of the paving and the edge restraints. It should also be clear that any *in situ* concrete infill used here must be strong and durable. SABS 1200 MJ requires that such concrete

- have a cube strength of ***'15 MPa within 24 hours'***
- be made with a very fine aggregate
- be properly inserted into narrow gaps and small areas
- be properly compacted to the full depth of the adjacent blocks
- be cured as prescribed
- be regularly tested in accordance with SABS 1200 G or 1200 GA.

The fact that almost all cast *in situ* infill concrete observed in CBP countrywide is cracked and shows distress compared to the precast blocks alongside it, indicates that the standards required are difficult to achieve or are simply not being adhered to. It is considered that if the requirements of this clause were enforced with sufficient rigour to ensure compliance, this would not only improve the quality of infill concrete but it would also reveal block cutting to be the more practical option.

It should be noted that the use of *in situ* concrete infill prevents same day compaction and joint filling over the full width of the road as required by Clause 5.6.1.

It is recommended that

- cut blocks or closure units be used wherever possible (Appendix III shows how to avoid impractically small infill pieces by the simple expedient of changing the block pattern at the perimeter of the paving)
- where cast *in situ* concrete must be used, the requirements of SABS 1200 MJ Clause 5.5 be strictly enforced.

Clause 5.6.1 requires that *'at least two compaction passes be made over the paving as soon as practicable after laying, and before the introduction of any jointing sand'*. It also requires that all blocks laid be finally compacted by the end of each day and that a uniform even surface be obtained.

It does not 'save time' to put the jointing sand in first. This practice makes it impossible to properly compact the blocks into the bedding sand or level the individual units. If this is done it will result in the blocks having to be lifted and relaid. It is only sensible to finally compact at the end of each day's production as rain, pedestrians, cattle and unauthorised traffic can have a very disruptive effect on uncompacted paving with unfilled joints.

Ideally the open edge of the day's production of laid pavers should be restrained with suitable spikes and battens until work resumes. This prevents the blocks from creeping and the joints from widening.

Clause 5.6.3 requires that *'damaged units shall be replaced and compacted before joint filling is carried out'*.

It is a practical step to also adjust the level and line of the blocks at this stage.

Clause 6.1.1 states that *'... the finished surface of the paving shall, in the opinion of the engineer, present a regular and smooth appearance to the eye'*.

This requirement is a very important one. On many contracts it has been found that if the paving 'looks good' it generally is good, in which case it is not necessary to resort to detailed measurements of the difference in level between individual blocks to determine compliance or non-compliance. The contractor can make representations to the engineer but the decision on this aspect is the engineer's alone. However, the engineer must not seek to achieve an unreasonably high standard and should take cognisance of all pertinent factors relating to the road and its construction when determining the acceptable standard. (See comments on Clause 7.2 below.)

Clause 6.1.2 requires that deviations from flatness of plane surface will be measured using a 3 m long straight edge.

Although the surface profile of the paving may be within the tolerances specified when a 3 m long straight edge is used, the overall road profile can be unacceptable in terms of performance specifications. While a 3 m straight edge is suitable for minor roads, local roads and streets, a 5 m straight edge should be used wherever it is practical to do so, to measure deviations on CBP collector and distributor roads, particularly those designed for traffic in excess of 60 kph.

Clause 6.2 lists permissible deviations for *'units, foundation layers, finished paving, line of pattern, vertical deviation from a 3 m straight line, surface levels of adjacent units, and deviation of finished surface level from designated level'*. It makes provision for any one of three degrees of accuracy being required.

As stated in Part I above, the deviations listed do not impose an unreasonable standard. In fact it is possible to comply with a literal interpretation of these and produce a paved surface that does not *'present a regular and smooth appearance to the eye'* owing to the cumulative deviations in levels between blocks being unacceptable. This is the reason for the presence and importance of Clause 6.1.1.

The degree of accuracy required **must be specified by the engineer in the project specification.** It is suggested that a CBP road should be carried out to *Degree of accuracy I*, as detailed in this clause. If the engineer decides that a lesser degree of accuracy is required (II or III), then he must set out the actual measurements that constitute this in the project specification.

Clause 7.2 describes a trial section of paving that must be laid by the contractor and which, when it is approved by the engineer, must remain as a reference for the quality of the material and workmanship on all subsequent work.

This is a very important tool in determining and setting standards. No permanent paving should be undertaken until suitable trial sections have been laid and approved by the engineer. The trial sections should be carried out on the least trafficked routes and should be representative of the construction process.

