Government of South Australia
Department of Planning, Transport and Infrastructure

Safety and Service Division

Guide to Bikeway Pavement Design Construction & Maintenance for South Australia

FOREWORD

The purpose of this Guide is to present a basis for designing, constructing and maintaining bikeway pavement configurations that should generally provide acceptable in-service performance. The Guide is intended for a range of users that includes technical and professional staff in local government, consultants, and experienced pavement specialists within and external to DPTI.

An early version of this document was published by Transport SA in October 2001 as a draft for comment. Feedback from many sources and various changes to the Austroads pavement design procedures for light traffic have been incorporated within this update. The economic analysis and Whole-of-Life Costing of bikeways is no longer a part of the Guide as it has been the subject of a national development project under the direction of the Australian Bicycle Council and the former Department of Transport and Regional Services (DOTARS). The *User guide to bicycle and shared path selection using whole-of-life costing* ARRB (2005a) is available online.

The development of this Guide has been limited by the scarcity of recorded performance data for in-service bike paths within South Australia. Nevertheless the Guide summarises the pavement engineering principles and practices that DPTI considers are applicable to bikeway pavement structures.

CONTENTS

PART A – GENERAL

1 INTRODUCTION

Bikeway is a generic term for an off-road exclusive-use path for cyclists or a shared-use path for pedestrians and cyclists. Bike lanes on road pavements are not included within this definition.

The purpose of this Guide is to provide bikeway designers and asset managers with practical guidelines for the design, construction and maintenance of bikeway pavements. A structural design methodology and a range of example bikeway pavement configurations are included, together with practical construction detailing and maintenance advice.

The procedures presented in this Guide have been developed from an expert pavement engineering review and adaptation of Australian and overseas literature on bikeway and lightly trafficked road pavements. References from which designers can obtain more information are also identified.

The document is arranged in 5 principal parts, as follows:

- **A. General** – Presents the scope and purpose of the Guide, typical bikeway types and users, surfacing types and economic considerations.
- **B. Pavement Selection** – Defines flexible and rigid pavement types, and the selection criteria and attributes of the normal range of pavements and surfacings.
- **C. Design** – Discusses the pavement design components of subgrades, pavement materials, and design traffic, and provides typical minimum design configurations for all common pavement types**.**
- **D. Construction** – Considers many of the critical construction details and specification requirements of bikeways.
- **E. Maintenance** – Includes monitoring and maintenance activities and techniques, as well as safety issues to be considered when undertaking works.

Consideration of geometric design and traffic engineering practices are excluded from this document as these are comprehensively outlined in Austroads (2014a), Austroads (2009a), Austroads (2009b), and Austroads (1999).

2. BIKEWAY CHARACTERISTICS

2.1 Bikeway Types and Users

There are 3 main types of bikeways; shared use paths, separated paths with delineated pedestrian and cyclist zones, and those reserved for the exclusive use of cyclists.

Shared use bikeways are the most common type in South Australia and are generally constructed to service a wide range of users:

- Cyclists - including primary or secondary school children, recreational cyclists, commuter cyclists, touring cyclists, and sports cyclists; and
- Pedestrians - comprising children, elderly people, people pushing prams and strollers, various individuals and family groups, people walking dogs and joggers.

There are several other broad categories of bikeway users that may be less common than those described above. These include:

- people with disabilities - pedestrians with walking aids, wheelchair or electric gopher users;
- small-wheeled vehicles - children's pedal/motorised/electric cars, in-line skaters, skate boarders, roller skaters, and foot scooters; and
- maintenance vehicles - ranging from light mowing equipment to heavy trucks associated with maintenance of public utilities and associated infrastructure, or the emergency services (police, ambulance, fire etc.).

Bikeways are often located within linear reserves and service easements, or along coastlines and watercourses. Their placement in these areas can involve harsh environments, including weak subgrade conditions and the potential for periods of inundation by floodwater.

Figure 2.1: Shared use path

2.2 Bikeway Widths

Bikeway widths generally vary between 2.5 m and 4.0 m according to the type and nature of the bikeway as detailed in Austroads (2009a).

3. BIKEWAY SURFACES

3.1 Function of Bikeway Surfaces

The wearing surface is the uppermost layer of a pavement structure over which the users of a bikeway are required to travel. Its overall function is to provide a safe, economical and durable all-weather surfacing that is:

- smooth;
- skid resistant;
- dust-free;
- waterproof; and
- durable and protective of the underlying pavement.

In addition, bikeway surfacings are often required to perform aesthetic or social functions that include the following:

- visually enhance the bikeway environment for users and adjacent residents; and
- to assist in separating user groups.

3.2 Types of Surfacing

The general types of surfacing typically used for new bicycle pavements (and as resurfacing treatments) are briefly described as follows.

3.2.1 Unsealed Surface

Granular materials of up to about 20 mm in stone size are typically used as the principal load bearing layer and can also provide the riding surface. The mechanical interlock developed between the larger stones provides the shear strength while the plastic fines in the material bind the surface of the layer.

3.2.2 Sprayed Treatment

Sprayed seals consist of a layer of stone chips spread and rolled onto a thin film of bitumen to form a water-resistant surfacing over granular layer(s).

Figure 3.1 Spray sealed bikeway

3.2.3 Bituminous Slurry and Microsurfacings

A slurry is a mixture of sand, crushed rock, filler, cement, and bituminous emulsion applied to form a thin surfacing layer. Slurry surfacings tend to be very thin (<12 mm), have a fine surface texture, and are relatively brittle when compared to asphalt. They can also be used to correct minor surface irregularities. Microsurfacings are a form of slurry surfacing in which the conventional emulsion is replaced by a polymer-modified emulsion to provide faster setting times and improved flexibility.

3.2.4 Asphalt Surface

Asphalt (or Hot Mix) consists of a mixture of well-graded, clean, non-plastic granular material and 4.5% to 7% bitumen by mass, which is produced in a purpose built mixing plant. When compacted and cooled it forms a smooth, stable and durable riding surface.

3.2.5 Concrete

A concrete surfacing is the finished top of the structural base layer rather than a separately placed surfacing treatment.

3.2.6 Concrete Block Pavers

Concrete paving units about the same size as clay house bricks are placed over a thin sand bedding layer and granular material.

3.3 Performance Characteristics

Monitoring of the performance of a bikeway surfacing requires the assessment of relevant parameters in two principal categories-

- functional - surface shape and appearance, ageing effects, concrete slab faulting (stepping), roughness, skid resistance and surface texture; and
- structural - cracking, deformation, potholes, and pavement strength deterioration.

In practice, many of these factors are inter-related. Increasing roughness may be an indication of deteriorating structural strength. Loss of texture due to bleeding or stripping of a sprayed seal will lead to non-uniform skid resistance.

Ageing of surfaces may lead to cracking or increased permeability, thereby allowing moisture to enter and weaken the pavement structure. Ageing may also lead to ravelling and the initiation of potholing. The potential for skidding may be influenced by poor drainage, bikeway geometry, surface roughness, as well as surface cleanliness.

3.4 Investigation Levels

The levels at which investigation should take place are referred to as indicative investigation levels (IILs). Investigation levels and intervention treatments based on broad experience are provided for general guidance in Part E and Appendix A. However, there are likely to be circumstances in which these are inappropriate for local operating environments, or for technical or economic reasons.

The parameters most readily assigned numerical investigation levels are:

- surface shape;
- roughness;
- skid resistance; and
- cracking.

4. ECONOMIC CONSIDERATIONS

Cost effective designs for bikeway pavements should take into consideration not only the initial construction costs, but also those associated with the maintenance and rehabilitation of the pavement structures. These costs are directly or indirectly related to the following:

- pavement loads;
- environmental factors;
- material properties;
- construction practices;
- pavement performance; and
- maintenance treatments.

The cost of bikeway pavements can vary significantly depending upon a number of parameters, particularly the surfacing and base type. If sufficient capital funds are provided for a well designed and constructed facility, this will usually minimise on-going long-term maintenance costs.

It is usual to adopt a structural design period of 20 to 40 years unless the bikeway is to be developed in stages as outlined in Section 6.1. Unsealed, sprayed seal, and asphalt surfaced pavements would normally require resurfacing at intervals of less than 20 years. Typical life expectancies of the main surfacing types are indicated in *Table 4.1*.

Most bikeway designs prepared in this Guide are based on a design period of 20 years, but concrete pavements have been designed for 40 years.

Table 4.1: Typical Surfacing Life Expectancies

Surfacing type	Expected service life of surfacing (years)
Sprayed seal, 5mm / 7mm	5 to 10
Double application seals	8 to 15
Dense graded asphalt	10 to 20
Fine gap graded asphalt	15 to 20
Slurry & Microsurfacings	8 to 15
Concrete	20 to 40
Concrete Block pavers	15 to 25

In addition to periodic resurfacing, other maintenance activities are often required to ensure that the pavement remains effectively waterproofed throughout its service life.

As with road pavements, the costs for various types of bikeway pavement construction, the performance during the design life, and the on-going maintenance costs vary considerably. To compare projects on an equitable basis, whole-of-life costing can be undertaken in the same way as for road pavements.

Methods of economic comparison include the Net Present Value (NPV) Austroads (2012), and Equivalent Annual Cost, (EAC) Bennett and Moffatt (1995).

ARRB (2005a) provides more recent information about the economic analysis of bikeways and is available online. Associated with that work, ARRB also developed an Excel worksheet analysis tool and user directions (ARRB 2005b).

PART B – PAVEMENT SELECTION

5. PAVEMENT TYPES

Bikeway pavement types fall into two broad categories, flexible and rigid.

Flexible pavements, as the name implies generally have a structure that deflects or flexes under load. They include sprayed sealed pavements, asphalt pavements, and unsealed pavements. Concrete block pavers and pavements incorporating cement stabilised materials are also classified as flexible and use a similar design methodology.

Rigid pavements have a rigidity associated with their slab action and comprise cement bound concrete pavements. The structural design procedure differs fundamentally from that used for flexible pavements.

Given the large range of pavement types from which to select, it is important to adequately consider the advantages and disadvantages of each.

6. SELECTION OF PAVEMENT TYPE

The performance of a bikeway pavement is strongly influenced by the pavement materials, quality control during construction, and the amount and timeliness of maintenance. Generally, the higher capital cost bikeways with concrete or asphalt surfaces have lower ongoing maintenance requirements, and provide better cycling conditions.

Some authorities may have preferences for particular pavement types using local materials and based on knowledge of regional soil conditions. Where possible, maximum use should be made of local materials to gain experience in their performance, to minimise costs and to better blend with the environment.

6.1 Unsurfaced Granular

An unsealed granular or gravel bikeway may be considered as the first stage of the development of a route, especially where:

- the volume of cyclists initially expected to use the bikeway is low;
- gradients are relatively flat (i.e. <3%);
- the environmental amenity of the area may be reduced by a surfaced bikeway; and
- construction costs need to be minimised.

An asphalt, slurry, sprayed seal or concrete surfacing may then be provided at a later stage.

Gravel paths can vary significantly in terms of design and construction details, materials, and hence performance and costs. Generally they have higher rolling resistance and are not as easy or as safe for cyclists to traverse as asphalt or concrete paths, particularly in wet periods. While construction costs are lower, weed control and regular surface grading and replenishment with additional material would generally result in higher maintenance costs. High velocity or high volume drainage flows that intersect an unsealed bikeway may result in significant scour and erosion.

Materials such as crushed limestone and granitic sand that have significant cohesion and texture have been found to provide good service. Stabilisation with a cementitious binder may also be appropriate in some situations.

Suitability for traffic

Gravel is not a suitable surface for small-wheeled devices such as in-line skates, skateboards, wheel chairs, or those with high tyre pressures and is more appropriate for recreational routes or where bicycles with wider tyres are predominant.

6.2 Granular with Sprayed Treatment

One or more granular layers are placed and compacted prior to the application of a sprayed seal surfacing.

- Sprayed seal (Prime and sprayed seal) - a prime (refer below) followed by a thin layer of sprayed hot cutback or emulsion bituminous binder onto which a single size aggregate is spread and rolled. Coarsely textured surfaces such as the single application of a large size aggregate should be avoided because of the high rolling resistance, and greater risk of rider injury and bicycle damage from a fall. Multiple application seals utilising a smaller aggregate size in the top layer, are desirable to improve surface texture.

- Primerseal - an application of a *primer-binder* applied to a prepared granular base to provide penetration of the surface, but with sufficient retained on the surface to hold a subsequent layer of small size aggregate.

  A primerseal also provides an adequate surfacing for cyclists as long as a small size aggregate is used. The primerseal is sprayed on a crushed rock or gravel base similar to that thickness used for asphalt paths. For road pavements a primerseal is regarded as a short term surfacing option (up to 12 months) but under bikeway traffic up to 5 years may be achievable.

- Multiple application seal - a seal using multiple applications of binder and different size aggregate, e.g. first coat 7 mm or 10 mm aggregate, second coat a 5 mm aggregate. A 10/5 seal is usually the better option.

The following are treatments used in conjunction with sprayed surfaces:

- Prime - an application of a primer to a prepared base, without a subsequent aggregate cover, to provide penetration of the surface for waterproofing purposes and to obtain a bond between the pavement and the subsequent sprayed seal or asphalt wearing course.

- Surface enrichment treatment - a light application of bituminous binder, without aggregate, to increase the binder content and extend the life of an existing sprayed seal surfacing.

Where wide cracks in the seal develop, weed and grass invasion can occur.

Suitability for traffic

Sprayed seal surfacings may not be suitable for small wheeled devices such as in-line skates, skateboards etc. Whilst considered to be a practical surfacing for cyclists, sprayed seals are less preferred than either concrete or asphalt surfacing due to their inherent coarser or more variable surface texture.

6.3 Granular with Bituminous Slurry Surfacing

One or more granular layers are placed and compacted prior to priming and surfacing with a slurry or microsurfacing.

- A basic slurry surfacing comprises materials from sand to 5 mm aggregate, with filler, cement and bitumen emulsion. Slurry seals tend to be <12 mm thickness.

- Microsurfacing is similar to a slurry seal but includes a polymer modified bitumen emulsion to provide faster setting for earlier trafficking, greater durability and improved flexibility. The nominal size of microsurfacing is usually in the range 4 mm to 10 mm, placed in layers of up to 3 times the nominal size.

Slurry and microsurfacings are susceptible to surface cracking and loss of surface shape, which can be initiated by soil movements or thermal and age effects.

<u>Suitability for traffic</u>

Good rideability and serviceability for all wheeled and pedestrian traffic.

6.4 Granular with Asphalt

One or more granular layers are placed and compacted prior to priming and surfacing with hot mixed asphalt layers.

- Dense graded asphalt, or asphaltic concrete (AC) - a dense, durable, continuously graded mixture of coarse and fine graded aggregates, mineral filler and bituminous binder which is produced, placed and compacted whilst hot.
- Fine gap graded asphalt (FGGA) - a dense, durable mixture containing some coarse aggregates in a mastic of fine aggregate, filler and binder, for use in lightly trafficked applications.
- Light duty asphalt (L) - typically another term for FGGA with additional binder that reduces the initial air voids of the mix.

Asphalt paths are also subject to deterioration by surface cracking and loss of surface shape resulting soil movements or thermal and age effects. The onset of cracking due to age effects, which is a common distress mode in lightly trafficked asphalt pavements, can be deferred by constructing a surfacing with low insitu air voids (≤ 4%). The pavement strength and load capacity is improved by providing additional asphalt layer(s) below the wearing course. The characteristics of asphalt bikeways are summarised in Table 6.1.

<u>Suitability for traffic</u>

Good rideability and serviceability for all wheeled and pedestrian traffic.

6.5 Concrete

These pavements normally consist of a low strength granular subbase layer supporting a high strength cement bound base layer with textured surface:

- Hessian dragged - a medium surface texture for main roads and residential streets.

- Transversely broomed - a fine texture for low-speed applications such as bikeways.

Several types of concrete road pavements are constructed in Australia with the most common being a jointed unreinforced (plain) concrete pavement (PCP). For bikeways, a variant of this with continuous mesh reinforcement within the concrete base slab is common within the eastern States. They are usually expected to provide better long-term performance where the alignment is constructed on reactive soils and non-uniform support, or is located near trees that can cause root damage.

The contrast between the colour of line marking and concrete surfaces may be poor in some situations but the reflectivity of concrete tends to assist path definition in low light. The characteristics of concrete bikeways are summarised in Table 6.1.

Suitability for traffic

Good rideability and serviceability for all wheeled and pedestrian traffic.

CRITERIA	ASPHALT	CONCRETE
Surface	Flexible, smooth; no construction or expansion joints. Allows a smoother surface where adjacent tree roots cause deformations in the pavement. Suitable in areas susceptible to ground movement, but may still result in cracking and deformation.	General surface is smooth but construction and expansion joints can introduce rider discomfort. Tree roots can cause faulting or stepping.
Construction	Construction not difficult where equipment has the room to manoeuvre. Detail work, e.g. ramps at kerb lines, may require a mixture of concrete and asphalt work. Asphalt has to be hand-laid in confined areas. Edge restraint preferred, especially in developed areas. Full depth asphalt recommended around service and inspection pits to prevent subsidence and uneven surface. Trench and other reinstatements become patchwork, affecting surface uniformity and aesthetics. Less costly to reinstate than concrete because repairs are restricted to the disturbed area.	Less and smaller equipment required to construct. Single material, one-step construction process, including details such as ramps and kerbs. No edge restraint required. Concrete surface more easily matched to be flush with service holes and pits with little likelihood of subsidence. Reinstatements can be made flush with adjacent paving with less likelihood of subsequent subsidence. However, reinstatement can still be patchwork in appearance unless complete slabs are reconstructed. More costly to reinstate whole slabs in cases of minor disturbance.
Construction Detail Requirements	Suitable edge restraint flush with surface is preferable for AC surfaced bikeways. Backfilling to the edge restraint should be finished to the level of the path surface. Flush shoulders required if no other permanent edge restraint is provided.	No edge restraint required. Contraction joints should be sawn rather than formed Provide a non-slip surface, usually a broom finish.
Maintenance	Bitumen acts as a nutrient for grasses such as couch and tends to attract and promote such growth. Maintenance spraying to control weed ingress is essential.	Expansion jointing material should be kept marginally below the finished surface. Construction and expansion joints require regular weed control.

Table 6.1: Summary of Asphalt and Concrete Bikeway Characteristics
(based on Bikewest 1988)

6.6 Concrete Block Pavers (CBPs)

Interlocking concrete block pavers of various types are used for a range of road and path pavements. They are often selected for their aesthetic appeal and placed in local recreational areas with substantial foot traffic.

Pavers are normally placed over one or more granular layers and about 25 mm of bedding sand. Jointing sand is required to assist the mechanics of interlock.

Suitability for traffic

CBPs with chamfered edges are generally unsuitable for small wheeled devices such as in-line skates, skateboards etc.

