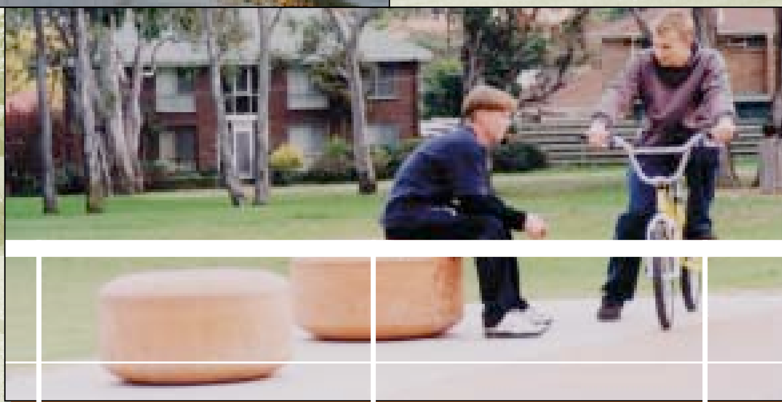
C&CAA T51

Guide

Guide to Residential Streets and Paths



CEMENT & CONCRETE ASSOCIATION OF AUSTRALIA

Guide

Guide to Residential Streets and Paths

Cement and Concrete Association of Australia

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C&CAA T51

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CEMENT & CONCRETE ASSOCIATION OF AUSTRALIA

The Cement and Concrete Association of Australia is a not-for-profit organisation established in 1928 and committed to serving the Australian construction community.

The Association is acknowledged nationally and internationally as Australia's foremost cement and concrete information body – taking a leading role in education and training, research and development, technical information and advisory services, and being a significant contributor to the preparation of Codes and Standards affecting building and building materials.

The Association's principle aims are to protect and extend the uses of cement, concrete and cement-based products by advancing knowledge, skill and professionalism in Australian concrete construction and by promoting continual awareness of products, their energy-efficient properties and their uses, and of the contribution the industry makes towards a better environment.

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Contents

Preface

THIS GUIDE supersedes the first edition (with the title 'Pavement Design for Residential Streets') published by the Association in 1997. In addition to routine updating of the content, the new guide covers a wider range of elements for which concrete can be used in residential subdivisions. The most significant changes distinguishing it from the first edition are:

- Revision of the recommended pavement thicknesses to reflect the latest changes adopted by Austroads in their 'Guide to the Structural Design of Road Pavements' published in 2004.
- Expansion of the text covering all design and construction aspects of concrete pavements.
- The inclusion of material on subsidiary elements typically required in land development, ie footpaths, bikeways, thresholds, parking bays and kerb-channels.

01 Introduction

For many years, residential streets were designed primarily for vehicular access. Today, however, equal consideration is given to residents, cyclists and pedestrians. Traffic calming techniques are used to provide a safe environment for all. In addition, the road reserve is now being used as a landscape element to enhance the environment and at the same time add value to the adjoining properties. Concrete pavements have become a key element in enhancing the streetscape as concrete easily provides a variety of colour, textures and forms. The durability of concrete provides the pavement with a long service life requiring minimal maintenance.

This guide covers the design, detailing and construction of concrete pavements for residential streets, bikeways and footpaths. It has been prepared to assist designers and contractors with the design and, more importantly, the detailing of concrete pavements to ensure that the pavement provides a high level of service ability during its design life. The content of the manual is arranged in the order in which the design and construction processes are performed.

Residential streets can be classified as minor, local access or collector and, as safety is important, are designed for vehicle speeds of 60 km/h and less. Pavement widths can vary from a single lane for minor roads to four lanes or more for collector roads. A kerb and channel or dish drain is generally provided along the edge of the pavement to facilitate drainage. For narrow roads, a one-way crossfall can be adopted to minimise stormwater drainage. Alternatively, the pavement can have a central dish drain that does not require any kerb and channel. Traffic volumes have an Annual Average Daily Traffic (AADT) in the range of less than 150 vehicles for minor roads and up to 2000 vehicles for collector roads.

02 Terminology

2.1 DEFINITIONS

The elements of a typical concrete pavement are shown in Figure 2.1. For this guide the key terms are defined as follows:

Base The main structural element of the concrete pavement.

Reinforcement Reinforcing bars or reinforcing fabric complying with AS/NZS 4671 *Steel Reinforcing Materials*[1].

Subbase The layer of selected material placed on the subgrade.

Subgrade The natural or prepared formation on which the pavement is constructed.

Wearing surface The trafficked surface and the top surface of the base.

Additional terms used in this manual and common for residential streets are defined in Appendix A.

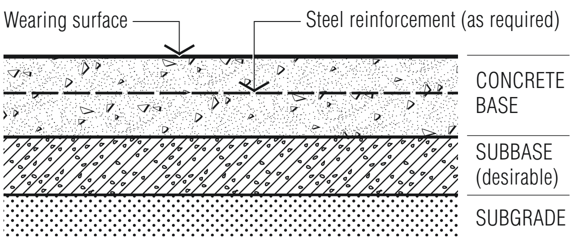


Figure 2.1 Elements of a concrete pavement

2.2 PAVEMENT TYPES

The two pavement types covered in this manual are illustrated in Figure 2.2.

