CMAA
CONCRETE MASONRY ASSOCIATION OF AUSTRALIA

PA02

Concrete Segmental Pavements - Design Guide for Residential Accessways and Roads

ABN 33 065 618 804.

The Standards referenced in this manual were current at the time of publication.

Cover: Mersey Bluff

Product: Adbri Masonry Trihex®

CMAA
CONCRETE MASONRY
ASSOCIATION OF AUSTRALIA

PO Box 370, Artarmon NSW 1570 Australia
Suite 3.02, Level 3, 44 Hampden Road Artarmon NSW 2064 Australia
Telephone +61 2 8448 5500 Fax +61 2 9411 3801
ABN 30003873309

www.cmaa.com.au

1 Scope

This Guide supersedes *Interlocking Concrete Road Pavements, a Guide to Design and Construction* (T35) published in 1986 by the Cement and Concrete Association of Australia.

It provides information on the design of concrete segmental pavements for residential accessways and other public roads. Pavements for heavy-duty, off-road or specialised materials-handling vehicles and domestic driveways are beyond its scope. This Guide is not intended to serve either as a standard or a specification and its use or reference in such a way is not intended or authorised.

The information is intended for use by persons experienced in pavement design and related soils engineering who are able to assess the criteria used in this Guide and any limitations included in them.

The information is based on characteristics of concrete segmental pavements developed from dedicated laboratory and full-scale test pavements and by the performance of in-service concrete segmental pavements over about 20 years. Accordingly, much of the information may be inappropriate to other forms of paving. It is not intended that this Guide should take precedence over local experience or research which has produced good performance from thicknesses and materials that may vary from those mentioned herein.

It is an axiom that no two projects are identical. The information given in this Guide cannot be expected to apply in detail to the wide range of climatic and soil conditions in Australia. Accordingly, designers need to apply their own engineering judgement of local conditions in reaching design decisions for individual projects.

The successful completion of a concrete segmental pavement requires the use of surface detailing and relevant construction techniques. Information on pavement detailing is contained in a companion document *Concrete Segmental Pavements – Detailing Guide* (T46).

Most of the manufacturers of concrete segmental pavers in Australia are members of the Concrete Masonry Association of Australia (CMAA). To enhance the performance of particular projects, it is recommended that advice is obtained from local CMAA members to adapt or supplement information contained in this Guide.

2 Introduction

2.1 APPLICATION

In Australia, concrete segmental pavements have been in use in roads and residential streets for over 20 years. Although aesthetic appeal had an early influence on their use, they are recognised as serviceable load-carrying pavements with a satisfactory riding quality for most urban-traffic speeds and having particularly favourable characteristics contributing to safety[1,2].

Contemporary residential developments often include curved street alignments with varying pavement widths to restrict traffic speed, maximise land use and to add visual appeal. Concrete segmental pavements offer particular advantages in these situations. The construction process allows them to fit varying geometry. In traffic-management schemes to control traffic flow in established areas, the visual contrast offered by concrete segmental paving assists in defining the character of streets and pavement usage. Permanent colour and road markings can be incorporated at the time of construction.

Concrete segmental paving can be restored after disturbance (eg to gain access to underground services) without a 'patched' appearance.

2.2 PAVING UNITS

The properties of concrete segmental pavers are covered in a companion document *Concrete Segmental Pavements – Guide to Specifying* (T44). With continuing developments in paving units and construction techniques for pavements using them, designers and specifiers are advised in all instances to consult CMAA members who will advise on availability and selection of specific paving units and related construction procedures for all projects.

2.3 TECHNOLOGY DEVELOPMENT

Since the mid-1970s there has been extensive dedicated research, development and performance evaluation of concrete segmental paving. Australia has been at the forefront of technology development. There is now published documentation on the good performance of urban concrete segmental pavements in Australia after 20 years which confirm the suitability of current design practice[3]. Major texts by Shackel[4] and Lilley[5] are available. The first of these is a principal technology source for this Guide.

Computer software for thickness design of concrete segmental pavements, 'LOCKPAVE®', has been developed in Australia and is in use internationally. The criteria used, and the development and confirmation of LOCKPAVE is contained in a paper by Shackel[6]. Some of the key points are set out in Clause 4.5. LOCKPAVE is available through the CMAA. Example thickness designs derived from it are included in this Guide.

2.4 SEGMENTAL PAVING CHARACTERISTICS

When properly designed and constructed, and particularly on an unbound basecourse, the stiffness of the surface layer of concrete paving units increases progressively under traffic, manifested by a gradual decrease in the development of rutting[7]. The LOCKPAVE software enables the designer to assign stiffness values in the form of elastic moduli to the layer of paving units based on the expected design traffic and the characteristics of different categories of concrete segmental paving units. In minor residential streets where the estimated number of commercial vehicles may not exceed about 10^4, the full development of stiffening and modulus may not be realised. Allowance can be made for this in assigning the elastic moduli for design and is incorporated in LOCKPAVE.