Figure 6.1: Concrete block paver shared bikeway

6.7 Coloured Pavements

6.7.1 Concrete

The colouring of concrete pavements can be achieved through the use of oxides and pigments added to the topping mix, for a limited range of colours. Information about the performance of these products should be sought from the supplier. Concrete block pavers come in a range of colours.

6.7.2 Asphalt and Slurry

6.7.2.1 Mixes

Coloured asphalt became available in South Australia during the late 1980s using two methods. In the first, clear synthetic binder and oxide colourings are added to the mix through the batch plant, requiring thorough cleaning and preparation of the equipment. High production costs result in unit rates about 3.5 to 4 times that of conventional asphalt.

Alternatively, standard black bitumen binder is coloured with very heavy dosages of oxide, to produce a limited range of colours. This process is also expensive compared to the cost of normal asphalt, and the large amount of additive may affect the asphalt properties.

Both methods of preparing coloured asphalt are assisted by the use of a compatible aggregate colour.

6.7.2.2 Coatings

The following characteristics are critical to successful long-term performance of coloured coatings for asphalt and slurry surfaced bikeways:

- ease of maintenance;
- high skid resistance for the life of the coating;
- no visible wear (% area intact) after 5 years; and
- colourfastness for a period exceeding 5 years.

The application of conventional coatings to dense or open graded asphalt pavements generally results in localised reduction in skid resistance and a loss of texture depth, which will compromise the performance of the bikeway for users. Coatings must therefore incorporate particles that reinstate the micro-texture of the pavement. These characteristics are achievable with a number of commercially available coating systems, but at a relatively high cost ranging between \$40/m^2 and \$55/m^2 (2006). The cost is a function of the specialty binders and aggregates used to provide colourfastness, durability and skid resistance.

The application of a coating system also introduces long-term maintenance obligations if the appearance and performance of the pathway is to be effectively maintained. For this reason the use of coatings to provide a coloured pavement surface would not normally be regarded as a routine pavement treatment. It is more likely that they would be limited to special conditions that warrant the high additional costs such as approaches to road pavements or path intersections.

6.7.3 Spray seals

Where available, naturally occurring coloured aggregates can be used with conventional binders to provide a coloured surface.

The use of any coating system with a sprayed seal is not recommended due to limitations in the durability and the likelihood of significant maintenance costs. In addition, the coarse surface texture requires high application rates of the coating that increases the initial and subsequent treatment costs.

6.8 Paving Fabrics

Geotextile reinforced seals have been used successfully with marginal pavement materials or can be applied directly to stabilised clay subgrades in low traffic situations. They are also suitable for resealing cracked pavements and in situations where cracks are large but crack movement is relatively slow.

Paving fabrics used with sprayed seals or as an interlayer treatment with slurry, microsurfacing or asphaltic wearing courses are likely to provide better resistance to reflective and environmental cracking of these surfacings. Their actual field performance on bikeways in South Australia has not yet been studied to quantify the benefit versus cost of their usage in different applications.

6.9 Bikeway Selection Based on Structural Criteria

In selecting the pavement and surfacing type for a particular bikeway design situation, there are several parameters that require careful consideration. The common pavement and surfacing types can be designed to provide acceptable service for a wide range of environments and users. However, not all will be the most appropriate and/or cost effective for the specific design situation.

Some of the key factors that require adequate consideration in the pavement and surfacing selection include:

- presence of expansive soils;
- expected condition monitoring and future maintenance effort;
- drainage and moisture environment;
- user needs and traffic type;
- community expectations;
- material availability, preferences, costs;
- available construction expertise, equipment, access, supervision, timing;
- level of performance and service life required; and
- initial and ongoing funding.

Most of these issues are related to the structural performance of the bikeway pavement and their relevance or importance to a particular project can usually be evaluated against objective criteria. The design should then be completed within the appropriate design assumptions and project constraints to ensure satisfactory performance.

General guidance relating to some key considerations in selecting pavement type is provided in *Figure 6.2*.

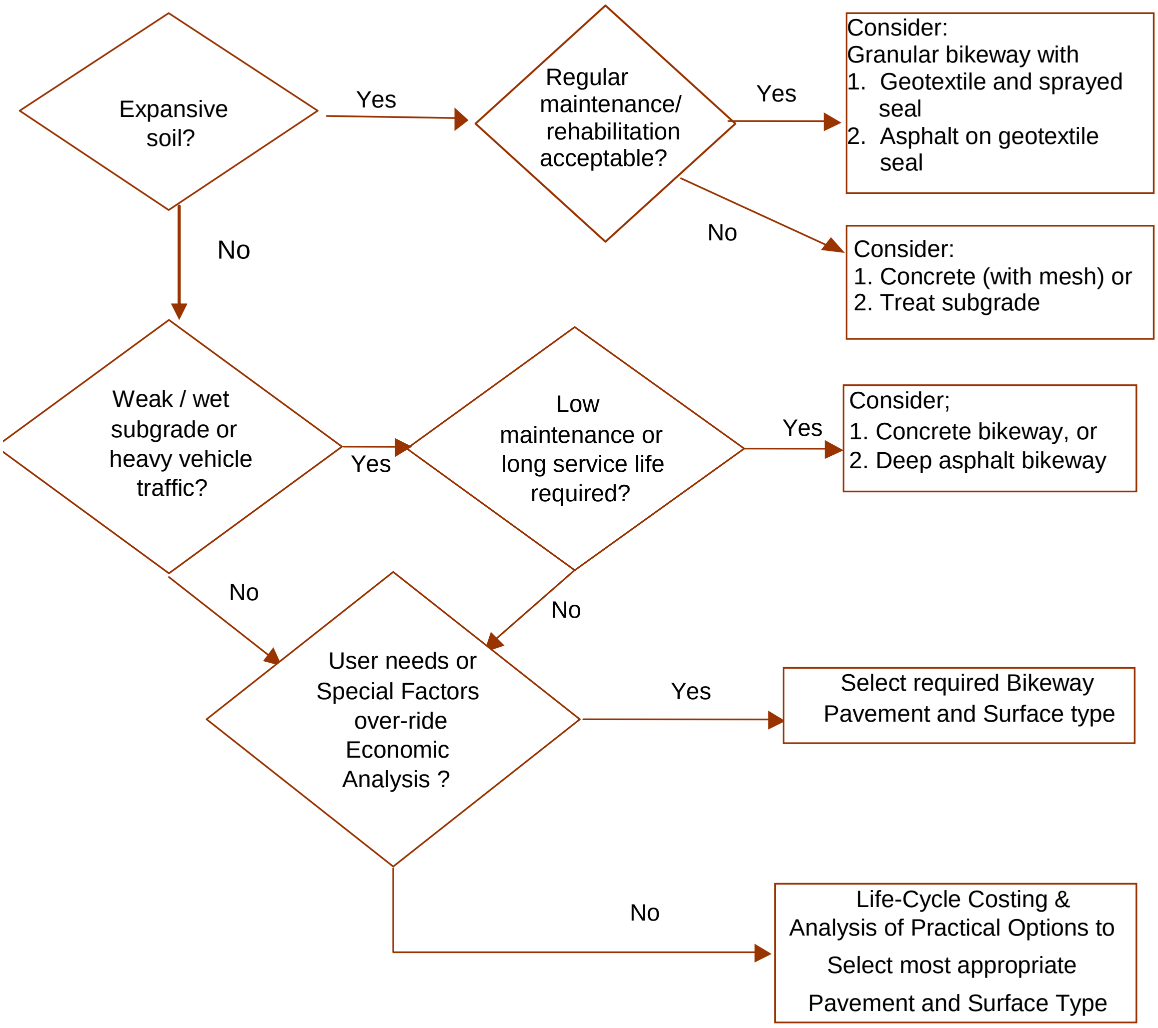


Figure 6.2: Bikeway Type Selection - Structural Factors

6.10 Bikeway Selection Based on Functional Criteria

The functional requirements and factors affecting the selection of the bikeway type are likely to be much more difficult to categorise. Their assessment tends to be more subjective and the importance assigned to them is likely to vary significantly between different sites, users, and owners. Hence it is not practicable to 'flowchart' this selection process. However, while not necessarily a complete list, the following items may assist the consideration of other functional factors affecting the selection of the bikeway pavement type.

Delineation:
- Surface type (and hence colour) to define a shared-use path or define the bikeway crossing another paved area?
- High use at night; thus a surfacing of a lighter colour?

Aesthetics:
- Visual impact on adjoining residences/businesses?
- Compatibility with natural surroundings?
- Heritage issues for surface type?

Ride Quality:
- No joints at all?
- A quiet surface required? (e.g. roller-blades and skateboards).

Construction:
- Access for mechanical pavers or large equipment?
- If hand-laid or small plant used, will surface finish quality be acceptable?
- Does industry have the equipment, materials, and skills available locally?
- Are there numerous vertical level constraints to be accommodated along the bikeway?
- Does the time of year (climate or industry supply) have an effect on the pavement type?
- Gradient and change of grade

Design:
- Are bikeway pavement edge restraints to be avoided?

Trees:
- Will roots grow beneath and distort the pavement?

Flooding:
- Is inundation of pavement a concern? May also lead to loss of structural integrity.

Maintenance:
- Access for works, condition monitoring, timeliness, funding, work quality.

Widening:
- Possibility of future improvements?

PART C – PAVEMENT DESIGN

7. DESIGN PROCESS

The general design process for the bikeway pavement is shown diagrammatically in *Figure 7.1* with the relevant Section references.

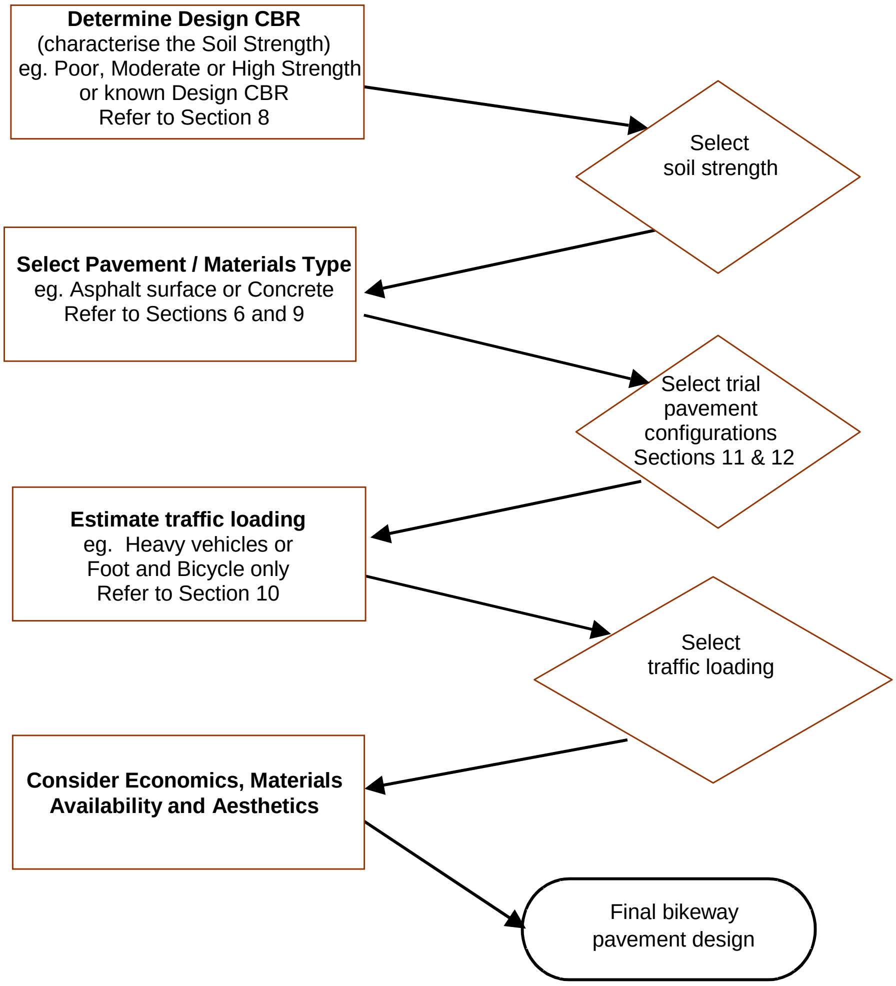


Figure 7.1: Design Process

Appendix B provides a brief description of the technical basis and assumptions associated with the selection of the subgrade and traffic loading design parameters used in this Guide.

8. SUBGRADE EVALUATION

8.1 General

The subgrade is the soil horizon (or rock deposit) upon which the bikeway pavement is founded. It may also comprise imported soils or granular materials, placed many years prior to, or as part of the works associated with the bikeway.

The support provided by the subgrade is one of the key factors affecting the long-term performance of the bikeway. Pavement thickness requirements are highly dependent on the amount of support provided by the subgrade, particularly for bikeways subjected to heavier vehicle movements.

If there is uncertainty in the selection of an appropriate support value for use in structural design, then conservative values should be used or expert advice sought from pavement engineering specialists.

8.2 Subgrade Strength

For design purposes, this Guide characterises the subgrade into three broad categories based on subgrade strength:

- Low Strength (Design CBR 2%)
- Moderate Strength (Design CBR 5%)
- High Strength (Design CBR 10%)

Where a more rigorous design approach is considered appropriate, the designer can adopt a specific subgrade strength as occurs for normal road pavement designs.

Subgrade strength has traditionally been defined by determining the California Bearing Ratio (CBR) and a typical range of values representing weak to very strong soils would be 2% to 15%.

The recent use of computer modelling for pavement design (mechanistic analysis) has required subgrades to be characterised by an elastic or resilient modulus. Austroads has adopted a simple empirical relationship between CBR and modulus: E (MPa) = 10 x CBR.

In selecting the soil strength category or a Design CBR, the aim is to assign a value that best represents the weakest subgrade condition that the bikeway will need to endure during its design life. This may not be the condition occurring during construction, and should generally be a conservative determination for several reasons:

- It is difficult to accurately predict changes in soil strength for 20 or more years into the future. The effectiveness of in-service pavement drainage and the large range of environment influences often introduce significant uncertainties.
- The amount of test data on soil strengths for bikeway projects is likely to be limited.
- The bikeway designer usually has little direct control of construction variables or the future maintenance effort.
- The additional construction costs of an adequate pavement design are invariably relatively minor in comparison to the cost of the remedial works associated with deficient designs.

A further consideration in selecting the design strength of the subgrade relates to the preparation that occurs during construction. Except for loose granular soils, most subgrades are likely to benefit from minimal disturbance, as the undisturbed insitu soil structure will have an intrinsic strength that is usually worth preserving. This can only be achieved with adequate site supervision, controlled plant and equipment movements, and compatible pavement construction methods.

In addition to subgrade strength, the soil moisture content can have other effects. In SA, increasing the insitu moisture content of clay subgrades by reworking them or from exposure to wet weather, can also lead to in-service pavement cracking and deformation if the effects of vegetation, low rainfall, and high evaporation rates later dry back these soils. Hence, DPTI road construction practices usually aim to avoid altering the moisture conditions of the subgrade when they are considered to be near equilibrium. Careful proof-rolling is used for quality assurance of sound areas and to identify any soft spots for local improvement, and a similar approach is recommended for bikeways.

8.2.1 Low Strength Subgrade

Low strength subgrades typically comprise soils that, if in their weakest condition at the time of construction, would require pre-treatment to enable the pavement to be constructed. This pre-treatment may comprise:

- removal and replacement with a stronger fill material to provide a better construction platform;
- insitu stabilisation using lime, if soil conditions are compatible; or
- use of a geosynthetic as a support and separation layer.

Of these subgrade improvement options, DPTI commonly uses a geosynthetic for subgrade support and separation for road pavements, and this practice is also recommended for bikeways.

The requirement for subgrade improvement may not arise if poor soil strength is not evident during construction, such as may occur with heavy clays during summer in South Australia. For this reason, there are often cost savings or expediencies to be gained if the construction timing is selected accordingly.

The design of bikeway pavements detailed in Sections 11 and 12 include ‘Low soil strength’ based on a design CBR of 2%.

Some situations where these soil conditions may exist are:

- along river valleys and flood plains where alluvial soils occur,
- zones subject to poor drainage and inundation; or
- areas with climatic conditions that maintain a moist environment.

8.2.2 Moderate Strength Subgrade

These soil conditions generally would not require special pre-treatment of the soil apart from removal or compaction of any loose materials prior to the placement of the pavement.

Bikeway pavement designs detailed in Sections 11 and 12 include a ‘Moderate soil strength’ based on a design CBR of 5%.

Some situations where these soil conditions may exist are-

- zones which have good drainage, e.g. embankments;
- climatic conditions causing perennially low soil moisture content; or
- sands and low plasticity clays not subject to saturation.

It is expected that Low and Moderate strength soils would be the most common soil strength categories used in bikeway designs.

8.2.3 High Strength Subgrade

High strength soils have been assigned a design CBR of 10%, which equates to the maximum value generally used by DPTI for road pavements. Designs for high strength subgrades are also included in Sections 11 and 12.

Assignment of high soil strength for a bikeway project should only follow expert advice and a site inspection, and preferably be based on a detailed site investigation and laboratory testing.

Some situations where these soil conditions may occur are where:

- the soil consists of weathered rock;
- the soil has or will be stabilised and laboratory testing has confirmed high strengths; or
- the bikeway is constructed in a semi-arid and well drained locality.

It is expected that High Strength soils would occur rarely within significant lengths of a bikeway project. Some exceptions might include a sandy coastal environment or through hilly areas of rock or gravel deposits.

8.3 Presumptive Values

Austroads (2012) provides presumptive values of subgrade support for the common soil groups. These should only be used indicatively when no testing data is available, and are summarised in *Table 8.1*.

Table 8.1: Austroads Presumptive Design CBR Values

Description of Subgrade		**Typical CBR Values (%)**	
Material	**USC Classification**	**Excellent to good drainage**	**Fair to poor drainage**
Highly Plastic Clay	CH	5	2–3
Silt	ML	4	2
Silty Clay Sandy Clay	CL SC	5-6	3-4
Sand	SW, SP	10-15	5-10

8.4 Soil Strength Assessment and Testing

It is good engineering practice to test the subgrade in order to both assess the founding conditions and to determine the appropriate Design CBR or strength category, rather than to estimate or assign a soil strength classification. TRL (1996) recommends that where the subgrade CBR design values have not been assessed, a value of 2% be adopted.

Determination of a representative Design CBR from which the appropriate soil strength category (Section 8.2) is selected, may be based on some or all of the following steps.

8.4.1 Available Soil Strength Data

If an adjacent road pavement has been constructed within the last decade or so, soil strength data may be available in the design investigation report for that project. This should be used with caution, as the thicker road pavement is likely to be founded at a lower depth, and the bikeway supporting soils and drainage conditions may differ.

