RECENT DEVELOPMENTS IN TRAFFICKED INTERLOCKING CONCRETE PAVEMENTS IN AUSTRALIA

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SUMMARY

Australia now has almost a decade of experience in the design and construction of trafficked interlocking concrete pavements. Applications range from lightly trafficked residential streets to inner urban thoroughfares, major road intersections and heavy-duty industrial pavements accepting high wheel loads. They have been constructed throughout Australia in a variety of climatic zones and over a wide range of soils.

Technical recommendations for the design and construction of these pavements have been developed from extensive laboratory and full-scale pavement testing in both Australia and South Africa. Whilst test pavements provide a basis for design the real success of any design approach must be the assessment of actual pavements in service. The general lack of either operational problems or failures in service has provided field validation of the adequacy of the design and construction procedures adopted.

The paper reviews a number of significant pavements, including the 60 000 m^2 rail/road freight terminal at Islington in South Australia.

1 INTRODUCTION

The building industry in Australia generally suffers from a lack of skilled tradesmen. Any product which is dependent on extended apprenticeship or protracted training for its handling and placement is, therefore, seriously disadvantaged. Consequently, there was little interest in interlocking paving in Australia prior to the advent of the complex profile 'self-locating' unit which could be laid successfully using unskilled labour.

Interlocking concrete pavements were first introduced in Adelaide in 1974, and became generally available, in our major cities, over the following three years.

The first complex profile to be manufactured, and the one that has enjoyed the greatest usage to date, is the 'Unipave' unit. This was followed by the 'Pavelock' unit. Both are self-locating, capable of being laid in herringbone bond, and by their geometry control the spread of joints in two directions. This was to prove a fortuitous choice as later demonstrated by research (1).

Both of these units met the essential requirements of the Australian industry - being suited to laying by unskilled labour with a minimum of skilled supervision, given proper on-site organisation.

Subsequently, a wide variety of other shapes have been introduced. However, the only other unit to have secured large scale use is the Australian Cobblestone - a rectangular unit, normally rumbled after manufacture to remove arrises. It has proved the most popular unit for home improvements, general landscaping and for lightly-trafficked driveways and access ways (Figure 1).

In the early years interlocking paving was used primarily for its aesthetic appeal, particularly in municipal work. It was welcomed by local authorities for its ease of construction, the contribution it could make towards controlling the 'scale' of urban space, and maintaining ease of access to underground services. The wide range of monochromatic and multi-chromatic colours available helped local authorities and developers give identity and distinction to particular areas.



Figure 1: Housing Estate, Gold Coast, Queensland

Today, interlocking paving is seeing increasing usage for trafficked pavements and is gaining engineering respect as a pavement well suited to handling heavy-duty off-road vehicles such as those found in freight and container handling facilities.

The publication of interim design and construction guides (2) in 1980 gave a basis for design for traffickable pavements. This was developed from research findings in Australia and at the National Institute of Transport and Road Research in South Africa, as reported by Shackel (3) to the Concrete Society of South Africa Precast Block Paving Conference in Johannesburg in 1979.

These guides were updated in 1982 (4), following Dr Shackel's final assessment of the full scale accelerated traffic loading research programme in South Africa (5)

They are about to be further improved to take advantage of the most recent experiences, and will be accompanied by a companion guide to design of interlocking pavements for heavy-duty industrial vehicles.

Perhaps the most rewarding aspect of development of these guides has been that the assumptions underlying the original interim guides, have required only limited modification as the testing programmes have proceeded. The essential conclusions, ie:

. pavements tend to stiffen ('lock-up') with repeated load applications;

. complex profile units which control the spread of joints give superior performance;

. joint widths must be controlled within reasonable limits;

. grading and depth of sand bedding is critical to the performance of the pavement;

. increases in unit thickness give an improvement in performance; and

. the critical consideration is to control sub-base deformation prior to 'lock-up';

have all been vindicated by subsequent testing and field experience.

