



## Paving the way for success

Paving the Olympic precinct

While sporting achievements were naturally the focus of the Sydney Olympic Games, great performances behind the scenes contributed to the success of the event. Homebush Bay, a vast complex created in a disused industrial area, provided the perfect backdrop to the action. In this article, Marc Mearing and Glen Fuller from Rocla Pavers & Masonry, and Sam Harb, 'Sam the Paving Man', detail the development of the segmental concrete interlocking pavers used across 160,000m<sup>2</sup> of Olympic precinct.



The requirements of the many stakeholders - from architects, designers, and client committees to manufacturers and builders - in the Olympic complex construction had to be incorporated in the selection and construction of its pavement areas. Consultation among all parties in choice of materials, manufacturing processes and construction techniques ensured aesthetic goals were met within the required timeframe.

A number of criteria played a part in the choice of pavers for the vast boulevard and plaza areas:

- Interlocking characteristics for the boulevard pavement;
- Durability under very high volumes of pedestrian traffic;
- Shape of an existing paver used around the Aquatic Centre;
- Sustainability of the large shade trees;
- A high degree of polish (without exceeding the slip resistance for pedestrians);
- High strength to ensure minimal breakage in pavement;

- Seamless transition from thoroughfares to ecological pavements to the boulevard, as no kerb and channel was to be used.

Unipave was selected for vehicular trafficked areas and Trihex for pedestrian thoroughfares and plazas (see Fig 1). The sustainability of shade trees was addressed by Eco-Trihex, an ecologically sensitive paver which has a specifically designed base material that allows trees to breathe and provides moisture to their root systems. Edge detailing is in Trupave units of 110mm x 220mm.

### Colour

Manufacturable criteria meant the three colours initially requested - yellow, mauve/lavender and bluestone - were produced (after several modifications of initial samples) as Sierra (yellow), Terracotta (earthy red) and Charcoal (grey/blue).

The size of the plaza areas meant the designers initially wanted three shades of each colour laid randomly to hide potential colour variations of production over the three year period of construction. However, QA certification IS9002 showed that control of small quantities of pigment was achievable and this requirement was removed.

In order to ascertain public response to the scheme, large pavement reference panels were laid incorporating edge details, lights and seating. Specifications were confirmed following strong support for the sample.

### Specification

The specification for the project evolved over a two-year period. Separate contracts covered different sections of the complex and issues that arose on the first contract

Figure 1.  
Paver Shapes  
(In a clockwise direction)  
Eco-Trihex, Trihex,  
Trihex, Unipave.

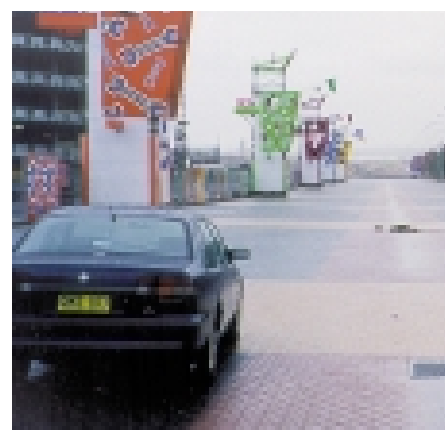
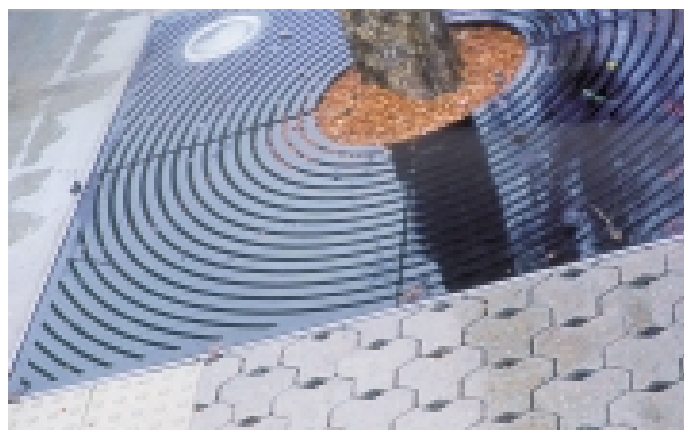


Table 1 - Specification of Pavers

	<b>Time of Trafficking</b>	<b>Time of Delivery</b>	<b>Test Method</b>
Dimensional Accuracy - Plan/Height	Work Size Mean $\pm 2.00$ Std Dev 2mm		ASNZ4456.3 ASNZ4456.3
Compressive Strength	60MPa	55MPa	CMAA MA20
Breaking Load - Boulevard - Plaza	10kN 5kN		ASNZ4456.5 ASNZ4456.5
Flexural Strength - Boulevard - Plaza	4MPa 3MPa		ASNZ4456.5 ASNZ4456.5
Abrasion Resistance	3.5	<4.0	ASNZ4456.9
Slip Resistance	>0.4		ASNZ3661.1
Absorption	<5.0%		Custom
Surface Integrity	0.3gm/mm <sup>2</sup>		Custom
Chamfering	3 x 3 mm		

(Homebush Bay Rail Plaza) were able to be addressed in successive contracts.