2.5 DESIGN CO-OPERATION

It is essential that thickness design, materials selection and construction practice are integrated in order to achieve the desired pavement quality. Co-operation among designer, specifier, constructor and manufacturer has been shown to have a significant beneficial influence on pavement quality[9].

3 Pavement Structure

3.1 GENERAL

Concrete segmental pavements include three basic layers as shown in Figure 1:

- **Subgrade** The subgrade is the prepared and compacted insitu soil or fill on which the pavement is constructed.
- **Basecourse** The basecourse includes one or more layers of high quality unbound crushed rock or natural gravel, cement-modified or cement-bound materials or lean-mix concrete.
- **Surface** The surface layer includes the concrete segmental paving units. A bedding course and edge restraints. Gaps, more commonly referred to as 'joints', between paving units are completely filled with a fine joint-filling material.

On low-strength subgrades a sub-base can be incorporated in the pavement to provide a firm and stable platform for further construction. Some guidance on this additional layer is given in Clause 4.5.2.

3.2 PAVEMENT LAYERS AND COMPUTER-AIDED DESIGN

The LOCKPAVE software enables rapid evaluation of a range of combinations of pavement layers to be made, either at project-feasibility or detailed-design stages. These combinations are shown in Table 1.

The information in this Guide provides only a summarised discussion of the range of options available to the designer. The charts in Figure 5 provide computed basecourse thicknesses for commonly used basecourse materials. With the speed of computer-aided design, designers are encouraged to investigate a range of layer options both for structural adequacy and costs before reaching the final design decision. Commentary on basecourse material selection is given in Clause 4.5.4.

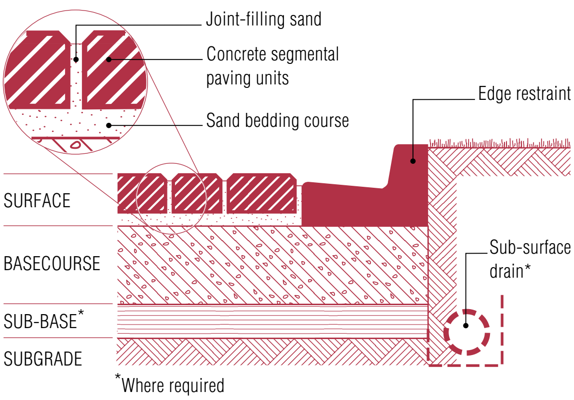


Figure 1 Concrete segmental pavement structure

Table 1 Combinations of pavement layers covered by LOCKPAVE

	Alternative											
Layer	1	2	3	4	5	6	7	8	9	10	11	12
Paver and sand	■	■	■	■	■	■	■	■	■	■	■	■
Base												
Crushed rock		■	■	■	■							
Stabilised					■	■	■	■				
Asphalt									■	■	■	■
Sub-base												
Gravel		■			■					■		
Stabilised			■			■					■	
Stabilised subgrade				■			■					■

3.3 SURFACE DETAILING

Good surface detailing represents an opportunity for the designer to combine visual appeal with pavement serviceability. Surface detailing includes pavement perimeters, edge restraints, roadside gullies, surface penetrations, sub-surface drainage, medians and traffic islands and connections with adjacent or other pavements.

Surface detailing is an important aspect of concrete segmental pavement design and construction where designers can benefit from consulting CMAA members for advice on available techniques and materials which will enhance the pavement.

Guidance on surface detailing is in included in *Concrete Segmental Pavements – Detailing Guide* (T46).

3.4 DRAINAGE

Good surface, sub-surface and subsoil drainage is essential for satisfactory pavement performance. Drainage needs to be considered during the design, specification and construction phases of a project. Requirements for surface profile, location and sizes of kerb gullies and surface inlets and the provision of sub-surface and subsoil drainage are the same as for other pavements on the same site.

During its early life, some rainwater may penetrate the pavement via the filled joints. Experience indicates that as detritus is deposited in these joints, pavement permeability is substantially reduced. This process may take some time and the use of a bituminous prime coat on the basecourse before placing the bedding course can minimise early water penetration into the basecourse.

Information on detailing of the drainage of the bedding course at pavement perimeters where heavy rainfall may occur, or on wide pavements, is contained in *Concrete Segmental Pavements – Detailing Guide* (T46).

4 Thickness Design

4.1 GENERAL

There are five essential steps in the thickness design of a concrete segmental pavement:

- Traffic estimation
- Subgrade investigation
- Surface design
- Basecourse thickness design
- Design considerations for low-strength subgrades or irregular-shaped areas.

4.2 TRAFFIC ESTIMATION

Traffic for the design 'traffic lane' is estimated in terms of the number of commercial vehicles exceeding 3 t gross mass. Vehicles weighing less than 3 t do not significantly affect thickness design and simplified design is possible for this type of traffic. The period over which the traffic is estimated and the need to include annual growth factors over the design period are matters for decision by the designer.

For a given number of commercial vehicles, LOCKPAVE and the examples in this Guide utilise a published spectrum of proportions of axle types (ie single, tandem and triple axles) and axle loads for each axle type based on Australian load studies(10). This spectrum, which is given in Figure 2, includes heavily loaded trucks and is considered to be conservative for application in urban and residential pavement design.