This has been very rewarding as it is one thing to develop design guides based on testing pavements in a controlled environment, no matter how extensive that testing programme may have been, and quite another to demonstrate their effectiveness in practice.

The design guides have now been used over the last three years for the design of a large number of pavements, scattered throughout all climatic zones, both in Australia and elsewhere, and over a wide range of subgrades and soil types. Currently some 2.5 million m^2 of interlocking pavement is constructed annually within Australia.

To date very few significant problems have been encountered. Where the few problems have occurred they have normally been traceable to poor sub-base material selection or inadequate supervision of subgrade and sub-base compaction.

The one qualification to current practice the authors would make, however, is to emphasise their preference for subgrade stabilisation where the subgrade has a California Bearing Ratio of less than four per cent, when tested in a soaked condition. Also, control of sand bedding thickness within the range of 20 to 40 mm and the use of a properly compacted first-quality sub-base material is imperative to control deformation within acceptable limits during the period prior to 'lock-up'.

2 SPECIFICATION OF UNITS

At present there is no Australian Standard for interlocking concrete paving units. However, the industry has adopted a manufacturing standard. Units are manufactured in two grades of 35 and 45 MPa characteristic compressive strength assessed on the nett plan area of the unit. Shape is classified as a function of the geometry of the unit and its ability to control joint spread in one or more directions.

The manufacturers are currently reviewing this standard. They have found that control of compressive strength is not always an adequate production control indicator of likely abrasion resistance, or resistance to spalling and/or transverse cracking of individual units during compaction and early service life. They are currently considering the advisibility of adopting a specification based on characteristic transverse strength, and absorption; and are investigating a number of techniques which may provide an improved production control indicator of likely abrasion resistance as assessed by one or other of the generally recognised tests.

3 CONSTRUCTION PRACTICE

The current construction practice guide owes much of its success to recommendations put forward by Lilley & Knapton of the Cement & Concrete Association in England. These have been adapted to suit local conditions, and modified in the light of field experiences and research in both Australia and South Africa.

As with all types of pavements a requirement for the selection and use of materials of suitable quality within the pavement, the employment of appropriate construction practices to ensure proper preparation and compaction of the subgrade, and provision of adequate drainage, need to be continually fostered. The subgrade remains the weakest link in the pavement chain and we should not lose sight of the fact that it is the poor quality of most subgrades which necessitates the construction of a pavement in the first instance.

Perhaps the most common problem encountered has been the failure to achieve proper compaction of the sub-base immediately adjacent to structures and edge restraints. As a result, there has been some tendency to experience localised settlements in excess of design expectations immediately adjacent to drainage outlets, road openings, separately constructed table drains and the like. For this reason it is now recommended that all sub-base material within about one metre of these features should be stabilised with a small quantity of cement prior to final compaction. Where this procedure has been adopted the problem has been avoided.

There is a continuing need to encourage both the designer and the builder to give greater attention in both design and setting out to the simplication and improvement of edge details, to avoid unsightly fragments where units are cut to fit to edge restraints particulary at kerbs, junctions with other pavements and structures, and at entrances to buildings. Fortunately there have been many examples of

excellent work by some designers and builders to allow these points to be demonstrated (Figure 2). Two such projects are reviewed in this paper.

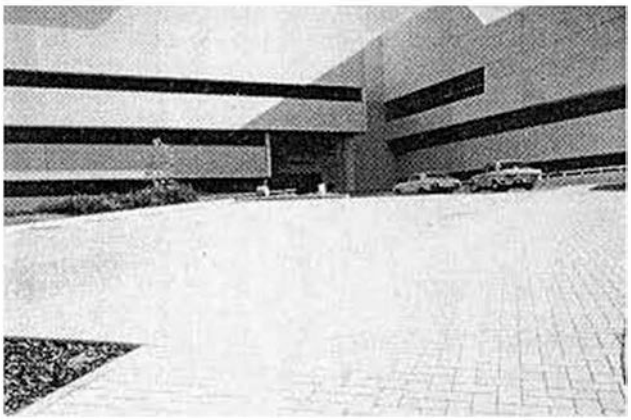


Figure 2: Water Board Building, Perth, Western Australia.