The major criteria was characteristic compressive strength. As requested by the specifiers, the height to thickness ratio from the old CMAA MA20 Specification for Concrete Segmental Paving Units was used in this calculation. The new test procedure described in ASNZ4456.4, Determining Compressive Strength of Masonry Units, is not applicable to pavers as the height to thickness ratios for unconfined values are not compatible with the characteristic value taken from CMAA MA20. The values of breaking load and flexural strength were also mandatory.

Once it was recognised that certain properties might not be achievable in the time window between manufacture and arrival on site, a lower value was accepted for delivery - follow-up testing showed that specification properties were achieved by time of trafficking (see Table 1). Abrasion is another property that increases with curing and time, and this was adjusted on the same basis. The final specification can be seen in Table 1.



### Surface Integrity

Surface integrity was key to achieving the Olympic Organising Authority goal of “a carpet of paving to the entry of each venue”. Colour makes the carpet appear soft; surface integrity makes it appear smooth. To achieve the desired surface integrity and absorption values, the blending of specifically graded aggregates, cement and fillers was required to achieve a low void content on a dry cast compaction machine. The size of aggregate played a critical role in the surface integrity result; at Homebush Bay Rail Plaza, 15mm decorative aggregate left “bug holes”.

### Slip Resistance

The honed surface, used principally to provide the smooth carpet effect, works against the requirements of slip resistance. A compromise between density/void content and grit size of polishing is needed to address this. The honing media chosen was one that would remove scratches without giving a glass-like finish.

### Chamfering

Up to 2mm lipping occurred at the Homebush Rail Plaza using a non-chamfered product, and as a result an all-round chamfer was specified in successive contracts.

### Materials

Selection of materials was a critical part of achieving the desired end result. The aggregate used was 7mm crushed basalt blended with alluvial medium sand and fine sand (at Homebush Bay Rail Plaza, 15mm aggregate caused problems with edge and surface integrity. A high early type cement was used as described in AS3972 .

### Mix Design

Mix design was based on minimum void content grading, which is realised largely by aggregate shape and particle distribution. The coarse aggregate had to be less than 10mm to achieve edge and surface integrity and generally less than 7mm to achieve the aggregate exposure after honing.

The final mix design used was:

- 20% Cement + Filler
- 21% 7mm Aggregate
- 59% Combined Sands

### Manufacturing Techniques

The pavers were manufactured on a Columbia C50 machine of a half-square metre pallet size. The ancillary equipment was a Meridian automatic batching system with Hydronix moisture probes, supplied by Autocon Systems, and Granumat automatic oxide dosing system by Brockhues.

The polishing equipment was based around a Cassani four spindle head polishing machine with a calibrating head and two product turnovers.

Manufacture operated for two shifts, six days a week, with maintenance on the third shift. Honing was carried out three shifts, six days a week, with maintenance on weekends.

To ensure the specifications were met, statistical process control techniques were needed on the green product. These were based on:

- Green weight to achieve a density between 2200 and 2300kg/m<sup>3</sup>.
- Product height monitoring of 80 ± 1.0mm
- Batch weights ±1% of master mix design
- Moisture content 7.0±0.3%

A characteristic compressive value of 60 MPa for a total population on a dry cast machine with less than 5% void value is not easy to maintain. Increasing density produces very high strengths, increasing the overall standard deviation which in turn lowers the overall population characteristic value. With low density product, colour changes occur; the voids trap light rather than reflecting it, causing the product to appear dull or faded. A high density product will polish to a slippery glass-like finish; in lower density product, the sand particles are not as

