

INTERLOCKING CONCRETE PAVEMENTS: THEN AND NOW

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ABSTRACT

This paper briefly summarises the historical development of block paving - whether it be concrete, stone or wood - as a pavement surfacing material. The reasons for the late development of the concrete paver are explained in terms of the traditional use of stone and wood and the late development of concrete as a pavement material generally. The development of interlocking concrete pavements in Australia over the last ten years is briefly summarised and some questions proposed that may still need to be addressed and adequately answered.

The title of my address is 'Interlocking Concrete Pavements: Then and Now'. In the strict sense of the word, the 'then' for concrete block paving in Australia is the mid-1970s, when they were first introduced into this country. In the technical sense, the 'then' is probably the Workshop held at ARRB in 1978, when design curves for interlocking concrete pavements were introduced by the Cement and Concrete Association of Australia as a result of research carried out by Brian Shackel at the University of New South Wales (Sharp and Metcalf 1979).

Although pavers made out of concrete may be a new product, the use of paving blocks as a surfacing material is anything but new (Lay 1986). The first record of stone paving dates back to 4000 BC in Assyria, and by 2000 BC flagstones were being used to pave village streets. Cobblestones were the traditional method of stone paving, being uncut and often water-worn stones or large pebbles about 150 mm in size. Later, hand-cut stone blocks were introduced.

Clay brick paving was being used in India in 3000 BC and road making using bricks was common in Mesopotamia in about 2000 BC. Burnt clay bricks have continued to be used as a pavement surface for major roads and particularly local streets.

It was the Romans who introduced cement and concrete into road making. It is known that they used hexagonal shaped flagstones as a surface course, so the concept of shaped, rather than rectangular blocks, is certainly not new. However, with the departure of the Romans, the art of using cement and concrete in road construction was lost for over 1000 years.

Many other materials have also been used as blocks to pave streets, including timber, asphalt and even iron.

The concrete block as we know it today, then, is not really a development of a well-known and developed concrete technology, but rather a clone of the clay bricks and stone setts in use before Roman times.

The arrival of asphalt as a pavement material, and the development of pneumatic-tyred, power-driven vehicles, really sounded the death knell of many of the stone sett pavements, both in terms of their cost compared to asphalt, and in terms of their lack of driving comfort.

Areas of Western Europe, particularly The Netherlands, had continued to use clay bricks as their most common pavement material, particularly in urban areas. It was probably World War II that led to the introduction of concrete blocks as a paving material. Large areas of The Netherlands were destroyed during the War and, because clay bricks were in short supply - and what were available were being used to rebuild housing - concrete blocks were introduced as an alternative. Eventually they became the natural successor to clay bricks; not a new material in the context that they were viewed in, say, the U.S., U.K. or Australia.

I have already mentioned the Workshop on Concrete Block Pavements held at ARRB in 1978. At that time, the amount of research information available on the design of interlocking concrete block pavements was very limited; the data that were available had mainly been generated from the U.K., particularly the Cement and Concrete Association.

U.K. design practice has traditionally been based on Road Note 29 (TRRL 1970) and early research was geared towards finding a materials 'equivalency' for the concrete block surface layer that could be adapted into the Road Note 29 design charts. The research was limited from the point of view that testing was carried out in the laboratory; however, it was felt that it was more important to recommend a design based on existing flexible pavement design guides already acceptable to, and used by, road engineers.

When what are now termed 'interlocking concrete pavements' were introduced into Australia, it was quickly realised that, if the material was to be considered as a viable alternative to more traditional pavement types, then design charts were required. The problem facing the masonry industry was that to adopt a materials equivalency of about 1.5 as done in the U.K. would result in designs too conservative, especially on a cost basis, compared with asphalt or spray seal pavements. Also, of course, the type of pavements built in Australia were different from, and generally thinner than, those built in the U.K.

The use of the term 'interlocking' in concert with 'block pavements' is now taken for granted; however, the term is very significant because it has really been used as a basis to define a new form of pavement behaviour. The Romans, Assyrians or even early Australians did not use the term 'interlocking'; they were simply blocks, even if they were shaped. Is it simply an improvement in manufacturing standards that has led to the birth of 'interlock'? Do we take the term too seriously?

In the early stages of the development of concrete block pavements in Australia, they were, and still are, being marketed heavily on the basis of aesthetics. The combination of colour, laying pattern and a little imagination has resulted in some excellent examples of block paving in Australia. Another claimed advantage heavily promoted at this time was that block pavements were easy to construct. This was interpreted by some to mean that 'anyone' could lay block pavements. Unfortunately, this sometimes led to problems in construction and the industry quickly learnt the desirability of educating potential users in the correct way of constructing block pavements.

The research carried out by Brian Shackel in the late 1970s and early 1980s remains the most comprehensive ever conducted into the performance of concrete block pavements (e.g. Shackel 1982). A hierarchy of block shapes was developed, the existing design curves were examined, the role of the bedding and jointing sands was examined in earnest, second-class base and sub-base materials and cement-stabilised bases were tested. This research was seen as confirming the interim design guides produced by CACA in 1980, but one problem remained: block pavements had still not been tested at low subgrade CBRs in Australia, though such investigations had commenced in the U.K.