4 REASONS FOR USAGE

As engineering confidence has grown in the ability of these pavements to tolerate a wide range of loading conditions it is interesting to study some of the reasons given for the selection of interlocking pavements. In assessing these it is important to realise that in Australia these pavements are often cost-competitive in heavy-duty applications over soils of poor bearing capacity, or where there is a high risk of settlement, but there can be a cost premium payable compared to flexible pavement construction, in lightly trafficked applications over good subgrades.

Some of the most common reasons given for willingness to tolerate an initial cost premium are:

. The risk of asphalts softening under oil spillage.

. Better resistance to transverse rutting (shoving) in heavy braking zones, such as at intersections, with resulting damage to traffic light detector loops.

. Reduced upkeep through ease of permanent surface demarcation by use of contrasting coloured units.

. The safety aspect of audible and visible definition at intersections which otherwise may be concealed.

. Ease of access to underground services without permanent despoilage of the pavement.

. Improved land values for property developers or more rapid sales where residential streets are constructed in interlocking paving.

The latter has been the prime reason behind the growing use of interlocking paving in private housing estate road construction. Developers have found the land more readily saleable when compared with similar areas with asphalt pavements and have generally reported improved prices, with price gains more than sufficient to offset any additional costs, resulting from the use of interlocking paving.

5 RECENT PROJECTS

Although experience with interlocking pavements in Australia has been limited to something less than ten years there has already been one city bus terminal where pavements have been traversed by more than one million buses (Circular Quay in Sydney, Figure 3) and major freight handling facilities, each of more than 60 000 m^2 constructed in Melbourne (Webb Dock) and Adelaide (ANR Terminal). Although these may be small compared with some installations in Europe they have proved important milestones in Australian developments.



Figure 3: Bus Terminal, Circular Quay, Sydney, NSW

A selection of both large and small projects is given hereunder, to provide some idea of the type of work currently being undertaken.

ANR Terminal, Islington, South Australia

One of the largest projects completed to date is the 60 000 m^2 pavement for the Australian National Railways Terminal at Islington, near Adelaide.

The terminal is designed to handle both the transfer of rail freight and to act as a road-rail freight interchange. It is expected to handle some two million tonnes of freight and 150 000 heavy vehicle movements per annum.

The site was formerly the disposal area for a sewage treatment plant. It was levelled using imported filling of poor bearing capacity and had been subject to a variety of compacting techniques. Interlocking paving was selected as offering a good engineering solution for this combination of site conditions and service requirements.

Interlocking paving proved to be competitive on first cost.

The pavement structure comprises 80 mm Unipave 45 MPa pavers laid in herringbone bond over 30 mm compacted thickness of bedding sand complying with the recommended grading over a base course of 150 mm of first quality 20 mm crushed rock and a sub-base of 150 mm of second quality fine crushed rock.

The project was notable for a number of reasons. Firstly, the large insitu concrete surface drains and edge restraints were spaced to suit the use of full-sized and half-sized units - elminating the need for cutting and trimming around major structures. Secondly, a number of innovative techniques (for Australia) were introduced to speed the construction process. These included the use of a small loader fitted with an adjustable bar to screed the sand bedding to correct levels (Figures 4, 5).

