The performance of interlocking block pavements under accelerated trafficking

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Introduction

RESEARCH into the performance of interlocking concrete block paving now spans more than fifteen years. Initially, engineers sought to observe and quantify the load-spreading ability of the paving units which was quickly recognised to be the major factor influencing the performance of interlocking pavements. Beginning in the mid-1960's with the pioneering work of Balado in the Argentine and the Portland Cement Institute in South Africa, several laboratory-scale studies of block paving were reported[1 2 3 4]. Generally, these studies were based on static plate loading evaluations of small areas of interlocking concrete block paving typically less than 4 m^2 in area. The test panels were either unsupported[2] or else were constructed over unyielding rigid bases[3]. These studies established that interlocking blocks are capable of considerable sideways load transference. However, they provided little indication of how interlocking blocks behave in real pavements subjected to the dynamic and repetitive loadings applied by road traffic. Consequently, design procedures for block pavements based on these tests needed to be treated with caution. For this reason, a need was established for the evaluation of the performance of block paving under traffic and for the application of the knowledge gained in such evaluations to the development of soundly based road pavement design methods. The problem of design has been considered in detail elsewhere[5 6 7]. This paper is confined to a consideration of the behaviour of interlocking concrete block pavements under actual or simulated traffic.

Types of trafficking test

In recent years increasing effort has been directed towards explaining the behaviour of full-scale prototype block pavements under loads chosen to simulate truck wheel loads. Such tests fall into three categories. In ascending order of research usefulness these are:

1. Static or repeated plate-load tests on prototype pavements[8].
2. Observations of actual block pavements under real traffic[9 10].
3. Accelerated trafficking tests of prototype pavements[11 12 13].

Each of these categories is now considered in more detail.

1. *Plate-load tests on block pavements*

To date, the only tests reported in this category appear to be those conducted by Knapton and Barber[8]. These workers studied a test pavement 6 m long and 3 m wide comprising 80 mm rectangular blocks laid in herringbone bond over a granular basecourse tapering from 400 mm to 50 mm above a clay subgrade having an in-situ CBR of 2%. A load of 6.4 tonne was applied to the pavement via a rigid plate, 200 mm in diameter, with up to about 1 000 load repetitions. Each load repetition was claimed to be equivalent to 30 standard axle loads but this figure appears to be excessively optimistic in terms of AASHTO equivalency factors. After the pavement was loaded, observations of rut depth were made to an accuracy of 0.25 mm.

2. *Tests of actual pavements under traffic*

The first scientific study of block-paving under actual traffic appears to be that conducted by the South Australian Institute of Technology[9] in 1976. Here test pavements were constructed at the entrance to a block manufacturing plant where a record of the numbers and weights of trucks traversing the pavements could easily be obtained. Unfortunately, the experiment failed because of inadequate compaction of the basecourse. More recently, a similar approach has been implemented in the United Kingdom by Barber and Knapton[10]. Here measurements have been reported for a maximum of about 4 000 standard axle loads. However, this amount of traffic is too low to permit any conclusions to be drawn concerning the long-term performance of the pavements. It is understood that a similar type of experiment was initiated in late 1980 by the Australian Road Research Board in Melbourne.

3. *Accelerated trafficking tests*

The problem of subjecting a test pavement to a realistic volume of traffic can be most conveniently solved by using accelerated trafficking tests. The first such study was conducted by the author in Australia in 1978[11 12] and made use of the full-scale road simulator at the University of New South Wales[14]. Here, more than twenty full-size block pavements were subjected to up to 13 000 simulated axle loads. Block thicknesses between 60 and 100 mm and base thicknesses between 60 and 160 mm were studied and three block shapes were compared. The study served to delineate the principal mechanisms associated with the performance of block paving and to provide the basis of the design method currently being published in

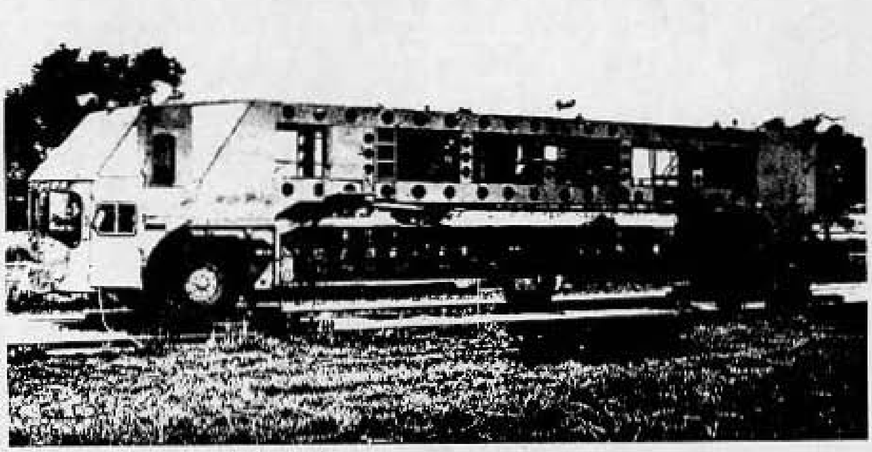


Figure 1: The heavy vehicle simulator

Australia by the Concrete Masonry Association[5 15].