8.4.2 Field Testing

Testing in the field (after locating underground services), can provide good insitu strength information if undertaken during winter or spring. Seasonal effects usually limit the value of testing conducted in summer and autumn in SA. Typically an investigation would include:

- Test pits or boreholes to inspect and sample the soil strata and moisture regime. Pocket Penetrometer testing of the exposed soil profile; for cohesive soils a rough correlation of CBR = 3 x PP (kg/cm^2) has been used by DPTI.
- Dynamic cone penetrometer (DCP) testing adjacent to the pit so that the CBR strength and soil profiles can be correlated. The DCP test can efficiently provide the insitu strength profile at multiple test sites.

8.4.3 Laboratory Testing

Samples retrieved from the test pit would normally undergo:

- identification of the generic soil types;
- grading tests to determine the particle size distributions;
- Atterberg Limits testing to provide the Liquid and Plastic Limits (and hence the Plasticity Index), and Linear Shrinkage of the soils;
- determination of field moisture content and calculation of Estimated CBR values (DPTI 2010); and
- unsoaked and/or soaked laboratory CBR testing (particularly for larger projects).

Given the above data an experienced geotechnical or pavements engineer is better able to assign an appropriate Design CBR for the bikeway subgrade. Estimated CBR values can be useful for soils where ≥ 75% passes the 2.36 mm sieve, but these values need to be used with caution and in consideration of the insitu moisture conditions. Using the ratio of the Field Moisture Content to the Plastic Limit, DPTI have observed the following general trends in Estimated CBR values for cohesive soils:

- if the FMC/PL ratio is < 1.0, the Estimated CBR value is usually a conservative representation of the insitu CBR;
- when the FMC/PL ratio is within the range 1.0 to 1.3, the Estimated CBR value is usually a reasonable representation of the insitu CBR and is often similar to a DCP test result; and
- for a FMC/PL ratio > 1.3, the Estimated CBR value can overestimate the insitu CBR and should not be used in designs.

8.4.4 Further Reading

The following references provide more detailed assessment methods of subgrade support:

- Austroads (2012) Guide to Pavement Technology Part 2 Pavement Structural Design.
- ARRB (2005c) Sealed Local Roads Manual.

8.5 Expansive Subgrades

8.5.1 Effects and Treatments

Expansive subgrades comprise volumetrically unstable clay soils that shrink on drying and swell on wetting, and are characterised by low, moderate, high, or very high reactivity.

Moisture changes occurring in clay subgrades with even low to moderate reactivity can cause surface damage in light duty pavement structures such as bikeways. Severe subgrade movements often lead to the development of numerous wide surface cracks and long wavelength undulations (typically > 0.5 m to 10 m long), which may result in poor rideability for cyclists. If the pavement surfacing cracks are very wide and longitudinal or a step fault develops due to the volume change, this may also present a safety issue. Undulations can cause surface water to pond, affecting users and often resulting in further localised damage to the pavement.

Some methods of minimising the effects of expansive soils include:

- removal and replacement of localised expansive soil deposits;
- capping with a substantial thickness of non-expansive fill;
- installation of moisture barriers horizontally under the bikeway and vertically at the edge of the seal to a depth of 2 to 2.5 m;
- lime stabilisation of the expansive subgrade.

In general, it can be difficult to provide successful solutions for highly or extremely reactive subgrades. This particularly applies to situations where the transpiration of nearby trees and shrubs has a large influence on the moisture levels of soils underlying the bikeway. As the problems associated with expansive soils are directly related to their moisture variations, treatments that minimise the moisture changes are usually the most effective.

In South Australia, where low rainfalls and high evaporation rates are common, the depth from the surface to soils that maintain a year round equilibrium moisture content is about 4m. This means that stabilisation of subgrades located within the uppermost 0.2 m to 0.4 m of the soil profile may not be an effective reactive soil treatment for deep deposits.

The selection of pavement and surfacing types for bikeways constructed on reactive subgrades is a critical issue in managing the performance risk and the future maintenance requirements of the facility. Geotextile seals or interlayers should be considered for highly or very highly expansive soils to minimise surface cracking and moisture ingress.

8.5.2 Assessment of Soil Reactivity

The presence of expansive soils can often be determined from a site inspection. Indicators of the presence of expansive soils include:

- severe cracking of dried-out soils;
- longitudinal and meandering cracks in existing pavements;
- tilting signposts and other minor structures which are founded near the ground surface;
- evidence of differential movement in nearby buildings; typically, severe cracking in masonry walls; and
- undulating kerb and channel, often with ponding occurring in the channel.

Table 8.2 provides a guide to classification of expansive soils.

Table 8.2: Guide to Classification of Expansive Soils (Austroads 2012)

Expansive Nature	Liquid Limit (%)	Plasticity Index	PI x % < 0.425 mm	Potential [1.] Swell %
Very high	>70	>45	>3200	>5.0
High	>70	>45	2200-3200	2.5-5.0
Moderate	50-70	25-45	1200-2200	0.5-2.5
Low	<50	<25	<1200	<0.5

Note: 1. Swell at OMC and 98% MDD using Standard compactive effort; 4-day soak, 4.5kg surcharge.

8.6 Subgrade Stabilisation

Stabilisation is the process of modifying the non-desirable properties of the soil. For weak clay subgrades, this usually involves adding a binder by insitu mixing equipment and compacting this material to develop a stronger pavement support layer. Further information is available in Austroads (2006).

9. PAVEMENT MATERIALS

9.1 Granular Material

Some granular materials can provide an adequate riding surface for bikeway pavements but more commonly they are used to construct the base and subbase layers.

Granular material comprises a range of stone particle sizes compacted to a dense matrix to spread traffic loads to the underlying weaker materials. The component particles range from clay size (< 2 μm) to silt and sand, to aggregate size. The diameter of the largest size aggregate (mm) is typically used to name the granular material; e.g. a nominal 20 mm material may be called a *fine* crushed or a 20 mm dense-graded aggregate. DPTI uses the terminology of PM1/20 to denote a 20 mm Class 1 material.

Granular material may comprise either naturally occurring soils such as gravel and coarse sands or be processed by crushing and screening a larger size source rock or recyclable material such as waste concrete.

9.1.1 Unsurfaced Granular Materials

When required to act as a surfacing layer, it is generally advisable to ensure that the Plasticity Index (PI) is in the range of 6 to 10 or that the material has natural cementing properties, as occurs with many calcareous derivatives. The cohesive fines bind the material to resist the abrasive traffic loadings and environmental erosion.

For unsealed surfaces, the maximum aggregate size in the granular material should not exceed 20 mm and there should be adequate finer material to ensure good rideability. DPTI Master Specification for Roadworks Part 215 include crushed rocks of 20 mm size that are designed to meet the stability and stiffness requirements of moderate to heavy traffic loadings. Other quarry materials may also be suitable for unsealed bikeways, such as well-graded crusher sands (Type C Sand in Appendix C.3) or fine gravels. The minimum soaked CBR of these materials should be 60%.

9.1.2 Base and Subbase Granular Material

Base and subbase material quality is defined by several engineering properties, such as-

- a particle size distribution (grading), to produce mechanical strength;
- a limited range of plasticity, so when moist it retains good strength; and
- values of hardness or durability that resist long term deterioration within the pavement.

Table 9.1 summarises the DPTI granular materials used in the bikeway designs presented in Sections 11 and 12. Details of these specifications are given in Appendix C.

Table 9.1: Granular Material Descriptions

Base quality	PM1/20Q or PM1/20R	20 mm Class 1 crushed rock, Q designates quarry sourced, R for Recycled material	Used as base for high traffic roads, not for bikeways.
Base and Subbase quality	PM2/20Q PM2/20R	20 mm Class 2 crushed rock	Used as pavement layers on medium traffic roads, subbase on high traffic roads.
	PM3/20Q PM3/20R	20 mm Class 3 crushed rock	Used as pavement layers on low traffic roads, subbase on medium traffic roads.

9.1.3 Bedding Sand

A well-graded coarse sand/fine gravel material of low to nil plasticity is recommended to bed Concrete Block Pavers. Washed sand is often selected so that plastic fines and any salts that may cause efflorescence are removed. Similarly, jointing sand is required between blocks to ensure that the pavers lock-up and spread the heavier loads. Typical bedding and jointing sand specifications are provided by CMAA (1997b).

9.1.4 Select Fill

Select fill serves as a capping layer over weak subgrades to provide an immediate and long-term increase in bearing capacity, which facilitates placement and compaction of the pavement layers.

Type A Material (DPTI Master Specification for Roadworks Part 210) is a select fill with good shear strength and workability due to its granular nature and controlled plasticity.

Two other properties required for select fill comprise:

- a weighted PI (% passing the 0.425 sieve x the PI) of less than 1000, to eliminate expansive material; and
- a maximum particle size of less than 40% of the constructed layer thickness, to provide some mechanical interlock, minimise segregation, and reduce permeability.

Table 9.2 provides the specification for Type A Material. The material may be a sand, sandy clay, natural rubble, quarry or pit overburden or by-product. Mica, shale and similar laminated materials, adherent coatings or other foreign material shall not be present in form or sufficient quantity to produce adverse effect upon the usage and performance of the material.

Table 9.2: Specification for Type A Material

Property	*Limit*
% passing 75 mm	100
% passing 37.5 mm	80 – 100
% Passing 0.075 mm	0 - 25
Plasticity Index	Maximum 12
Linear Shrinkage	Maximum 6
Weighted Plasticity Index	Maximum 1000

9.2 Asphalt

Asphalt or asphaltic concrete is used primarily as a surfacing material for bikeways and to a lesser extent as both surfacing and base layers if constructed as a thick asphalt pavement.

Asphalt comprises a range of sizes of mineral aggregates, bitumen binder and air, that is mixed, placed and compacted whilst hot. As with granular material, the largest size aggregate in millimetre diameter is used to define the particular mix. DPTI asphalt mix designations are based on ensuring there is a minimum of 10% of the nominal size material within the mix. (Asphalt containing a mixture of aggregate of maximum 7 mm size produces size 7 asphalt, usually referred to as AC7).

Typical sizes of asphalt used for bikeways include 5 mm, 7 mm, 10 mm and 14 mm. The finer the size the more closed the asphalt surface is in terms of texture. Smaller size mixes are used for surfacing layers, as these may be laid thinner than larger size mixes and are generally easier to hand-place to obtain a good finish. However, the smaller mixes have lower stability and shear strength than larger mixes. If very heavy axle loadings are expected, or the surfacing/base layer is reasonably thick, a larger size mix may be more appropriate.

9.2.1 Asphalt for Thin Surfacing

Asphalt placed in thin surfacing layers can be relatively porous compared to a sprayed seal, and the underlying granular base needs to be treated using a prime or primerseal (refer to Section 6.2).

The prime comprises bitumen either dissolved in kerosene (hot cutback) or emulsified in water (emulsion) such that when applied it is able to penetrate the top few millimetres of the granular material. This deposits a dispersed matrix of bitumen particles within the surface of the granular material and thereby assists in moisture proofing and bonding to overlaid bituminous surfacings. If the underlying pavement material or subgrade is particularly sensitive to moisture ingress (expansive soils etc), a cutback or emulsion primerseal will provide a much better moisture barrier than a prime.

A tack coat is placed over the primed surface just prior to placing the thin asphalt surfacing to bond the surfacing to the granular base layer. Tacking between clean fresh layers of asphalt is generally not required as the heat within the overlaying mix assists adhesion.

9.2.2 Low Air Voids Asphalt

Most asphalt is specified and produced for use on relatively heavily trafficked pavements where tyre pressures, axle loads, and the number of repetitions of these loads are high. The design of these asphalt mixes allows for the reduction of air voids caused by traffic during the initial few years of service.

If similar asphalt is used on bikeways where it would not be sufficiently worked by traffic to reduce the air voids content, it remains susceptible to oxidisation and degradation by contaminants. This may result in the asphalt surfacing becoming prematurely brittle and more susceptible to ravelling, cracking and fretting.

Special asphalt mixes have been designed for light traffic applications. To reduce the initial air void content, the mix may be gap-graded and/or more bitumen binder added. *Table 9.3* shows some of the available mixes used for light traffic.

Table 9.3: Asphalt Types for Light Traffic.

Source	Name	Properties	Reference
DPTI	FineAC7L, FineAC10L (7 mm and 10 mm)	Dense graded mix with additional 0.5% binder	DPTI Master Specification Division 2: Roadworks
ARRB Group	ARRB Gap-graded mix	10 mm size with 6.8% Class 170 bitumen by total mass	Oliver (1986) & Mulholland (1989)
Austroads	Dense and Fine Gap Graded and Stone Mastic Asphalt	Sizes 7 mm and 10 mm; (Part 4B)	Austroads (2014b)
Australian Standard	Dense and Fine Gap Graded and Stone Mastic Asphalt	Sizes 7 mm and 10 mm; 5% to 7% bitumen by mass	AS 2150 – 2005 Hot mix asphalt

9.2.3 Bitumen Binder

Bitumen binder should preferably comprise Class 170 complying with AS 2008 - 1997. However local climatic conditions in conjunction with very light or significantly heavier loadings may warrant the use of either Class 50 or Class 320 bitumen respectively.

For example, a bikeway in a very cold climate region may utilise the lower (viscosity) grade bitumen, whereas a bikeway likely to sustain heavy axle loads in a very hot areas should utilise a stiffer (more viscous) binder such as the Class 320.

The use of the softer Class 50 binder may also have some advantages in resisting environmental cracking where this is likely to be more prevalent. However, in South Australia there is little local experience with C50 binder and the supply of small amounts for bikeway projects is unlikely to be practical or economically viable.

9.2.4 Modified Binders

The bitumen binder may be modified by the addition of a range of elastomeric and plastomeric polymers or crumbed scrap rubber, to enhance the asphalt mix properties for specialised applications. These include better fatigue and deformation resistance, reduced reflection cracking, and increased durability. The development of modified asphalt has mainly targeted heavily trafficked situations and it is difficult to extrapolate this performance experience to bikeway facilities.

The higher costs associated with modified asphalt may be warranted if an extended service life or better resistance to environmental cracking has been observed in comparative trials or local studies of lightly trafficked pavements.

9.3 Concrete

9.3.1 General

Concrete comprises a homogenous mixture of cement binder, fine and coarse aggregate, sand and water. Chemical admixtures can be included to retard set, reduce water, or for air entrainment. The concrete aggregate suitable for bikeways would generally be limited to a maximum size of 20 mm. Unconfined compressive strength requirements range from f'_c = 20 MPa for footpath construction to 32 MPa for bikeways that are likely to have heavy vehicle loads.

Higher concrete strengths generally provide greater durability and better resistance to structural fatigue cracking. Thickness design for light duty pavement slabs mainly involves consideration of the magnitude and number of stress repetitions imposed by the expected loadings.

Durability is important for concrete pavements and is indicated by the longevity of the surface texture, and the resistance to spalling, minor edge breaks, and stepping or faulting between adjacent slabs.

Minimum strengths of concrete are provided in *Table 9.4*.

Table 9.4: Recommended Minimum Concrete Compressive Strengths

Loading	Minimum Compressive Strength (f'_c)
Foot and bicycle traffic	20 MPa
Heavy vehicles	32 MPa

9.3.2 Recycled Concrete

Crushed recycled concrete can be used as unbound or bound subbase and base layers of road pavements in accordance with DPTI Master Specification for Roadworks Part 215.

9.4 Concrete Block Pavers (CBPs)

Concrete Block (or Segmental) Pavers are individual high strength paving units of 60 mm and 80 mm standard thickness. Pavements should be designed and laid with interlock in both directions.

Pavers are small in size and are not bonded to adjoining units. Hence, they also require additional sub-layers to provide adequate pavement strength over weak subgrades.

10. DESIGN TRAFFIC LOADING

Two loading regimes of traffic have been adopted as follows:

- foot and bicycle traffic only;
- heavy vehicle traffic.

The pavement design procedure for most situations can be completed by selecting the appropriate loading from one of these two categories. However, if better information is available for a particular bikeway project, it should be used to calculate the design traffic.

10.1 Design periods and units of loading

For flexible and concrete block pavements the recommended design period is 20 years and the design traffic loading is expressed in terms of the cumulative number of Equivalent Standard Axles (ESA) over the 20 year design period.

For rigid pavements a 40 year design period is used. In this case the design traffic loading is expressed in terms of cumulative number of Heavy Vehicle Axle Groups (HVAG) occurring within the 40 year period.

Table 10.2 provides design traffic loadings based on these periods, but other cumulative traffic loadings could be determined for different design periods.

10.2 Foot and Bicycle Traffic

The foot and bicycle traffic category assumes that these and similar loadings are all that will occur on the bikeway pavement during its life. However, if the bikeway can be accessed by motor vehicles it is prudent to assume that it will be. In general, there will also be a need for access by emergency services such as police, ambulance, fire control etc, as well as for normal maintenance of the path or environs.

In practice, selection of this very light loading regime for design is rarely appropriate and should only be made if it is not physically possible for a heavy motor vehicle to access the bikeway. If no access is available to emergency and maintenance trucks, and very few if any 2WD vehicles will traffic the facility, then this loading category may be appropriate.

10.3 Heavy Vehicle Loading

In developing minimum pavement configurations in this Guide it was assumed that all the loading is due to 2-axle rigid trucks commonly used as road maintenance vehicles.

These minimum designs for flexible pavements provide in Section 11 were based on 4,000 ESA of loading. As detailed in Appendix B, such a loading would be caused by one pass of a 2-axle rigid truck per week over 20 years with the following axle loads:

- 5 tonne (49.0 kN) on a single axle single tyres (SAST)
- 7 tonne (68.6 kN) on single axle dual tyres (SADT)

These loads represent a partly-laden truck with a gross mass (12 tonne) that is about 80% of the maximum prescriptive gross mass. If the bikeway is likely to sustain more frequent or heavier axle loadings, it is recommended that the design be undertaken in accordance with Austroads (2012) with the design traffic loading being increased by a factor of 3 to allow for channelisation (refer Appendix B).

A design traffic loading in terms of Heavy Vehicle Axle Groups (HVAG) is required for the design of rigid pavements. The minimum designs for concrete are based on 12,000 HVAG over the 40 year period, or 6000 2-axle rigid truck load repetitions of the 12t gross mass axle loadings. If the bikeway is likely to sustain more frequent or heavier axle loadings, it is recommended that the design be undertaken in accordance with Appendix F.

10.4 Summary

Table 10.1 summarises the loading characteristics used in selection of designs in this Guide.

Table 10.1: Indicative Loadings for Bikeway Traffic Categories

Design Traffic Category	**User or Vehicle Type**					
		 motor car (2WD)	 light utility (2WD)	 Light truck <3tonne	 Trucks with gross mass less than 12 tonnes	 Trucks with gross mass greater than 12 tonnes
Foot and bicycle	✓	?	?	✗	✗	✗
Heavy vehicles	✓	✓	✓	✓	✓	✗

? indicates a few repetitions per year of this load type may be acceptable.