Plain Concrete Pavement (PCP) This pavement type contains no drying shrinkage reinforcement except in irregular-shaped slabs or slabs containing pits. Transverse contraction joints are placed across the pavement at approximately 3- to 4-metre intervals.

Plain concrete pavement is the lowest initial cost concrete pavement, with the simplest construction method. Where ground conditions are prone to large uneven settlements it should be used with care due its lack of a positive connection across contraction joints and risk of unplanned cracking mid-slab.

Reinforced Concrete Pavement (RCP) This type of pavement is characterised by transverse contraction joints typically spaced in the range 10 to 15 metres. Steel reinforcement is provided to control, but not prevent, cracking which may occur between these joints.

Reinforced Concrete Pavements may be used on most subgrades, including those prone to uneven settlements.

For a particular application, both of these pavement types would have the same thickness, the reinforcement is used to control drying shrinkage cracking and is not designed to add to the load-carrying capacity of the pavement.

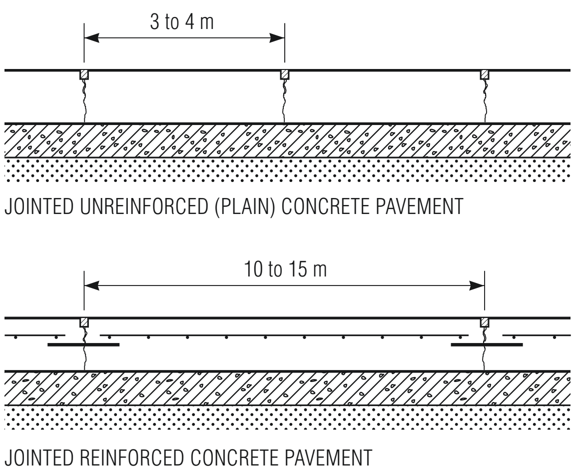


Figure 2.2 Concrete pavement types

The choice between these two pavement types requires an assessment of a number of factors. In general, a jointed unreinforced pavement offers a lower construction cost and a simpler construction procedure for straight paving runs. A jointed reinforced pavement will cost slightly more to construct, but offers considerable simplification in designing joint layouts for intersections and in turning areas of cul-de-sacs or minor roads. It will also often require less future maintenance. On problem sites, the use of a reinforced pavement may be prudent to control unplanned cracking.

In many projects there will be a case for a mixture of both pavement types to utilise the benefits of each.

Continuously Reinforced Concrete Road Pavement (CRCP) This pavement type is rarely used for residential streets due to its higher cost; it is used mainly on major road projects. Transverse contraction joints are not formed in the pavement since the continuous longitudinal reinforcement is designed to limit the width of any cracks that form. CRCP pavements develop transverse cracks at spacings in the range of 0.5 to 2.0 metres. The design procedure for this type of pavement is covered in the Austroads pavement design guide[2].

Steel Fibre Reinforced Concrete Pavements are commonly used at roundabouts, intersections and bus bays where there is an unavoidably high incidence of odd-shaped slabs. Steel fibre concrete is easy to place in odd shapes and provides good control of shrinkage stresses in acute slab corners where conventional reinforcement is of little benefit.

A wide range of steel fibre size and type is currently available and the fibre dosage required to achieve a given performance varies considerably. Design procedures therefore need to recognise the characteristics of the fibre to be used and guidance should be sought from the fibre supplier.

03 Streetscape

3.1 STREETSCAPE DESIGN

Residential streets have traditionally been designed by engineers and surveyors solely to meet the needs of vehicles. Today the emphasis has changed to creating a streetscape meeting the broader needs of people, rather than just providing for the carriage of vehicles.

If the designer starts from the viewpoint of streets as being an important open space for the community, then a much more pleasing environment results. These sentiments are not new. Edna Walling, the famous Australian landscape designer (quoted by Matthews[3]), expressed the sentiment that *'streets are the front gardens of our nation'*. The street that embraces this concept creates a much more livable environment than the street designed on the vehicle-only basis. In this scenario, residents, pedestrians, cyclists and motorists all have equal status.

AMCORD[4] provides guidelines for the overall planning, street design and construction to also cater for pedestrians, cyclists and public utilities. AMCORD encourages both the development of attractive streetscapes in new residential areas and provides guidance on existing streetscapes in established areas. The resultant narrow pavement widths and various traffic-calming techniques combined with the need to consider aesthetics mean that a versatile pavement material is required.

Concrete can provide a variety of colours, textures and forms to achieve different appearances. Concrete can easily be constructed to the narrow trafficable widths often required for traffic calming because it does not need specialised laying equipment and rollers.

To provide pleasant streetscapes, an overall landscape plan is developed for the full road reserve. Apart from the pavement, other design elements include:

- street furniture;
- walls and fences; and
- vegetation and landscaping.

This enables the street, or area, to have a distinctive theme or feel.

The plan developed must be appropriate for the area and must consider various values including –

- historical;
- cultural and social; and
- environmental.

The fundamental objective in street design is to make streets safe for pedestrians, cyclists and motorists. Measures to limit vehicle speed, provide adequate turning facilities, parking bays for visitors, site access and to maximise visibility are essential requirements.