The results of the Australian study were sufficiently encouraging to persuade the National Institute for Transport and Road Research, South Africa, acting in conjunction with the Portland Cement Institute, Johannesburg, and the Concrete Masonry Association to initiate accelerated trafficking studies of interlocking block pavements in May 1979. These studies of block paving have made use of the unique research capabilities of a Heavy Vehicle Simulator (HVS) drawn from the fleet operated by the NITRR. A photograph of the HVS operating on a block pavement is given as Figure 1 and a detailed description of the equipment has been given elsewhere by Van Vuuren[16]. Between May 1979 and May 1980 some forty full-scale block pavements had been constructed at the NITRR Test Site at Silverton near Pretoria and had been tested using the HVS; and it is planned to construct and test a further thirty-six block pavements during 1980. First results from this experiment[13] were reported in 1979 and further reports will be issued during 1980.

Concurrently with the South African study, accelerated trafficking tests of interlocking block pavements have been conducted in the circular test track of the University of Canterbury, New Zealand. The initial results of this investigation have been published by Seddon[17].

This paper is primarily concerned with the findings of the author's Australian and South African accelerated trafficking evaluations of block pavements. It is convenient to consider these two investigations together because the two studies complement one another. Where relevant, the results of other full-scale tests of block pavements are also discussed. The purpose of the paper is to attempt to summarise the current state of knowledge of the behaviour of interlocking block paving under traffic.

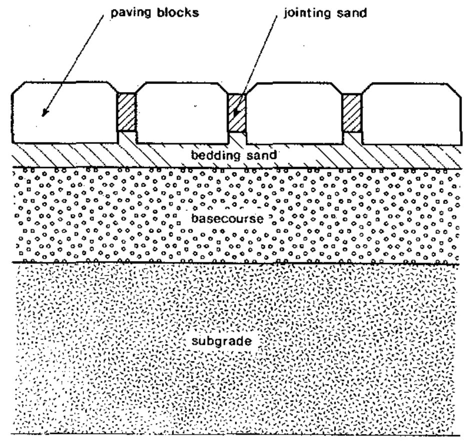
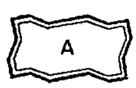
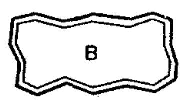
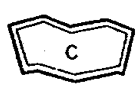
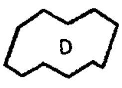


Figure 2: Typical profile of block pavement

TABLE 1:
Details of the paving blocks studied in the accelerated trafficking tests

BLOCK SHAPE	APPROX SIZE (mm)	THICKNESSES TESTED (mm)	APPROX. NO BLOCKS/m^2
	220 x 110	60 80 100	40
	176 x 88	80	50
	216 x 116	60 80	45
	204 x 97	60 80 100	50
	200 x 100	60	47
	200 x 100	60	50
	200 x 100	80	50

Pavement characteristics

The principal components of a typical block pavement are illustrated schematically in Figure 2. It may be seen that the pavement is made up of four distinct components. These are:

(i) The interlocking block surfacing.
(ii) The bedding and jointing sand.
(iii) The basecourse.
(iv) The subgrade.

Before the performance of block pavements can be understood and before any meaningful design method can be formulated, it is necessary to isolate and study the separate contributions of each component of the pavement to the overall performance under traffic loading. This is now considered in more detail.

The interlocking block surface course

The factors which may contribute to the performance of the interlocking blocks under traffic are:

(a) The shape of the blocks.
(b) The size of the individual blocks.
(c) The thickness of the blocks.
(d) The laying pattern or bond.
(e) The strength of the individual blocks.

(a) *The effects of the shape of the paving blocks*

According to Bergerhof at least forty block shapes have been patented in Europe[18]. However, relatively few of ıese are claimed to be suitable for ›ads or industrial applications[19]. he shapes that have been studied to ate by the author are shown in able 1. Shapes A, E and F in Table 1 ere studied in the Australian ıvestigations and shapes A to E ere examined in the South African IVS work. Thus shapes A and E, oth widely used in block pavements round the world, were common to oth investigations. Of the two ıvestigations into block shape, the IVS study[13] was the more compre- ensive. This established that block hape can have a major influence on avement performance. In the experi- ıent, 60 mm-thick blocks were laid ver 20 mm of bedding sand on a 00 mm-thick basecourse of a poor- uality natural gravel overlying a ıbgrade having an in situ CBR of bout 20%.

Trafficking of the pavements using he HVS began with a single wheel ɔad of 40 kN at a tyre pressure of 00 KPa. The results of the experi- nent are shown in Figure 3. From his figure it may be seen that only wo block types (shapes A and B in Table 1) were capable of supporting he 40 kN wheel load. These pave- nents exhibited initial deformations ›etween 15 and 20 mm but thereafter ıssumed an interlocked condition in which increases in the wheel load up o 70 kN and increases in the ıumbers of wheel passes had very ittle effect. By contrast, pavements constructed from block types C, D and E each failed in less than 3 000 passes of the 40 kN wheel load. Here failure was manifested by the develop- ment of excessive rutting in the pavements followed by subgrade failures which led to heaving along either side of the wheel path.

For block types C, D and E it was decided to see whether commencing the test with wheel loads smaller than 40 kN would be beneficial. Accord- ingly, replicate pavements con- structed from these blocks were loaded with a single wheel load of 24 kN. It was then found that, as shown in Figure 4, block types C and D could develop interlock and sub- sequently withstand a loading history in which the HVS wheel load was progressively increased from 24 kN to 70 kN. By contrast, pave- ments constructed using the rec- tangular blocks (shape E) again failed.

