CONCRETE SEGMENTAL PAVEMENTS AESTHETIC AND PERFORMANCE SOLUTIONS

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SUMMARY

This paper summarises the historical development of Concrete Block Paving (CBP) to the present day state-of-the-art in Australia. The advantages and ever increasing applications of CBP is discussed. As well as the traditional residential applications, CBP is increasingly being specified into high aesthetic appeal sectors such as landscaping, municipal mall, residential accessways and streets. In addition, CBP have been established as a viable alternative for heavy duty pavements, in areas such as hardstands, materials handling facilities and container/port areas. More recently CBP has been used in high performance aircraft pavements in areas such as runways, aprons and taxiways. Recent case histories of such applications are presented.

To facilitate the rapid development and growth of engineered CBP solutions, the industry has recently revised its technical design and detailing documentation and computer software. These developments are briefly discussed together with the newly released industry product performance specifications and the new Australian Standards for CBP. The technical background to these developments is then summarised. The paper concludes that the latest generic technical design, detailing and specification information now offers a new platform for CBP to grow that is soundly based on well-researched technology.

INTRODUCTION

Over the last 30 years concrete block paving (CBP) has achieved rapid market penetration worldwide [1,2]. Outside Europe, Australia is the only country to have exceeded an annual per-capita consumption of CBP in excess of 0.5m2 [2]. This is largely because of the underpinning provided by a comprehensive engineering technology developed under the aegis of the Concrete Masonry Associations of Australia and South Africa using both laboratory tests and accelerated trafficking trials of more than 200 full-scale prototype concrete segmental pavements [1,3].

The success of CBP can be attributed to the unique way in which segmental paving combines the three fundamental paving attributes of aesthetics, structural capacity and environmental amenity. Indeed, CBP can be said to be "Good Looking, Strong and Green" because it is these attributes that, in various combinations and with varying emphasis form the basis for utilising CBP. This is illustrated schematically in Figure 1.

In Australia, CBP has been successfully used in almost all forms of pavement. These applications range from pedestrian areas to residential and arterial streets, intersections and roundabouts, hard landscaping, airports, ports and other industrial areas. Details and case histories of many of these projects are presented below.

AESTHETICS

Aesthetics assumes its greatest significance in municipal engineering. Here, CBP is more often laid by hand than by machine. For this reason, it is easy to adjust the installation of segmental paving to the narrow widths and curvilinear alignments that are common in urban design. CBP offers the benefits of not only a choice of colours but also a wide range of surface finishes including rumbled, washed, sandblasted, bush hammered or polymer flame coated surfaces. About 20% of paver production in Europe offers such value-added finishes. By contrast, in Australia, coloured pavers have always been more widely used than natural pavers and rumbled pavers have long been the most common product. Thus, CBP in Australia has always helped the designer to control the colour, texture and pattern of the pavement. In addition, designers recognise that, in contrast to asphalt or cast-in-place concrete, CBP provides a human sense of scale because of the size of the pavers and their associated joints.

An important element of urban design is to control traffic speeds, and behaviour, by providing visual cues to help drivers to identify the road function and to adjust their driving behaviour accordingly. CBP provides the means to delineate road function by associating particular paver shapes, colours or laying patterns with the intended pavement use. In addition visual clues provided by the road surface can be reinforced by audible cues provided by the within-vehicle road noise generated by different types of small-element paving. This is discussed further below under the heading of environmental amenity.

Subjective aesthetic judgements of colour and surface finish can be supplemented by engineering measurements of the luminance factor; a measure of the proportion of light reflected by the pavement surface. Measurements in Australia show that concrete pavers typically exhibit luminance factors between about 14% and 29% [4]. By contrast, the luminance factor for asphalt is usually only about 7% to 9% depending on the colour of the aggregate used.