3.2 DECORATIVE SURFACE FINISHES

3.2.1 General

Concrete pavements offer a significant advantage over other forms of paving in that they can be provided with a very durable, skid-resistant surface in both dry and wet condition which can have a wide variety of appearances. For example, a coarser texture to improve skid resistance can be provided at curves, intersections and on steep gradients, while the wide variety of colours and forms achievable in the surface enable the pavement to form an integral part of the streetscape. The texturing and colouring is done as part of the concreting process[5].

Tyre/road noise from the wearing surface of residential streets is not a relevant issue since at low traffic speeds (ie < 60 km/h) noise from the vehicle's power train is the dominant noise source. Tyre/road noise is dominant only at speeds of about 80 km/h or more. Therefore, with residential streets it is important to focus on safety. Providing a rough texture to the wearing surface is one method of maintaining low vehicle speeds.

Decorative concrete has been used in many new residential developments to:

- provide prestige to selected pavement areas (eg signature statement);
- provide a unique themed look for individual projects;
- increase delineation for different pavement functions, such as through pavements, pedestrian crossings and parking areas;
- highlight the entrance to smaller streets from the main thoroughfare;
- reduce vehicle speeds in residential areas.

It is important with all finishes that effective quality control methods are put into place to ensure durability. In all applications the concrete should be well compacted and properly cured. For more information see *Guide to Concrete Construction* [6].

3.2.2 Simple Finishes

Simple surface textures can be applied using steel tynes, brooms, wood floats or a dampened hessian drag.

A suitable low-speed surface to provide adequate skid resistance can be produced by either wood floating or by dragging hessian over the surface of the finished concrete. Brooming or tyning can be used where greater skid resistance is required.

A tyned texture is usually specified to provide adequate skid resistance on high-speed roads where vehicle speeds are equal to or in excess of 70 km/h and aquaplaning is also a concern. It is not normally used or required on low-speed residential streets. Alternatively, a tyned texture may be used on steep grades (ie > 16%) to improve traction for vehicles. See *Road Note 24*[7]

3.2.3 Stamped Concrete

Stamped concrete can be used to imitate cobbles, brick, timber and slate. Almost any texture can be achieved including timber board textures. Care must be taken to avoid a surface that is too smooth. A secondary process may be required to provide adequate skid resistance.

Depending on the texture and depth of the pattern selected, various levels of ride quality can be achieved. This variation can be used to advantage in residential areas to encourage a low-speed environment and to alert drivers to intersections, pedestrian slow points, parking areas and bus stops.

Stamped concrete patterns are formed by using integral (full-depth) coloured concrete or by broadcasting and trowelling a coloured dry shake into the surface of the fresh concrete in two applications. A minimum concrete strength of 32 MPa is recommended. Depending on the texture required for the finished wearing surface, flexible moulds or stamping tools (metal grids) are placed and worked into the surface of the concrete. The application of uniform force to the rubber moulds or stamping tools is required to ensure a uniform impression is achieved. Prior to stamping with the flexible moulds, a release agent is first broadcast onto the surface to aid in release. Alternatively, the pavement is covered with a sheet of plastic prior to the application of the stamping tools in order to give rounded edges to the indentations.

Residue release agents/powders should be removed by stiff brushing, detergent washing or high-pressure hosing. These processes should be undertaken following 3 days of curing. To remove any additional residue, an application of a mild acid wash, at a ratio of 1 part acid to 25 parts water is suggested. This will remove remaining release agents/powders and slightly etch the surface, providing a key for subsequent sealer coats. The surface should be rinsed with clean water to neutralise the acid. A sealer may then be applied to the completed pavement to protect the wearing surface and enhance the colour as required. Stamping does not replace the proper procedure of jointing within the pavement, as the depths of indentations are too shallow to act as weakened-plane joints.

For more information on stamping, see *Briefing 01*[8].

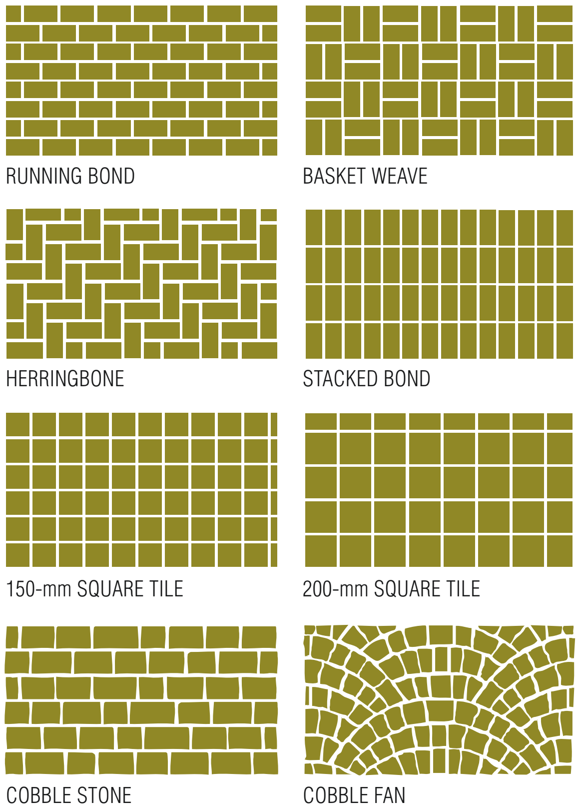


Figure 3.1 *Stencil patterns– many of the patterns offered by segmental paving are replicated by stencil and stamp techniques*

3.2.4 Stencilled Concrete

Stencilling can be used to achieve a variety of brick and tile-like finishes, complete with mortar lines. Patterns available include running bond, stacked bond, basket weave, herringbone, square tile, cobblestone and cobble fan. Additional special stencils are available, including circular patterns, motifs and street names.