Table 10.2 provides the actual design traffic loadings used to generate the pavement designs.

Table 10.2: Recommended Design Traffic Loadings for Bikeway Structural Designs

Loading	**Characterised by**	**Flexible and concrete block pavements** 20 year design period	**Rigid pavement** 40 year design period
Foot and bicycle	Foot and bicycle loading only	NA	NA
Heavy vehicles	1 pass of two-axle rigid truck per week, 12t gross mass per veh	4,000 ESA	12,000 HVAG or 6000 truck repetitions

11. FLEXIBLE PAVEMENT DESIGN

11.1 General

There are five different types of flexible pavement configurations (described in Section 6) that are considered most likely to provide the practical range of design options for South Australian bikeways:

- Unsurfaced granular.
- Sprayed seal granular (with or without paving fabric).
- Slurry seal granular.
- Asphalt surfaced granular.
- Concrete block paver granular.

The structural methods used to design these flexible bikeway pavements are based on the performance of lightly trafficked road pavements. However, the performance of bikeways may differ from lightly trafficked roads due to many factors, including differences in cross-section, drainage, edge loading and maintenance. Validation of the flexible bikeway design procedures in this Guide requires completion of a number of reasonably detailed case study reviews, none of which are available or proposed at this stage. Hence, although due diligence and sound engineering judgement have been used to develop the configurations within this Guide, the lack of bikeway performance data means there is a higher performance risk associated with these designs than occurs with road pavements.

Detailed designs indicating minimum layer and total thicknesses are tabulated for all five pavement configurations, at three subgrade strengths and two traffic loadings. However, the Foot/bike configurations would be unsuitable for most facilities as they are not designed to cater for maintenance vehicle loadings.

Alternative pavement configurations and designs can be prepared for these and other subgrade and traffic conditions by applying Austroads (2012), usually requiring some pavement design expertise.

11.2 Unsurfaced Granular Bikeways

Table 11.1 provides the recommended configurations for bikeways comprising unsurfaced (or unsealed) granular material for the standard loading and soil strength categories. These pavements may not provide satisfactory performance in wet environments.

Table 11.1: Minimum Designs for Unsurfaced Granular Bikeways

Soil Strength	**Foot/bike traffic (no vehicle access)**	**Heavy Vehicles (eg maintenance) N_{DT} = 4000 ESA**
Low Strength (CBR ≥ 2%)	80 mm PM3/20 or Sa-C 100 mm Type A Material ***180 mm Total Thickness***	100 mm PM3/20 130 mm PM3/20 130 mm Type A Material ***360 mm Total Thickness***
Moderate Strength (CBR ≥ 5%)	100 mm PM3/20 or Sa-C ***100 mm Total Thickness***	100 mm PM3/20 130 mm PM3/20 ***230 mm Total Thickness***
High Strength (CBR ≥ 10%)	100 mm PM3/20 or Sa-C ***100 mm Total Thickness***	150 mm PM3/20 ***150 mm Total Thickness***

Notes: Soaked CBR of Type A Material to exceed 15%.
Sa-C is crusher sand. Refer Appendix C.3.

The designs for Foot/bike traffic are based on engineering judgement. The pavement thicknesses for Heavy Vehicle loadings have been determined from an empirically derived relationship (Fig. 12.2 Austroads 2012). The design chart is reproduced in Appendix E. This permits the designer to interpolate where the design CBR of the soil is known and differs from 2%, 5% or 10%.

11.3 Sprayed Seal Granular Bikeways

Table 11.2 provides the recommended configurations for bikeways comprising granular material surfaced with a sprayed seal, for the standard loading and soil strength categories.

Table 11.2: Minimum Designs for Sprayed Seal Granular Bikeways

Soil Strength	**Foot/bike traffic** **(no vehicle access)**	**Heavy Vehicles (eg maintenance)** **N_{DT} = 4000 ESA**
Low Strength *(CBR ≥ 2%)*	10/5 double seal 80 mm PM3/20 or Sa-C 100 mm Type A Material ***180mm Total Thickness***	10/5 double seal 100 mm PM2/20 130 mm PM2/20 or PM3/20 130 mm Type A Material ***360 mm Total Thickness***
Moderate Strength *(CBR ≥ 5%)*	10/5 double seal 100 mm PM3/20 or Sa-C ***100mm Total Thickness***	10/5 double seal 100 mm PM2/20 130 mm PM2/20 or PM3/20 ***230 mm Total Thickness***
High Strength *(CBR ≥ 10%)*	10/5 double seal 100 mm PM3/20 or Sa-C ***100mm Total Thickness***	10/5 double seal 150 mm PM2/20 ***150 mm Total Thickness***

Note: Soaked CBR of Type A Material to exceed 15%.

The designs for Foot/bike traffic are based on engineering judgement. The pavement thicknesses for Heavy Vehicle loadings have been determined from empirically derived relationships (Fig. 12.2 Austroads 2012). The design chart is reproduced in Appendix F. This permits the designer to interpolate where the design CBR of the soil is known and differs from 2%, 5% or 10%.

Table 11.3 and *Table 11.5* provide guidance for bitumen and aggregate application rates for a 10/5 double seal with and without geotextile. The geotextile option is a more robust and durable treatment usually reserved for subgrades with moderate to very high reactivity and/or facilities requiring better surfacing performance. Sprayed seals must be swept clean of loose stone chips before use by cyclists.

Table 11.3: Sprayed Seal Bikeways 10/5 mm double seal

Treatment		**Nominal application rate**
Prime (medium)	(l/m^2)	1.0
Bottom coat C170	(l/m^2)	1.0-1.2
10 mm agg.	(m^3/m^2)	130
Top coat C170	(l/m^2)	1.0
5 mm agg.	(m^3/m^2)	250

Table 11.4: Sprayed Seal Bikeways with Geotextile

Treatment	Nominal application rate
Prime (AMC 0) (*l/m²*)	1.0
Bond coat (C170) (*l/m²*)	0.7
Geotextile Type (Refer *Table 11.5*)	Grade 1
Bottom coat (C170) (*l/m²*)	1.2-1.4
10 mm agg. (*m³/m²*)	130
Top coat (C170) (*l/m²*)	1.0
5 mm agg. (*m³/m²*)	250

Note: during hot weather a reduced bond coat application rate may be required to avoid fabric pickup.

Table 11.5: Key Properties of Paving Geotextile

Properties	Units	Grade 1
Mass per unit area	g/m^2	> 135
Wide-strip Tensile Strength (AS 3706.2)	KN/m	> 7.0
Maximum Elongation Range (AS 3706.2)	%	40 - 60
Minimum Melt Temperature	^oC	> 195

11.4 Slurry Seal Granular Bikeways

Where a slurry surfacing is considered to be an appropriate treatment, the underlying granular pavement structure is effectively the same as for a sprayed surfacing. *Table 11.6* provides the recommended configurations for bikeways constructed of granular material with slurry surfacing for the standard loading and soil strength categories.

Table 11.6: Minimum Designs for Slurry Seal Granular Bikeways

Soil Strength	Foot/bike traffic (no vehicle access)	Heavy Vehicles (eg maintenance) N_{DT} = 4000 ESA
Low Strength *(CBR ≥ 2%)*	10 mm of 5mm Microsurfacing 80 mm PM3/20 or Sa-C 100 mm Type A Material ***180mm Total Thickness***	10 mm of 5mm Microsurfacing 100 mm PM2/20 130 mm PM2/20 or PM3/20 130 mm Type A Material ***360 mm Total Thickness***
Moderate Strength *(CBR ≥ 5%)*	10 mm of 5mm Microsurfacing 100 mm PM3/20 ***110mm Total Thickness***	10 mm of 5mm Microsurfacing 100 mm PM2/20 130 mm PM2/20 or PM3/20 ***230 mm Total Thickness***
High Strength *(CBR ≥ 10%)*	10 mm of 5 mm Slurry 100 mm PM3/20 ***110mm Total Thickness***	10 mm of 5mm Microsurfacing 150 mm PM2/20 ***160 mm Total Thickness***

Note: Nominal application rate for primes – 1.0*l/m²* and tack coats – 0.3 *l/m²* (residual).

The designs for Foot/bike traffic are based on engineering judgement. The pavement thicknesses for Heavy Vehicle loadings have been determined from empirically derived relationships (Fig. 12.2 Austroads 2012). The design chart is reproduced in Appendix E. This permits the designer to interpolate where the design CBR of the soil is known and differs from 2%, 5% or 10%.

11.5 Asphalt Surfaced Granular Bikeways

Table 11.7 provides the recommended configurations for bikeways comprising granular material with asphalt surfacing for the standard loading and soil strength categories.

Table 11.7: Minimum Designs for Asphalt-Surfaced Granular Bikeway

Soil Strength	Foot/bike traffic (no vehicle access)	Heavy Vehicles (eg maintenance) N_{DT} = 4000 ESA
Low Strength *(CBR ≥ 2%)*	25 mm FineAC7L 100 mm PM3/20 100 mm Type A Material ***225 mm Total Thickness***	35 mm FineAC10L 100 mm PM2/20 100 mm PM2/20 or PM3/20 125 mm Type A material ***360 mm Total Thickness***
Moderate Strength *(CBR ≥ 5%)*	25 mm FineAC7L 125 mm PM3/20 ***150 mm Total Thickness***	35 mm FineAC10L 100 mm PM2/20 100 mm PM2/20 or PM3/20 ***235 mm Total Thickness***
High Strength *(CBR ≥ 10%)*	25 mm FineAC7L 100 mm PM3/20 ***125 mm Total Thickness***	35 mm FineAC10L 120 mm PM2/20 ***155 mm Total Thickness***

Notes: Soaked CBR of Type A Material to exceed 15%.
Nominal application rate for primes – 1.0*l/m*^{2} and tack coats – 0.3 *l/m*^{2} (residual).
L; Light grade asphalt with C170 asphalt binder.

If required, a geotextile interlayer could be placed prior to the asphalt wearing course on a C170 bond coat applied at 0.7l/m^2. (Some 5mm aggregate may need to be spread in the paver wheelpaths to prevent wrinkling of the geofabric during asphalt laying.)

The designs for Foot/bike traffic are based on engineering judgement. The pavement thicknesses for Heavy Vehicle loadings have been determined from empirically derived relationships (Fig. 12.2 Austroads 2012). The design chart is reproduced in Appendix E. This permits the designer to interpolate where the design CBR of the soil is known and differs from 2%, 5% or 10%.

11.6 Concrete Block Paver Bikeways

Table 11.9 provides the recommended configurations for bikeways comprising concrete block pavers over granular material for the standard loading and soil strength categories.

The designs for Foot/bike traffic are based on engineering judgement. The pavement thicknesses for Heavy Vehicle loadings have been determined from empirically derived relationships (Fig. 12.2 Austroads 2012). For each subgrade design CBR, the total thickness of granular material under the blocks and bedding sand was determined by subtracting the total thickness of blocks and sand (105 mm) from the total granular thickness in Figure 12.2. This design chart is reproduced in Appendix E. This permits the designer to interpolate where the design CBR of the soil is known and differs from 2%, 5% or 10%.

Table 11.8: Minimum Designs for Concrete Block Paver Bikeways

Soil Strength	Foot/bike traffic (no vehicle access)	Heavy Vehicles (eg maintenance) N_{DT} = 4000 ESA
Low Strength (CBR ≥ 2%)	60 mm CBP 25 mm bedding sand* 150 mm Type A Material ***235mm Total Thickness***	80 mm CBP 25 mm bedding sand* 125 mm PM2/20 130 mm PM2/20 or PM3/20 ***360 mm Total Thickness***
Moderate Strength (CBR ≥ 5%)	60 mm CBP 25 mm bedding sand* 50 mm PM3/20 ***135mm Total Thickness***	80 mm CBP 25 mm bedding sand* 125 mm PM2/20 ***230 mm Total Thickness***
High Strength (CBR ≥ 10%)	60 mm CBP 25 mm bedding sand* 50 mm PM3/20 ***135mm Total Thickness***	80 mm CBP 25 mm bedding sand * 100 mm PM2/20 ***205 mm Total Thickness***

Note: * Refer to Appendix D for bedding and jointing sand properties.
Soaked CBR of Type A Material to exceed 15%.

11.6.1 Vehicle Crossover Design for CBPs

Vehicular crossovers and other areas subject to heavy vehicle loading should use the thicker 80 mm CBPs due to their better performance under heavy wheel loads.

12. RIGID PAVEMENT DESIGN

12.1 General

The principal types of cementitious concrete pavements for roads are (Austroads 2012):

- jointed plain (unreinforced) concrete pavements (PCP), generally undowelled skewed joints at 4.2 m spacings
- jointed reinforced concrete pavements (JRCP), typically mesh reinforced with square dowelled joints at spacings of 8 to 12 m
- continuously reinforced concrete pavements (CRCP), continuous steel reinforcement to induce transverse cracking at random spacings of about 0.5 to 2 m and no contraction joints are required. Transverse reinforcement is provided to support the longitudinal steel.

For bikeways the preferred pavement type is continuous lapped SL72 mesh, with contraction joints sawcut transversely at no greater than 1.2 times the path width apart. A bound subbase is not needed as pumping and erosion of subbase/subgrade is unlikely for the expected low-speed and low repetitions of loading. However, a minimum 150 mm thick unbound subbase is required to obtain uniform support over variable material.

Alternative pavement configurations and designs can be prepared for these and other subgrade and traffic conditions by applying Austroads (2012) or Appendix F if loading is limited to two-axle rigid trucks. Generation of alternative designs will usually require some pavement design expertise but are unlikely to be necessary for most projects.

The structural method used to design the following rigid bikeway pavements is based on the performance of lightly trafficked road pavements. However, the performance of bikeways may differ from lightly trafficked roads due to many factors, including differences in cross-section, drainage, edge loading and maintenance. Validation of the concrete bikeway design procedures in this Guide requires completion of a number of reasonably detailed case study reviews, none of which are available or proposed at this stage. Hence, although due diligence and sound engineering judgement have been used to develop the concrete configurations within this Guide, the lack of bikeway performance data means there is a higher performance risk associated with these designs than occurs with road pavements.

12.2 Minimum Pavement Configurations

Table 12.1 shows the minimum composition for bikeways comprising a continuous lapped mesh concrete base and unbound granular subbase, for the range of standard loading and soil strength categories. A SL62 and SL72 mesh is used for Foot/bike and Heavy vehicle configurations respectively. The Foot/bike configurations would be unsuitable for most facilities as they are not designed to cater for maintenance vehicle loadings.

Sand must not be used as the subbase layer for concrete, as the fine particles will eventually enter the joint spaces and restrict the cyclic slab expansion/contraction cycle.

Table 12.1: : Minimum Designs for Concrete Bikeways

Soil Strength	Foot/bike traffic[1] (no vehicle access)	Heavy vehicle[2,3] (eg maintenance) N_{DT} = 12,000 HVAG
Low Strength *(CBR ≥ 2%)*	100 mm concrete (25MPa) 50 mm PM3/20 ***150mm Total Thickness***	185 mm concrete (32MPa) 150 mm PM2/20 ***340 mm Total Thickness***
Moderate Strength *(CBR ≥ 5%)*	100 mm concrete (25MPa) 50 mm PM3/20 ***150 mm Total Thickness***	175 mm concrete (32MPa) 150 mm PM2/20 ***325 mm Total Thickness***
High Strength *(CBR ≥ 10%)*	100 mm concrete (25MPa) 50 mm PM3/20 ***150 mm Total Thickness***	170 mm concrete (32MPa) 100 mm PM2/20 ***260 mm Total Thickness***

Note: 1. For Foot/bike crossovers, use Heavy vehicle base thicknesses with 25MPa concrete.
2. 10 mm construction tolerance has been added assuming pavement constructed in accordance with DPTI Master Specification for Roadworks. Additional tolerance may need to be added where other specifications apply.
3. Designs assume maximum load on the SADT drive axle is 7 tonnes. If higher loads are expected calculate required base thickness in accordance with Appendix F.

Designs given in *Table 12.1* are derived from the procedure given in Austroads (2012). Interpolation of these designs based on different bearing capacity is not necessary due to the general insensitivity of thickness to this parameter. Where different traffic loadings to those given in *Table 12.1* are expected, it is recommended that the design procedure in Appendix F be followed.

12.3 Detailing

Concrete pavement designs require careful detailing of all the design elements, particularly the joints (refer to Section 17.2), to ensure that good long-term performance is achieved. The adequacy of the detailing has often proven to be as critical as the general thickness and reinforcement design determinations.

PART D - CONSTRUCTION

The sound performance of the bikeway design configuration is highly dependent on the quality of the construction works and there are a range of critical details that affect the long-term serviceability.

Bikeway pavements are constructed using many of the practices associated with conventional road pavements. Austroads (2009e) provides further information on road pavement construction which supplements the discussion of bikeway construction issues within this Guide. Austroads (2009f) also includes links to a number of useful technical notes, *pavement work tips* and other publications provided by Austroads, Austroads member organisations and industry associations.

13. SURFACE TOLERANCE

The new surface of a bikeway pavement should be placed to match existing features such as pit covers, edgings or driveways, to within 5 mm. It is also desirable (Austroads1999) that the finished surface of a new bicycle lane or path complies with the following:

- does not deviate from a 3 m straight edge by more than 5 mm at any point; and
- has no sharp vertical curves, or the rate of change in vertical deviation is less than 1 mm in 240 mm as shown in *Figure 13.1*.

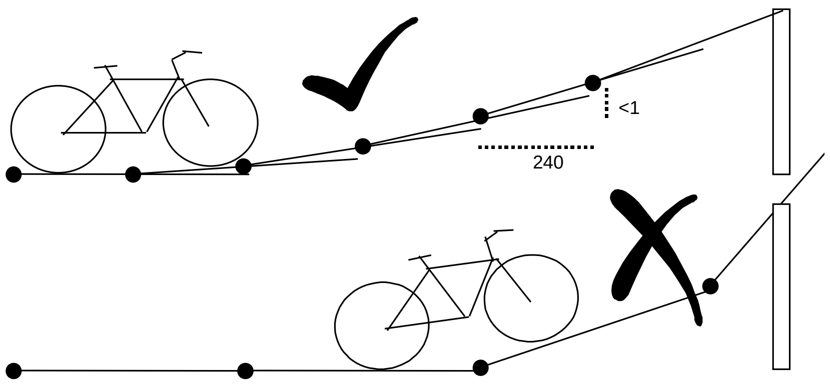


Figure 13.1: Recommended Limit for Vertical Curves.

14. EDGE RESTRAINT AND SEPARATION

14.1 Restraint

Materials such as gravel and concrete block pavers require lateral restraint at the pavement edges to preserve their structural integrity. Thin asphalt surfacing also often requires edge restraint to ensure proper compaction and poured concrete base similarly utilises a formwork system.