Good recent examples of the application of aesthetics to paving are provided by the Southbank Parklands development in Brisbane, and at the Sydney International Athletics (Olympic) Centre. In the Brisbane project, three distinct colour tonings were chosen to delineate different pavement areas and to complement landscaping and street furniture. Moreover, the concrete paving was periodically interrupted at about 5m intervals with bands of stone setts, terracotta and clay paving to provide variations in texture [5]. At the Athletics

Centre the forecourt is surfaced with honed concrete pavers provided in three shapes and five colours. These have been combined to evoke such archetypal Australian images as ripples in a dry water course, and the cracked clay of inland deserts [6]. An interesting feature of these pavements has been the incorporation of fibre optic lighting to emphasise the paver patterns at night. A view of these pavements is provided as Figure 2. Other notable examples of paving laid to high aesthetic standards are to be found in several of the Sydney beach promenades [7].

STRUCTURAL CAPACITY

As shown in Figure 1, many forms of pavement involve more than just aesthetics and require structural design to resist a wide spectrum of traffic loads. To meet this requirement a comprehensive technology for the design and specification of CBP has been developed in Australia and promulgated by CMAA. This is discussed below. Using this technology, engineers have successfully applied CBP to such diverse problems as residential streets and intersection, downtown streets and arterial roads, bus termini, interchanges, ports, container yards and airports

Case Histories

Road Traffic

Australia can demonstrate a full range of trafficked paving applications including urban arterial roads (eg King William Road [8]), residential streets in most Australian cities, bus termini and bus/rail interchanges at major transport nodes. Amongst the applications, the one that has shown the most sustained growth is the residential street market. A good example of this is Cockburn Waters Estate in Perth, Western Australia, which was first opened 15 years ago. To date, some 15 km of residential street (approx. 300,000 m^2) has been constructed in CBP. In creating an estate where all carriageways and walkways were planned and constructed using CBP, the developers achieved a strong and aesthetically pleasing paving combination, that was also extremely economical.

Industrial Pavements

Heavy duty CBP is another success story of the Australian industry. The superior qualities of CBP continues to attract favourable attention by owners and specifiers for heavy duty applications such as container terminals, material handling areas and the like.

Experience with heavy duty CBP in Australia goes back to the early 1980s where container yards such as Webb Dock [9] was constructed using CBP. The paving system at Webb Dock was so successful that further pavement extensions have recently been designed and specified using CBP (500,000 m^2). Another recent example of this momentum was the choice of CBP systems for the Port of Brisbane Authority container terminal at Fisherman Island, Brisbane, Queensland. From 1986 to 1991, 17,000 m^2 of surfacing work at the port was CBP compared to 45,000 m^2 of asphalt. In 1993 and 1995 two subsequent projects were specified in CBP for 45,000 m^2. The Port of Brisbane Authority is committed to the CBP system and future CBP

expansion (200,000 m^2) at Fisherman Island is planned. A view of these pavements is provided in Figure 3.

Airports

Although CBP has been used in airports around the world, Cairns International Airport was the first airport to routinely accept fully-laden B747 aircraft on CBP. Technical details have been given elsewhere [10].

Another pioneering application has been recently made at Thevenard Island, some 25 km off the coast of Western Australia. An aircraft runway has recently been constructed for West Australian Petroleum Pty Ltd using some 26,000 m^2 of CBP (1,000 m long, 20 m wide). This represents one of the first commercial airports utilising CBP as a runway rather than restricting its use for aprons or taxiways. A view of the runway is provided in Figure 4.

ENVIRONMENTAL AMENITY

In Australia, four aspects of environmental engineering are of particular relevance:

1. Traffic Calming
2. Road Noise
3. Permeable Paving
4. Terrain Conservation

Traffic Calming

Traffic calming is the measure most widely applied in Australian municipalities to achieve improvements in the environmental amenity of roads and streets. The most common techniques are road narrowing at intersections, reduction in lane widths and the provision of medians. At each location it is now common to use CBP. Such measures increase traffic friction and, thereby, reduce traffic speed. At intersections, traffic may be controlled by roundabouts. These are often constructed using segmental paving beneficially both to resist traffic encroachment and to improve visibility. Additional traffic calming measures are frequently employed on local roads. The most common treatment is to use CBP speed humps. Other successful examples of calming using CBP have been reported elsewhere [4]. In addition to the beneficial environmental impact of traffic calming, Australian data suggest that the various measures described above lead to improved accident statistics [4].