Installing a contrasting bond pattern to pavement edges and joints often enhances the appearance of stencilled areas to highlight joints, penetrations and changes in gradient.

Placing a cardboard stencil into the surface of the wet concrete forms a stencilled surface. A minimum concrete strength of of 32 MPa recommended. A coloured dry shake surface hardener consisting of oxides, cement, fine aggregate and hardeners is spread onto the surface by hand-casting and trowelling, in two applications, to achieve a uniform colour and thickness. When the surface has hardened, the cardboard stencil is lifted from the pavement. A sealer may then be applied to the completed pavement to protect the wearing surface and enhance the colour as required.

Effective quality control is very important when stencilling concrete. The processes for stencilling are relatively simple. The timing of each stage and the application of dry shakes are, however, critical to the success and durability of the finish.

For more information on stencilling, see *Briefing 01*[8].

3.2.5 Exposed Aggregate

For an exposed aggregate finish, one to three millimetres of surface paste is removed to expose the coarse aggregate to achieve an attractive finish which may improve skid resistance. By varying the colour of the aggregate and cement paste, in conjunction with the depth of exposure, a variety of visual effects can be achieved. Concrete mixes with gap-graded aggregates give the best visual stone density on exposed aggregate surfaces. Alternatively, special coloured aggregates may also be 'hand seeded' onto the surface. A minimum concrete strength of 32 MPa is recommended.

An exposed aggregate finish is obtained by applying a set-retardant to the surface of the concrete approximately 2 to 3 hours after placing and then covering the pavement with plastic sheeting. After 18 to 24 hours, 1 to 3 millimetres of the cement paste is removed using a low-pressure hose and a stiff broom or by dry mechanical brushing, to expose the aggregate. The finish can be achieved without a surface retardant, but timing is very critical and working times will be much shorter.

For more information on stencilling refer to *Briefing 02*[9] and *Road Note 64*[10].

3.2.6 Coloured Concrete

Coloured concrete may be used for any form of concrete pavement. The concrete is normally coloured with the use of metallic or synthetic oxides, either mixed through the concrete (integral colouring) or worked into the surface as a 'dry shake'. Integral colouring ensures that the colour has the same life as the concrete, whereas with the dry-shake method the colour may be lost with surface wear. Contrasting colours are often used. For example, one colour for 'through pavement' areas and another colour for traffic islands, medians, parking or pedestrian areas.

3.3 TRAFFIC CALMING

Traffic calming is achieved by the use of a variety of techniques to encourage driving at lower speeds, thus improving pedestrian safety and the amenity of the area. Vehicles can be restricted to the selected design speed through:

- limiting the length of straight sections in the street;
- introducing bends;
- controlling on-street parking;
- incorporating speed-control devices.

Limiting the length of the straight path in which a vehicle can be driven is possibly the most important traffic safety measure since it limits the speed that a vehicle can physically attain. The low-speed environment provides more reaction time for drivers and pedestrians, and if there is a collision it reduces the severity of the accident. Straights can be limited by winding the street through the road reserve either by general curves or by off-set straights. Interrupting long straights with speed-control devices is another alternative.

Speed control devices include:

- roundabouts;
- skewed intersections;
- slow points;
- narrow pavements;
- curved or staggered alignments (limiting the length of straights);
- threshold treatments;
- change of surfacing;
- speed humps.

Landscaping can also be used to modify driver habits, but it must be planned not to impair vision.

Concrete can be used in all of the above techniques and with imagination and appropriate landscape design can achieve an attractive streetscape. A lateral change in direction is usually less obtrusive to drivers than a speed hump, see Figures 3.2 and 3.3.

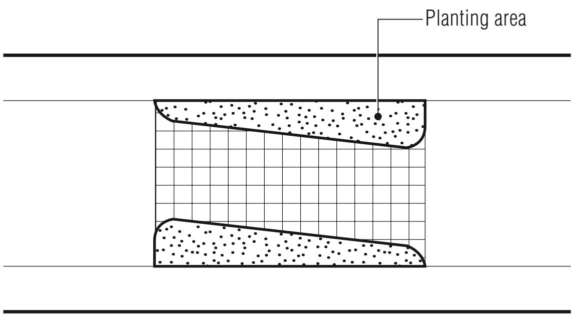


Figure 3.2 *Slow point*

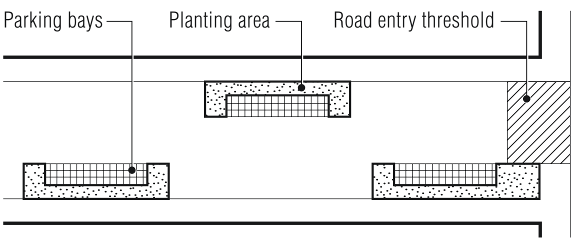


Figure 3.3 *Staggered alignment*

04 Design Process

4.1 GENERAL

This section outlines the various elements considered in determining the design thickness of the concrete base and detailing of the pavement in order that it will remain functional throughout its design life. Each element is then discussed separately in Sections 5 through to 10.