Construction against a kerb section, wall, or concrete path provides good lateral support. Trafficking of the full width of the bikeway can then occur without a tendency to develop edge cracking and breakages.

Figure 14.1 shows the cross-section of typically used edge restraint systems.

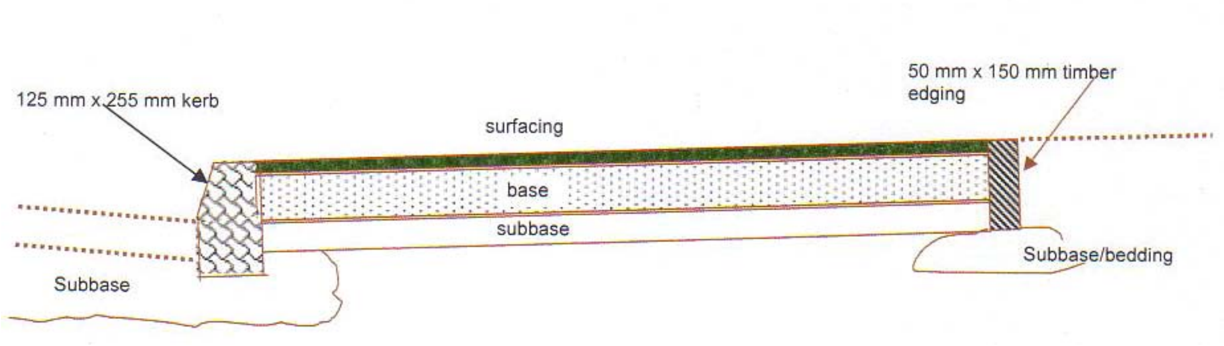


Figure 14.1: Bikeway Edge Restraint

14.2 Separation

Installation of an edging system also separates the bikeway materials from the adjacent vegetation, and may reduce moisture ingress from the adjacent soil to the pavement structure. Edge treatments comprising unbound granular materials or concrete block pavers will often eventually become contaminated with topsoil or vegetation, leading to spreading and deterioration at these locations.

14.3 Edge Restraint Systems

The edge restraint/separation treatments described in *Table 14.1* are recommended. Alternatives such as cast-in-place concrete plinths, kerbs and drainage channels, fences and walls would also serve the same purpose.

Table 14.1: Edge Restraint Systems

Restraint type	Dimension	Source	Pavement type
Concrete kerbing (usually chamfered) refer *Figure 14.1*	125mm x 255 mm	TRL (1996) p8-1	all flexible
Timber (bull-nosed where standing proud) refer *Figure 14.1*	50mm x 150mm	TRL (1996) p8-1	all flexible
Additional width of granular base; refer *Figure 14.2*	150mm minimum	Austroads (1993) p99	Not for CBPs
	300mm desirable	DPTI	

The location and type of edge restraint may have implications for the maintenance and aesthetics of the bikeway. An exposed concrete edge of 100 to 150 mm width may assist the definition of the bikeway path (which may be important at night), and provide an edge that is more easily maintained. The additional support provided by a wider granular base allows better edge compaction of the asphalt surfacing.

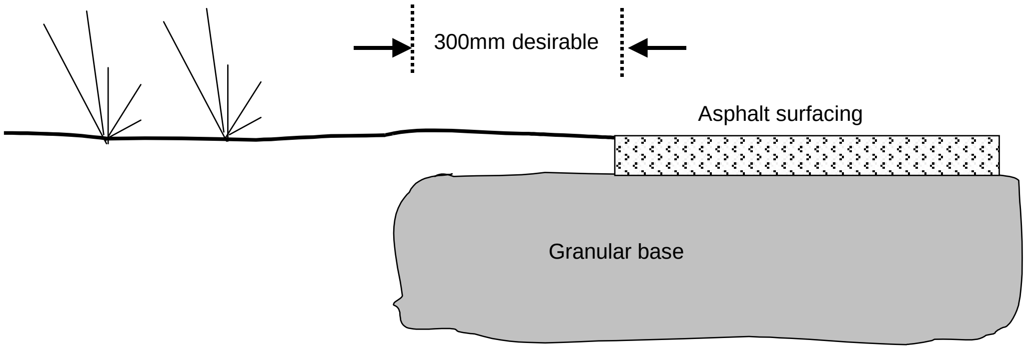


Figure 14.2: Restraint by additional width of granular base material

15. GRANULAR MATERIAL CONSTRUCTION

For unsurfaced bikeways, aggregate sizes of 20 mm or less are preferred to ensure a satisfactory ride. With a 20 mm product, the material needs to have sufficient fine fraction and not be too hard, with an LA Abrasion[1] value greater than 35, e.g. PM3/20.

The surface should be tightly bound and loose material should not be allowed to accumulate on the surface. Granular layers need to be adequately compacted through the full pavement depth to ensure good strength and stability. Minimum compaction requirements are indicated in *Table 15.1*.

Table 15.1: Recommended Modified Compaction levels for Granular Layers

Layer	Materials	Foot/bike traffic	Heavy vehicle N_{DT} = 4000 ESA
Base	PM2/20	Not Applicable	96%
	PM3/20	95%	96%
	Sa-C	95%	Not Applicable
Subbase	PM2/20	Not Applicable	95%
	PM3/20	Not Applicable	95%
	Type A	95%	Not Applicable

Where granular pavements are to be surfaced, it is desirable to dry the compacted materials back to below the Optimum Moisture Content before priming or sealing. This improves the stiffness of the unbound granular materials significantly to maximise the load spreading properties and provide the hard surface required prior to spraying. Sprayed seals must be swept clean of loose stone chips before use by cyclists.

[1] Mechanical test of the source rock to determine its per cent breakdown when tumbled for a standard period; the lower the LA Abrasion value the better the toughness and abrasion resistance.

16. ASPHALT BIKEWAY CONSTRUCTION

16.1 Pre-treatment

As indicated in Section 6.2 a prime or primerseal is essential to aid adhesion both within the surface structure of the granular base, and between the granular base and a thin asphalt surface. The prime or primerseal also acts as a waterproofing membrane.

16.2 Spreading and Compaction

The thin layers used on bikeway pavements cool more quickly than the thicker layers typical of those used on heavily trafficked roads. Hence to achieve adequate compaction while the mix remains hot, placement should not be undertaken in cold or wet weather. Typical rates of cooling are indicated in Austroads/AAPA (2006).

The performance of the asphalt is highly dependent upon achieving good compaction to reduce permeability and improve the resistance to both load induced and environmental cracking.

17. CONCRETE BIKEWAY CONSTRUCTION

17.1 General

The construction of concrete bikeway pavements requires good placement practices and design detailing. In addition to this Guide, further information is provided in C&CAA (1997, 1999a) and RTA (2009).

Either double-beam vibrating screeds or slip-form pavers should be used to compact the concrete.

A high standard surface finish can be achieved by:

- The use of extended bullfloats[2] (up to 4 m wide) to reduce the frequency and height of transverse corrugations that are undesirable on bikeways where cyclists travel at high speed.
- Saw-cut contraction joints completed after bullfloating; trowelling and broom finishing, but minimising surface discontinuities and hence roughness. Wet-formed contraction joints made using a grooving tool should be avoided as discussed in Section 17.2.1.2.

17.2 Joints

Joints in bikeway concrete pavements mainly include contraction joints, expansion and isolation joints.

17.2.1 Contraction Joints

Contraction joints are required in the concrete base to control the location of cracks resulting from the shrinkage that occurs as concrete sets. These joints are sawn within 24 hours of casting as soon as the surface is capable of accepting the operation without damage to the base surface (refer 17.2.1.1).

[2] The bullfloat is a large float on a long handle, which is worked back and forth on the concrete in a direction parallel to the ridges formed by screeding. Bullfloating is useful as an initial floating operation to smooth the concrete surface immediately after screeding, and should be completed before bleed water appears on the surface. A second use of the bullfloat may be required but care must be taken not to overwork the surface. (C&CAA 1999a)

Contraction joints should be no more than 3 mm wide and extend into the slab by about a quarter to a third of the slab thickness (refer to *Figure 17.1*) but not to the depth of reinforcing mesh. These transverse saw cuts are usually required at 3.5 to 4 m spacing (but < 1.2 x path width) and should be sealed with silicone to about 10mm depth over a suitable backer rod.

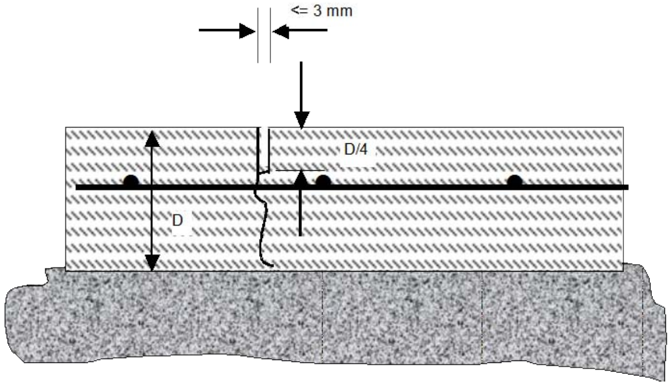


Figure 17.1: Contraction joint detail

17.2.1.1 Saw Cutting

The purpose of shallow saw cutting is to induce shrinkage cracking only below the sawn joints where the pavement thickness (and hence strength) has been reduced. Determining the timing of the saw-cutting operation is critical, as sawing too early causes tearing or ravelling and too late results in unplanned cracking away from these joint locations.

Prior to commencement of a concrete bikeway project, an offsite trial section of about 12 - 20 m length should be constructed to establish and refine the proposed construction methodology. The time period between concrete placement and optimum sawing is dependent on the type and slump of the concrete and the prevailing weather conditions. Adequate sawing equipment (including spare plant) and skilled operators are required onsite during the limited time available for this critical work component.

17.2.1.2 Hand-formed transverse contraction joints

The traditional grooving tool should be avoided as it usually forms a very wide joint at the surface (greater than 3mm) and the flat pan edges of this tool tend to create an additional surface discontinuity. Any wet-formed joints must be made without disturbing the concrete within 50mm of the joint to avoid unnecessary constructed roughness. Transverse brooming up to the joint opening to provide fine surface texture may reduce the magnitude of very small surface irregularities.

17.2.1.3 Areas comprising odd shaped or re-entrant slabs

Odd shaped slabs or slabs containing re-entrant corners require very careful attention to joint design and location; refer RTA (2009) Concrete Pavement Manual for further advice.

17.2.2 Expansion Joints

Expansion joints accommodate thermally induced extensions of the concrete during hot weather. These joints are often omitted on concrete roads but the RTA and Austroads (2012) current best practice favours their inclusion for bikeways to ensure good long term performance. Expansion joints are generally placed at every 5th transverse joint location (e.g. 17.5m spacing when contraction joints are sawn at 3.5m intervals), but are also used at the 2nd joint away from junctions with existing flexible pavements or other structures. The reinforcing mesh is terminated 50 mm either side of the joint.

Expansion joints (refer *Figure 17.2*) must be 10-15 mm wide, sawn or formed to extend the full depth of the slab, filled with compressible filler, and provided at a minimum of 12 m to 40 m intervals (Aguero 1996).

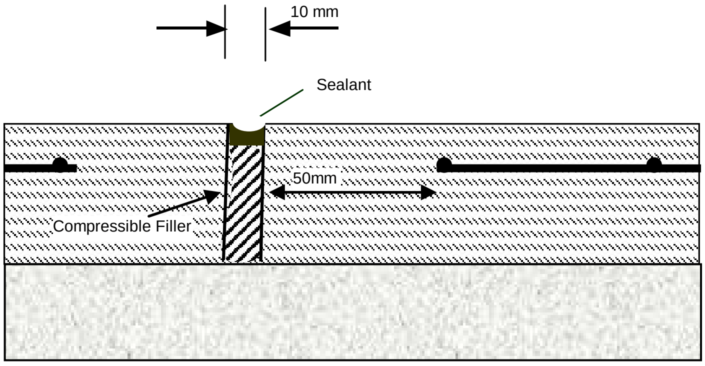


Figure 17.2: Expansion joint detail

17.2.3 Isolation Joints

An isolation joint is an expansion joint abutting a non-moveable object placed transverse to the direction of the bikeway. For example, an isolation joint would be placed at a bridge abutment or driveway crossover. These joints may also be required parallel to the bikeway direction where there are lateral restraints such as kerb and channel.

17.3 Anchor Blocks

Where the slope of the path exceeds 5%, the use of anchor blocks should be considered to prevent slippage of the slab. The blocks comprise a beam of concrete typically measuring 200 mm high by 300 mm wide cast integrally and transverse to the path. For longer slopes, a spacing of about 40 m between blocks is recommended. When the anchor block is cast at the end of the path it is often referred to as a terminal block as shown in Figure 17.3.

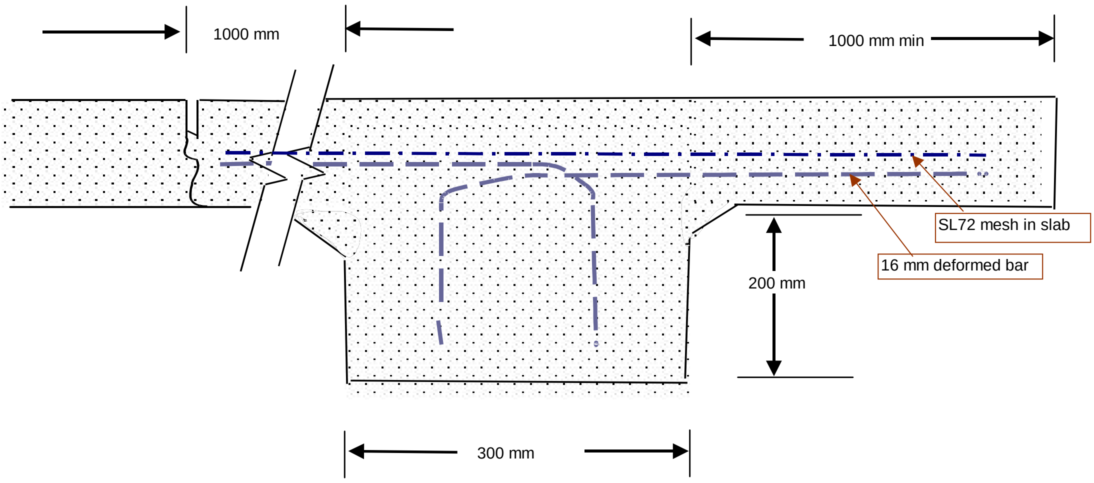


Figure 17.3: Terminal Block Detail

Additional reinforcement (deformed bars) to the slab mesh is placed in the slab and anchor block to prevent transverse cracking at the leading edge of the anchor block.

17.4 Vehicle Crossovers

Where pavements designed for Foot/bike are subject to vehicular crossings, it is recommended that the design in this zone be changed to the base thickness required for the Heavy vehicle category (*Table 12.1*).

17.5 Reinforcement

Continuous steel mesh reinforcement is required for the concrete bikeway designs in Table 12.1. The recommended mesh size is SL72 with 200 mm overlaps (one mesh row) on adjoining sheets.

Reinforcement should be placed on bar chairs at the mid point or within the upper half of the pavement slab for effective crack control. A minimum top cover of 40 mm is required for pavements less than 150 mm thick, and 50 mm cover for slabs greater than or equal to 150 mm. The use of broken bricks etc. to support reinforcing steel is unacceptable.

Reinforcing is also used for anchor blocks and vehicle crossovers as previously discussed.

17.6 Surface Finish

Surface finishes produced from a hessian drag, wooden float or light broom should provide sufficient skid resistance for bicycles. On shared paths, other finishes such as a stamped or coloured surfacing can be used for delineation.

17.7 Curing

Curing of the concrete involves ensuring that adequate moisture is available for hydration of the cement, which is essential for the development of concrete strength and durability. Methods of curing include sealing the surface or continual dampening with a fine water spray. Plastic sheeting or a sprayed water or wax based curing compound are generally likely to be the most practical and effective curing options.

18. CONCRETE BLOCK PAVER CONSTRUCTION

The performance of CBPs is very dependent upon the specification of the paving units and the manner of their construction. The Concrete Masonry Association of Australia (CMAA 1997c) has produced a Detailing Guide, which provides comprehensive specification and construction information. Consideration of the following apects should ensure good long-term performance of CBP bikeway:

- CBP thickness: 60 mm or 80 mm;
- Selection of shape types: fully, partial or non-interlocking units;
- Laying pattern;
- Selection and detailing of the edge restraint system;
- Edge pattern/treatment of CBPs;
- Detailing of the transitions between paving types;
- Bedding course drainage; and
- Detailing around utility pits.

19. DRAINAGE

19.1 Surface Drainage

Good drainage is critical in the design of roadways, paths and tracks. In addition to the safety and convenience of bikeway users, the drainage design will contribute significantly to the structural performance of the pavement.

Uncontrolled flow of surface water can cause severe erosion of unsurfaced pavements and side channels, and undermine the unprotected edges of sealed bikeways. It is essential to prevent the ponding of surface water that may infiltrate the base of the path and weaken the pavement structure. Water should be drained by adequate surface crossfalls (refer Austroads 1999) and side channels into the storm water system.

The subgrade should also be constructed with these crossfalls to allow free drainage of pavement layers, without depressions that may hold water and weaken the substrate.

19.2 Subsurface Drainage

In localised areas subject to springs, seepage flows, or excessive irrigation, the construction of a subsurface drain may be required to preserve the soil strength of the bikeway subgrade. The cost and complexity of installing good subsurface drainage systems means that they need to be both warranted and well engineered. In South Australia, situations requiring this treatment tend to be relatively uncommon.

Design of subsurface drainage for road pavements is detailed in Austroads (2009c). Manufacturers and suppliers of prefabricated geo-composite drainage products also provide technical design and installation information in their promotional literature.

20. VEGETATION

20.1 Pavement Damage Considerations

Landscaping issues for bikeways are usually associated with the geometric design and aesthetics of the facility. However the damaging effect of vegetation can be substantial.

Spraying the path and a strip to either side with a suitable weedkiller prior to construction, and the use of permanent edge restraints and grass trimming, are usually necessary to adequately control weed and grass invasion.

In pavements constructed on heavy clay soils (PI greater than 30), the most pronounced movement occurs near trees and shrubs as a result of soil moisture losses during dry periods. Both small and large tree species can cause surface shape loss and cracking. The following factors may influence the extent of such damage:

- mature height of the tree;
- mature canopy width;
- species type;
- plantation density,
- soil characteristics; and
- planting techniques.

Species that grow rapidly and are vigorous in their search for moisture can cause large deformations in expansive soils.

Wherever possible trees and shrubs should be set back a distance equating to the greater of 1½ times the mature height or twice the mature canopy width of the tree.