The concept of Equivalent Standard Axles (ESA) developed many years ago and often used with conventional flexible pavements(12) is not considered to be an appropriate pavement design factor for use in concrete segmental pavements. However, designers may use ESA when comparing concrete segmental pavements with other pavement types.

In the absence of local design traffic standards or data, it is possible to make estimates of traffic loads using data provided by ARRB(11) in conjunction with a local street hierarchy. The estimates can include provision for:

- building-construction traffic – in situations such as a residential street where the pavement is built before the houses;
- garbage-collection traffic;
- the likelihood of 'double trafficking' of vehicles entering and leaving narrow residential streets where entering and departing traffic tracks over the same area.

An illustration of a street hierarchy and traffic, derived from Potter(10), is shown in Table 2.

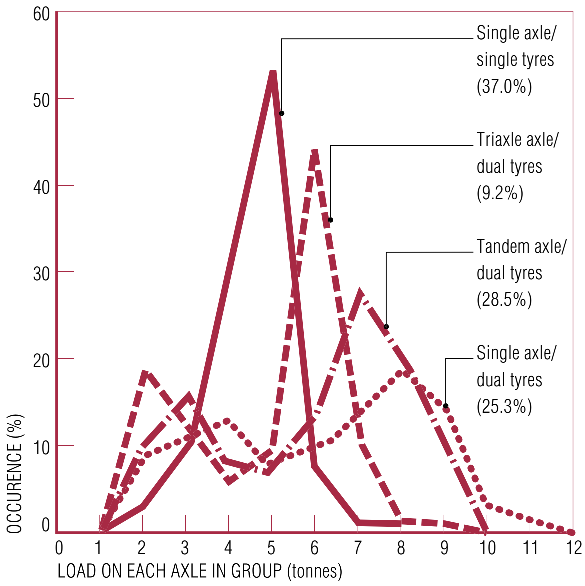


Figure 2 Typical distribution of truck axle loads in Australia

Table 2 Traffic statistics for residential streets (updated figures from Mulholland 1986) – *figures in brackets are mean values*

Street type	AADT limits	% CV	ESA/CV	ESA/ day/lane	r
Minor	<150	1.0–15.0 (3.6)	0.01–0.70 (0.20)	0.03–5.0 (0.40)	0.00
Local access	150–1000	1.0–25.0 (5.0)	0.10–1.00 (0.50)	0.02–15 (4.0)	0.01
Collectors	1000–3000	2.0–20.0 (7.0)	0.10–1.20 (0.50)	5–90 (30)	0.015
Distributors	>3000	2.0–8.0 (3.7)	0.20–0.90 (0.50)	20–190 (60)	0.025

AADT = Average Annual Daily Traffic
CV = Commercial Vehicles
ESA = Equivalent Standard Axles
r = Growth Rate

Traffic estimation may also include the following factors:

- For pavements catering essentially for slow-moving or parked vehicles, a two-tiered estimate may be economical, ie differentiating between areas catering primarily for vehicles less than 3 t and driveways or aisles carrying a mixture of vehicles including those expected to exceed 3 t.
- Theoretical basecourse thickness calculations for estimated numbers of commercial vehicles less than 10^4 can be less than 100 mm. This can be less than a practical minimum value for construction purposes which then controls thickness design for these low traffic volumes. The thicknesses shown in Figure 5 for unbound basecourses incorporate this factor.

- For narrow or minor residential accessways, the concept of a design 'lane' may not be suitable and it may be necessary to assume that the carriageway accepts the full traffic load and 'double trafficking' occurs, ie each vehicle travels twice over the same area for cul-de-sac type pavements. This can apply to both building-construction and garbage-collection traffic.

4.3 SUBGRADE INVESTIGATION

Thickness design requires the assessment of the subgrade in terms of the California Bearing Ratio (CBR). The charts in Figure 5 are based on CBR values obtained from soil tested in a soaked condition. The use of a soaked CBR, particularly in clay or silty soils in major urban regions, is supported by research into existing pavements under Australian conditions(11,16). In arid areas, the use of an unsoaked CBR may be suitable. AUSTROADS(12) and ARRB(11) provide detailed guidance on methods for estimating design CBR values.

Estimates of CBR values should include an allowance for the natural variability of subgrade soils, particularly high-plasticity soils. Sufficient locations should be sampled and evaluated to identify variations either between or within individual streets or paved areas. Where sufficient locations are investigated to permit the tabulation of a frequency distribution, a design CBR not exceeding the lower ten-percentile value is recommended.

The assigning of design CBR values is a key decision in pavement design and should always be made by an experienced engineer.

4.4 SURFACE DESIGN

4.4.1 Paving Units

Three factors are involved in the selection of a surface layer of concrete segmental paving units: shape, thickness and laying pattern. Units manufactured in accordance with T44 are classified into three paver shape types (A, B and C). Examples of these are shown in Figure 3. Laying patterns are shown in Figure 4, while recommended paving units and laying patterns for various traffic loads are set out in Table 3.