The differences in performance between the various block shapes have been discussed in detail else- where[13]. In general it can be con- cluded that blocks which provide geometrical interlock along all four sides tend to yield similar levels of performance regardless of shape, and that shaped (interlocking) blocks yield much better performance than

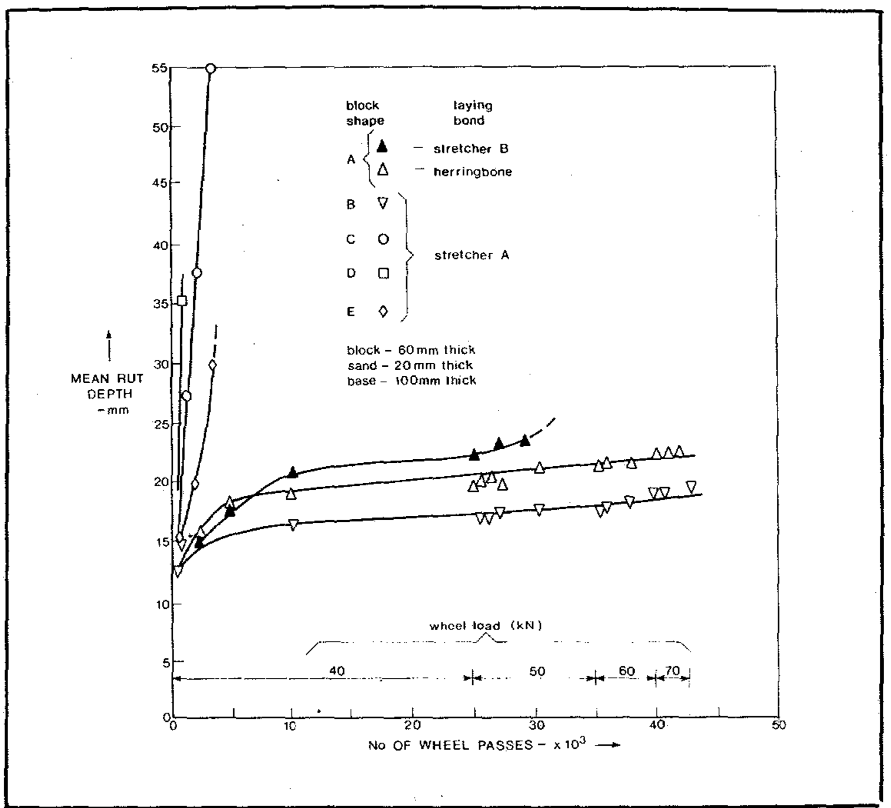


Figure 3: Comparison of block shapes

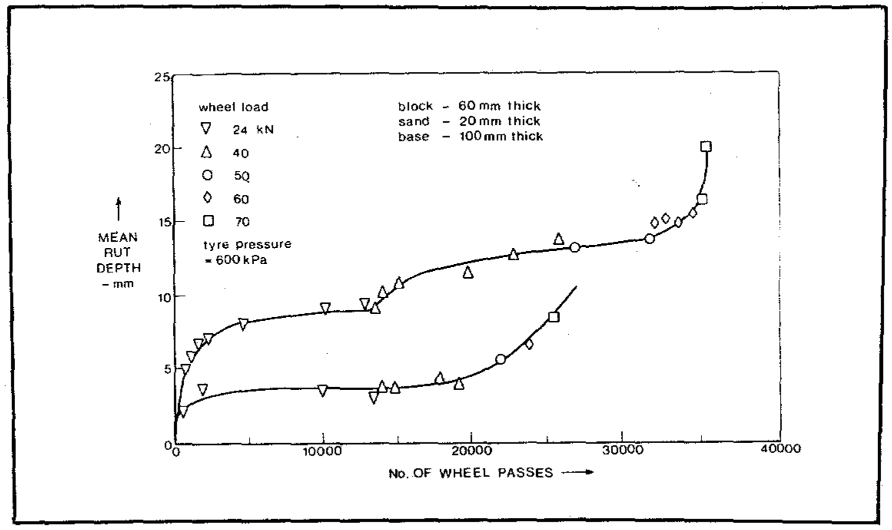


Figure 4: Effects of accelerated trafficking on block types C and D

rectangular (non-interlocking) blocks. These findings were consist- ent with the earlier Australian study[12] which showed that block types A and F yielded similar levels of performance under traffic and that these were superior to those exhibited by rectangular blocks.

(b) *The effects of the size of the paving block*
The Australian study[12] included an examination of the effects of chang- ing the size of block A in Table 1. The approximate sizes of the blocks studied were 220 x 100 mm and 176 x 88 mm corresponding to 40 or 50 blocks/square metre of pavement respectively. This comparison, although limited in scope, estab- lished that, for shape A, changes in the size of the block had no effect upon the performance of block pavements under traffic.

(c) *The effects of block thickness*
European studies of the effects of block thickness have been incon- clusive. For example, Knapton[2] claimed pavement performance was essentially independent of block thickness whereas Clark[4] reported a small improvement in performance with increase in block thickness. For this reason the Australian study[12] included an examination of block thicknesses ranging from 60 to 100 mm.