If it is impractical to provide adequate clearance between trees and the bikeway, then construction of root barriers or inclusion of reinforcement in concrete bikeway slabs adjacent to trees should be considered to reduce the extent of cracking.

Planting techniques that encourage deep root growth, rather than lateral growth towards the bikeway, may also minimise pavement damage. Common techniques include-

- deep ripping prior to planting to break up heavy soil; and
- regular and thorough watering during the establishment period (first 1 to 2 years).

Barry (1986) provides a limited list of potentially suitable trees and shrubs for plantations on expansive clay soils.

21. CONSTRUCTION OF SERVICE CROSSINGS

Installation of services should be undertaken prior to bikeway construction.

Services installed after bikeway construction should be installed through a jacked sheathing culvert.

If narrow and/or deep trenches are excavated across the bikeway, it may be necessary to reinstate with a flowable-fill material to avoid long-term settlement. These materials are available from ready mixed concrete suppliers as Controlled Low Strength Materials (CLSM) and comprise a sand, cement, flyash and water mixture that is flowable, self-levelling and does not require compaction. Various strength mixes are available, and 0.7 MPa mixes are typical for subgrade reinstatements (Transport SA 1997).

Open trenching across a bikeway requires the following:

- sawing of the surfacing;
- replacement and thorough compaction of all back-fill from the service asset to the top of subbase level using a subbase quality material;
- reinstatement of the base and surfacing layers in materials equivalent to the original;
- replacement and dowelling of concrete slabs to preserve shear load transfer; and
- for thin asphalt surfacings an *additional* 50 mm thickness of asphalt.

PART E – MAINTENANCE

22. MAINTENANCE OF BIKEWAYS

22.1 General Requirements

Bikeway pavements can be maintained using many of the practices associated with conventional road pavement types. Austroads (2009g) provides further information on road pavement maintenance which supplements the discussion of bikeway maintenance issues within this Guide. Austroads (2009f) also includes links to a number of useful technical notes, *pavement work tips* and other publications provided by Austroads, Austroads member organisations and industry associations.

Smooth, debris free surfaces are a fundamental requirement for cycling safety. Most bicycles have no suspension or shock absorbers and many have relatively thin tyres inflated to high pressures. As some bikeway cyclists travel at speeds of around 30 km/h on flat grades and up to about 50 km/hr on downhill grades, a rough surface or pothole can be particularly hazardous. Regular maintenance activities on bikeways should include (Austroads 1999):

- filling of cracks;
- patching of potholes
- trimming or removal of grass so that it does not intrude into the path;
- sweeping of paths to remove debris such as broken glass and fine gravel (including that arising from construction and maintenance activities such as crack sealing);
- repainting of pavement markings,
- cleaning of signs; and
- trimming of trees and shrubs to maintain safe clearances and sight distances.

22.2 Pavement Surface Tolerances

Austroads (1999) advises that bikeway surfaces should be within the tolerances given in *Table 22.1*.

Table 22.1: Existing Surface Tolerances

	Not to exceed (mm)	
	Width of groove	Height of step
Parallel to direction of travel	12	10
Perpendicular to direction of travel	-	20

Source: Caltrans (1995)

22.3 Drainage

The gradual deterioration of the drainage system often manifests itself in other faults and distress patterns on the bikeway, which in turn can become the focus of a more comprehensive and expensive maintenance effort.

Drainage maintenance mainly requires the provision of:

- Adequate bikeway surface crossfall, either one way or two way with crown.

- Maintenance of verges and immediate surrounds of the bikeway to clear grass and other debris from culverts and drainage paths and ensure good surface runoff.

Due to its importance in the prevention of more severe distress, drainage systems warrant regular monitoring and timely intervention.

22.4 Crack Filling

Crack-filling is undertaken to seal the underlying pavement layers from moisture ingress and prevent strength loss or swell in these materials. Cracks appearing as fractures in the surfacing are difficult to fill without forming a profile extending proud of the surface.

Crack sealants are normally bituminous compounds, and are modified with polymers or ground rubber for active cracks, and finished with 2mm grit to provide skid resistance. Excess grit should be removed to minimise the hazard to cyclists.

Crack filling using epoxy or urethane is sometimes undertaken on concrete pavements; refer to RTA (2000).

22.5 Resurfacing

Resurfacing restores the function of the original surfacing and could be undertaken to waterproof the base layers, upgrade skid resistance, or improve the shape and riding quality of the bikeway.

The treatment options generally comprise thin flexible bituminous treatments, but over concrete and block pavers these are likely to reflect the jointing pattern. The most appropriate resurfacing treatments for bikeways generally include:

- Sprayed reseal. A modified binder may be used to improve the resistance to crack reflection. Paving fabric may also be placed for crack interception and additional waterproofing.
- Microsurfacing. This can be used to correct minor surface irregularities.
- Asphalt overlay. Can be used for shape correction. Modified binder may improve resistance to crack reflection, but little performance data is available for bikeways.

Other restorative treatments are available for sealed surfaces that are structurally sound, but have an excess or lack of bituminous binder. These comprise the softening and addition of additional aggregate to the surface (for binder excess) and enrichment treatments for binder deficit.

Some asphalt types, such as stone-mastic asphalt and open-graded asphalt (Foley 2001) appear to be able to resist the reflection cracking occurring in road pavement surfacings better than others.

Further detailed information regarding sealing and restorative treatments may be obtained from Austroads (2009d).

23. MAINTENANCE CONSIDERATIONS

23.1 Flexible Pavements

23.1.1 Unsealed Surface

Unsealed or gravel surfaces rely on the cohesion and grading of the soil particles to maintain a hard and durable surface. The critical maintenance activities for these surfaces are usually related to drainage and include:

- maintaining an adequate surface crossfall, either one way or two way with crown;
- ensuring that grass and other debris does not build up along the pavement margin; thereby preventing surface runoff;
- checking and clearing culverts and drainage paths;
- reshaping to eliminate any low points, potholes etc.; and
- periodic resheeting to preserve base thickness and shape.

23.1.2 Spray Sealed and Thin Asphalt Surfaces

The waterproofing of the base material by the surfacing treatment minimises or eliminates some of the maintenance tasks associated with an unsurfaced pavement. To preserve the integrity of this surfacing it is important to-

- repair any discontinuities that allow water to pond and/or penetrate into the base course;
- maintain the margin of the surfacing edge support and waterproof or crackseal any gap that occurs;
- prevent the verge vegetation from encroaching onto and penetrating the asphalt or seal; and
- maintain the general drainage efficiency of the bikeway and environs as described for unsealed surfaces.

The condition or amount of binder at the riding surface may sometimes require an intervention treatment.

Too much bitumen on the surface usually results in bleeding or slickness when the aggregate particles become deeply embedded or at times enveloped in a bitumen film. The loss of aggregate and skid resistance can become a safety issue for bikeway users.

Loss of bitumen binder from the surface (or hardening) can lead to stripping of the seal and ravelling of asphalt, reducing the ability of the surfacing to act as an effective moisture barrier for the underlying granular base. Variable skid resistance and eventually potholing often results. Binder loss may primarily be due to the age of the bitumen, oxidation, and exposure to sunlight. The lighter fraction of the bitumen tends to evaporate leaving the heavier and more brittle bitumen components that have a less tenacious grip of aggregate particles.

Methods of repair of bleeding, flushing, binder embrittlement, stripping and ravelling are contained in Austroads (1991) and ARRB (2005c).

23.1.3 Asphalt Surfaced Pavements

If specific edge restraint to the top of the asphalt layer is not provided, some lateral support to reduce the occurrence of edge breaks may be achieved by topping up and maintaining the adjoining surfaces or shoulders of the bikeway.

Treatment of ravelling and bleeding of the surface may also be required.

23.2 Rigid Pavements

Most maintenance activities associated with concrete pavements relate to the joints, where spalling of the concrete arris, step-faulting or other vertical discontinuities may occur.

23.2.1 Spalling

Spalling occurs when joints become blocked with incompressible particles and are unable to relieve the high thermal expansion stresses by slab movement. Low concrete strength (and durability) also tends to result in concrete spalling where edges or joints are trafficked by vehicles.

Repair of spalling at slab joints is difficult, as any cementitious repair should not extend across the joint. As this can be a labour intensive task, spalls are often treated with flexible filler such as fine 5 mm size asphalt. However, this type of treatment would impact adversely on the aesthetics of the bikeway.

23.2.2 Faulting

Step-faulting and other vertical misalignment across joints occurs when tree roots or swelling soils cause localised heave or subsidence of a slab. This can require milling of the step or replacement of slabs in severe cases.

Heavy commercial vehicle loadings may also fracture individual slabs requiring an appropriately designed repair.

23.2.3 Slab Jacking

This technique is used on concrete roads where the relative movement between adjacent slabs is substantial. A fine cementitious grout or 'mud' ('mud jacking') is injected to level adjoining slabs. For bikeway pavements, slab replacement is likely to be a better option where this type of distress occurs.

As for all other pavement types, attention to drainage is important. Settlement of slabs in a poorly drained section of concrete bikeway also requires correction of the drainage problem. Slab jacking will only be effective while the underlying subbase or subgrade is protected from further erosion and subsequent settlement.

23.2.4 Cracked Slabs

Slabs that have cracked and appear stable (no spalling or pumping etc.) should be monitored, as the bikeway traffic loading may not require slab replacement. For unreinforced concrete and/or wide cracks, crack-sealing using a flexible bituminous sealant should be considered, with the performance risks of not waterproofing the crack weighed against the loss in ride quality.

24. SAFETY DURING WORKS

Maintenance and construction operations should be undertaken so that the safety of workers, cyclists, and other users remains at an acceptable standard. Austroads (1999) provides comprehensive recommendations on the signing and delineation of works, and these are attached as Appendix G of this document.

25. MONITORING

25.1 Surface Shape

Pavement surface shape is generally assessed in two ways:

- roughness; the cumulative variations in longitudinal profile are measured to assess the ride quality, for determining network performance and prioritising maintenance activities; and
- local shape variations; these are primarily measured by manual means for the quality control of construction and rehabilitation treatments.

25.1.1 Roughness

Roughness is a measure of the ride quality or smoothness of a pavement surface and is primarily reported in:

- NAASRA Roughness Meter counts (nrm, c/km); or
- International Roughness Index (IRI, m/km)).

IRI units are common overseas and for comparison with nrm, a reasonable correlation has been determined by Prem (1989) as:

$$nrm\ (c/km) = 26.5 \times IRI - 1.27$$

Roughness is measured by-

- Laser profilers are the most common for Australian road pavements, operating at speeds above 30 km/h and providing test results in both IRI and NAASRA counts;
- NAASRA Roughness Meter, which comprises a sensor, mounted on the rear axle of a standard vehicle. This has been virtually superseded by laser profilometry. The slowest calibrated test speed is normally 50 km/hr; and
- ARRB walking profiler, which measures pavement surface roughness as it is pushed along at walking speed. While it can access very narrow paths, it is relatively slow and is more suited to high precision small area applications.

Roughness values of less than 40 NAASRA counts/km on the road network are considered very smooth and typical of good quality new pavement. Motorists tend to find roughness levels up to 110 nrm acceptable, particularly for speeds of less than 80km/hr. Roughness measurements greater than 150 nrm usually require some intervention treatment to reduce the roughness. The 110 and 150 nrm levels typically define the broadly accepted terminal roughness values for rural main roads or highways and the main urban arterial road alignments.

There appears to have been little if any development work to determine an appropriate terminal condition or intervention level for bikeway roughness. However, roughness measurements on existing facilities could be used in conjunction with user feedback to initially develop these values. Alternative interim limits could be based on those associated with road pavements, as these roughness standards are imposed on cyclists using the normal road network.

Typical DPTI requirements for the mean maximum NAASRA lane roughness for each 100 m section of new road pavement construction are:

- 50 c/km for speed zones of less than or equal to 70 km/h; and
- 40 c/km for speed zones greater than 70 km/h.

This standard of construction is unlikely to be achievable for most bikeway constructions and there is some user survey data to indicate that higher roughness is acceptable. Interim initial roughness values for bikeways are suggested in Table 25.1, with Recreational and Commuter facilities providing convenient category definitions.

Table 25.1: Suggested Maximum Average Initial Roughness per 100m length

Recreational Bikeways	**Commuter Bikeways,** (and high standard applications)
100 counts/km	75 counts/km

25.1.2 Local Pavement Shape Variability

Local shape variations can be related to:

- rutting, wheelpath deformation from vehicle loads;
- pavement edge drop-off;
- surface irregularities associated with tree roots or soil movements; and
- step faulting of concrete slabs.

Shape is usually measured as a deviation in millimetres from a 1.2 m or a 3.0 m length straight edge, and is often part of rating systems commonly in use. Refer also to *Table 22.1, Table 25.3* and *Table 25.4.*

25.2 Skid Resistance

The skid resistance of Australian pavements is generally measured as a friction number or coefficient:

- Grip Number determined from the GripTester: continually measured by a towed device, which can also be pushed by hand in narrow areas.
- British Pendulum Number (BPN): measured by the British Pendulum (BP), a portable device which tests a small and discrete area of surface; and
- Sideways Force Coefficient (SFC): continually measured with a device known as SCRIM (mounted on a heavy commercial vehicle) but test speeds of 50 km/hr and significant clearance requirements generally exclude the use of this equipment on bikeways;

All three devices measure the skid resistance of the wet surface.

Testing of bikeway skid resistance at a network level is uncommon and is more likely to be required for the assessment of local problems. These may be due to surface polishing, contamination or where the texture is substandard. The most appropriate testing device would be the British Pendulum or GripTester. A minimum Grip Number of 0.40 is recommended for Bikeways.

Investigatory levels for road pavement surfaces recommended by DPTI are indicated in *Table 25.2*.

Table 25.2: Recommended Investigatory Levels for Skid Resistance

Road Situation	Minimum Grip No.	Maximum Vehicle Speed km/h
Difficult sites - steep grades, tight bends, traffic signal approaches, roundabouts.	0.50-0.55	60-80
Urban Arterial Roads	0.45	60
Rural Arterial Roads	0.45	110
Urban/Lightly Trafficked/ **Bikeways**	**0.40**	60

Note: The approximate conversion from British Pendulum No. to the Grip No. is Grip No.= 0.01x BP

25.3 Cracking and other Surface Irregularities

Cracking and other pavement defects may be assessed for bikeways. Austroads (2011) and ARRB (2005c) provide examples of these distress types for flexible and rigid pavements.

25.4 Rating Systems for Paths

Pavement asset management systems usually rate condition indicators such as roughness, rutting, and skid resistance, by collecting data automatically at normal motor vehicle speeds. Estimates or measurements of cracking, potholing, texture and strength, may also be undertaken.

Only a few of these parameters would normally be measured or assessed for bikeways, generally by means of a pavement inspection.

The Department of Urban Services, Canberra (Robinson *et al*. 2001) has developed rating categories for concrete and asphalt 'community paths' as summarised in *Table 25.3* and *Table 25.4*.

Table 25.3: Concrete Paths Rating System (DSS 1998)

Rating	Description
Poor	Extensive cracking of the pavement; concrete is loose, spalling, broken or subsided. Large (> 10 mm) wide cracks with vertical displacement (i.e. step > 25 mm). Severe ramping of the pavement (typically two bays of path uplifted to form a peak at the joint line).
Fair	Large (> 10 mm) cracks with horizontal displacement of concrete producing a step of < 25 mm. Ramping < 30 mm. Generic comment: A fair to poor pavement is reached where maintenance intervention is required to preserve the asset and/or ensure public safety.
Good	Fine to medium cracks < 10 mm in width in width and single longitudinal cracking with little or no vertical displacement. Ramping < 30 mm. Generic comment: A good condition is where the pavement has not deteriorated to extent that maintenance work is deemed to be essential, for reasons of public safety and/or asset preservation.
Excellent	New paths and hairline cracks.

Table 25.4: Asphalt Paths Rating System (DSS 1998)

Rating	Description
Poor	Longitudinal and transverse cracking width > 10 mm. Extensive, concentrated crocodile-like pavement cracking. Continuous lengths of weed infested pavement generally located along the path edge in combination with pavement failure. Rippling (height > 20 mm) typically due to tree root damage of the pavement resulting in poor riding conditions. Eruptions (height > 20 mm) typically due to tree root intrusion or base course chemical reaction.
Fair	Longitudinal or transverse cracking of the wearing surface (< 10 mm) Rippling of wearing surface or eruptions < 20 mm. Patches as distinct from continuous lengths of weed infested pavement, generally located along the path edge, in combination with pavement failure. Isolated patches, as distinct from continuous areas of crocodile like surface cracking. Generic comment: A fair to good pavement condition is reached where maintenance intervention is required to preserve the asset and/or ensure public safety.
Good	Paths with a satisfactory ride quality (deviation from a 3 m straight-edge not exceeding 5 mm at any point). Minor surface deterioration not requiring maintenance intervention. Generic comment: A good condition is where the pavement has not deteriorated to the extent that maintenance work is deemed to be essential, for reasons of public safety and/or asset preservation.
Excellent	New Paths.

25.5 Intervention Treatments

Tables A1 to *A4* (from Robinson *et al*. 2001) in Appendix A suggest treatments for a range of distress modes for gravel paths, asphalt paths, paver-surfaced paths and concrete paths. *Table A2* has been modified from the original reference to include spray sealed and slurry surfaced bikeways. The recommended treatments provide some additional detail for repair strategies for bikeway pavements.

APPENDIX A: PROPOSED INTERVENTION TREATMENTS

(from Robinson *et al*. 2001)

Table A1: Proposed Intervention Treatments for Gravel Paths[1]

Defect	Comments and Treatment
Erosion of the path	Redirect the water flow where possible. There is a requirement to fill any areas of erosion with additional gravel. Stabilising the gravel with lime may also be required.
Loose surface	This may require the gravel to be stabilised with lime at 2% by volume.
Water ponding	Place additional gravel to ensure water runs off the path.
Grass on the path	Spray the path with weed killer and chip weeds where required.