4.2 SITE INVESTIGATION

The site investigation consists of undertaking a soil investigation, estimating the design traffic and carrying out a site survey.

The soil investigation determines the characteristics and strength of the natural soil on which the pavement is to be constructed. The soil properties influence subgrade preparation, the need for a subbase and the determination of the concrete base thickness.

The thickness design procedure for concrete pavements incorporates not only the number of axle loads and commercial vehicle axle groups (CVAG) but also the spectrum of the axle loadings. Axle loads are not converted into equivalent standard axles (ESAs) as in designing flexible pavements. Thicknesses for lightly trafficked residential streets are controlled by construction, service or delivery vehicles since axle loads from cars have little impact on base stresses. For collector and other street types, bus traffic or other heavy commercial vehicles will usually control the thickness.

It is necessary to carry out a site survey for the proposed pavement to evaluate the site topography and features such as existing or proposed public utilities which may influence the pavement design. Drainage of residential street concrete base and subbase layers is not considered as crucial as for flexible pavements. This is because, unlike flexible pavements, the concrete base provides the vast proportion of the load-carrying capacity of the pavement. Also, unlike granular pavement layers, the strength of the hardened concrete pavement is not reduced by water.

4.3 THE SUBGRADE

The high modulus of elasticity of concrete enables concrete pavements to distribute loads over large areas. Concrete pavement thickness is therefore not particularly sensitive to the strength of the subgrade. It is much more important that the subgrade provides reasonably uniform support.

Subgrade uniformity is influenced by moisture/density control, variations in material type and expansive soils. These are discussed in detail in Section 6.3 *Subgrade Uniformity.*

Where highly expansive subgrades occur, a cover of low-volume-change soil over the full width of the subgrade is recommended. This is also recommended where moderately to highly expansive subgrades occur in temperate areas subject to prolonged periods of dry weather Alternatively, a layer of the existing soil may be stabilised by the addition of lime and/or cement. This is discussed in detail in Section 6.4 *Stabilised Subgrades.*

4.4 THE SUBBASE

As previously stated, the concrete base provides the pavement's major structural capacity. The functions of a subbase in a concrete pavement include:

- providing uniform support to the concrete base;
- reducing deflection at joints and hence maintenance of effective load transfer across joints (see RTA's roundabouts publication[11]).
- assisting in controlling volume changes in moderately to highly expansive soils;
- eliminating erosion and pumping of the subgrade (especially at joints) as a potential failure mode (generally for heavy trafficked pavements);
- providing a stable working platform for pavement base construction.

For heavily trafficked roads (beyond the scope of this guide) cement stabilised or lean-mix concrete subbases may be used to control subbase erosion due to pumping (in accordance with the Austroads guide[2]).

4.5 CONCRETE

The principle properties of a pavement material requiring consideration are surface finish, flexural strength, skid resistance and durability. The various types of surface finishes are discussed in Section 3 *Streetscape*, while the other properties are discussed in detail in Section 8 *Concrete*.

4.6 JOINTS

4.6.1 General

Joints are provided in a concrete pavement for construction considerations, to minimise the risk of unplanned cracking and to avoid conflict with other structures and/or penetrations. The types of joints that may be required in concrete pavements covered by the guide are:

- ***Contraction joints*** – control transverse and longitudinal cracking in the pavement due to drying shrinkage and warping. Reinforcement placed in the upper third of the pavement (except for thin pavements) is frequently used in conjunction with contraction joints to achieve this objective.
- ***Construction joints*** – divide the pavement into suitable lengths and widths for construction purposes.
- ***Isolation joints*** – isolate pavement elements from each other or other structures in certain situations.
- ***Expansion joints*** – accommodate expansion of the pavement, primarily due to elevated temperatures.

These are discussed in detail in Sections 10.2 *Contraction Joints,* 10.3 *Construction Joints,* 10.4 *Isolation Joints* and 10.5 *Expansion Joints*.

4.6.2 Joint Sealants

It is recommended that pavement joints designed to accommodate movement should be properly sealed. This is discussed in detail in Section 10.6 *Joint Sealing.*

4.6.3 Joint Layout

After determination of joint types and slab dimensions, a joint layout can be prepared. The principal aim should be to develop a simple layout to maximise the use of uniform slab dimensions. This is discussed in detail in Section 10.7 *Joint Layout*.

05 Site Investigation

5.1 GENERAL

The site investigation covers three areas: soil investigation, traffic estimation and site survey. The time devoted to these preliminaries will vary according to the size and status of individual project and previous experience. However, to meet the design objectives, each of the areas warrants some consideration.

5.2 SOIL INVESTIGATION

An investigation should be made of the characteristics and strength of the soil on which the pavement is to be constructed.

The soil properties will influence subgrade preparation; the need for, and specification of, a subbase; and the thickness of the concrete base. However, it should be noted that the design thickness of the concrete base is not particularly sensitive to the subgrade strength.