Three parameters were used to assess the response of the pavements.

These were:

(i) The surface deformations or rutting.

(ii) The surface elastic or resilient deflections.

(iii) The vertical compressive stresses transmitted to the subgrade.

As shown in Figures 5, 6 and 7, it was determined that an increase in the thickness of the paving blocks led to a reduction in the rutting deformations, surface deflections and subgrade stresses. These improvements in performance were independent of the thickness of the basecourse or the magnitude of the wheel load and were a non-linear function of block thickness. In this respect, a change in block thickness from 60 to 80 mm was more beneficial to performance than a change from 80 to 100 mm. It should be noted that, at the higher of the two wheel loads studied (36 kN), block thickness was the principal arbiter of pavement performance in respect of deformation and deflection, whereas at the lower wheel load (24 kN) both base and block thickness significantly influenced the pavement response.

Irrespective of the wheel load, it was found that changes in block thickness had a bigger effect on performance than corresponding alterations in the thickness of the basecourse. These findings clearly contradict earlier claims that the thickness of the paving unit had no effect on pavement performance and have important implications for the design of block pavements[6, 7]. The effects of block thickness are being studied further in the 1980 NITRR research programme.

The mechanisms by which the blocks deformed are of interest. Generally no damage (i.e. cracking, spalling or rupture) of the individual blocks was observed. Pavement deformation therefore resulted from the movement of the intact blocks relative to one another. These movements were of two types, viz rotation about joint lines and faulting along joints. Rotation was found to be the predominant mechanism in both the Australian and South African accelerated trafficking tests. Significant faulting normally occurred only where blocks were laid in stretcher bond with the long axes of the blocks parallel to the direction of trafficking.

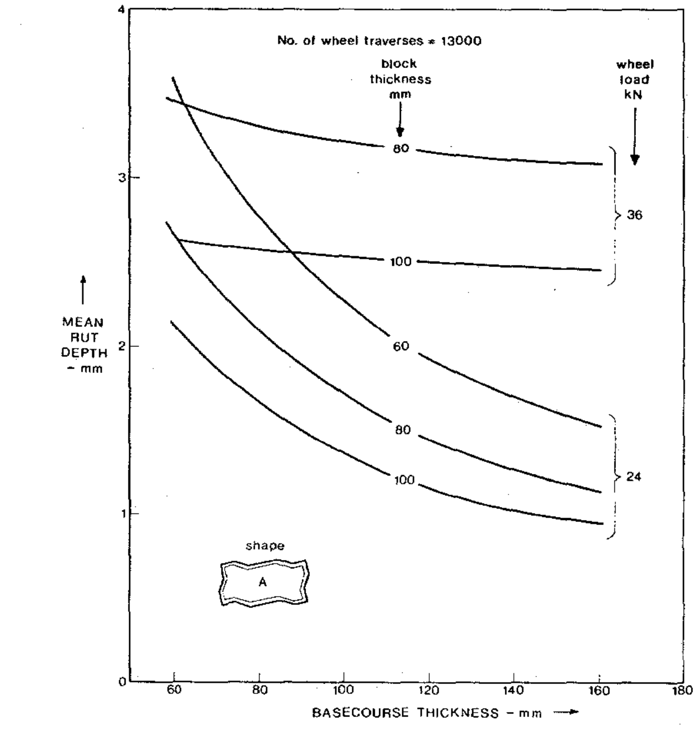


Figure 5: Rutting deformation as a function of block and base thickness

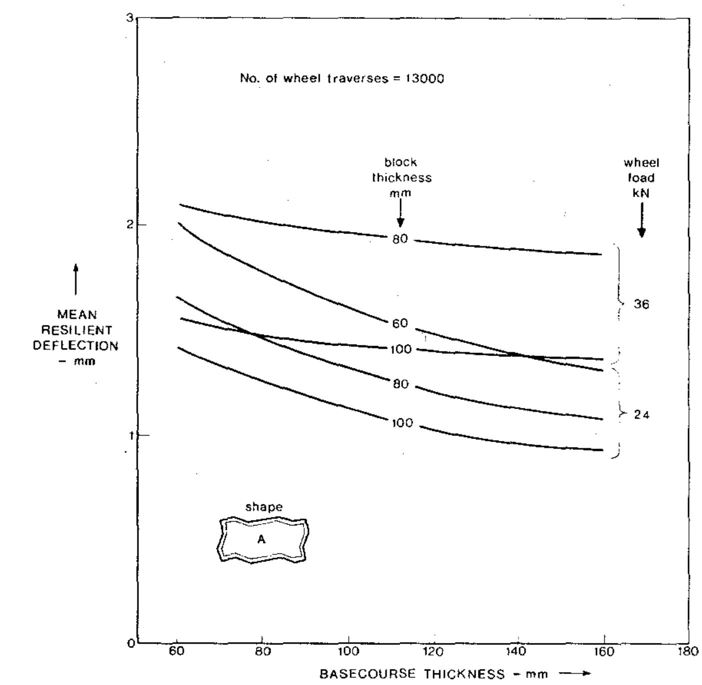


Figure 6: Resilient deflection as a function of block and base thickness

(d) *The effects of the laying pattern*
It is generally claimed that blocks laid in a herringbone bond will perform better under traffic than blocks laid in a stretcher bond. To date, this has not been convincingly demonstrated by experiment. For this reason an examination of the effects of changing the laying pattern or bond has been included in the current NITRR block paving experiments. Preliminary results from these tests are incorporated in Figure 3. Here, for block shape A, a comparison is possible between a pavement laid in a herringbone bond and a pavement laid in a stretcher bond with the long axes of the blocks parallel to the direction of trafficking (designated Stretcher Bond B). It was found that the pavement laid in Stretcher Bond B did not fully develop interlock. Indeed, this pavement failed by faulting along the joints as the wheel load was increased. By contrast, the pavement laid in herringbone bond developed full interlock and successfully withstood increases in the wheel load up to 70 kN. This suggests that pavements laid in herringbone bonds