1. Paths used for pedestrians, cyclists and other users.

Table A2: Proposed Intervention Treatments for Asphalt Paths

Defect	Comments and Treatment
Crack width less than 3 mm	No action
Crack width between 3 mm and 10 mm	These cracks do not present a problem to the user unless the pavement lifts, causing pedestrians to trip. These can be filled with a crack filling material, but care must be taken to ensure that the product does not leave a slippery surface (longitudinal cracking only). Extensive cracking may require the surface to be replaced.
Cracks wider than 10 mm	These cracks can cause pedestrians to trip, and cycles, wheelchairs and strollers to be thrown off course. These cracks must be filled to remove the hazard. Coldmix may be able to be used, a modified crack filling material may be appropriate or the surface may need replacing.
Cracking from vehicles (no displacement)	No action.
Substantial cracking, shoving and surface breaking up	Remove surface, recompact base material and replace asphalt, sprayed seal or slurry surfacing.
Trench subsidence below 8 mm	No action unless ponding is a problem.
Trench subsidence over 8 mm	Remove surfacing in the affected area, re-level the base and replace asphalt, sprayed seal or slurry surfacing.
Sharp subsidence/uplift and dangerous bumps	Remove surfacing in the affected area and replace, removing the subsidence/uplift. Where this is resulting from tree root intrusion, remove root.
Sulphate attack	Remove surfacing and base and relay a new base and asphalt, sprayed seal or slurry surfacing.. The alternative to this is to mix lime with the base material and then place the new surfacing.
Potholes	Fill pothole with coldmix.
Water ponding	Drain the bikeway where possible by removing soil from the side of the path to allow water to escape. Where this is not practical, a section of the bikeway may need to be replaced or overlayed.
Deterioration of surface with age	Replace the surface or overlay the bikeway with asphalt, slurry or sprayed reseal.

Table A3: Proposed Intervention Treatments for [Concrete] Paver Paths

Defect	Comments and Treatment
Displacement below 8 mm	No action.
Displacement greater than 8 mm	Remove pavers, level and compact the base and relay the pavers. Where the pavers are stuck to the base, it may require grinding of the pavers to provide a level surface.
Subsidence/Uplift below 8 mm	No action.
Subsidence/Uplift of individual pavers greater than 8 mm	Remove pavers, fix base and relay the paver.
Constant slope below 25 mm in 1m	No action.
Constant slope towards centre of subsidence/uplift greater than 25 mm in 1 m	Remove the pavers, install additional base material, compact and relay the pavers in the subsided area. Where tree roots cause the problem, either remove the root or reduce the slope of the ramp.
Cracked pavers	Where the paver is cracked and not moving - no action.
Missing pavers	As a temporary repair fill with sand or gravel, install a new paver.
Gaps between pavers	Narrow gaps between pavers may be filled with sand. Larger gaps may require additional sections of pavers to be placed in the gaps.
Slippery surface of pavers	Slippery paver surfaces may be ground to remove the slippery surface. Glazed tiles are normally slippery when wet and should be avoided as much as possible. Removal is the best solution.

Table A4: Proposed Intervention Treatments for Concrete Paths

Defect	Comments and Treatment
Vertical displacement below 8 mm	No action.
Vertical displacement between 8 mm and 25 mm	The step should be removed by grinding or ramped with coldmix asphalt.
Vertical displacement greater than 25 mm	Localised displacements on sections in good condition should have a coldmix asphalt ramp installed Extensive areas of displacement, in areas of trees, cut roots, install root barrier and replace concrete or regulate with asphalt. If severe damage caused by vehicles that are unable to be kept off the path, replace concrete to comply with Section 12 including steel mesh.
Joint/crack widths below 8 mm	No action.
Joint/crack widths between 8 and 20 mm	Individual cracks can be filled with grout. Extensive cracking of the bikeway requires replacement, refer Section 12, and include steel mesh.
Joint/crack widths greater than 20 mm	Fill cracks with coldmix if the path is still serviceable. If the bikeway is extensively cracked or unserviceable, refer Section 12 include steel mesh.
Skid resistance problem	This may be as a result of frost or incorrect finish of the concrete. Replacement of the section of path or overlay with bituminous wearing course if reflection of joints and cracks is acceptable.
Ponding of water	This may be in association with subsidence. Altering the landscaping or replacement of the section of path may be required.

APPENDIX B: TECHNICAL BASIS FOR BIKEWAY DESIGNS.

This Appendix contains a summary of the technical basis for the development of data in *Table 10.2, Table 11.1, Table 11.2, Table 11.6, Table 11.7, Table 11.8,* and *Table 12.1*.

B.1 Subgrade Strengths

Subgrade strengths have been selected at CBR values of 2%, 5% and 10% to represent *Low Strength, Moderate Strength* and *High Strength* founding conditions respectively.

B.1.1 Low Strength (Design CBR of 2%)

Given the likely location of bikeways in zones of low-bearing soils (e.g. paths meandering around river flats/plains, amongst seasonally watered vegetation/gardens, and the relatively narrow structural width of the bikeways themselves, which expose them to a relatively greater moisture ingress than road pavements), this low (2%) value is considered suitable.

In addition it would be less likely for these facilities to have a stabilised foundation (subgrade) as compared to road pavements. Thus, while most design charts for roads commence at a design CBR of 3%, this lower value of 2% is considered prudent.

B.1.2 Moderate Strength (Design CBR of 5%)

This represents an often-used design value for reasonably sound bearing soils.

B.1.3 High Strength (Design CBR of 10%)

Austroads presumptive CBR design values for the range of common soil types have an upper limit of 15% for well graded sands with excellent drainage. Wherever possible DPTI undertakes a thorough investigation of support conditions and generally adopts an upper limit of CBR 10% to characterise road and bikeway pavement subgrades.

B.2 Traffic Loading

B.2.1 Foot Traffic/Bicycles

This loading represents the uncommon case of nil maintenance (or other) vehicles that are substantially heavier than pedestrian or bicycle loadings (typically a maximum unit mass of about 100 kg), and cannot be equated to any units of ESA (flexible pavement) or HVAG (rigid pavement).

B.2.2 Heavy vehicles

The minimum pavement design listed in Sections 11 and 12 are appropriate for heavy vehicle loading of an (average) weekly one-way passage of a two-axle rigid truck with the following loads:

- 5 tonne (49.0 kN) single axle single tyre (SAST)
- 7 tonne (68.6 kN) single axle dual tyres (SADT)

These loads would are considered typical of a road-patrol truck with gross mass (12 tonne), which is about 80% of the maximum prescriptive gross mass.

For the design of flexible pavements using the empirical design chart (Figure 12.2 Austroads 2012), the cumulative number of Equivalent Standard Axle (ESA) over the design period is required. This design number of ESA is abbreviated to DESA in Austroads (2012).

The cumulative number of truck repetition over the 20 year design period is about 1040 (20 years x 52 weeks x 1 vehicle/week). However because of the restricted width of bikeways compared to roads, the loading is more channelised and hence the number of load repetitions is multiplied by a factor of 3 (TRL 1996). Hence the minimum pavement designs have been based on 3 x 1040 = 3120 truck repetitions.

Using equation 7.3 of Austroads (2012), the ESA of damage due to 5 tonne single steer axle (SAST) is 0.73 ESA and for the 7 tonne single drive axle (SADT) is 0.54. Thus each pass of the 12 tonne rigid truck causes a total of 1.27 ESA of damage. Figure B.1 allows the ESA of loading to be calculated for other axle group loads.

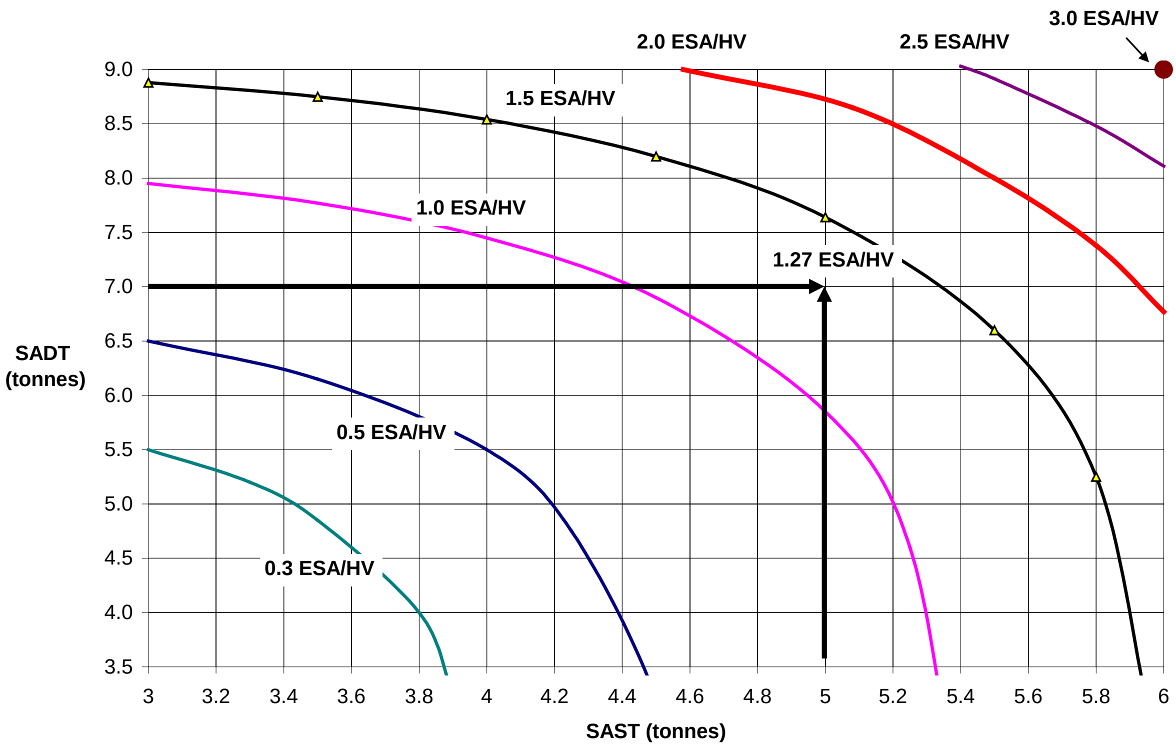


Figure B.1: ESA of loading due to a single pass of two-axle rigid truck

Hence the minimum flexible pavements designs are appropriate for a design traffic loading of

DESA = 3120 x 1.27 = 3960, this figure has been rounded to 4000 ESA in the Guide.

Design traffic in terms of Heavy Vehicle Axle Groups (HVAG) is required for the design of rigid pavements. Over the 40 year period there are 1.2 x 10^4 HVAG (40 years x 52 weeks x 1 vehicle/week x 2 axles/ vehicle). For simplicity this, is expressed as 6000 truck repetitions in the Guide.

B.3 Minimum Pavement Configurations

Minimum pavement configurations are given in Guide for the above-mentioned design traffic loading. If the bikeway is likely to sustain more frequent or heavier axle loadings, it is recommended that the bikeway pavements be design using Austroads (2012). However because of the restricted width of bikeways compared to roads, the loading is more channelised. Hence the DESA calculated using Austroads needs to be multiplied by a factor of 3 (TRL 1996).

For concrete bikeways on which the loading is limited to 2-axle rigid trucks, a simplified design procedure is provided in Appendix F.

APPENDIX C: MATERIAL SPECIFICATIONS

Table C1: CLASS 3 QUARRIED PAVEMENT MATERIAL [GRADING BASED]

TEST PROCEDURE	MANUFACTURING TOLERANCE				
QUALITY CONTROL TESTS					
	Product	**20 mm Class 3 PM3/20QG**	**40 mm Class 3 PM3/40QG**	**55 mm Class 3 PM3/55QG**	**75 mm Class 3 PM3/75QG**
Particle Size Distribution TP134	Sieve Size (mm)	**Percent Passing**			
	75				100
	53		100	100	75 – 95
	37.5		90 – 100	75 – 95	
	26.5	100			50 – 75
	19	90 – 100	60 – 85	50 – 75	
	13.2				
	4.75	40 - 65	25 - 50	20 – 45	20 – 40
	0.075	5 - 15	3 - 11	3 - 11	3 - 11
AS1289.3.1.2	Liquid Limit	Maximum 35%			
AS1289.3.3.1	Plasticity Index	Maximum 15%			
AS1289.3.4.1	Linear Shrinkage	Maximum 8%			
AS1141.23	LA Abrasion Grading 'A'	N/A	Maximum 45%		
AS1141.23	LA Abrasion Grading 'B'	Max 45%	N/A		

Table C2: CLASS 2 QUARRIED PAVEMENT MATERIAL [GRADING BASED]

TEST PROCEDURE	MANUFACTURING TOLERANCE [Grading Based]			
QUALITY CONTROL TESTS				
	Product	**20 mm Class 2 PM2/20QG**	**30 mm Class 2 PM2/30QG**	**40 mm Class 2 PM2/40QG**
Particle Size Distribution TP134	Sieve Size (mm)	**Percent Passing**		
	53			100
	37.5		100	90 – 100
	26.5	100	90 – 100	74 – 96
	19	90 – 100	77 – 95	62 – 86
	13.2	74 – 96		
	9.5	61 – 85	51 – 75	42 – 66
	4.75	42 – 66	35 – 57	28 – 50
	2.36	28 – 50	24 – 44	20 – 39
	0.425	11 – 27	9 – 22	8 – 21
	0.075	4 – 14	4 - 12	3 – 11
AS1289.3.1.2	Liquid Limit	Maximum 28%		
AS1289.3.3.1	Plasticity Index	Minimum 1% - Maximum 8%		
AS1289.3.4.1	Linear Shrinkage	Maximum 4%		
AS1141.23	LA Abrasion Grading 'A'	N.A.	N.A.	Maximum 45%
AS1141.23	LA Abrasion Grading 'B'	Maximum 45	Maximum 45%	N.A.

C.3 SOURCE MATERIALS: SAND Type C

Shall be a crushed quarry product only.

Table C3: SAND TYPE C PRODUCT QUALITY CONTROL

TEST PROCEDURE	MANUFACTURING TOLERANCE	
QUALITY CONTROL TESTS		
	Product	**Sa - C**
Particle Size Distribution TP134	Sieve Size (mm)	Percent Passing
	9.5	
	6.7	100
	4.75	70 – 100
	2.36	35 – 100
	1.18	
	0.600	
	0.425	25 – 70
	0.300	
	0.150	
	0.075	8 – 23
AS1289.3.1.2	Liquid Limit	Max 25%
AS1289.3.3.1	Plasticity Index	Max 6%
AS1289.3.4.1	Linear Shrinkage	Max 3%
AS1141.34	Organic Impurities	Satisfactory

APPENDIX D: CONCRETE BLOCK PAVER SAND GRADINGS

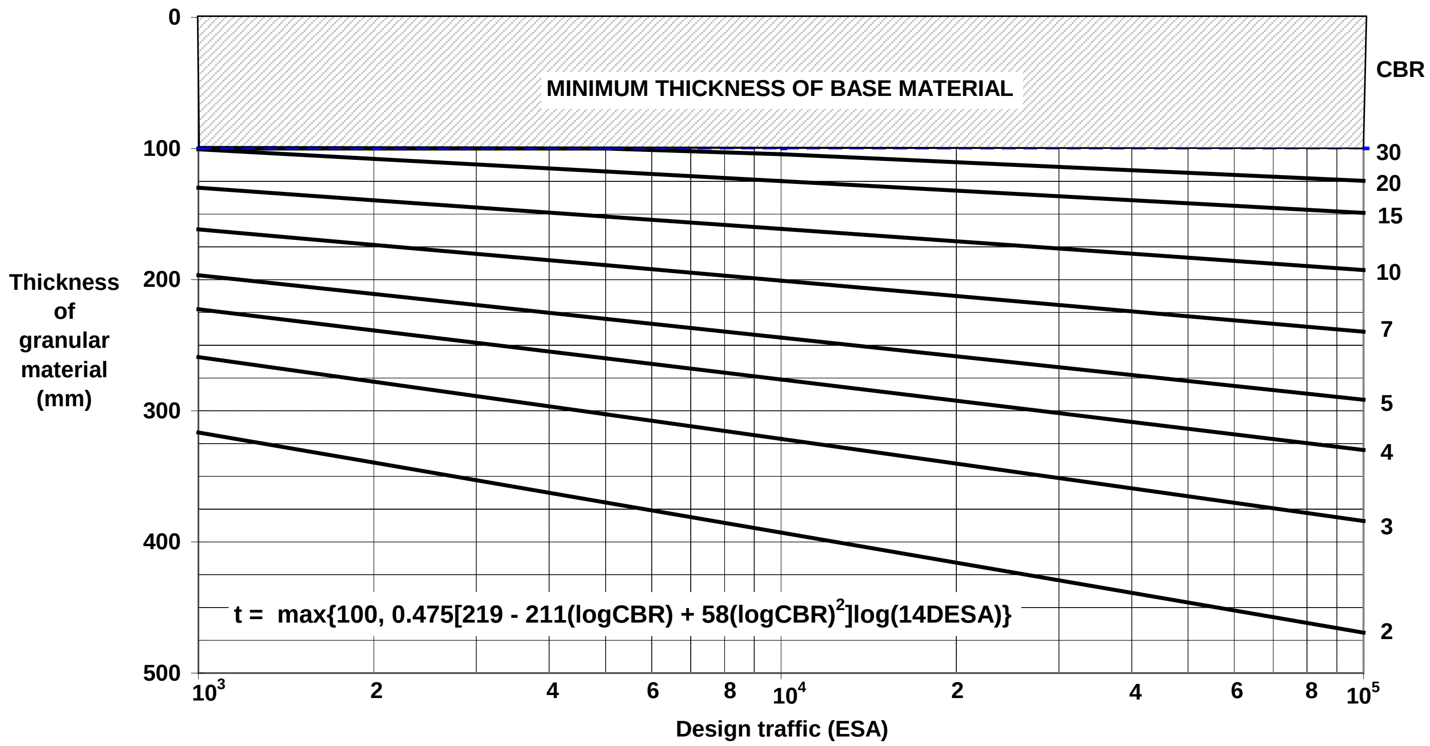
Table D1: Grading Envelope for Bedding Material (CMAA 1997b)

Sieve Size (mm)	% Passing
9.52	100
4.75	95-100
2.36	80-100
1.18	50-85
0.6	25-60
0.3	10-30
0.15	5-15
0.075	0-10

Table D2: Grading Envelope for Joint-filling Material (CMAA 1997b)

Sieve Size (mm)	% Passing
2.36	100
1.18	90-100
0.6	60-90
0.3	30-60
0.15	15-30
0.075	5-10

APPENDIX E: DESIGN CHART FOR GRANULAR PAVEMENTS WITH THIN BITUMINOUS SURFACING (AUSTROADS 2012)



Note:

1. Appropriate local conditions, environmental and drainage issues must be considered in using these design curves.

2. Thin asphalt surfacings may be included in total granular thickness. However, the minimum thickness of the granular base is 100 mm.

APPENDIX F: THICKNESS DESIGN OF CONCRETE BIKEWAYS

The minimum concrete designs given in Table 12.1 are applicable for 6000 load repetitions of a 2-axle rigid truck with a maximum load of 7 tonnes on the single axle dual tyre (SADT) Note that the truck steer axle (SAST) does not cause fatigue damage to the concrete provided the axle load does not exceed the legal limit of 6 tonnes.

Where a higher number of load repetitions or SADT load exceeding 7 tonne is expected, the following procedures may be used to determine the required thickness of concrete base.

Using the procedures in Section 9.3.2 of Austroads (2012), calculate the equivalent subgrade CBR. Where 100 -150 mm of granular subbase (min CBR = 15%) is provided under the concrete base, Table F.1 lists the equivalent subgrade CBR values for a range of subgrade CBRs.