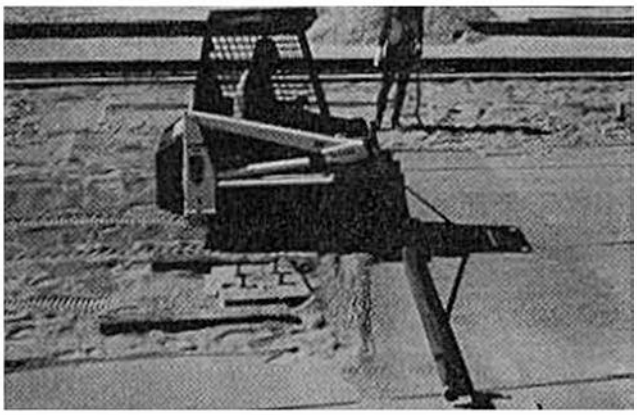


Figure 4: Mechanised Screeding of Bedding Sand

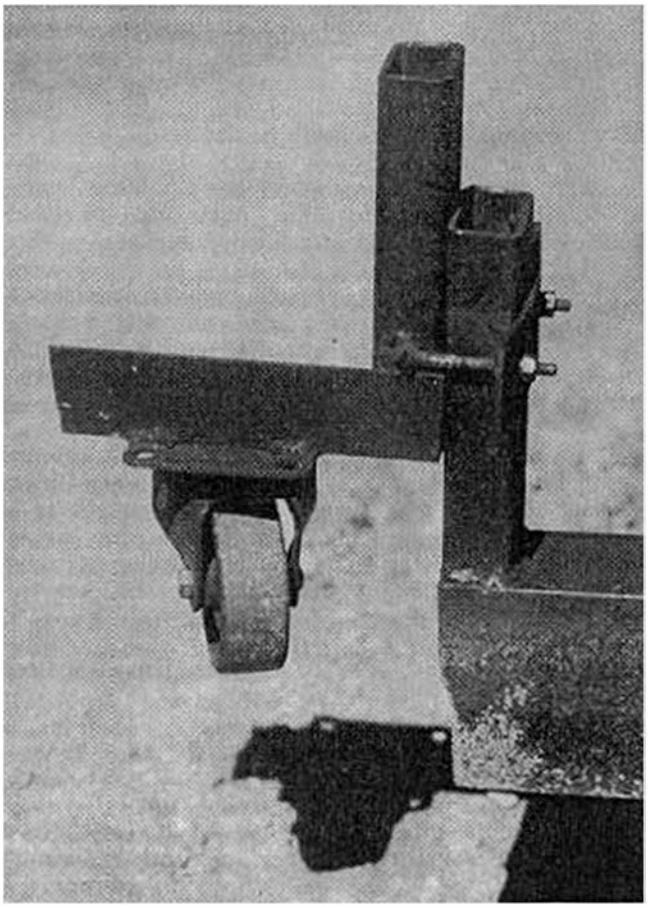


Figure 5: Depth Adjustable Screed Control

Motorised trolleys fitted with clamps were used to move the paving units from delivery points to the laying face. These proved capable of servicing the needs of up to ten layers (Figures 6, 7). Laying was on a continuous face allowing layers to rotate positions to ensure maintenance of uniform laying. Most of the labour employed by the contractor was previously inexperienced in block laying.