The most effective laying pattern is herringbone bond. The direction of traffic has little effect on the performance of paving units laid in this bond irrespective of the orientation of the rows of paving units. Other laying patterns, in descending order of effectiveness are basket-weave and stretcher bond. From Table 3 it can be seen that a wide range of surfacing designs are suitable for lightly trafficked pavements.

For parking areas catering principally for passenger cars and light utility or delivery vans, and for pedestrian areas likely to be subject to occasional service-vehicle use, the paving unit recommendations for traffic loads up to 10^4 commercial vehicles should be used.

4.4.2 Bedding Course

The quality and thickness of the bedding course have a significant influence on the performance of the pavement. However, its thickness is controlled by considerations of construction expedience rather than by a design process. For the purpose of thickness design, the bedding course has a nominal compacted thickness of 25 mm. The use of a bedding course thicker than about 30 mm is not recommended as it can result in differential compaction and will add unnecessary cost.

4.4.3 Edge Restraint

An edge restraint is required at the perimeter of the pavement to maintain bond in the surface layer. Restraints can also be used to separate areas having different laying patterns. The function of the edge restraint is to prevent movement of paving units near the perimeter under the action of traffic and to limit any consequent opening of joints and spreading of paving units. Edge restraints are required to have sufficient stability to withstand occasional vehicle impact.

Information on the selection and detailing of edge restraints is contained in *Concrete Segmental Pavements – Detailing Guide* (T46).

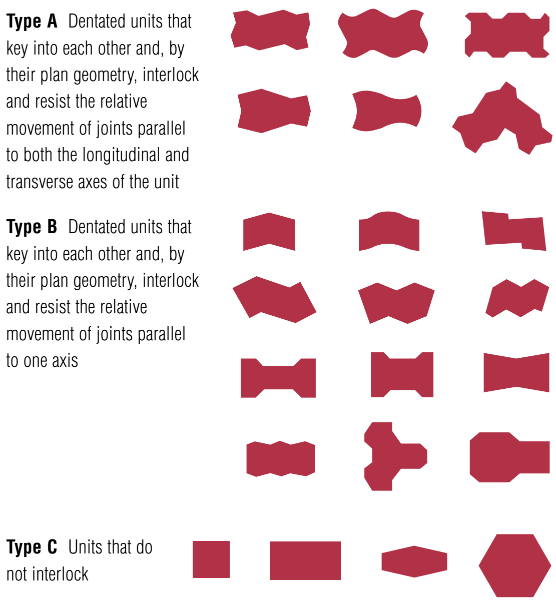
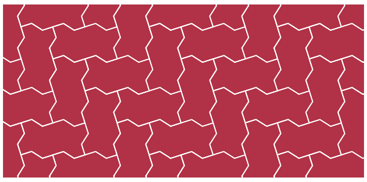
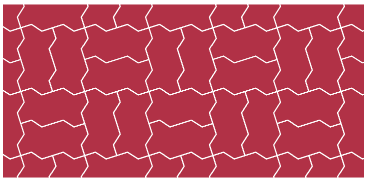


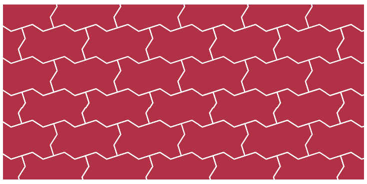
Figure 3 Paver shape types



Herringbone bond
(Most effective, traffic direction not critical)



Basket-weave bond
(Less effective)



Stretcher bond
(Least effective)

Figure 4 Laying patterns

Table 3 Paving-unit shape, thickness and laying pattern

Estimated traffic† (commercial vehicles exceeding 3 t gross)	Recommended surface layer		
	Shape type	Thickness (mm)	Laying pattern*
Up to 10^3	A,B or C	60	H,B or S
10^3 to 10^4	A	60	H only
	A, B or C	80	H,B or S
Over 10^4	A only	80	H only

†Including building construction traffic
*H = Herringbone, B = Basketweave, S = Stretcher

Notes

1 If 80-mm shape Type A paving units, laid in herringbone bond only, are selected for a pavement subject to traffic loads up to 10^4 commercial vehicles, a basecourse thickness may be reduced by 20 mm.

2 For parking areas catering for family cars and station wagons only, the recommendations for traffic below 10^4 commercial vehicles are suitable. For access driveways or loading docks incorporated in a parking area and which may be regularly used by commercial vehicles exceeding 3 t gross, the surfacing should be appropriate for the estimated traffic load.

3 For pedestrian-mall pavements likely to be subject to occasional heavy construction service-vehicle usage, the recommendations for traffic loads up to 10^4 commercial vehicles should be used.

4.5 THICKNESS DESIGN

4.5.1 General

Design examples for commonly used basecourse materials computed from LOCKPAVE are shown in Figure 5. The properties of materials used in the computations are given in Table 4.