For very weak subgrades having a CBR of less than 2% (refer to Section 6.2 *Subgrade Support*), the subgrade will require improvement, either some form of stabilisation (ie lime/cement) or additional filling in order to support construction loads. Austroads pavement design guide[2] provides more information.

5.3 TRAFFIC ESTIMATION

The performance of a residential street pavement is affected by the nature and level of traffic loading encountered over its design life. Pavement thicknesses for lightly trafficked residential streets are generally controlled by service or delivery vehicles.

Flexible and rigid pavement designs are both based on axle loads. However, rigid pavement design uses commercial vehicle axle groups (CVAG), which may include the spectrum of axle loads, in contrast to converting axle loads to equivalent standard axles (ESA) for flexible pavements.

CVAG spectrum data are not readily available for residential streets. However, during the development of ARRB Special Report No. 41[12], load spectrum data were collected for 57 local road sections, sufficient to give a reasonable estimate of the average and 90 percentile values for each traffic category listed in Table 5.1.

The 90 percentile values can be taken as conservative estimates of design traffic, taking into account construction traffic during the staging of subdivisional work.

The designer may undertake a traffic survey or use existing data to determine the design number of CVAG. If no traffic data is available, the values shown in Table 5.2 may be used.

The design life of concrete pavements is normally 40 years compared with 20 to 25 years for flexible pavements. It is important when comparing pavement alternatives in a life-cycle-costing analysis that the same analysis period is used for all pavement types. With a concrete pavement, the additional thickness required for the difference between a design life of 40 years and 20 years is not significant compared to the total thickness of the pavement.

TABLE 5.1 Street Classifications (APRG 1998[13] *Table 13.7.2*)

	AADT† limits	Percent	AADCV‡
Street Type	(two-way)	CVs††	(two-way)
Minor:	30–90	3	1–3*
Local access:			
without buses	400	4	16
with buses	500	6	30
industrial	400	8	32
Collector roads:			
without buses	1200	6	72
with buses	2000	7	140

† *Annual Average Daily Traffic*

‡ *Annual Average Daily Commercial Vehicles (over 3 t gross mass)*

†† *Commercial vehicles*

* *These traffic volumes usually are not halved for one-way traffic due to narrowness of Minor Roads*

5.4 SITE SURVEY

5.4.1 General

It will be necessary to carry out a site survey for the proposed pavement. The site topography, drainage and surface features such as existing or proposed public utilities will influence the pavement's geometric design.

5.4.2 Public Utilities and Service Reinstatement

In both construction and reconstruction projects, the planning lead time should allow for installation or relocation of public utilities. The various mains and services can be installed in advance of pavement construction or, in the case of electrical services, conduits can be placed with draw wires for later insertion to the requirements of the relevant authority. The use of conduits for various services also allows easy later modifications or maintenance. It is worth remembering that additional conduits placed in advance of pavement construction will cost less and cause much less inconvenience than future road openings or boring.

An advantage of concrete pavement is that the location of utility conduits can be marked in the pavement surface.

It is important to design a concrete pavement with services in mind. Other options to allow for later reinstatement, where aesthetics and colour matching are of concern include:

- contrasting coloured or textured strips of concrete;
- removable pavement types, such as pavers or pitchers across the pavement.

5.4.3 Drainage

Residential streets are not heavily trafficked by high axle loadings. Inadequate drainage is more likely to affect the performance of granular materials in the subgrade and subbase rather than that of the concrete base. With concrete pavements, the concrete base provides the vast majority of the structural strength. With residential street concrete pavements, little benefit for high cost is therefore achieved by the provision of subsurface drainage. Other considerations such as presence of spring activity or other known excessive moisture exposure may therefore govern the need for subsurface drains for residential streets.

TABLE 5.2 Design commercial vehicle axle groups by street type (based on APRG 1998[13] *Table 13.7.4*)

Street Type	Design life (years)	Annual traffic growth rate (%)	Lane factor†	Mean axle groups per CV	Design CV axle groups
Minor:					
single-lane traffic	20	0	2‡	2.0	1.5×10^4
	40	0	2‡	2.0	2.5×10^4
two-lane traffic	20	0	1	2.0	2×10^4
	40	0	1	2.0	4×10^4
Local access:					
without buses	20	1	1	2.1	1.5×10^5
	40	1	1	2.1	3×10^5
with buses	20	1	1	2.1	2.5×10^5
	40	1	1	2.1	5.5×10^5
industrial	20	1	1	2.3	3×10^5
	40	1	1	2.3	6.5×10^5
Collector roads:					
without buses	20	1.5	0.9	2.2	6.5×10^5
	40	1.5	0.9	2.2	1.5×10^6
with buses	20	1.5	0.9	2.2	1.5×10^6
	40	1.5	0.9	2.2	3×10^6

† *One-way traffic volume to design lane volume*

‡ *For streets ≤5 m width or where two-way traffic traverses a common wheelpath*

Longitudinal and cross gradients for concrete pavements are the same as for other pavements. The choice of one-way (for narrow pavements) or two-way crossfalls will influence both the location of construction joints and the direction of paving runs. The narrow pavement widths resulting from AMCORD's recommendations allow a one-way crossfall to be adopted with resultant cost savings. Surface drainage is minimised and this results in only one storm water drainage line being needed for these pavements as shown in Figures 5.1 and 5.2.