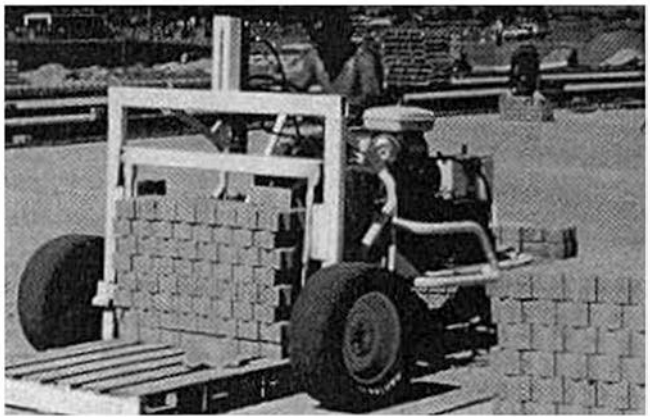


Figure 6: Delivery Trolley

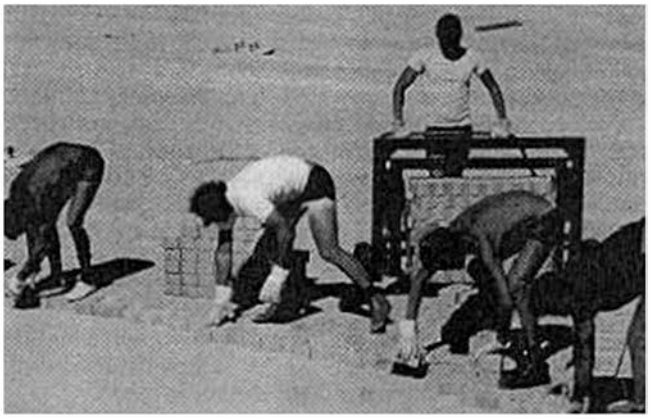


Figure 7: Supplying Paving Units to Laying Face

Road Intersection, Gilles Plains, South Australia

The first major arterial road intersection including interlocking concrete paving was completed some two years ago by the Highways Department of South Australia. It is located at the intersection of Grand Junction Road and Sudholz Road, Gilles Plains. The section paved includes three lanes of traffic-light-controlled mixed traffic and a left turning lane which handles a high frequency of heavy truck traffic (Figure 8).

The pavement was installed in a bid to control transverse rutting due to braking and deformation induced by slewing wheel loads, and consequent damage to electro-magnetic inductive loops controlling the traffic lights (Figure 9).

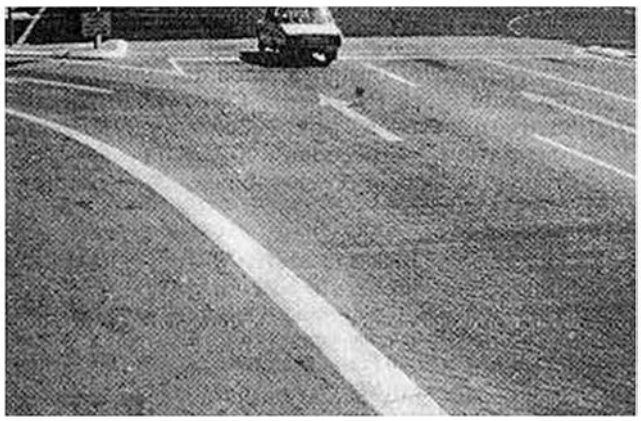


Figure 8: Grand Junction Road, Adelaide, South Australia



Figure 9: Typical Intersection Traffic, Grand Junction Road

To date, the experiment has been entirely successful. The loops were successfully installed in narrow conduits beneath the sand bed.

The pavement has been constructed over a poor-quality black soil subgrade topped by 200 mm of selected crushed dolomite filling. The Highways Department elected to construct the pavement using a similar structure to the adjoining flexible pavement, but with the sub-base courses adjusted to accommodate the pavers and bedding sand. The pavement consists of 80 mm pavers laid in herringbone bond, and purpose cut to edge restraints, a base course of 150 mm of 20 mm fine crushed dolomite and a sub-base of 140 mm of quarry rubble.

Wooldumpers Container Storage, Adelaide, South Australia

The ability of interlocking concrete paving units to function as an excellent heavy-duty wearing course and 'semi-rigid' structural layer resulted in Wooldumpers SA Ltd of Adelaide resolving to use them to pave their container storage yard near Port Adelaide.

The total area paved to date is 2800 square metres with a further 2000 square metres planned for construction. The subgrade, reclaimed swamp overlaid by sand and silt which had been pumped and spread and had an estimated CBR value less than two per cent, has been topped with a layer of stabilising fabric, 290 mm of fine crushed rock sub-base, 30 mm (compacted thickness) of sand and 80 mm natural-coloured fully-interlocking Type A concrete paving units.

35 tonne forklift loads are common in this yard.