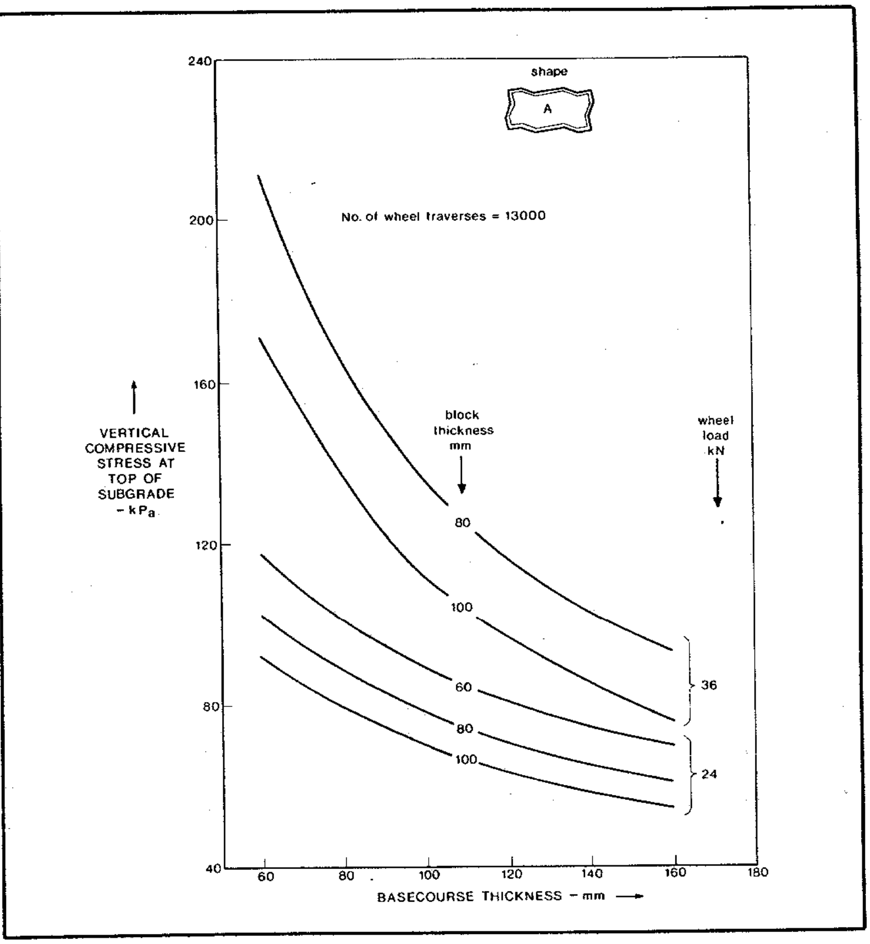


Figure 7: Vertical stress in subgrade as a function of block and base thickness

will yield superior performance to pavements laid in stretcher bonds, but further experimental verification of this is needed.

(e) *The effects of block strength*
As reported elsewhere[13], in the NITRR experiments the effects of varying the compressive strengths of the paving blocks were studied for shapes D and E in Table 1. This investigation established that the load-associated performance of the block pavements was independent of the wet or dry compressive strengths or the flexural strengths within the range studied (25 to 55 MPa wet compressive strength).

The bedding and jointing sands
Both the Australian and South African trafficking tests of block pavements have shown that, although the bedding sand is only included in block paving as a construction expedient, the sand nevertheless contributes significantly to the structural capacity of the pavement[11 12 13]. Specifically, a substantial attenuation of the stresses applied to a block pavement occurs within the sand while much of the deformation (rutting) in a pavement has been shown to originate in the bedding layer.

Three factors have been determined to have an important influence on the response of block pavements to traffic.

These are:

(a) The thickness of the sand layer.

(b) The grading and angularity of the sand.

(c) The moisture content of the sand during compaction and in service.

(a) *The effects of the thickness of the sand layer*
Barber and Knapton[10] have reported that, in a block pavement subjected to truck traffic, a significant proportion of the initial deformation occurred in the bedding sand layer which had a compacted thickness of 40 mm. Similar results have been reported by Seddon[17]. These investigations tend to confirm the findings of the earlier Australian study[12] which demonstrated that a reduction in the loose thickness of the bedding sand from 50 mm to 30 mm was beneficial to the deformation (rutting) behaviour of block pavements. Here an almost fourfold reduction in deformation was observed.

Experience gained in more than twenty-five HVS trafficking tests of prototype block pavements in South Africa has confirmed that there is no necessity to employ bedding sand thicknesses greater than 30 mm in the loose (initial) condition which yields a compacted thickness typically close to 20 mm.