Integral kerb and channel, kerb only, roll or mountable kerbs, and dish drains can be readily provided.

Kerb-inlet type gullies are preferable for concrete pavements, as they do not intrude into the carriageway. However, grated gully pits can be accommodated in a concrete pavement, detailed procedures are provided in Section 10.7 *Joint Layout*.

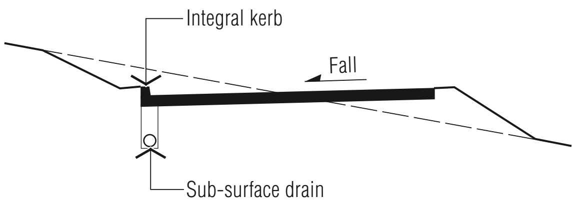


Figure 5.1 *One-way crossfall*

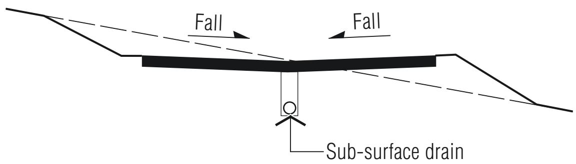


Figure 5.2 *Central dish drain*

06 Subgrades

6.1 GENERAL

A reasonably uniform foundation is essential to the good long-term performance of a concrete pavement. An assumption that a concrete pavement will bridge over a poor subgrade could lead to a false sense of security. However, concrete pavements have been constructed successfully on a wide range of poor sites including floodplains, mine subsidence areas and very weak soils.

6.2 SUBGRADE SUPPORT

6.2.1 General

The high modulus of elasticity of concrete enables concrete pavements to distribute loads over large areas. As a result, deflections are small and pressures on the subgrade are low. Concrete pavement thickness is therefore not particularly sensitive to the strength of the subgrade. As stated above, it is much more important that subgrade support be reasonably uniform with no abrupt changes in the degree of support.

Subgrade strengths for pavements have traditionally been defined by determining the California Bearing Ratio (CBR) of the founding material. A typical range for weak to strong soils would be 2% to 15%. This guide uses the following very broad categories for which pavement designs have been prepared:

TABLE 6.1 CBR values used for pavement designs in this manual

Strength of soil foundation	**Design CBR** (%)
Poor	2
Moderate`	5
High	10
Very high	15

In selecting the soil strength category (or a 'Design CBR'), the designer is attempting to assign a value that best represents close to the weakest soil strength condition to be endured during the design life. This may or may not be present at or during construction, and should be a conservative rather than optimistic value, for several reasons:

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

6.2.2 Poor Strength Soil Foundation

Poor strength soils are those that would normally require pre-treatment if the pavement were to be constructed while they are in that state. This pre-treatment may comprise:

- placing of a stronger fill material to provide a better construction platform;
- chemical stabilisation using lime and/or cement if soil conditions are accommodating; or
- use of a geosynthetic as a separation layer.

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

Pavement designs given in Section 9 *Thickness Design* are inclusive of 'Poor 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 may predominate;

- in zones subject to poor drainage and inundation; or
- where climatic conditions result in high moisture content.

6.2.3 Moderate Strength Soil Foundation

These soil conditions generally would not require special pre-treatment of the soil apart from compaction prior to the placement of the pavement. However, in except for loose frictional soils or granular materials, most subgrades will benefit from minimal disturbance, as the insitu undisturbed soil structure will have an intrinsic strength that is worth preserving. Many road authorities generally avoid routine reworking of insitu subgrades in favour of soft spot identification by proof-rolling, followed by local improvement.

Pavement designs given in Section 9 are inclusive of 'moderate soil strength' based on a design CBR of 5%.

Some situations where these soil conditions may exist are:

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

Generally, Poor Strength soils and Moderate Strength soils are the dominant soil strengths.

6.2.4 High Strength Soil Foundation

High strength soils have been assigned a design CBR of 10%, which equates to the maximum design strength that State road authorities generally allow. Designs in Section 9 are also inclusive of this soil strength.

A design CBR of 10% should be assigned only following expert advice and inspection, and preferably a detailed site investigation.

Some situations where these soil conditions may exist are where:

- native soil comprises weathered rock;
- good quality selected fill has been placed with good compaction;
- soil has or will be stabilised and laboratory testing has confirmed high strengths; or
- pavement is constructed in a semi-arid and well-drained locality.

It is expected that high strength soils would only rarely occur within significant lengths of a proposed pavement. Some exceptions might include a sandy coastal environment or through hilly areas of rock or gravel deposits.

6.2.5 Very High Strength Soil Foundation

Very high strength soils have been assigned a design CBR of 15%, which is the maximum design strength that most State road authorities permit. Designs in Section 9 are inclusive of this soil strength.

As with the assignment of a CBR for a high strength soil, the CBR for very high strength soil should also be assigned only following expert advice and inspection, and a detailed site investigation.

Some situations where these soil conditions may exist are where :

- native soil comprises rock and is levelled using a granular layer including, where appropriate, a granular drainage layer;
- structural fill (a designed layer of laboratory-tested material) has been placed using controlled compaction;
- select or structural fill has or will be stabilised and laboratory testing has confirmed very high strengths; or
- a granular subbase 100 mm thick is placed on a subgrade characterised as a high strength soil.