Road Noise

A recurrent feature of recommendations for the improved planning of residential streets in Australia is the suggested use of different materials side by side to provide visual stimuli to drivers, eg. by placing bands of stone setts across the pavement. This approach needs to be treated with caution, especially in residential neighbourhoods, because experience shows that natural stone cobbles or setts may generate traffic noise levels up to 8 dBA higher than an asphalt surface. By contrast, measurements in various Australian cities have shown that, at vehicle speeds at or below 60 km/h, the noise associated with CBP is very similar to that generated by asphaltic roads [4]. Overall, these measurements indicate that, in contrast to

other forms of small element paving, CBP is not associated with traffic noise problems at the design speeds common in urban areas.

Permeable Paving

In many Australian municipalities the pressures for urban consolidation have raised new environmental challenges. A fundamental concept underlying demands for urban consolidation is that existing services, such as water supply or sewerage, frequently have excess capacity. The benefits of utilising this excess capacity are, however, often offset by the costs of upgrading roads and stormwater drainage systems. However, the recent development of permeable eco-paving provides important new options both for municipal consolidation schemes and for industrial areas. Such permeable pavements can:

a) reduce the amount of rainfall runoff from pavement surfaces and, thereby, eliminate or minimise the extent of the stormwater drainage system
b) reduce the size or need for rainwater retention facilities in roadworks
c) reduce or avoid downstream flooding
d) help recharge and maintain aquifers and the natural groundwater
e) help trap pollutants that would otherwise contaminate groundwater or drainage systems
f) assist in the biological decomposition of hydrocarbon contaminants.

Tests of eco-paving have been conducted at the University of New South Wales since 1994. These have shown that eco-pavements can accept storm intensities of up to about 600 l/ha/sec. This means that ecopaving is suitable for the full range of rainfall intensities encountered in Australia which is much wider than that in Europe. Moreover, it appears possible to achieve structural performance that is comparable with that measured for conventional forms of CBP [11].

Terrain Conservation

Because Australia has huge areas of environmentally protected fragile sand eco-systems, a local concrete masonry company has developed a new environmentally friendly CBP system which allows rapid, non-invasive and easy construction of a roadway over sand terrain. The system eliminates the need for excavation and the use of imported road base. Rather it uses plastic mats (290 mm by 290 mm) made from recycled plastic to lock the pavers together in a continous but articulated mat. This mat of pavers then uses the in-situ sand subgrade as the base. The concrete pavers are 390 mm by 290 mm by 90 mm and are provided with vertical holes in each corner. These enable the pavers to hook onto vertical spigots on the plastic mats and to lock together to eliminate horizontal creep

The system can be easily hand laid over a graded surface using unskilled labour. It requires no edge restraints and there is no need for cutting of the pavers as it is not necessary for the units to be even. The only imported base material required is the plastic mats which hold the concrete pavers in position. Once laid, sand is swept over the surface to fill in gaps, giving additional stability. Where appropriate, additional sand can be swept over the pavers to provide and maintain the illusion of a untreated natural sand surface.

As well as providing cost-effective and environmentally sensitive access to wilderness and other areas, the new system is a highly practical solution for allowing tourist bus and heavy equipment access to environmentally-sensitive areas. The versatility of the system makes it ideal for construction of permanent or temporary access roads for requirements such as carrying defence forces heavy equipment. Other applications include parking areas, camping and beach sites, boat ramps, sand stabilisation, culverts, embankments, country saleyards, dairy walk-ups and feed lots.

The new system was first trialed at Williams Retreat Tourist Complex on one of Australia's most unique wilderness environments, Fraser Island. A view of this pavement is provided in Figure 5. Laboratory trials are about to commence at the University of New South Wales.

THE TECHNOLOGY OF SEGMENTAL PAVING

From the introduction of CBP to Australia in the mid 1970s a high emphasis has been placed on the development of appropriate support technology. Two elements that make up the technology are of particular significance. These comprise:

a) Paver and CBP Construction Standards
b) CBP Thickness Design Procedures

Recent Australian developments in these areas are now summarised.