(b) *The effects of the grading and angularity of the sand*
Recently in South Africa a series of HVS accelerated trafficking tests of block pavements has been carried out with the prime objective of determining the desirable properties of the bedding and jointing sands. Here pavements utilizing block A in Table 1, laid in herringbone bond, have been constructed using a loose thickness of 70 mm of sand laid over a rigid concrete base. (This was used so that the effects of base and subgrade deformation could be eliminated from this particular experiment.) After compaction, the sand layer thickness was reduced to between 45 and 55 mm depending on the sand type. Nine different sands ranging from river sands to crusher sands and having a variety of gradings have been evaluated.

It has been found that, under the action of a 40 kN single wheel load, up to 30 mm of deformation could be induced in the sand layer within 10 000 wheel traverses. This clearly demonstrates the need to select the bedding sand with care. However, it has been determined that provided the grading of the sand falls within the limits recommended by Morrish[20] and given as Table 2, a satisfactory level of performance can be achieved under traffic. Here, rutting deformations typically between 1.5 and 4 mm have been recorded after 10 000 wheel passes where the same sand has been used for both bedding and jointing the blocks. Where, however, a finer sand typically having a maximum particle size smaller than 1.0 mm has been used as a jointing sand, an improvement in performance has been observed with the total deformations typically being less than 2 mm after 10 000 load repetitions. Generally, for the bedding sand, it appears that, within the limits given in Table 2, coarse sands tend to yield better performance than fine sands and that angular sands exhibit a marginally better performance than rounded sands.

Unacceptable levels of performance have been observed where the proportion of fine material smaller than 75 μm in the sand exceeds about 15%. In sands with clay contents between 20 and 30%, substantial deformations (up to 30 mm) have been observed especially where the sands are wet.

(c) *The effects of the moisture content of the sand layer*
Experience gained in accelerated trafficking studies in both Australia and South Africa has shown that adequate compaction of the sand

bedding can be achieved at moisture contents typically lying within the range from 4% to 8%, with a value of 6% representing a satisfactory target value. However, Seddon[17] has recently suggested that, for optimum compaction of the sand layer, the moisture content should be close to saturation. For sands whose grading complies with the limits set out in Table 2 the effects of water content appear to have little influence on the behaviour of the pavement under traffic. This has been confirmed by running HVS trafficking tests whilst maintaining the sand in a soaked condition. Generally this has had little effect on the rate of deformation, nor has pumping been observed. However, where the bedding sand contains a significant proportion of clay, greater than (say) 15%, the addition of water to the bedding sand has been found to produce substantial increases in deformation accompanied by pumping. For this reason, the use of sands containing plastic fines should be avoided in the bedding layer. Limited experimental evidence suggests that such sands are nevertheless suitable for jointing sands both in respect of their mechanical properties and as a means of inhibiting the ingress of water into the joints.

The basecourse
All pavements require properly designed basecourses to ensure good performance under traffic, and block pavements are no exception to this rule. The principal factors influencing the performance of a basecourse are:

(a) *The effect of basecourse thickness*

(b) The quality of the materials used.

(a) *The effect of basecourse thichness*
In the Australian experiments[12] basecourse thicknesses ranging from 60 to 160 mm were studied. They were chosen to cover the range of thicknesses (75 to 150 mm) normally found to be economically viable in block pavements incorporating high-quality granular bases. These base thicknesses were examined in conjunction with the three most commonly available block thicknesses, i.e. 60, 80 and 100 mm. The effects of the changes in basecourse and block thickness upon the deformations, deflections and stresses are summarized in Figures 5, 6 and 7 for single wheel loads of 24 and 36 kN.

From the figures it may be seen that, as would be expected, an increase in basecourse thickness generally led to a decrease in deformation, deflection and subgrade stress. This was most pronounced at the lower of the two wheel loads studied. As noted above, a change in basecourse thickness has

TABLE 2: Recommended grading for bedding sand

Sieve size	*% Passing*
9.52 mm	0
4.75	95-100
2.36	80-100
1.18	50-95
600 μm	25-60
300	10-30
150	5-15
75	0-10

less effect on pavement performance than a corresponding change in block thickness. As demonstrated elsewhere[5 7] the data shown in Figures 5 and 6 can be used in the formulation of design procedures for block pavements incorporating either granular or stabilized bases. For this reason the effects of changes in basecourse thickness are being investigated further in the current NITRR block paving experiments. Thicknesses ranging between 75 and 225 mm are being studied.

(b) *The effects of basecourse quality*
Some indications of the effects of basecourse quality can be obtained by comparing the results of the Australian and South African accelerated trafficking studies because they used basecourses of vastly different qualities. In the Australian work a crushed rock (dolerite) base was used[12] whereas in the South African work a poor-quality natural gravel base was used[13]. In order to make a meaningful comparison between the two material qualities it is necessary to eliminate the effects of block shape and thickness and of subgrade strength. The effects of the block shape and thickness can be eliminated by confining the comparison to shape A in Table 1 laid in a thickness of 60 mm in herringbone bond. In the NITRR tests completed to date the basecourse thickness was 100 mm over a subgrade having a CBR slightly over 20%. According to conventional CBR design curves, this base thickness could be reduced to about 60 mm on a subgrade having a CBR value of 60%, i.e. the conditions ruling in the Australian tests. Fortuitously this base thickness value corresponds to the lower limit used in the Australian work. Thus, assuming basecourse quality to have no influence on block paving performance, the performances of the 60 mm blocks overlying the 60 mm of dolerite and 100 mm of natural gravel should have been similar. In fact, the deformation exhibited under similar loading conditions in the pavement having the natural gravel base was found to be more than four times greater than that exhibited by the pavement having the crushed rock base. This clearly demonstrates that the effects of basecourse quality should not be ignored in the design of block pavements. For this reason the current NITRR studies of block paving include investigations of the suitability of crushed rock, natural gravels, slags and stabilized materials as basecourses.