Clause 7.7 allows the engineer to reject any work where ponding can occur on the surface of the paving even if the requirements of Clause 5.1.1.3 have been met.

This clause, as per Clause 6.1.1, acknowledges and makes provision for the fact that although the constructed product is within the permissible deviations, the final product may not meet the performance specifications.

Part III: Design and estimating for CBP roads projects

6. Estimating the cost of CBP and bituminous roads

Consultants are very familiar with conventional (bituminous) road works and the cost of these. They are therefore able to give fairly confident estimates of the cost of such a project in a particular area. However, they are not so familiar with CBP nor do they have historical records of the costs of constructing roads with this medium. Their estimates for CBP roads therefore tend to be very broad and include for unknowns.

This situation has resulted in clients being advised by their engineer that they could not afford to consider CBP *'as it will cost twice as much as a conventional road'*. Document No 8, Section 12.2 deals with these comparative costs and the information is still valid. However, a later study of DBSA-funded projects indicated that the cost of CBP roads ranges from 96-116% of the cost of roads of a comparable standard **that are constructed in a conventional manner**.

If the cost comparison on a particular project is outside of the range given, then there are likely to be circumstances that are peculiar to the project and warrant further investigation. It is also possible, particularly in the case of low volume roads, that the use of CBP represents a much higher standard of road than the bitumastic one that would normally be provided.

When comparing the costs of the various proposals it is essential that the life cycle cost of the different technologies be taken into account. The consultant should therefore prepare a complete life cycle cost analysis for the road, for each of the technologies considered, reflecting their particular maintenance requirements and the likely residual value of the road at the end of its design life.

A further cost comparison was recently given by Messrs Sonderland and Schutte who reported having evaluated three labour-intensive roadmaking methods in Soweto in 1995. These were

- CBP, using blocks supplied by a commercial manufacturer
- water-bound macadam finished with asphalt surfacing using conventional plant
- hyson cells packed with stones and cement grout.

They found *'no significant difference with respect to construction cost or expenditure per unit of employment created'*.

DBSA's experience is that had the concrete paving blocks been manufactured on site using local labour, CBP would have been shown to create more employment opportunities than the other methods that were evaluated.

7. Design

7.1 Design of layerworks

Since it was established DBSA has provided R1,8 billion for roads out of a total investment of R5,8 billion. Most of the road designs submitted for funding are derived from catalogues. The use of these set out in TRH 4 predominates, with the CBP road designs being simply a modification of these, or derived from UTG 2. While the use of catalogues for the design of road pavement structures is common practice, this approach has a number of weaknesses, some of which are the following:

- the design is restricted to certain traffic and road categories and specific materials
- the risk associated with these designs is not always known, but tends to be on the low side
- use of the latest technology in pavement design can only be implemented when the catalogues are updated.

To these weaknesses can be added another. Dr Malcolm Mitchell, Deputy Director-General of the Department of Transport, referred to this in the course of an interview published by SABITA in early 1994, when he commented as follows: *'Whilst those few practitioners who have a thorough understanding of, and feeling for, the abilities and deficiencies of road and particularly pavement design theories and procedures, are able to properly use the 'recipes' to achieve an appropriate design, it is my contention that nowadays too many practitioners of the 'art' of road and pavement engineering blindly follow the recipes without a proper appreciation of the limitations of the procedures.'*

Much of the difficulty encountered by DBSA in its attempts to contain the cost, or to increase the developmental impact of its projects stems from the inappropriate or overconservative use of these catalogues and, as Dr Mitchell has observed, a lack of a proper appreciation of the limitation of the procedures.

There is no doubt that proper use of the 'recipes' would bring about an improvement over the present situation. For example, if UTG 2 is being used, simply delineating the areas of subgrade as described in Section 7.4 and adjusting the design in each of these areas, as indicated in Figure 14, would produce savings over the common practice of assuming that a subgrade in the weakest normal condition (ie with a California Bearing Ratio of 3-7%) exists over the full length of the road. TRH 4 similarly recommends delineation of subgrade areas in Section 5.5. The applicable figure in this case is listed as Table 18.