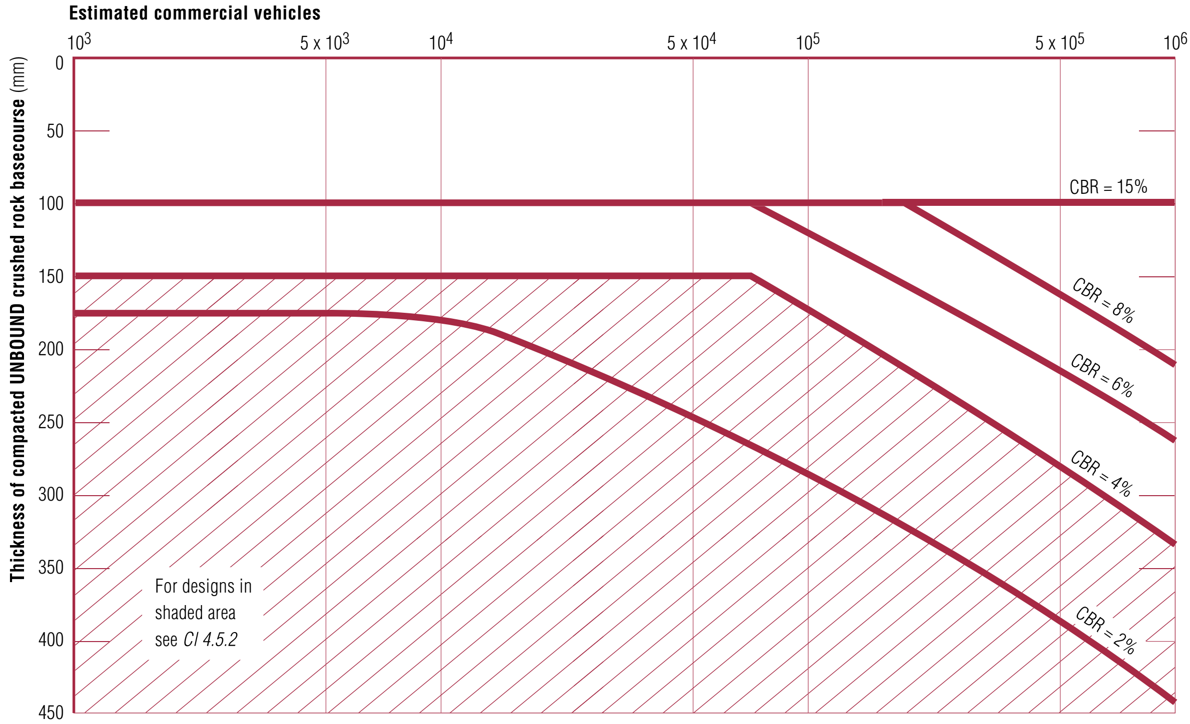
The design recommendations given here are dependant upon the use of base and sub-base materials meeting the standards set out herein. The use of non-complying materials may invalidate the design assumptions of this Guide and needs to be investigated by a competent pavements engineer.

Three key design criteria included in LOCKPAVE are:

- For unbound materials, the aim of thickness design is to limit permanent deflection or rutting.
- For cement-bound material (or lean-mix concrete), the aim of thickness design is to avoid flexural cracking at the bottom of the layer.
- As a result of the segmental or 'pre-cracked' nature of the surface, fatigue is not a consideration in the surfacing.

Table 4 Properties of unbound basecourse materials

	Maximum nominal aggregate size		
	20 mm	20 mm	40 mm
	Class A	Class B	Class B
% passing sieve size			
53.0 mm	–	–	100
37.5 mm	–	–	95–100
26.5 mm	100	100	80–90
19.0 mm	95–100	95–100	69–83
13.2 mm	78–92	78–92	56–74
9.5 mm	68–83	69–83	44–64
4.75 mm	44–64	44–64	29–49
2.36 mm	29–47	30–48	21–37
425 microns	12–20	14–22	10–17
75 microns	2–6	6–10	5–8
Liquid limit (max)	20	23	23
Plasticity index (max)	6	8	8
Los Angeles Test % loss (max)	40	50	50
CBR after soaking at 98% modified maximum dry density (min)	100	80	80