Containers and their contents weighing up to 20 tonnes each are stacked three high resulting in forces of 141 kilonewtons on each of the four support pads.

Experience has shown that these loads, which caused unacceptable deformation in an earlier bituminous pavement, have been successfully handled by the interlocking pavement.

Dowling Street Railyard, Launceston, Tasmania

The Dowling Street Railyard, Launceston is the first stage in the development of a rail/road container transfer yard for Australian National Railways. This section adjoins a similarly paved container yard operated by Sea Pak Transport Services. The subgrade had an assessed CBR varying between 5 and 10 per cent but local experience suggested actual values may have been lower. The site was levelled and overlaid with 200 to 300 mm of fill having a CBR in the range of 25 to 50 per cent. The pavement comprises 80 mm 45 MPa Unipave pavers, laid in herringbone bond, over 30 mm compacted bedding sand and a 400 mm non-plastic sub-base (having a PI of 2) compacted to 95 per cent to 100 per cent modified compaction. The design allowed for anticipated axle loads of 80 tonnes.

Interlocking paving was also selected because it was cost-competitive with flexible pavement alternatives.

Container Shed, Port Adelaide, South Australia

This container cargo shed at Outer Harbour, Port Adelaide, saw the first major Australian use of interlocking paving inside an industrial building (Figure 10).



Figure 10: Container Shed, Port Adelaide, South Australia

Some 3800 m^2 of paving was laid by the Department of Marine and Harbours using their own labour force. The standard of laying is particularly commendable.

Great attention to detail and setting out completely eliminated the need for cutting paving units at perimeter walls.

The pavement, which is on reclaimed land, has been designed to withstand 50-tonne axle loads. The pavement comprises 80 mm 45 MPa Unipave concrete paving units laid in a herringbone pattern; a 30 mm compacted sand bed; a 175 mm fine crushed rock sub-base; and a 75 mm levelling layer of quarry rubble over the insitu reclaimed ground.

Whitford Beach Estate, Western Australia

Some 5000 m^2 of paving have been constructed for subdivisional roads in the Whitford Beach estate, north of Perth (Figure 11).



Figure 11: Whitford Beach, Perth, Western Australia

The first stage involved a length of dual carriageway at the entrance to the estate, which handled all earthmoving and construction traffic for the shaping of the coastal dunes and construction of services for the second stage of land development.

This proved so successful in service the developer decided to complete the subdivision roads to match.

An exemplary standard of laying was achieved throughout.

The pavement consists of 80 mm units bedded in 30 mm sand over 150 mm of crushed limestone over the dune sand subgrade.

6 REFERENCES

1. Shackel, B. 'The Evaluation & Design of Interlocking Concrete Block Pavements Subjected to Road Traffic' Technical Report RP/9/80, National Institute for Transport & Road Research, Pretoria, October 1980.

2. Morrish, C.F. and Hodgkinson, J.R. 'Interim Guide to the Design of Interlocking Concrete Pavements for Vehicular Traffic' Technical Note TN34, Cement & Concrete Association of Australia, 1980.

3. Shackel, B. 'A Design Method for Interlocking Concrete Block Pavements' Concrete Society of Southern Africa and Concrete Masonry Association, Proceedings - Symposium on Precast Concrete Paving Block, Johannesburg 1979.

4.(a) Hodgkinson, J.R. and Morrish, C.F. 'Design of Interlocking Concrete Pavements for Road Traffic' TN40, Cement & Concrete Association of Australia, March 1982.

(b) Hodgkinson, J.R. 'Specification for Construction of Trafficked Interlocking Concrete Pavements' TN41, Cement & Concrete Association of Australia, March 1982.

5. Shackel, B. 'An Experimental Investigation of Factors Influencing the Design of Interlocking Concrete Block Pavements for Roads' Part 2, Proceedings Eleventh Australian Road Research Board Conference, Melbourne, August 1982.