We have seen, however, that even the meticulously correct use of design catalogues will not always lead to optimum designs in terms of cost-effectiveness, availability of material, road function and acceptable risk. One means of obtaining appropriate and cost-effective designs is to use analytically based pavement design methods. These methods can take a wide range of design variables into account which allows the designer to

- adapt a design to specific conditions, needs and risks
- make optimal use of site-specific material
- adjust the design to use the intrinsic strength of the *in situ* material to the full
- evaluate a range of different design and construction scenarios.

The *South African Mechanistic Design Method* is such an analytical design method and its use is well documented. However, it is understood that this and the recent improvements to the mechanistic design model for granular materials, are generally not used by consultants, mainly because the information is not available in an easily accessible form. This circumstance is being addressed by both DBSA and Transportek on behalf of the Committee of State Road Authorities. It is intended to provide tools that will make mechanistic design analysis the norm rather than the exception.

In the meantime, since mechanistic design programmes such as LOCKPAVE and others exist (see Document No 8, Part IV, Sections 5 and 6), it is not really necessary for consultants to rely on the 'recipes'. Against this background it is only logical that DBSA insist that any consultant who requires to use the design catalogues, makes proper use of the 'recipes' and exercises a professional expertise that includes a proper understanding of the limitations of the procedures, while at the same time, expressing a preference for designs that are the product of a mechanistic design analysis.

7.2 Alignment and geometric design

Road widths, the provision of shoulders, footpaths and passing lanes have all been vigorously debated. One of the most effective methods of saving on the construction costs of a road is to reduce its width. The width should be the narrowest compatible with use and safety. When considering the width of CBP road, credit should be given to the fact that the edge of a CBP road is confined by a kerb. This obviates the need for the 0,6 m wide shoulder that is a necessary feature of an unkerbed bituminous road.

Alignment, or rather the realignment of an existing road when it is being upgraded, was identified as a major factor in the cost of these roads. Of the upgrading projects studied not one took account of the residual strength of the existing road. The reasons given were that 'the realignment of the road makes it impossible to take account of what is there'. This reason was even advanced on a project where 75% of the new road followed exactly the path of the old one. On these sections the upgrading procedure involved the building of a weak layer on top of what tests had shown to be, a stronger one. The lack of logic involved in such an exercise is dealt with in *RR92/466/2, Guidelines for upgrading of low volume roads.*

RR92/466/2 also covers the fact that major realignment of a low volume road should be the last resort and that making efficient use of the residual strength of the existing road in the design of the upgraded one does reduce the costs.

In terms of its mission, DBSA funding is directed primarily at the reticulative system in both the urban and rural environments. If one accepts that these roads are by any rational definition **low volume roads**, then the importance of RR92/466/2 to road design in DBSA funded projects increases. Designers are referred to two papers that define low volume paved roads, and propose a philosophy and methodology that are intended to help the designer create more cost-effective and appropriate roads.