Twenty-five papers by authors from seven countries were presented at the First International Conference on Concrete Block Paving in the U.K. in 1980. An interesting aspect of this Conference was the 'them' and 'us' syndrome, the 'them' being the traditionalists, such as the Dutch, who viewed research into concrete block paving as more or less a waste of time because everything was already known, whilst the 'us' were Australians and Americans who were trying to explain that they had no tradition, so research was a vital precursor to acceptance in practice.

The major disagreement centred on block shape, and the rectangular versus shaped debate rages to this day, though we all seem to agree that every shape has its place.

Another aspect of the First Conference of note was that it was dominated by manufacturers, some of whom appeared to be more interested in decrying their opposition's product rather than promoting the industry as a whole. It seems to me that effort is more successfully employed in better promoting the industry as a whole. Overall, the product has been promoted well in Australia, if sometimes a little in advance of technical proof of the systems, as evidenced by the success of the product since its introduction.

A major breakthrough in the commercial viability of block paving in modern times has been the ability to manufacture blocks to close dimensional tolerances, high strength and to a large output. The need for a manufacturing standard is obviously paramount; it is pleasing that the interim manufacturing standard has been updated and especially that a standard for abrasion resistance has now been produced.

The ARRB research (e.g. Sharp and Armstrong 1985) was probably initially seen as a setback to the industry in Australia. I am convinced, however, that, in the long term, the industry will gain.

We wanted to test block pavements under poor subgrade conditions because we believed that a few unsubstantiated claims were being made about the structural capacity of block pavements; what we could call the 'optimistic sales approach'. For example, there was in 1980, and still is not, little information concerning the moisture movement in all layers of a concrete block pavement under field conditions to support any claim to impermeability of the joints. It seemed incongruous to us that a pre-cracked pavement would be impermeable.

We were also interested in examining some of the other claimed advantages:

- \* good skid resistance over time - where were the data?
- \* colour differences compared to asphalt - where were the data?
- \* noise differences compared to asphalt - where were the data?

- \* construction tolerances - we were told levels should be plus or minus 10 mm, yet a just-completed ARRB study (Auff 1983) had concluded that this tolerance could not be achieved even with an autograde - once again, where were the data?

What the ARRB work succeeded in doing, I submit, was give the industry a chance to re-evaluate the state-of-the-art; the new design curves reflect the ARRB work, as well as the experience gained generally since 1980.

At the Second International Conference on Block Paving in Delft in 1984, the Dutch reported the results of field tests and theoretical studies. Research was also reported from Japan, Israel, South Africa and the U.S. and research also had been conducted by Interpave, the U.K. block manufacturers Association. In other words, the trend had very definitely moved from manufacture to research and investigation.

An interesting aspect of the Delft Conference was that both Dutch and Japanese authors analysed block pavements using finite element analysis, whereas the new CACA design charts and the British Ports Association design charts are based on elastic layer modelling. Elastic layer modelling is probably the best way to approach the design of block pavements for Australia - even if the surface is non-homogenous - because it is a technique known to, and becoming accepted by, Australian pavement designers and it is the basis of the revision to the NAASRA guide to the design of flexible pavements.

Another significant feature of the Delft Conference, especially to us in Australia, was the paper presented by Pino Iskandar from Indonesia. The labour-intensive nature of block paving construction is particularly suited to developing countries. It is gratifying that his company, Conbloc Indonesia, has sponsored field trails in co-operation with the Indonesia Highways Department, the results of which will be presented at this Workshop.

Whilst the labour-intensive nature of block laying is well suited to developing countries, it is possibly not so well suited to developed countries; hence, the advent of mechanical laying, a topic which John Rourke will tell us about at this Workshop.

In conclusion, it is obvious that a major change in the last ten years has been the research

information that has become available from a large number of countries as proof of the adequacy of interlocking concrete block pavements to carry increasingly heavy traffic has been called into question. From little information in 1978, we now have a large amount of it; however, it is significant that some authors at this Workshop still feel the need for further research.

The concept of 'block paving', whether it be stone, wood, clay, asphalt or even iron, is not new. We must not forget, however, that better design will not yield better performance unless it is accompanied by proper construction techniques and careful quality control.

Have we learnt enough over the last 4000 years or the last ten? Maybe I can pose some questions to help us answer that broad question.

- (1) Do we need to argue about block shape? What is interlock? How important is shape to interlock? What is 'lock up'? Is the 'lock up' behaviour unique to block pavements, or can it be argued that all flexible pavements 'lock up' under traffic?
- (2) Are we spending too much time on finding a modulus value for the block layer? What about the subgrade layer?
- (3) Is a block pavement flexible or rigid, or a bit of both?
- (4) Are the joints impermeable? If we assume that the block modulus increases after a period of time by locking up, should we also decrease the subgrade modulus to allow for wetting up?

- (5) The need to monitor the design, construction and performance of in-service interlocking pavements cannot be over-emphasised. What are the industry doing about this? Perhaps more importantly, what are users doing to inform the industry?

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