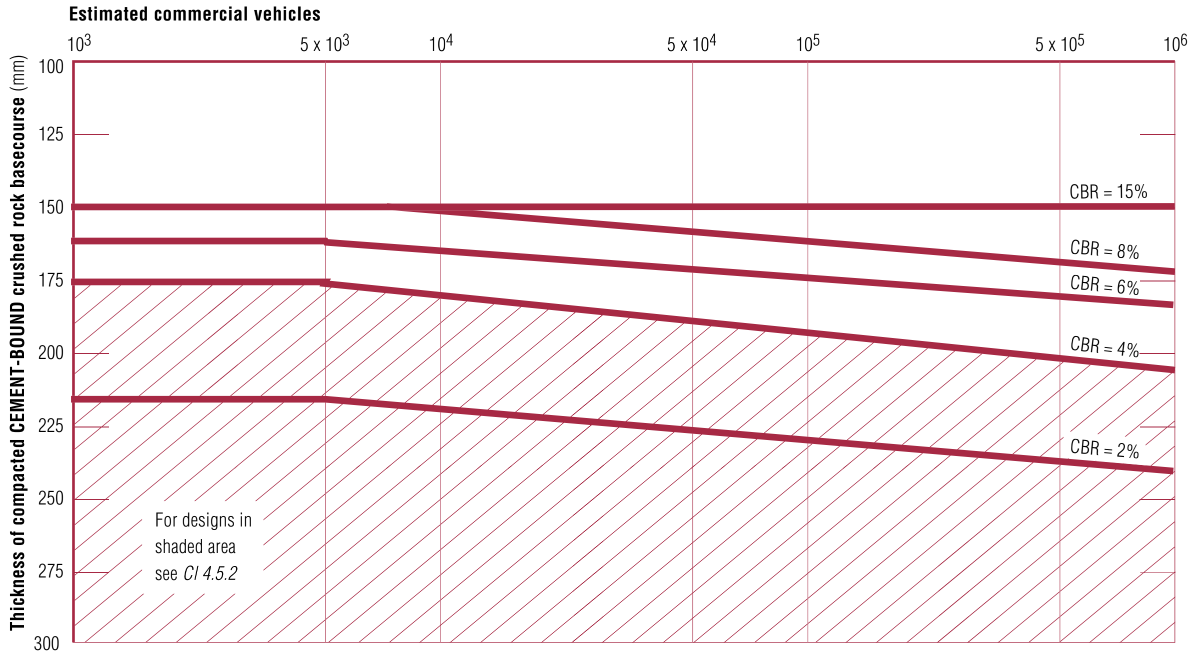


Figure 5 Example designs from LOCKPAVE

Note: The above examples are computed directly from LOCKPAVE for illustrative purposes using the following design factors:

- Average drainage
- Default moduli for unbound and cementitious-bound crushed rock basecourse material respectively
- Traffic load safety factor = 1.0

They assume normal subgrade preparation only. They do not incorporate the use of any of the options included in the discussion on low-strength subgrades in Clause 4.5.2.

The charts are based on 80-mm Category A paving units (for 60-mm units, basecourse thickness can be generated from LOCKPAVE).

For design traffic loadings below 10^4 commercial vehicles, 60-mm Category A, B or C units may be used as indicated in Table 3.

4.5.2 **Designs on Low-Strength Subgrades**

Irrespective of design loads, some low-strength subgrade soils may present construction difficulties which can be addressed by aspects of thickness design and materials selection.

For the purposes of this Guide, a low-strength subgrade is classified as one having a soaked CBR of 4%. Such subgrades can present difficulties in achieving a firm and stable platform for basecourse construction in their unmodified form using conventional compaction methods. The following options may be considered, subject to the designer's assessment of individual site conditions.

Stabilisation The subgrade may be suitable for chemical stabilisation by lime, fly ash, ground granulated slag or cement or some combination of these depending on subgrade material type, availability of stabilisation additives and required post-stabilisation properties. For pavements within the scope of this Guide, a minimum compacted depth of stabilisation of 100 mm is recommended. LOCKPAVE provides for the design of segmental pavements incorporating a stabilised subgrade with unbound or bound basecourses.

The information in Figure 5 can be used to include improvements in the subgrade after stabilisation. Where a subgrade with a soaked CBR less than 2% is stabilised, an improved CBR value not exceeding 2% may be used for basecourse design. Where a subgrade with a soaked CBR in the range 2–4% is stabilised, an improved CBR value not exceeding 6% may be used for basecourse design.

NAASRA[14] provides guidance on materials and construction procedures suited to subgrade stabilisation.

Very Low-Strength Subgrades For very low-strength subgrades with a typical site CBR not exceeding about 2%, it may become necessary to use techniques that achieve a firm and stable platform for construction without compaction using rollers. Two typical solutions are:

Lean-Mix Concrete Provision of a layer of lean-mix concrete having a nominal minimum 28-day compressive strength of 5 MPa. For pavements designed for traffic up to 10^4 commercial vehicles, a thickness of 100 mm is suitable; and for higher traffic loads, 125 mm. These thicknesses may need to be increased for construction practicability if accurate subgrade trimming is difficult. The use of lean-mix concrete for stabilisation under the above conditions assumes that a separate basecourse may be required. Its use should not be confused with the use of lean-mix concrete discussed in Clause 4.5.3 below.

Geotextile Fabric Overlaying the subgrade with a layer of geotextile fabric sometimes with a coarse granular surcharge. The assessment of design subgrade CBR and other design factors after using a geofabric for subgrade stabilisation needs to be discussed with the fabric supplier and is outside the scope of this Guide. However, the use of woven geofabrics is generally to be preferred to other fabrics for this application.

4.5.3 **Designs for Irregular-Shaped Areas**

Segmental paving is being successfully used for many irregular-shaped trafficked pavements. A common instance is a commuter bus terminal either at a shopping centre or bus/rail interchange. Such terminals can have a 'sawtooth' kerb alignment to allow minimum distance for alighting passengers to reach covered ways. The use of graders/rollers in such situations for basecourse construction is difficult. A mass-placed lean-mix concrete basecourse without joints or reinforcement using manual paving screeds has been successfully used beneath segmental paving. The cost of this material can be offset by more convenient and faster basecourse construction.