Standards

Standards provide the link between paver manufacture and the design and construction of CBP. The industry standard (MA20) for concrete pavers is being extensively revised and updated and will be reissued as MA34 - Guide to the Specification of Concrete Segmental Pavers. The background to these revisions has been discussed elsewhere [12]. The draft MA34 standard now refers to new Australian Standards currently in final draft for sampling and testing masonry units and segmental pavers and for determining abrasion resistance. The principal features of the revised industry standard are set out in Table 1. These standards supplement and extend earlier CMAA specifications [13, 14].

Design

Australia has been in the forefront of developing design methods for CBP. The evolution of these methods has been described elsewhere [1]. Hitherto, the principal tools for designing concrete segmental pavements in Australia have comprised:

a) Design nomographs for pavements carrying road traffic (T35-C&CAA, 1986).

b) The LOCKPAVE® computer program for designing road and industrial pavements and overlays. This is complemented by the SPECRITE program for automatically drafting model materials and construction specifications. Technical details have been given elsewhere [15]. These programs have recently been enhanced to include the design and specification of airport pavements. The Concrete Masonry Association will shortly

release updated versions of both the road design nomographs and the computer program. The nomographs will be published in MA-38 - Concrete Segmental Paving Design Guide for Residential Access Ways and Roads.

Figure 6 shows a draft version of the updated road nomographs for CBP laid on crushed rock or cement-stabilised basecourses. For other forms of basecourse, or where a combination of both base and sub-base is required the LOCKPAVE® computer program is the more appropriate methodology.

In another initiative to support CBP, CMAA will also shortly publish industry Specification MA39 - Concrete Segmental Paving Detailing Guide. This will consolidate earlier information on the detailing of CBP [10].

CONCLUSIONS

This paper has summarised the continued strong development of CBP in Australia. The authors believe that has primarily been the beneficial consequence of supporting the product by the establishment of a sound underlying technology for both paver performance and CBP design and specification. Therefore, the maintenance and further development of this technology remains a prime goal in the Australian CBP market. Much of this technology is of relevance beyond Australia.

In part, the rapid and wide-ranging usage of paving in Australia reflects recognition that pavers provide unique combinations of the essential attributes of aesthetics, structural capacity and environmental amenity. Indeed, pavers are truly "Good Looking, Strong and Green"!

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Table 1. GUIDE REQUIREMENTS FOR CONCRETE BLOCK PAVERS

APPLICATIONS	Characteristic Breaking Load Δ (kN)	Minimum Thickness (mm)	Shape §	Dimensional Deviations SD Plan	Dimensional Deviations SD Height	Abrasion Resistance Tumbler Index No.	Slip Resistance Co-efficient of Friction
1 Residential Pedestrian	2	No limit	Any	No require-ment	No require-ment	No limit	0.4
Not around pools	2		Any				0.4
Around pools							
2 Residential Driveways	3	No limit	Any	2	3	7	0.4
Light Traffic	5		Any	2	3	7	0.4
Medium Traffic *							
3 Public Footpaths	5	No limit	Any	2	3	5	0.4
Low Volume	5		Any	2	3	3.5	0.4
High Volume and * +							
Pedestrian Malls							
4 Roadways § +							
Minor	5	60	Any	2	3	5	0.4
Local, Collector	5	80	Any	2	3	5	0.4
Distributor	5	80	A	2	3	5	0.4
5 Industrial Pavements +	10	80	A	Agreement between supplier and purchaser		4	0.4

* Capable of taking occasional 8.2 tonne axle loads provided that design, detailing and construction, and maintenance is carried out according to CMAA recommendations.

\+ The resultant joint width is a combination of paver dimensional deviation and laying procedures – for large pavement applications manufacturer's advice should be sought.

Δ At the time of delivery.

§ Interlocking shapes offer superior performance in roadway applications – appropriate design approaches should be considered.

SD Standard Deviation – calculation method defined in Australian Standard.