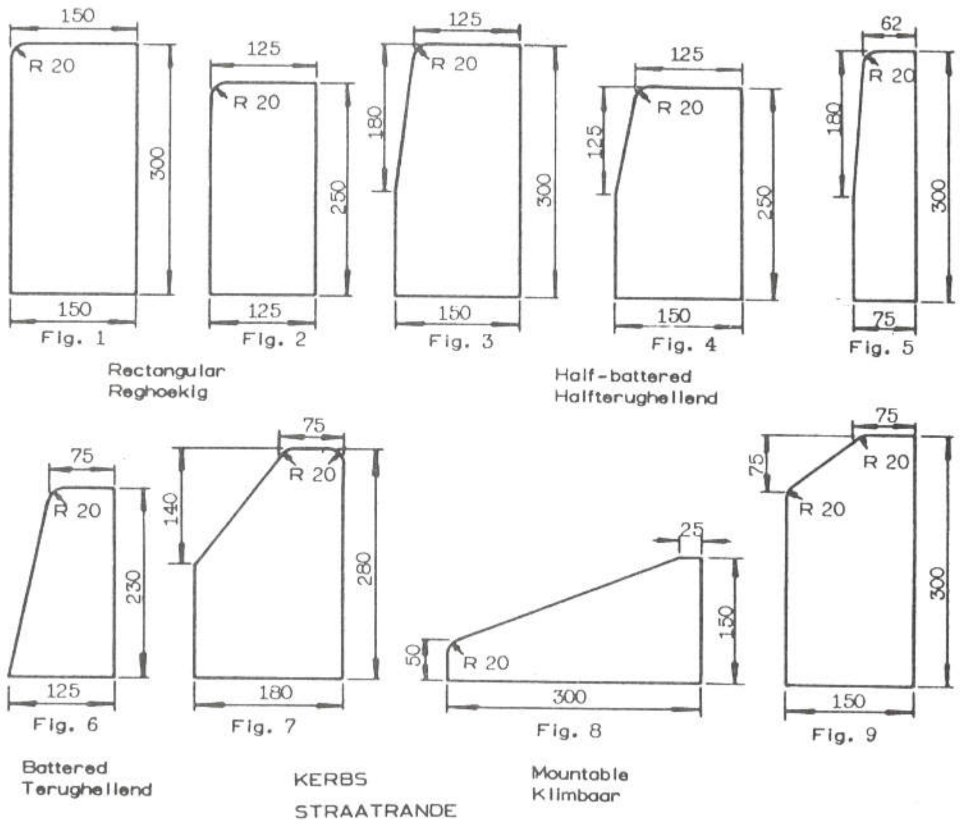
These are

- *Rural road design standards: systematic decision-making* by PA Pienaar and T van Niekerk, published in Section 4C of the proceedings of the 1991 Annual Transportation Convention, held at Pretoria
- *Funding for bituminous surfaced roads for development: the DBSA*

experience in South Africa by T van Niekerk, J Mans and PJ Copley, published in Volume 2 of the proceedings of the 6th Conference on Asphalt Pavements for Southern Africa, held in Cape Town in October 1994.

Appendix I

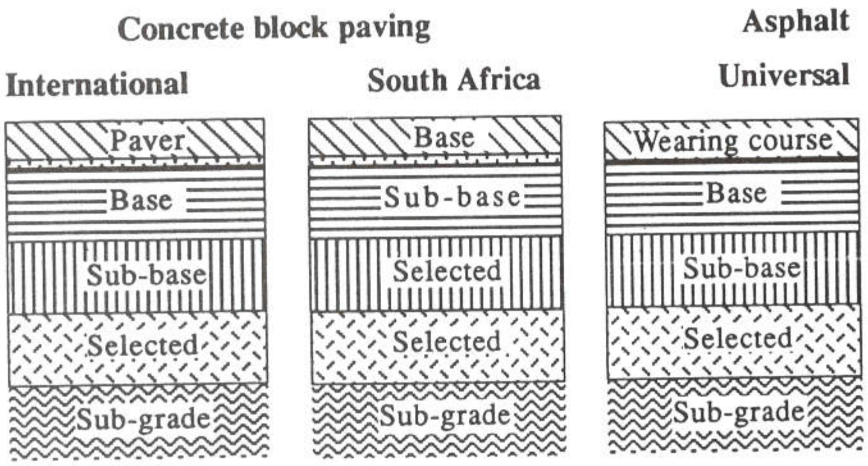
Kerbs – reproduced from SABS 927, 1969



Appendix II

The following figure appears on page 19 of Document No 8.

Figure 2: Comparison of terms used in road construction



When Document No 8 was published we in DBSA were confident that the title of Figure 2 made it clear that it presents a comparison of the names used to identify the different layers. However, in July 1994 at a meeting held to discuss a CBP road project, a professional engineer acting as a consultant to the regional government's Roads Department, stated that 'Figure 2 shows clearly that the DBSA requires three layers of material underneath concrete block paving', and that his estimates were based on satisfying this requirement.

We are surprised that the information given in Figure 2 could be so interpreted. However, the fact that this did happen makes it necessary that DBSA clear up any confusion regarding what is shown here. Accordingly it should be clearly understood that Figure 2

- illustrates the names used for paving blocks and the layers beneath them in international usage
- compares this with South African terms and for further information
- shows the terms that are used universally for asphalt pavements
- does not illustrate any prescribed or preferred road construction.

The design of the road, the number of layers and what these consist of, is the responsibility of the design engineer.

Appendix III

Cutting pavers at edge restraints to reduce the need for cast *in situ* concrete infill

The illustration shown below is reproduced from a paper by John Howe, BSc, Technical Manager of Boral Masonry, Brisbane, Australia. The paper was presented at the Second international workshop on concrete block paving held in Oslo, Norway in June 1995.

Two features shown are of particular interest:

- the reorientation of the paving blocks at the edge restraints eliminates cutting along the length of a paver
- the double cut, which means that a substantial section of paver can be placed adjacent to the edge restraint.

The 'Boral pavestone' shown on this diagram should be regarded as the edge restraint.