Table F.1 Effective Subgrade CBR values

Subgrade Design CBR (%)	Granular subbase thickness (mm)	Equivalent Subgrade CBR (%)
2	150	3
3	150	4
5	150	6
7	150	8
10	100	10
15	100	15

The expected number of 2-axle rigid truck load repetitions over the design period is then calculated. For example, if one truck pass per month is expected over a 40 year design period the number of repetitions is:

N_{trucks} = 12 (months) x 40 (yrs) x 1.0 (truck/month) x 3.0 = 1440 load repetitions

The maximum expected load on the SADT axle group needs to be estimated. This is the design SADT axle load.

Using the equivalent subgrade CBR, the expected load repetitions of the design SADT axle load, the required thickness of base is calculated using Figure F.1. Note that the thicknesses in Figure F.1 includes a 10 mm construction tolerance. This tolerance is appropriate when bikeways are constructed in accordance with DPTI roadworks specifications. Where other specifications are used, consideration needs to be given to adjusting Figure F.1 thicknesses.

As discussed above, the minimum concrete designs given in Table 12.1 are applicable for 6000 load repetitions of a 2-axle rigid truck with a maximum load of 7 tonnes on the single axle dual tyre (SADT). Figure F.1 indicates that the required base thickness for this loading is 175 mm, assuming that the 10 mm construction tolerance is appropriate.

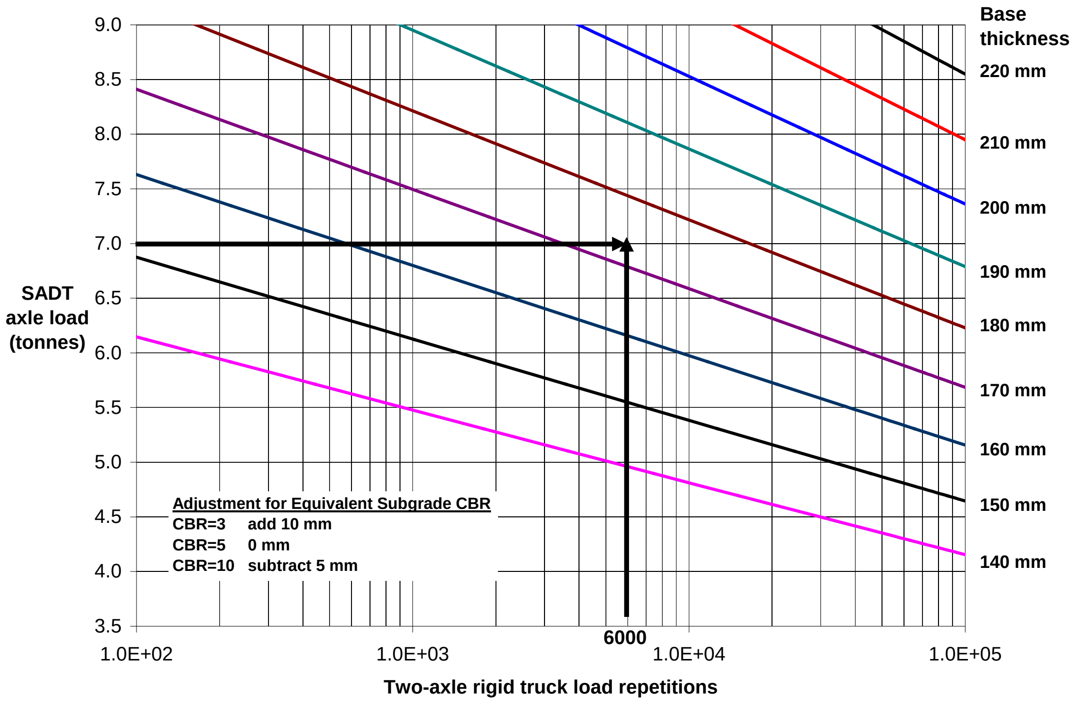


Figure F.1: Concrete base thickness (includes 10 mm construction tolerance)

The recommended pavement type for bikeways is a continuous lapped SL72 mesh, with transverse contraction joints saw cut at 4.0 m centres to 40 mm depth.

APPENDIX G: SIGNING AND DELINEATION OF WORKS

(Austroads 1999)

The signing and delineation of construction and maintenance works on roads and footpaths should be performed in accordance with Australian Standard AS 1742.3 (Standards Australia 1996) and any relevant local codes of practice and regulations. In general, provision for works on paths should be made in accordance with the principles of these standards. Additional consideration of cyclists should be made in accordance with the details set out below.

Section 8 (Austroads 1999) highlights a range of issues that are important to cyclists in relation to construction and maintenance works. As a principle objective of provision for cyclists adjacent to the works site, the riding surface should be maintained in a clean and smooth state. This may necessitate sweeping of the riding surface on at least a daily basis.

Figures G1, G2 and *G3* (in this Appendix) highlight the desired level of provision required in the vicinity of works, depending on he circumstances. The actual provisions to be made are dependent on the conditions that exist, including:

- presence of a traffic controller;
- existing level of bicycle use, and also of pedes- -trians in the case of shared use path diversions;
- available opportunities to provide for cyclists;
- road or path alignment;
- traffic speeds and volumes;
- duration of work;
- surface material and condition; and
- environmental impact.

Provision for cyclists on roads should be made in the following circumstances:

- where bicycle lanes exist;
- arterial roads;
- collector roads, with an AADT in excess of 3000 vehicles per day; or
- strategic and other significant bicycle routes.

Safety Barriers should be provided where required by AS 1742.3, and are generally appropriate where cyclists or pedestrians are detoured onto roads. Temporary (lower) speed limits may also be appropriate in this circumstance.

With reference to *Figure E*-l (Austroads 1999) where adequate provision for cyclists is not possible on a road, access along a path in the area of the roadside verge may be appropriate. Provided adequate separation from the work area can be maintained, it is generally acceptable to initiate and terminate the roadside verge bicycle access within the road lane transition zones either side of the work area.

For paths, reference should be made to Section 6.6 (Austroads 1999) (in relation to paths located away from road reserves) and to 6.6.2 (Austroads 1999) (separated paths) where temporary roadside verge access is required. The controls highlighted in these sections are applicable to temporary paths.

Containment fences should be provided in accordance with the requirements of AS 1742.3 and otherwise as required by Section 7.6.2 Austroads 1999). These may be appropriate to separate pedestrians and cyclists where a footpath is to be used for access by cyclists and where:

- significant pedestrian or bicycle volumes exist; or
- safety issues may arise due to the unexpected use of a footpath by cyclists.

Examples of provisions for paths located adjacent roads and in reserves are shown in *Figures G2* and *G3* respectively.

Temporary paths should be sealed. Whilst dependent on circumstances, such as bicycle volumes, safety and the extent of inconvenience to cyclists, this may be unnecessary where:

- the works are carried out during dry weather conditions;
- temporary path surface is firm, smooth and free of thorns.
- the works are carried out over a short period (e.g. less than 2 or 3 weeks duration); and
- path traffic is minimal;

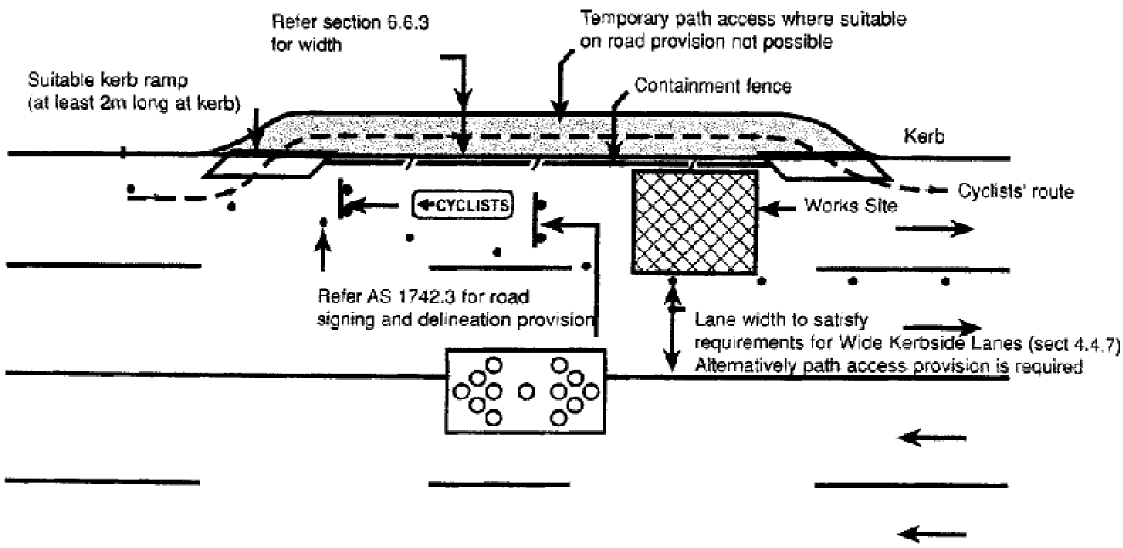


Figure G1: Works on Roads – Exclusive Bikeway Diversion

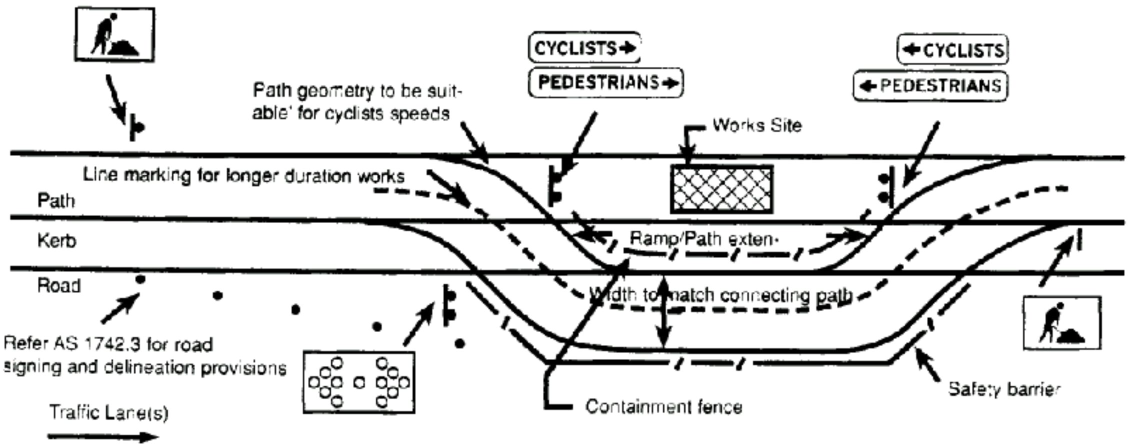


Figure G2: Works on Paths adjacent Roads – Shared Use Path Diversion

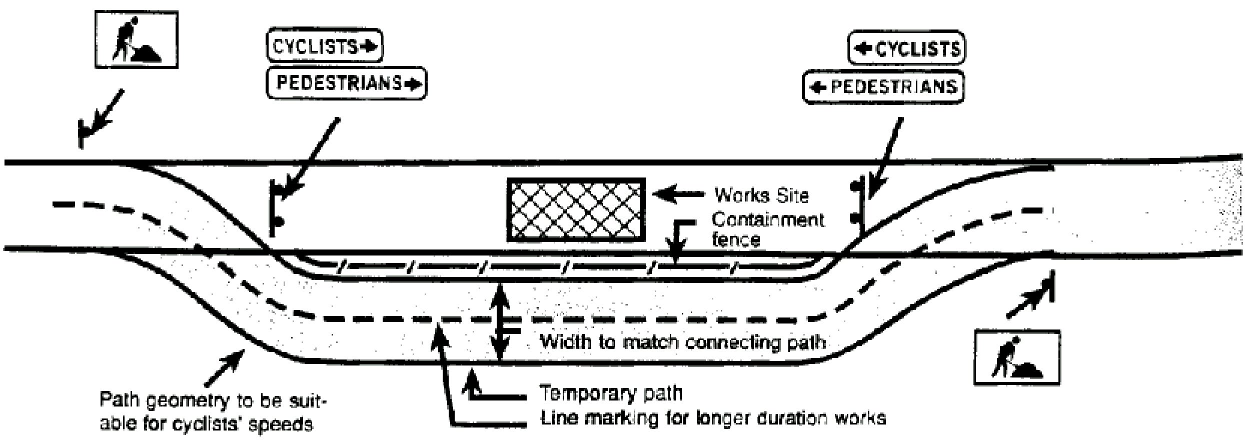


Figure G3: Works on Paths adjacent Roads – Shared Use Path Diversion

However, it is very desirable that temporary paths are sealed and delineated where works are carried out over longer periods. Separated paths should be suitably delineated regardless of the period of construction.

Where works on paths are carried out for a period exceeding one day, the works should be made sufficiently visible for night time path travel, so that path users are able to observe conditions under low ambient light conditions including temporary access paths, and take appropriate action. In addition, as a general principle, lighting on temporary access paths should not be less than the existing level on the original path.

Specific consideration may need to be given to the intersections of paths and roads. The measures taken to protect traffic should be balanced with consideration to all of the potential users and movements at such locations.

Where containment fences are used, to avoid catching the pedals of cyclists the fence should be set back from paths used by cyclists by at least 0.3 m. In the case of mesh fencing particular care is needed to ensure it remains tightly stretched and that it is supported regularly along its length.

Surface tolerances for bicycle riding surfaces are provided in Section 8.5.1 (Austroads 1999). Where steel road plates are used to cover excavated or damaged pavement surfaces, appropriate steps should be taken to ensure that any steps and grooves are within the tolerances of *Table 8-1* (Austroads 1999).

Reproduced from Austroads' Guide to Engineering Practice: Part 14 - Bicycles 2nd. Ed. 1999.

REFERENCES

Aguero, P. (1996). *Concrete dual use pathways and rider comfort: recent developments and review of guidelines*. Paper from Municipal Engineering 13th Annual State Conference Perth (WA), 6-8 March 1996, 12pp.

ARRB (2005a). *User guide to bicycle and shared path selection – using whole-of-life costing*. ARRB Group, Vermont South, Victoria.

ARRB (2005b). *Bicycle and Shared Path – Whole-Of-Life Costing Tool*. ARRB Group.

ARRB (2005c). *Sealed Local Roads Manual. Guidelines to Good Practice for the Construction, Maintenance & Rehabilitation of Pavements*. ARRB Group.

Austroads/AAPA (2006). Asphalt Cooling Rates, pavement work tips – no.46.

Austroads (1991). *Road Maintenance Practice*. 2nd Edition, Austroads, Sydney, New South Wales.

Austroads (1993). *Guide to Traffic Engineering Practice: Part 14 - Bicycles.*

Austroads (1999). *Guide to Traffic Engineering Practice: Part 14 - Bicycles.* 2nd Edition.

Austroads (2006). *Guide to Pavement Technology: Part 4D Stabilised Materials.*

Austroads (2009a). *Guide to Road Design: Part 6A: Pedestrian and Cyclist Paths.*

Austroads (2009b). *Guide to Traffic Management.*

Austroads (2009c). *Guide to Pavement Technology: Part 10 Subsurface Drainage.*

Austroads (2009d). *Guide to Pavement Technology: Part 3 Pavement Surfacings.*

Austroads (2009e). *Guide to Pavement Technology: Part 8 Pavement Construction.*

Austroads (2009f). *Guide to Pavement Technology: Part 9 Pavement Work Practices.*

Austroads (2009g). *Guide to Pavement Technology: Part 7 Pavement Maintenance.*

Austroads (2011). Guide *to Pavement Technology: Part 5 Pavement Evaluation and Treatment Design.*

Austroads (2012). Guide *to Pavement Technology: Part 2 Pavement Structural Design.*

Austroads (2014a). *Cycling Aspects of Austroads Guides.*

Austroads (2014b). *Guide to Pavement Technology: Part 4B Asphalt.*

Barry I.M. (1986). Te*chnical Report No. 75: The Influence of Trees and Shrubs on Pavement Loss of Shape*. Road Construction Authority, Kew, Victoria.

Bennett, D. and Moffatt, M. A. (1995). *Whole of life maintenance requirements of heavy duty pavements.* ARRB Research Report ARR 264.

BikeWest (1988). *Guidelines for the Design of Bicycle Facilities.* First Edition, Department of Transport, Nedlands, Western Australia.

Caltrans (1995). Californian Department of Transportation, *Californian Highway Design Manual: Chapter 1000 —Bikeway Planning & Design*. California, USA.

C&CAA (1997). *Concrete Pavement Design for Residential Streets*.

C&CAA (1999). *Road Note 56—Cycleways*.

CMAA (1997a). *Concrete Segmental Pavements, Guide to Specifying.* T44. Concrete Masonary Association of Australia, St Leonards, New South Wales

CMAA (1997b). *Concrete Segmental Pavements, Design Guide for Residential Accessways and Roads.* T45.

CMAA (1997c). *Concrete Segmental Pavements, Detailing Guide* T46.

DPTI (2010). *Method of Estimation of CBR from Classification Tests*, TP133

DSS (DYNAMIC SATELLITE SURVEYS) (1998). *Final Operations Report on the Canberra Community Paths Survey for A.C.T. City Services*. Report Number 97-55.

Foley, G.D. (2001). *Evaluation of Pavement Surfacing Characteristics – Victoria*, Draft ARR, ARRB Transport Research Ltd. Vermont South.

Mulholland, P.J. (1989). *Into a new age of pavement design. A structural design guide for flexible residential street pavements.* ARRB Special Report No. 41.

Oliver, J.W.H. (1986). *Road trials to evaluate mix designs for resurfacing residential streets: results after 6 years.* AIR 305-2, ARRB Transport Research, Vermont South.

Prem, H. (1989). *NAASRA Roughness Meter Calibration via the Road-Profile-Based International Roughness Index (IRI).* ARRB Research Report No. 164.

Robinson, P.D., Clayton, B., (2001). *Strategic Study into Asset Management, Condition Audit & Development of Performance Based Standards*. Contract Report RC1596, March 2001. ARRB Transport Research, Vermont South.

RTA (2000). *Interim Guide to the Maintenance of Concrete Pavements*. Roads & Traffic Authority Sydney, New South Wales.

RTA (2009). *Concrete Pavement Manual – Design and Construction (Edition* 2). Roads & Traffic Authority Sydney, New South Wales.

Standards Australia (1996). *AS 1742.3-1996 Manual of uniform traffic control devices - Traffic control devices for works on roads*. Standards Australia, Sydney.

Transport Research Laboratory (1996). *Application Guide No. 26: Footways - Design & Maintenance Guide*. Crowthorne, Berkshire, England.

Transport SA (1997). *MTRD Report No.105: Use of Controlled Low Strength Material as Infill*, Materials Technology, Walkley Heights, South Australia.

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