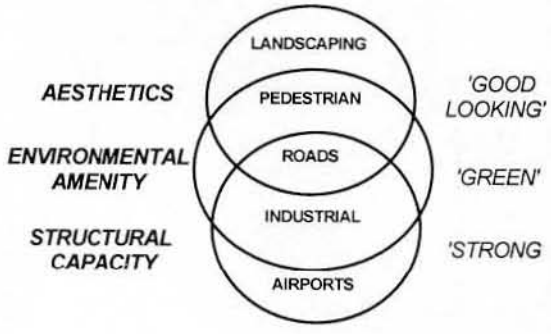

Figure 1. *The Essential Paver Attributes.*



Figure 3. *CBP Port Pavements, Brisbane.*

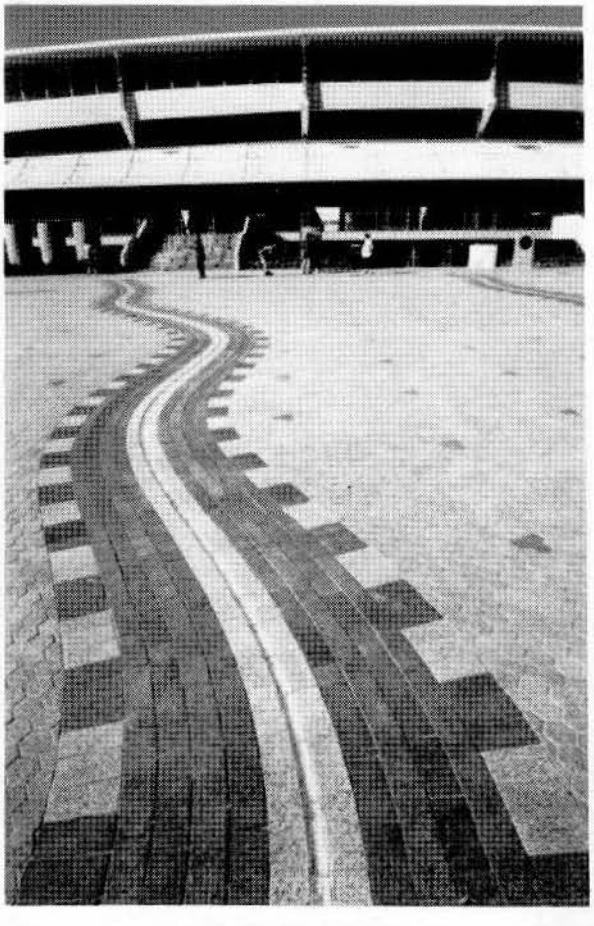

Figure 2. *Sydney Athletics (Olympic) Centre.*

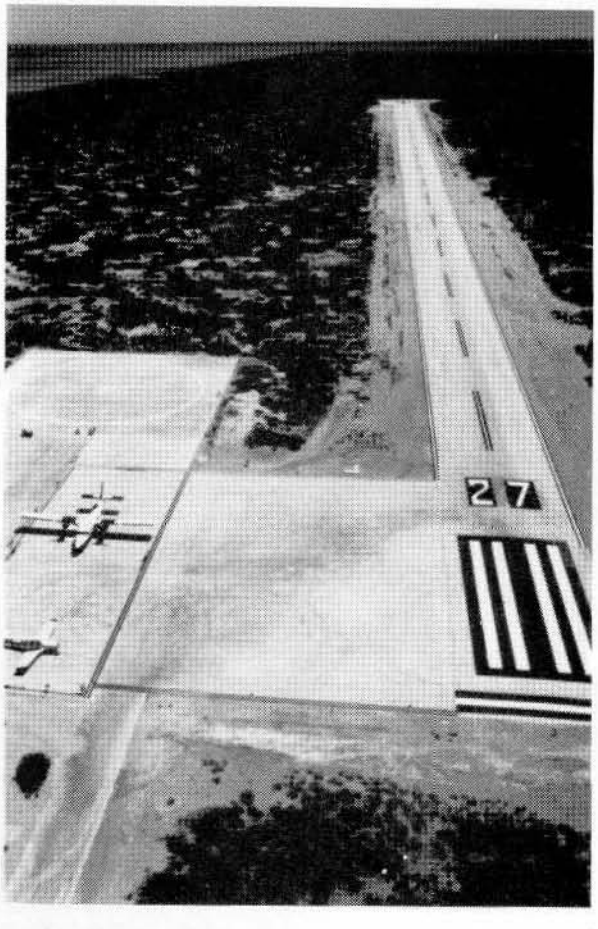