The Subgrade
For a particular intensity of traffic loading, the strength of the subgrade is the principal factor controlling the thickness of pavement needed. As noted elsewhere[7], current design methods for block pavements assume that the subgrade strength can be conveniently characterized in terms of such simple parameters as the Californian Bearing Ratio (CBR). Thus most design procedures postulate relationships between block thickness, basecourse thickness and subgrade CBR which will yield a satisfactory level of performance in a pavement for specified traffic conditions. The study of the effects of changes in the strength (CBR) of the subgrade underlying a block pavement is therefore crucial to the verification of any design method. So far subgrade CBRs of 60% and 20% have been studied in accelerated trafficking tests of block paving[12 13]. The NITRR plans to investigate CBR values smaller than 20% during its current research programme.

Traffic characteristics
The principal traffic-associated factors which influence the response of block pavements to traffic are:

(a) The gross wheel load.

(b) The number of wheel load repetitions.

For convenience these two factors will be considered together.

In both the Australian and South African tests the block pavements have been subjected to traffic loads applied via single wheels. As demonstrated elsewhere[13] this represents a more severe form of loading than that applied by normal truck traffic where, typically, 94% of all vehicles apply load via dual tyres. In the Australian studies[12] the wheel loads ranged from 24 to 36 kN whereas in the NITRR HVS tests wheel loads between 24 and 70 kN were used.

The Australian and South African acclerated trafficking tests established that block pavements develop interlock under traffic. As noted above, once interlock is achieved the response of the pavement becomes independent of the magnitude of the wheel loads (within the range from 24 to 70 kN) and the number of load repetitions. In the Australian tests[12] interlock was found to develop in as little as 5 000 wheel passes using wheel loads between 24 and 36 kN. By contrast, in the South African studies[13] up to 20 000 wheel traverses have been needed to ensure interlock. This discrepancy is believed to reflect the higher standards of block laying that were achieved in the Australian investigation. An interesting feature of the NITRR study[13] was that it was determined that, for certain shapes of block, interlock could not be developed at the maximum legally permitted wheel load of 40 kN but that partial interlock could be achieved by preloading the pavement with up to 10 000 passes of a 24 kN wheel load (See Figures 3 and 4 above).

The ability of interlocking paving blocks to achieve interlock confers an advantage of block paving which is not shared by another form of flexible pavement. The rapid promotion of interlock is therefore crucial to determining the magnitude of the wheel load which a pavement can support during its early life. Accordingly methods for developing interlock more fully during the construction of block pavements are currently being studied at the NITRR. The most likely means of promoting interlock during construction is to replace or supplement the use of the plate compactors now used to compact block pavements with heavier compaction plant such as pneumatic-tyred or vibrating rollers, but this remains to be fully evaluated.

Principal findings of block paving tests

The principal findings of the various accelerated trafficking tests reported to date are now summarized. Where relevant, corroborative evidence from other forms of block paving studies is also included.

(a) Except for a few crucial differences, noted below, such as the development of interlock, block pavements tend to perform under traffic in a manner which is qualitatively similar to conventional flexible pavements[11 12 13].

(b) Shaped (interlocking) blocks generally perform much better than rectangular (non-interlocking) blocks[12 13].

(c) Blocks providing geometrical interlock along all four sides tend to yield similar levels of performance regardless of shape[12 13].

(d) Blocks providing geometrical interlock along all four sides perform better under traffic than blocks which interlock along only two sides[13].

(e) Block pavements can sustain high deformations without damage to the block[8 10 13 17]. In this respect non-interlocking rectangular blocks are less susceptible to damage than shaped blocks[8 13].

(f) An increase in block thickness within the range of 60 to 100 mm produces non-proportional decreases in the deformation and deflection of prototype block pavements[12].

(g) The beneficial effect of increasing the thickness of the paving blocks is greater than that obtained by a corresponding increase in the thickness of a grangular basecourse[12].

(h) At high wheel loads (or contact pressures) block thickness is the principal determinant of pavement performance[12].

(i) In their early life block pavements stiffen progressively with the increase in the number of wheel passes. This indicates that there is an initial bedding-in period during which the blocks tend to develop interlock[12 13].

(j) Under trafficking block pavements tend to develop interlock[12 13 8 10]. This is manifested as increases in the load-spreading ability of the blocks and reductions in the rate of accumulation of deformation[12 13]. The development of interlock does not, however, appear to influence the magnitude of the resilient deflections of a block pavement[12].

(k) Once a block pavement becomes fully interlocked it attains a stable equilibrium condition which is unaffected by either the amount of traffic[12 13] or by the magnitude of the wheel load[13] (within the range of 24 to 70 kN). The blocks then act as a structural layer rather than merely as a wearing course[12 13].