Typical 28-day compressive strengths for lean-mix concrete are in the range 5–15 MPa, with elastic moduli in the range 10 000–15 000 MPa. For the range of traffic loadings and subgrade CBR values envisaged in this Guide, the LOCKPAVE software would indicate basecourse thicknesses using this material in the range 150–175 mm.

4.5.4 **Basecourse Selection**

It is recommended that, at design feasibility stage at least, a cost comparison is made for a series of basecourse designs. In some cases, the increased cost of a higher quality basecourse may be offset by the reduced costs of shallower excavation and disposal of lesser amounts of excavated material, particularly in urban areas.

In general, a cement-bound basecourse will be less susceptible to the effects of moisture ingress in areas subject to heavy rainfall and will offer better performance.

Although provided as examples only, one trend apparent in Figure 5 for basecourse thickness needs to be understood. The design models used in LOCKPAVE for unbound and bound basecourse materials are different. As noted in Clause 4.5.1, the design of unbound layers is based on rutting, whilst the design of bound layers is based on fatigue cracking.

This introduces some apparent anomalies. For both light traffic and higher stiffness subgrade conditions, the design models yield a computed bound basecourse thicker than the unbound basecourse. Conversely, for both heavier traffic and lower subgrade stiffness, the computed bound basecourse is thinner than the unbound basecourse. The crossover points can be estimated from Figure 5. The comparison between computed bound and unbound thicknesses can serve as a guide to general conditions of traffic loading and soil conditions where economies in thickness can be obtained.

The final design decision can be made on an informed basis from an assessment of the combination of materials availability, costs and engineering judgement.

5 Basecourse, Bedding and Jointing Materials

5.1 GENERAL

To ensure good performance in a concrete segmental pavement, it is essential to use appropriate quality materials in the basecourse and bedding layers and in joint filling. It should not be assumed that the segmental pavers will compensate for, or in some way bridge over a poorly prepared subgrade or sub-quality basecourse or for the use of unsuitable quality materials. Information on materials used in a sub-base, where required, is given in Clause 4.5.2.

5.2 BASECOURSE MATERIALS

5.2.1 General

To maximise the use of economically available materials and as specifications vary among State and Municipal Authorities, the following information should be used as a guide to preferred minimum requirements only. Designers should take into account local specifications, materials availability and experience.

Information is given on three basecourse material types: unbound, cementitious-bound and cementitious-modified.

5.2.2 Unbound Materials

Unbound materials should comply with local requirements for basecourse for an asphalt-surfaced pavement. The material may be either a crushed quarry material or a natural gravel.

Although not presented as a specification, the information in Table 4 is representative of specifications issued by Australian road authorities. Where, within the overall basecourse, a Class B material is used, it should be covered by not less than 125 mm compacted thickness of Class A material. It is preferable that no individual layer in the basecourse should have a compacted thickness less than 100 mm or more than 200 mm.

5.2.3 Cementitious-modified Materials

Where materials described above are not locally available, lesser quality materials can sometimes be upgraded by the addition of small amounts of cementitious binder. The main aim is to reduce the plasticity of the untreated material. The binder type can be either a GP or GB cement in accordance with AS 3972.

For reasonably well graded granular materials, a binder content of about 3% by weight would usually be sufficient. In the absence of local experience, the actual content should be determined by laboratory testing and/or field trials. The binder can be incorporated through pugmills or purpose-built road-stabilisation plant. Graders or rotary hoes are inefficient and are not recommended for this type of work. The moisture content should not exceed that required for compaction in the field.

As the purpose of the modification is only to improve materials properties rather than to achieve significant strength, pavement design using these materials should proceed as it would for unbound material. Further information on cementitious modification is provided by NAASRA(14).

5.2.4 Cementitious-bound Materials

These materials are designed to have sufficient strength and therefore elastic modulus for this property to be taken into account in thickness design.

In areas of high rainfall or where the water table is high, these materials offer improved performance compared with unbound materials. They are less susceptible to the effects of moisture ingress. Untreated materials should have properties not less than those meeting the properties designated for Class B materials in Table 4.

The strength of the bound material as measured by a 7-day unconfined compressive strength test should be consistent and not less than 2.5 MPa and not more than 5.0 MPa. Cementitious material meeting the requirements of a GP or GB cement in accordance with AS 3972 will usually be suitable. Where aggressive ground waters may be present, the use of a sulphate-resistant binder should be considered.

In the absence of local experience, the required binder content should be determined by laboratory testing. As a guide, a cement content in the range 3–5% by weight of untreated material will often be suitable. The moisture content should not exceed that required for field compaction, which should be to not less than 96% modified maximum density.

Equipment used for this type of material should be the same type as for cementitious-modified material.