Figure 4. *Airport Runway on Thevenard Island*

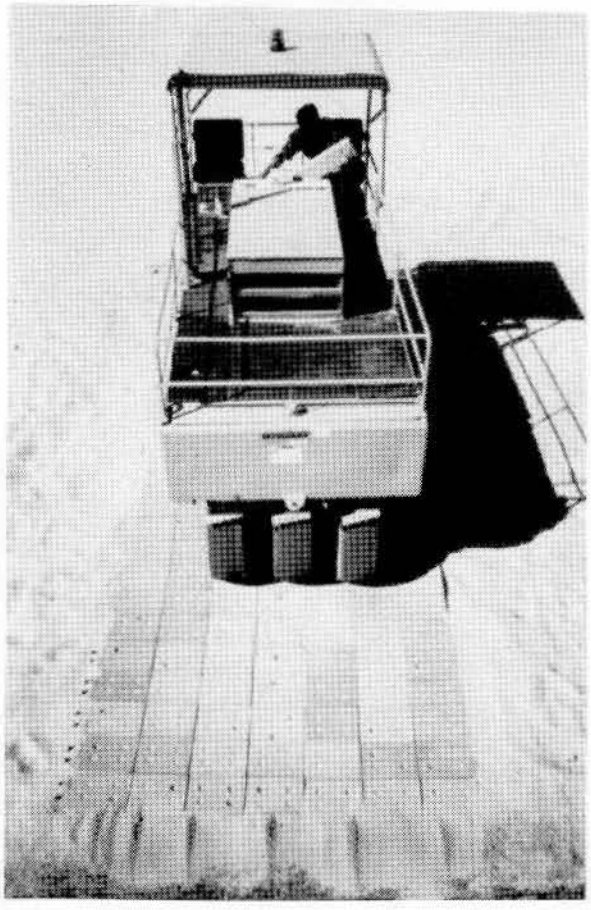

Figure 5. *Trials of New Environmental Paving at Fraser Island.*

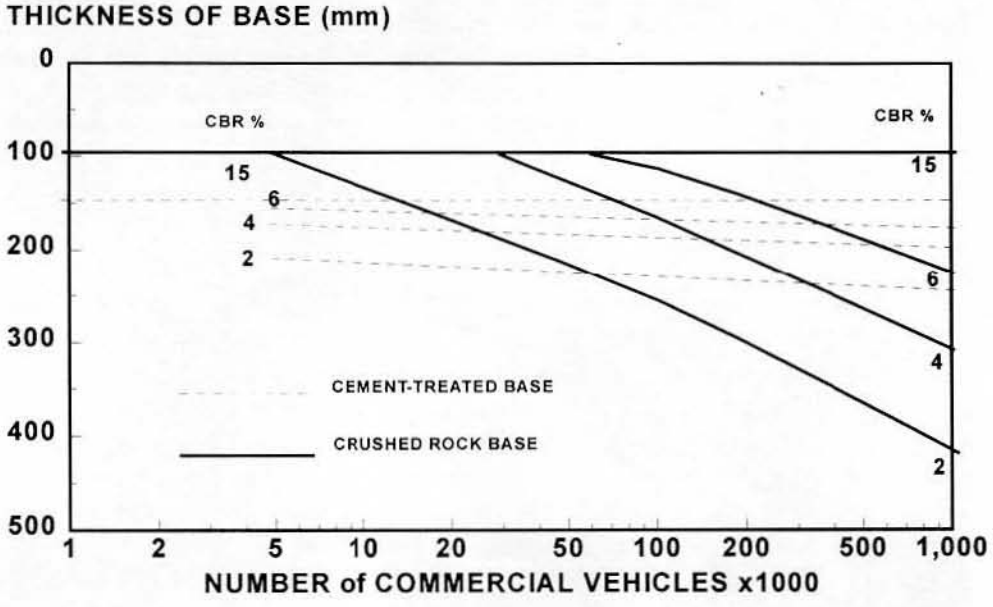

Figure 6. *New Design Nomographs for CBP.*