Table 2 - Summary Of All Test Results

	<i>Dimensions</i>			<i>Characteristic Value</i>			<i>Abrasion Index</i>	<i>Slip Resistance</i>	<i>Surface Integrity Index</i>	<i>Absorption %</i>	<i>Density kg/m<sup>3</sup></i>
	<i>Length</i>	<i>Width</i>	<i>Height</i>	<i>Compressive Fuc</i>	<i>Break Load kN</i>	<i>Flexural Fuf</i>					
	<i>mm</i>	<i>mm</i>	<i>mm</i>	<i>MPa</i>	<i>kN</i>	<i>MPa</i>					
Eco Trihex	188.4	93.4	79.1	67.5	14.3	4.7	3.3	0.65	0.073	4.38	2270
TriHex	188.1	93.1	79.0	62.4	12.0	4.3	3.3	0.63	0.092	5.00	2260
Unipave	242.1	106.1	80.2	57.7	11.0	4.6	3.8	0.65	0.093	4.74	2190
Trupave	222.0	110.0	79.7	61.9	11.9	4.4	3.3	0.66	0.087	5.14	2210
Population			79.3	62.4	12.2	4.4	3.3	0.64	0.089	4.90	2240
Std Dev			0.05	5.66	1.78	0.65					

well encapsulated within the matrix and can be plucked from the surface during polishing, giving a pock-marked finish.

Pavers with spacer nibs necessitated three moulds be rotated between production runs, to overcome the problem of product size creep due to nib wear. Checking and cleaning within the mould was needed to ensure nibs were present on the green product.

#### **Curing Regime**

A curing regime of approximately 16 hours at temperatures of 50 to 60°C and humidity of 60 to 80% was used. Humidity greater than this formed water droplets on the surface during the cool down period which created efflorescence. With a two shift operation and restricted kiln capacity, product was turned around in 16 hours and post cured in the stockyard. The months of October to February in Australia are hot and dry with little appreciable humidity, which tends to dry product rather than induce post-curing. Polishing within one month of manufacture was not successful: strength stagnated around 45MPa. This was overcome by calibrating the product within one or two weeks of manufacture, then soaking it and continuing curing. Honing was carried out two weeks later.

#### **Honing**

Honing was carried out on a four spindle head Cassani bed grinder with an initial calibrating head. The back was calibrated at one to two weeks and left to post cure for a further two weeks prior to final honing. A diamond wheel was used for final honing, followed by successive carborundum wheels to remove scratches without a glass-like polish.

Product heights were critical for successful honing. Although the

specification allowed  $80 \pm 2.0\text{mm}$  tolerance, this could not be accommodated through the grinder. Product had to be within  $80 \pm 1.0\text{mm}$  and optimally  $\pm 0.5\text{mm}$  was desired. Product outside these tolerances was either not calibrated (which meant flatness was not guaranteed) or too much was ground off the paver, slowing the process considerably. Final height was between 78 and 79mm, with 1.5 to 2.0mm ground away in the honing process. Physical properties can be seen in Table 2.

#### **Construction Details**

With deadlines firmly fixed to official opening requirements, the paving contractor took an innovative approach to meet his commitments.

- The base course for the pavement was a heavily bound crushed rock. Base levels had to be  $\pm 5\text{mm}$  over 3 lineal metres. Purpose designed undulations and crowns in the plazas' pavements were not allowed to be joint-line ridged or 'valleyed'. Final levels were cut immediately after forming the base course.
- Bedding material under the ecological pavers was a single sized 5mm crushed rock. This required special screeding techniques as it did not compact in the same manner as traditional bedding sand: a circular technique with a bed plate vibrator was required to overcome rutting. The 5mm aggregate for the ecological paver drainage holes was swept in with a 2.5 metre broom mounted on an all-terrain forklift.
- No kerb and channel was used at the boundary of the boulevard as no demarcation line between boulevard and plaza exists. This meant that paving joint lines extended for 300



metres across the plazas and up to 1.5 kilometres along the boulevard. Joint lines had to be straight to achieve the defined layout. Paver sizing, particularly spacer nib sizing, was critical to achieving this.

- The 'carpet' effect meant machine laying (which left cluster lines throughout the pavement) was not allowed. All pavers were laid by hand; leading up to key opening dates, up to 50 pavers were operating on the project 24 hours a day.
- Final profiles at paver colour intersections could not be cut in once laid. A purpose designed intersection piece had to be hand cut to ensure it was the major portion of a paver. This required approximately 10 diamond brick saws on site at all times.
- Inspection and acceptance of paved areas was mandatory prior to final sanding and tamping. Unacceptable pavers and areas were sprayed in iridescent paint and removed before proceeding to final joint filling and compaction.

In the weeks of intense activity that followed the Opening Ceremony, Homebush Bay was judged to have met its goals; in terms of aesthetic and functionality, the paving team turned in a gold medal performance - the successful result of extensive planning by all parties. **C**

Thanks to Marc Mearing, Technical Services Manager, and Glen Fuller, Product Engineer, both of Rocla Pavers and Masonry, and Sam Harb, Director, Sam the Paving Man Pty Ltd, for the information in this article.

#### References

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*AS3972, Portland and Blended Cements, Standards Australia 1997*