5.3 BEDDING COURSE MATERIAL

The quality of bedding course material and the uniformity of the bedding course have a critical effect on the pavement performance. Where these requirements are not met, localised differential settlement may occur early in the life of the pavement. Materials such as clean graded crushed quarry fines and good quality concreting sands have given good performance provided that the following requirements are met. In all cases, designers should seek the advice of local CMAA members as to the suitability of local materials based on experience in their use.

Table 5 details a grading envelope for bedding material that has given good performance based on dedicated research and experience(13).

Single-sized, gap-graded or material containing an excessive amount of fines will lead to reduced performance. The use of a cement-bound material is not recommended. When placed on the basecourse, the material should have a uniform moisture content. Saturated material should not be used. Moisture contents in the range 4–8% have been found to be suitable.

The material should be washed free of soluble salts or other contaminants which can cause or contribute to efflorescence.

5.4 JOINT-FILLING MATERIAL

The small gaps or joints between pavers, nominally 2–5 mm wide, are filled with a fine material. Table 6 details a grading envelope for joint-filling material which has given good performance based on dedicated research and experience(13).

Depending on local materials sources and experience, it may be possible to use the same material for both bedding and filling. Local CMAA members can provide information on this.

As with bedding material, the use of cement is not recommended. The filling material should be washed free of soluble salts or contaminants which cause or contribute to efflorescence.

The filling material can benefit from containing a small amount of dry clay or silt fines passing the 75-micron sieve. In this way, early water ingress through gaps can be controlled. Where used, an amount of fines in the range 5–10% has been found to give good results.

To assist in the complete filling of the gaps, the joint-filling material should be as dry as practicable when spread. Although more expensive, bagged and kiln-dried filling material incorporating additives which will give water-resistant properties after dampening are available in some areas.

Table 5 Grading envelope for bedding material

Sieve size	% Passing
9.52 mm	100
4.75 mm	95–100
2.36 mm	80–100
1.18 mm	50–85
600 microns	25–60
300 microns	10–30
150 microns	5–15
75 microns	0–10

Table 6 Grading envelope for joint-filling material

Sieve size	% Passing
2.36 mm	100
1.18 mm	90–100
600 microns	60–90
300 microns	30–60
150 microns	15–30
75 microns	5–10

6 References

1 Shackel B *Safety and Environmental Aspects of Concrete Segmental Paving* Proceedings of Biennial Conference, Concrete Masonry Association of Australia, 1986.

2 Kanzaki N et al *The Use of Interlocking Block Pavements for the Reduction of Traffic Accidents* Proceedings of 2nd International Conference – Concrete Block Paving, Delft University, 1984.

3 Pearson A R and Hodgkinson J R *A Performance Review of Concrete Segmental Pavements in Urban Redevelopment Projects* Proceedings of Seventh National Local Government Engineering Conference, Adelaide, September 1993

4 Shackel B *Design and Construction of Interlocking Concrete Block Pavements* Elsevier, 1990.

5 Lilley A A *A Handbook of Segmental Paving* E&FN Spon, 1991

6 Shackel B *Computer Methods for Segmental Concrete Pavement Design* Concrete Segmental Paving Workshop, Proceedings of Australian Road Research Board Conference, 1992.

7 Shackel B *An Experimental Investigation of Factors Influencing the Design of Interlocking Concrete block Pavements in Roads* Proceedings of Australian Road Research Board Conference, 1982.

8 Clark A J *Water Penetration Through Newly Laid Concrete Block Paving* Cement and Concrete Association (UK) Technical Report 529, 1979.

9 Pearson A R and Hodgkinson J R *Some Factors Affecting Success and Distress in Concrete Segmental Pavements in Australia* Proceedings of 4th International Conference – Concrete Block, New Zealand, 1992.

10 Potter D W and Donald G S *Structural Design of Road Pavements Workshop* Proceedings of Australian Road Research Board Conference, 1984.

11 Mulholland P J *A Structural Design Guide for Flexible Residential Street Pavements* Australian Road Research Board, Special Report No. 41, 1989.

12 AUSTROADS *A Guide to the Structural Design of Road Pavements*, 1992.

13 Shackel B *A Pilot Study of the Performance of Block Paving Under Traffic Using a Heavy Vehicle Simulator* Proceedings of Symposium on Precast Concrete Paving, Johannesburg, 1979.

14 NAASRA *Guide to Stabilisation in Roadworks,* 1986.

15 Shackel B *An Experimental Investigation of the Roles of Bedding and Jointing Sands in the Performance of Interlocking Concrete Block Pavements* Concrete Beton No. 19, 1980.

16 Sharp K G and Armstrong P J *The Performance of Concrete Block Pavements Constructed on Low CBR Subgrades* Proceedings of Australian Road Research Board Conference, 1984.

PO Box 370, Artarmon NSW 1570 Australia
Suite 3.02, Level 3, 44 Hampden Road Artarmon NSW 2064 Australia
Telephone +61 2 8448 5500 Fax +61 2 9411 3801
ABN 33 065 618 804
ISBN 0 909407 35 5

www.cmaa.com.au

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA