KING WILLIAM ROAD, ADELAIDE – REVISITED

Australia's Longest Streetscape Incorporating Concrete Segmental Paving

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King William Road was reconstructed in 1985. It is 2.2 km long and passes through the five suburbs of Unley, Wayville, Goodwood, Hyde Park and Unley Park. It is the longest and oldest length of urban arterial road in Australia to utilise concrete segmental paving. Much of the area traversed by the road has a Heritage Classification and as such the pavement and streetscape had to be designed in conformity with heritage and tourist requirements. Apart from the aesthetic and heritage considerations of pavers as a wearing course, the structural ability of the concrete segmental pavement to carry significant urban traffic loads has proven itself throughout the design life of this pavement.

This paper begins by reviewing the considerations that were considered in the design and construction of King William Road. These included the need to preserve, unaltered, a critical water main located under a major portion of the road. The paper then looks at the performance and maintenance history and the asset value of this unique pavement over its design life.

INTRODUCTION

King William Road was constructed in its current form in 1985. It was one of the largest and most imaginative urban-street-renewal projects to have been undertaken outside Europe utilising concrete segmental paving. Whilst many other large municipal segmental paving projects have been built in Australia including the paving of Salamanca Place, Hobart (1), the construction of malls, plazas and bus termini in most major cities and the commissioning of many kilometres of residential streets (1), it was not until the construction of the Homebush Olympic precinct in the late 1990's that a larger integrated urban paving project was undertaken. Nevertheless King William Road remains a significant landmark both from an Australian and international perspective as, even today, few projects outside Europe approach it in terms of scale. Accordingly, as King William Road now approaches the end of its design life it is appropriate to look at the history and performance of this significant project.

PROJECT HISTORY

King William Road is an urban arterial road some 2.2 km long. It is located about 2 km South West of the Adelaide CBD. The southern third of the road is predominantly residential in character passing through a central shopping and restaurant area to a mixed commercial/residential area as it proceeds towards Adelaide. In 1987 the average annual daily traffic, AADT, was reported to be 8000 vehicles per day in one direction (2).

Many of the buildings fronting the road were constructed in the 19th century and much of the area has a Heritage classification. This now attracts both locals and tourists to its fashionable shops and restaurants. The road was originally paved with asphalt but, in the early 1980's, local traders urged Unley Council to rehabilitate and upgrade the road because the pavement was inadequate for the type and volume of traffic being carried. In 1982 Unley Council estimated that the likely expenditure needed just to rehabilitate the existing pavement was $2 million without footpath or stormwater provisions (3). Accordingly, in 1983 a strategy was formulated to reconstruct the road (3).

In December, 1984, the Council obtained a grant through the Community Employment Program (CEP), a new employment initiative of the Federal Government of which the Jobs On Local Roads (JOLOR) scheme was an integral part. Under the CEP program Unley Council was awarded a total amount of $1,194,042 of which $779,226 was for labour. Council matched this grant with the sum of $1,069,712. It should be noted that, under the Roads Grant Act, 1981, King William Road was classified as an arterial road and therefore did not qualify for a JOLOR grant. However, with the support of both State and Federal governments the road was declassified in March 1984

The CEP/Council funding enabled King William Road to be completely repaved using concrete segmental pavers. Concurrently with the paving work extensive upgrading of the underground electricity, water, gas and telephone services also took place. These works included 600m of underground power lines (at a cost of $600,000), 1250m of water mains ($400,000) and complete replacement of all gas mains ($600,000). Stormwater drainage was improved at a cost of $800 000 (3,4,5).

Overall, the total project costs amounted to $5,535,600. Of this, $3,095,600 was for pavement construction (3,4,5).

The paving work included the footpaths, intersections and turnouts to intersecting streets. This ensured that the whole area was repaved to a single master plan thereby avoiding the inconsistencies that had so often been a product of municipal paving.

Following the award of the CEP grant in December, 1984, drainage works commenced in February 1985 with pavement works following in March that year. The project was completed, one month over schedule because of poor weather, in April, 1986.

PAVEMENT DESCRIPTION

The carriageway width of King William Road varies between about 11.2m and 15.5m within a road reserve varying between 15.5m and 22.5m. As shown in Figure1, there are four lanes at most places along the road with the kerbside lanes generally reserved for parking. This means that through traffic is carried by just one lane in each direction (AADT=8000). The footpaths are also paved using concrete pavers.

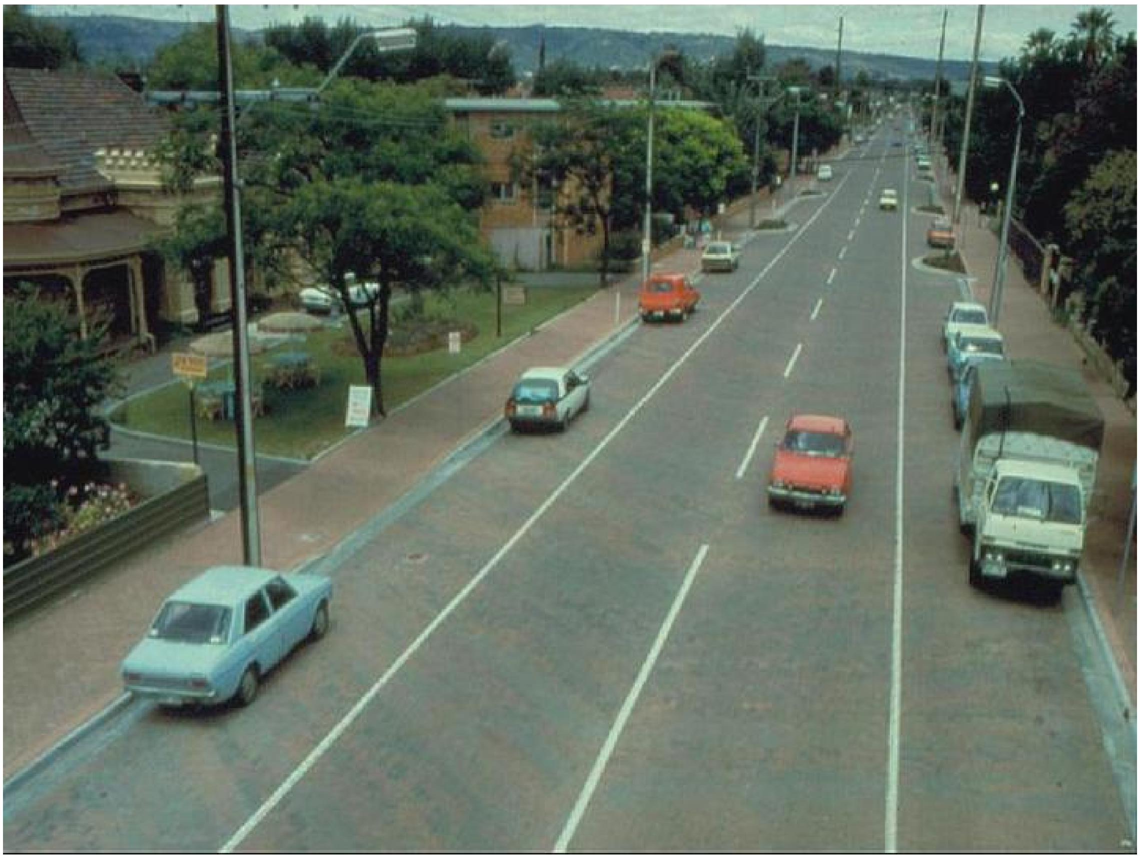

Figure 1. General View of King William Road

As noted above, multiple relocations and reconstructions of underground services were required along King William Road. This meant that it was not practical to retain the existing pavement as a foundation for the new construction. Rather, it was decided to completely rebuild the pavement. Such rebuilding needed to be consistent with the location of the underground services including one critical section of water main just 600mm below the finished surface.

The subgrade soils along the road comprise clays having Soil Classifications of CH/CL. At the time of construction the subgrade was reported to exhibit soaked CBR values of 1% to 2% (5). However, recent soil testing has yielded three *in-situ* Dynamic Cone

Penetration (DCP) CBR values of 6%, 8% and 12% in the upper 300mm of subgrade and two laboratory estimated CBR values of 3% and 3.5%.

The roadway and pavements were designed by B. C. Tonkin and Associates (now Tonkin Consulting Pty Ltd). A typical cross-section is shown in Figure 2. From this figure it may be seen that, because of the disturbance caused by the extensive work on the buried services and the proximity of some of these services to the road surface, the subgrade was overlayed by a working platform of 150mm of 7 MPa lean concrete before the pavement itself was constructed. This had the twin benefits of overcoming the effects of subgrade disturbance and of reducing the thickness of pavement required.

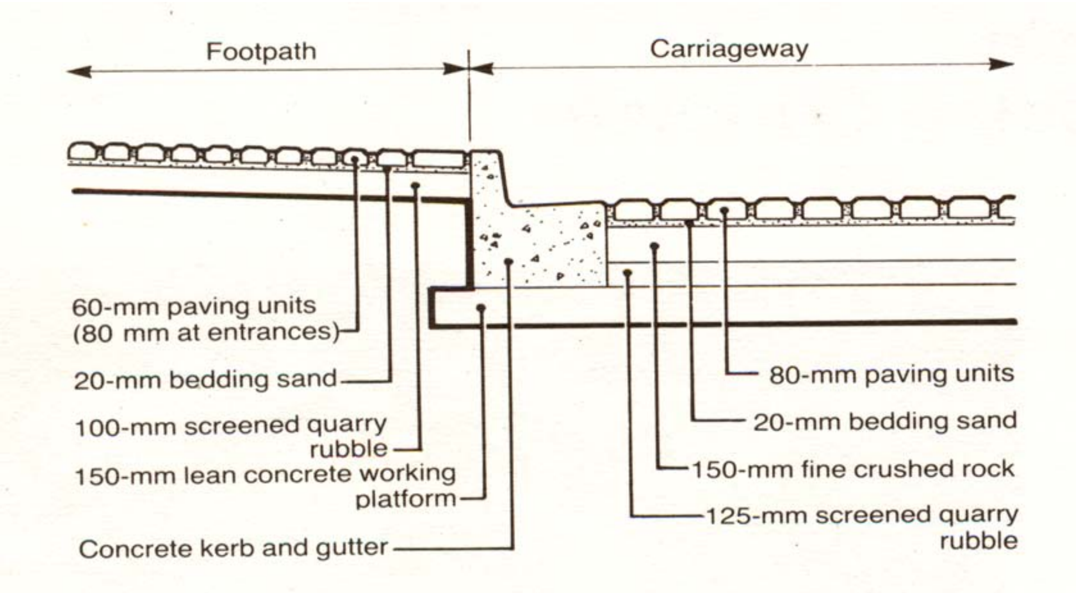

Figure 2. Typical Pavement Cross-section

For the carriageway, as shown in Figure 2, the pavement comprised 150mm of a 20mm crushed rock basecourse over 125mm of screened quarry rubble sub-base with a maximum particle size of 20mm. It has been commented that use of pavers and a lean concrete capping layer were crucial to the success of the project because, in places where services were close to the surface, the use of a conventional flexible pavement would have required surface levels to have been raised (4).

One criticism that must be levelled at the design is the lack of subsurface drainage provisions. So far as is known no sub-soil drains were installed in the pavement. Consequently, the use of the lean concrete working platform would have tended to prevent water draining from the unbound granular base and sub-base. The performance of such granular materials is highly dependent upon drainage conditions. The second criticism concerns the bedding sand layer. Experience gained since the construction of King William Road has established that it is crucial to drain the bedding sand of segmental pavements and the Concrete Masonry Association of Australia has published recommended details to achieve this (6).

The pavement was surfaced with 80mm concrete pavers having a Category A shape installed in herringbone bond on 20mm of bedding sand. The pavers were chosen to be a two-colour mix of charcoal and red. This colour combination was selected to mask oil droppings. In the Heritage area and at intersections a single-coloured charcoal paver was used to provide contrast.

The footpaths were surfaced with 60mm Shape A pavers laid in herringbone bond over 20mm of sand on 100mm of screened quarry rubble. At driveways and crossovers the paver thickness was increased to 80mm. The footpath paving was single-coloured terra-cotta or red to contrast with the roadway.

Rectangular Shape C units were used for edge detailing. This is now the recommended standard detail for roads and footpaths (6).

PAVEMENT CONSTRUCTION

A detailed description of the project has been given by D. J. McCarthy, then Director of Works for Unley Council (3). The key feature of the CEP funding was to provide jobs for the unemployed. At this time the construction of segmental paving was labour intensive which suited it to CEP requirements. The CEP scheme made provision for employing a total of 89 persons including one engineer and 54 construction workers. CEP required that all but the engineer had to be long-term unemployed i.e. at least 9 months out of work. Of this workforce, it was required 13 were to be disabled, 4 were to be aborigines, 35 to be women and 2 to be migrants with language difficulties. Except for the engineer and administrative staff who were employed for one year most persons were hired for around 26 weeks.

The Unley CES began recruiting workers in early 1986. Of the total labour force, 18 workers were engaged in laying pavers at any given time. They were trained on the job by Monier Besser, the supplier of the pavers. At that time, trained full-time paving installers were typically expected to achieve a finished output of about 50 m^2 per person per shift for the type of work involved in King William Road. Perhaps because of the composition of the workforce the actual construction rate was much lower than this. However, the quality of work achieved was satisfactory. Because of poor weather the project ran late and, to expedite completion, a supplementary CEP grant of $212,641 was successfully requested of which $138,217 was for labour. In this respect, it is worth noting that, at about the same time that King William Road was constructed, the first full-scale trials in Australia of mechanical laying were being successfully conducted nearby in the construction of Stage 2 of the ANR Intermodal Facility at Islington. These trials together with experience gained in large projects in Victoria and N. S. W. demonstrated that significant savings in both construction time and cost could be achieved where pavers were mechanically laid. Nowadays, construction of a project of the size of King William Road would normally utilise mechanical laying.

PAVEMENT CONDITION

After some 18 years of traffic the surface has lost much of its original colour due to wear. Moreover, there is now evidence of rutting occurring in the wheel paths along much of the road. Much of this deformation is only visible after rain. At this time, the severity of rutting is not yet critical i.e. needing immediate rehabilitation although there a few areas where water ponds in the ruts.

The rutting appears to be associated with a loss of both bedding sand and jointing sand along the wheel paths but may also be associated with deformation in the basecourse. The loss of jointing and bedding sand appears to be the consequence of pumping caused by the lack of sub-surface drainage. Whether the rutting originated within the basecourse or in the bedding sand layer beneath the pavers needs to be further investigated.

Most pavement distress that is visible to the unaided eye consists of a few areas in which the pavers have chipped because loss of jointing sand has allowed the pavers to come into direct contact with one another. These areas are to be found mainly in the southern residential areas of the road where, paradoxically, the traffic is lightest. The areas are generally small and highly localised and are similar in extent to the pothole damage commonly found in conventional flexible pavements. The most severe example, evident in February, 2004, is shown in Figure 3.

Figure 3. Localised pavement damage showing loss of sand and chipping adjacent to Location 4

To obtain a more quantitative assessment of the current condition of the road a rutting survey was conducted on 25 February, 2004. This involved taking the following measurements:

1. Rutting under a 2 m straightedge measured to an accuracy of 1 mm.
2. Rutting obtained by a profilometer to an accuracy of 0.5 mm

The locations of these measurements are shown in Figure 4.

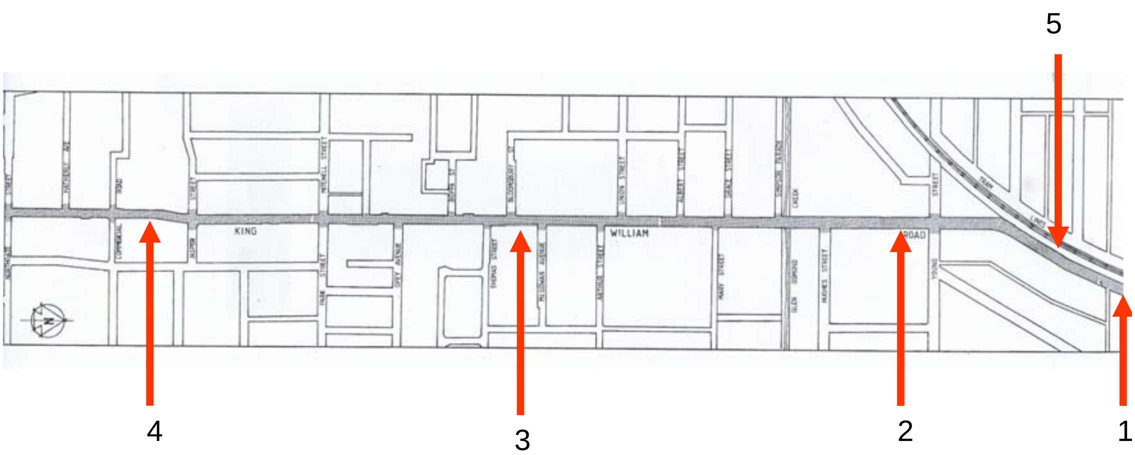

Figure 4. Plan of King William Road showing locations of the measurements.

As shown in Figure 4, most measurements were made on the southbound traffic lane of the road. This was because, in the opinion of the Council and its consultant, Tonkin and Associates, this lane showed more traffic induced distress than the northbound lane. Except at location 5, a bus stop on the northbound carriageway near Greenhill road, both the straight edge and profilometer measurements were made in the trafficked lanes not the parking (kerbside) lane. At the bus stop, measurements were made in both the centre and kerbside lanes because the buses customarily track across both lanes.

In all cases, the measurements were made in the outer wheel path (OWP) by measuring across the pavement from the lane markings dividing the parking lane from the traffic lane. Ten locations spaced at about 2m c/c along the roadway were randomly selected for the straightedge measurements. The positions for the profilometer measurements were also randomly chosen within the range of straightedge measurement locations.

Location 1 was just to the South of Greenhill Road. Here there is a short length of flexible pavement surfaced with asphaltic concrete (AC) before the commencement of the concrete block paving. For comparison, measurements were made on both the AC and concrete block paving (CBP) at this transition because both had carried the same traffic. However, the cross-section of this AC pavement is not known nor is it clear whether any resurfacing has been done since 1987. This limits the usefulness of comparisons between the AC and CBP performance. The deformation readings are summarised in Table 1.

A few straightedge measurements were made in areas of localised failure such as that shown in Figure 3. Here peak rutting deformations between 10mm and 30mm were observed. These data are not included in Table 1.

TABLE 1. Rutting Deformation Measurements in mm.

LOCATION (see Fig X)		**Rut under 2 m Straight Edge**		**Rut under Profilometer**
		Range	**Mean**	**Maximum**
1	AC	0 - 5	3.2	6
	CBP	0 - 3	1.5	2.5
2	CBP	0 - 4	1.9	3
3	CBP	3 - 10	5.2	8
4	CBP	0 - 3	2.7	2.5 (OWP), 3.8 (IIWP)
5	CBP	3 - 13	5.6	6 (kerbside), 6 (centre lane)

In the AC pavements ruts between 0 and 5mm were measured with an average of 3.2 mm. The maximum rut measured by the profilometer was 6mm. Interestingly, comparison of the profilometer plots suggested that the ruts in the AC tended to be wider than those in the CBP.

In the CBP, no rutting whatsoever could be measured at 7 of the 50 positions where straightedge measurements were taken. Elsewhere, as shown in Table 1, the rutting was generally less than 6mm although in a few places individual deformations up to 13mm were recorded. The rutting deformations in the paving averaged 3.4mm according to the straightedge measurements and 4mm according to the profilometer results. Overall, this represents a good level of performance for a pavement carrying nearly 20 years of urban arterial traffic without resurfacing.

As noted above, some loss of jointing sand had been observed in portions of the paving. For this reason, measurements of joint width were made at both locations 3 and 4. These were taken in serviceable areas of the paving and are reported as the mean of 10 randomly positioned readings in Table 2.

TABLE 2. Joint Widths.

LOCATION	JOINT WIDTH (mm)	
	Range	Average
3	2 - 4	3
4	2 - 4	2.7

From the table it may be seen that, at location 3, the mean joint width was 3mm whilst at location 4 the average was 2.7mm. In both cases the joint widths complied with customary requirements that joints should be within the range from 2mm to 4mm (7). Thus in general there was no evidence of pavers coming together except where there was severe loss of sand from the joints (e.g. as shown in Figure 3).

PAVEMENT EVALUATION

In this section of the paper the authors examine the factors that may have contributed to the pavement performance to date.

Pavement Design

It is believed that the original pavement design may have been based, at least in part, upon the then current recommendations published in 1982 as empirical design curves by the Cement and Concrete Association of Australia in Technical Note 40 (8). These simple curves made no provision for the use of a capping layer and it would have been necessary to assign a support value for the capping and subgrade combined. For the thicknesses selected it appears that a combined CBR value of just 4% was assumed i.e. little or no allowance was made for the stiffening effect of the lean concrete capping. This suggests that the pavement design was quite conservative.

Considerable advances in the technology of pavement design have been made since the construction of King William Road. It is therefore of interest to assess the adequacy of the as-constructed pavement according to current design methodology for segmental pavements. To do this, the LOCKPAVE-2003 program published by the Concrete Masonry Association of Australia has been used. This has been described in detail elsewhere (9).

For the purposes of analysis the following assumptions have been made:

AADT = 8000 vehicles/day in one direction (see Ref. 2)
Traffic Growth = 1% p.a.
Design Period = 20 years
Percentage of commercial vehicles, cv = 10%
ESAs/cv =0.6 (see Ref.10)

These data yield an estimated 20 year design traffic of 3.85×10^6 ESA.

For the paver type and paver, base and sub-base thicknesses shown in Figure 2, LOCKPAVE-2003 has been used to calculate the thickness of cement-bound capping layer required for various subgrade CBRs and drainage conditions. In these analyses the moduli assigned to the base and sub-base materials have been assumed not to exceed 250 MPa so as to represent low quality materials. The results are given in Table 3. As shown in this table the analyses reveal that the as-constructed design would be adequate for subgrade CBR values as low as 1% even under very poor drainage conditions

Table 3. Thickness of Cement-Bound Capping Layer (mm)

DESIGN CBR (%)	DRAINAGE CONDITION	
	Poor Saturated > 25% of time	Very Poor Saturated > 25% of time
1	150	155
2	120	130
3	105	110

Recent inspections have found as-constructed thicknesses of the lean concrete capping between 140mm and 230mm. Overall, therefore, the design appears to be adequate according to modern design methodology for a 20 year life at CBR values of 2% or more. In this respect it should be noted that the LOCKPAVE analyses assume a weaker capping layer material than 7 MPa lean concrete and weaker subgrades than that actually measured *in-situ* in recent tests (see above) i.e. the analyses are conservative. Overall, in assessing the in-service performance of the pavement, there is little scope for attributing defects to any lack of pavement thickness.

As shown above the deformation performance of the pavement has generally been quite good and there is little evidence of structural failures or deficiencies. Where distress is most evident it tends to be localised. This suggests that these failures are most likely due to occasional local construction or materials deficiencies such as poor compaction.

Pavement Materials

Investigations conducted by Tonkin Consulting in 2003 have revealed some anomalies in the base and sub-base materials. Combined samples of the two materials gave results that do not meet current TSA requirements for Class 2 quarried pavements material because of an excess of fines although plasticity requirements are met. However, it is not clear whether this is true of both materials of simply the graded quarry rubble sub-base. If the base and sub-base are simply considered as one granular layer then the quality of this layer falls below that required for a basecourse material in respect of grading and would not be expected to give satisfactory in-service performance. However, it is not clear whether the materials met current requirements when first installed or whether degradation and breakdown of the material has been caused by the 18 years of traffic since construction. There is also evidence that, in places, the bedding sand has been contaminated by fines pumping up from the basecourse. This tends to confirm the possibility of basecourse degradation in service.

In respect of the paving there has been relatively little cracking or spalling breakage of the pavers except in a few localised areas (e.g. Figure 3). However, wear leading to fading of the original colours is now widespread. In this respect, it is worth noting that, since the construction of the King William Road paving, considerable research has been conducted into the abrasion wear of concrete pavers and much better tests and standards for abrasion resistance in CBP are now in routine use (11,12).

DISCUSSION

King William Road has succeeded in its original aim of rehabilitating the urban areas through which it passes and must be considered a good example of urban renewal. As such, it remains a significant benchmark in Australian municipal engineering using segmental paving. As with all other types of pavement it now shows some distress but, as shown above, the pavement structural performance has generally been good for a road carrying arterial urban traffic. Nevertheless, as the road approaches the end of its planned design life, consideration needs to be given to methods for rehabilitating or upgrading the pavement. For this, the options include:

1. Spot maintenance or repair of localised distress.
2. Reconstruction or rehabilitation of entire pavement sections.

In 2001, CMAA published a guide written by the authors for maintaining concrete segmental paving in Australia (13). The procedures detailed in this guide cover both surface and structural maintenance and are relevant to most of the problems now beginning to appear in King William Road.

Maintenance and Repair of Localised Distress

Localised areas of distress can be most readily repaired by lifting and relaying just the areas affected. Recent experience in Adelaide shows that it is feasible to lift and recover pavers for between \$5/m^2 and \$10/m^2. This compares favourably with the replacement cost of around \$25/m^2. In both cases laying costs would be around \$15/m^2 if hand laying were used.

Such spot repairs can be made to be invisible provided the original pavers are used for the reinstatement and correct procedures are followed. These procedures are detailed elsewhere (7,13). This means that, after repair, the current appearance and patina of the current paving can be retained. It is also important to note that in the USA, major cities including Chicago, San Francisco and Seattle have reported that the effective service lives of downtown streets, defined as the intervals between resurfacings, are shortened by up to 65% by utility cuts (14). The use of correctly maintained CBP largely obviates this problem.

Surface and Structural Rehabilitation

In areas where reconstruction is required (e.g. to change or upgrade the roadway aesthetics) it is first necessary to consider whether the entire pavement needs to be replaced or just the paving itself. LOCKPAVE computer analyses indicate that the current pavement substructure would be viable for another 20 years of traffic were the surfacing to be replaced. However, this presupposes that the pavement materials currently in place meet normal requirements for grading etc. It was noted above that preliminary investigations of the base and sub-base materials suggest that this may not be the case although further tests are needed to confirm this. However, there is another option. This is to cement-stabilise the existing base/sub-base *in-situ*. LOCKPAVE analyses show that this could be accomplished without the need to replace materials or raise levels. Overall, subject to further investigation of the pavement basecourse material, it appears feasible either to retain the existing substructure or to stabilise it in place with cement. Replacement of the base or sub-base does not appear to be necessary. This means that the costs of any reconstruction can be minimised.

If it is deemed necessary to replace any sections of paving then consideration should be given to specifying machine installation of the pavers. Not only would this reduce the costs but the time required for laying the pavers would be greatly reduced. This would overcome one of the major criticisms of the original work that it restricted access to properties whilst construction was in progress. Experience overseas has shown that it is feasible to lay pavers over the length of an entire city block overnight without major disruption to traffic or property access.

CONCLUDING COMMENTS

King William Road has now successfully completed nearly 20 years of service with relatively little maintenance for a major urban road. In structural terms, the existing pavements are capable of being rehabilitated for at least another 20 years without the need for major reconstruction. In these respects the use of concrete segmental paving has maximised the asset value of the roadway to the Unley municipality in addition to successfully acting as the catalyst for revitalising and renewing an area with strong heritage characteristics. The need for maintenance has only become evident in recent years. This is consistent with studies of whole of life cost studies that show that concrete segmental paving offers significant economic advantages over conventional paving in downtown situations (14)

The project remains a milestone in applying concrete segmental paving in Australia. Recognising that, in the 20 years since King William Road was conceived, many advances have taken place in the manufacture and quality control of pavers and in the design, construction and maintenance of segmental paving the project reaffirms the importance and potential of concrete segmental paving in urban road engineering.

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