(l) Interlock is most readily and completely achieved in pavements using blocks which provide geometrical interlock along all four sides[12 13], e.g. shapes A, B and E in Table 1.

(m) Adequate base support is needed if interlock is to develop[4 8]. However, too great a rigidity of the base may inhibit interlock[4].

(n) Limited evidence suggests that interlock may be developed more rapidly where the joint widths are narrow than where they are wide[12 13].

(o) Block pavements can typically exhibit large elastic deflections while, at the same time, showing satisfactory rutting deformations[12 17].

(p) The strengths of the blocks within the range 25 to 55 MPa wet compressive strength have no influence on the structural performance of block pavements[2 13].

(q) Pavements laid in herringbone bond may perform better than pavements laid in stretcher bond[13].

(r) The bedding sand layer, although only included in the pavement as a construction expedient, nevertheless contributes to the structural capacity of the pavement[12 13 19].

Concluding comments

By mid 1980, the author had conducted more than 80 accelerated trafficking tests of full-scale prototype block pavements constructed from commercially available paving units and using normal pavement materials and construction techniques. A substantial body of research information is therefore currently available on the behaviour of interlocking block pavements under traffic. The purpose of this paper has been to summarize the more important features of this research effort. However, for details of the test procedures and materials the reader is referred to various earlier publications[12 13 14 16]. Generally it may be concluded that the current state of knowledge is already adequate to permit the formulation of design procedures for block pavements. However further experimental studies will be needed to verify the design procedures fully and to facilitate the effective use of a wider range of materials than those so far examined in the prototype pavements. Research is currently being done on these aspects at the NITRR. In the meanwhile it has become clear that block paving provides an important addition to the range of construction techniques available to the pavement engineer.

ACKNOWLEDGEMENT

This paper is published with the permission of the Director, National Institute for Transport and Road Research, CSIR, South Africa.

References

1. BALODO, G. Pavimento con blogues articulados de homigon. *V Congresso Argentino de vialidad y Transito*, Argentina, 1965.

2. PORTLAND CEMENT INSTITUTE. *Investigation into the load bearing capacity of SF concrete roadstones.* Unpublished report, PCI, Johannesburg, 1967.

3. KNAPTON, J. *The design of concrete block roads.* Tech. Rpt Cement and Concrete Association, UK, 1976.

4. CLARK, A.J. Block paving research and development. *Concrete*, July 1978.

5. SHACKEL, B. *The design of interlocking concrete block pavements.* Aust. Road Res. Board Res. Rpt ARR 90, pp.53-70, 1979.

6. SHACKEL, B. Progress in the evaluation and design of inter-

locking concrete block pavements. *Proc. Biennial Conf. of Concrete Masonry Assn of Australia*, Brisbane, 1980.

7. SHACKEL, B. The design of interlocking concrete block pavements for road traffic. *Proc. 1st Int. Conf. on Concrete Block Paving*, UK, 1980.

8. KNAPTON, J. and BARBER, S.D. The behaviour of a concrete block pavement. *Proc. Inst. Civ. Engrs*, Vol. 66, pp.227-292, 1979.

9. DOSSETOR, J.E. and LEEDHAM, A.G. Concrete block pavements. *Civil Engg. 111 C T Seminar*, South Australian Inst. Tech., 1976.

10. BARBER, S.D. and KNAPTON, J. An experimental investigation of the behaviour of a concrete block pavement with a sand subbase. *Proc. Inst. Civil Engrs*, Vol. 69, pp.139-155, London 1980.

11. SHACKEL, B and ARORA, M.G. The evaluation of interlocking block pavements – an interim report. *Proc. Conf. Concrete Masonry Assn of Australia*, Sydney. 1978.

12. SHACKEL, B. *An experimental investigation of the response of interlocking block pavements to simulated traffic loading.* Aust. Road Res. Bd Res. Rpt ARR 90, pp.11-44, 1979.

13. SHACKEL, B. A pilot study of the performance of block paving under traffic using a Heavy Vehicle Simulator. *Proc. Symp. on Precast Concrete Paving Blocks*, Johannesburg, 1979.

14. SHACKEL, B. and ARORA, M.G. The application of a full-scale road simulator to the study of highway pavements. *Australian Road Research*, Vol. 8, No. 2, 1978.

15. HODGKINSON, J. and MORRISH, C.F. *Interim guide to the design of interlocking concrete pavements for vehicular traffic.* Techn. Note TN 34, Cement and Concrete Assn of Australia, March 1980.

16. VAN VUUREN, D.J. The Heavy Vehicle Simulator. *Shell Bitumen Review*, Vol. 41, 1973. (SCIR Reprint RR/55).

17. SEDDON, P.A. *The behaviour of interlocking concrete block paving at the Canterbury test track.* Paper submitted to 10th Aust. Rd Res. Bd Conference, Sydney, 1980.

18. BERGERHOF, W. International developments in block paving. *Proc. Australia/New Zealand Concrete Masonry Assn Annual Conf.*, 1977.

19. STICHTING STUDIE CENTRUM WEGENBOUW. *Bestratingen van betonstenen (betonstraatstenenen).* Final Report of SCW workgroup D2, Arnhem, 1978.

20. MORRISH, C.F. Interlocking paving – a state of the art review. *Proc Symp. on Precast Concrete Paving Block*, Johannesburg, 1979.