Unless such soil conditions already exist, the benefits gained by using this soil strength are often marginal compared to the cost of providing such a foundation.

6.3 SUBGRADE UNIFORMITY

6.3.1 General

Factors that influence subgrade uniformity are:

- moisture/density control;
- variations in material type;
- expansive soils.

6.3.2 Moisture/Density Control

In clay or other fine-grained soils, subgrade uniformity can be enhanced by proper moisture/density control during construction. Two conditions can lead to movement within these soils in service:

- Soils that are compacted too dry, or are allowed to dry out before paving, resulting in subsequent moisture gain.

- Subgrades with varying insitu moisture contents, resulting in differential moisture change.

After some time in service, clay-type subgrades may reach an equilibrium moisture content approaching the plastic limit, typically slightly below the laboratory optimum moisture content. Once this condition is reached, further moisture change and the tendency to swell/shrink will be reduced.

As a general practice, it is recommended that clay-type subgrades be compacted at moisture contents slightly below the optimum values determined in the laboratory.

For low-plasticity or non-cohesive subgrades, the same moisture/density controls used for other pavements apply to concrete pavements.

6.3.3 Variations in Material Type

Any abrupt changes of material type should be eliminated during subgrade preparation. Selective grading or mixing of material to provide a transition between material types can control this factor.

6.3.4 Expansive Soils

Where moderately to highly expansive subgrades occur, a cover-layer of low-volume-change soil over the full width of the subgrade is recommended. Alternatively, a layer of the existing soil may be stabilised as discussed in Section 6.4 *Stabilised Subgrades*.

The function of the cover-layer is to minimise changes in moisture content and hence volume changes in the underlying expansive soil. The appropriate thickness for non-expansive cover layers will depend on expected site conditions before and after construction (depth of fill, etc) and on local experience.

6.4 STABILISED SUBGRADES

In many lightly trafficked streets or parking areas, subgrade stabilisation can provide a suitable subbase for both the pavement and construction equipment. Not all pavements will require subgrade stabilisation. Very weak subgrades (CBR values of 2% or less) will probably require some form of stabilisation in order to support construction loads.

The stabilisation of clay subgrades will enhance their stability under conditions of alternate wetting and drying and will extend the construction period by providing an all-weather working platform.

6.5 SUBGRADE PREPARATION

In addition to proper moisture/density control, the design drawings and specification should cover two points that will assist in achieving subgrade uniformity:

- The subgrade should be prepared for the full pavement formation, extending at least to the back of kerbs.
- The reinstatement of utility trenches during construction should be closely supervised to ensure that the requirements of the subgrade uniformity are achieved. The use of controlled low-strength materials –flowable fills that do not require compaction and do not settle after construction should be considered (see Matthews[14]).

07 Subbases

7.1 GENERAL

The function of the subbase layer in a concrete pavement should be distinguished from the equivalent layer in a flexible pavement. As the concrete slab provides the pavement's major structural capacity, it will usually be uneconomical to provide a subbase merely in order to reduce the concrete thickness.

The functions of a subbase in a concrete pavement are related to future serviceability and are listed in Section 4.4 *The Subbase.*

The Portland Cement Association[15] notes that concrete pavements designed to carry less than 100 to 200 heavily loaded vehicles per day do not suffer from erosion damage, and so do not require a subbase for this reason alone. However, the other functions of a subbase may be required on a specific project. Given that erosion is not a major concern for concrete pavements under light traffic, such as residential streets, the importance of sub-surface drainage is reduced. For industrial estates where heavy vehicular traffic is expected, a subbase will be required.

7.2 SUBBASE THICKNESS AND WIDTH

As the subbase does not contribute significantly to the load capacity of a concrete pavement, its thickness is empirically determined. Minimum suggested subbase thicknesses are shown in Table 7.1. Where kerbs are provided, the subbase, irrespective of type, should extend at its full depth to at least the back of kerbs or other edge stops. It should be placed at this width in advance of kerbs to provide for their support. On streets that have no integral kerbs, it is recommended that cement-treated and granular unbound subbases extend at least 300 mm beyond each side of the carriageway.

TABLE 7.1 Recommended subbase thickness (mm)

Concrete base thickness (mm)	Subbase thickness for soaked subgrade CBR values		
	≤5%	5–10%	>10%
Up to 125	100	–	–
125–150	125	100	100
Above 150	150	125	125

7.3 UNBOUND SUBBASES

Granular subbase material may be composed of sand-gravels, crushed rock, crushed slag, crushed recycled concrete or a mixture of these materials. The material should meet the following basic requirements:

Maximum size	Not more than 1/3 of the subbase layer thickness
Amount passing 75-µm sieve	15% maximum
Plasticity index	6 maximum
Liquid limit	25% maximum.

Materials not complying with these requirements may be used if they are suitably stabilised.

The material should be graded to permit compaction that will minimise post-construction densification. Recommended compaction requirements are the same as for other pavements.

Where unbound subbases are used, the increase in effective subgrade strength is minor and should be ignored for design purposes.

7.4 BOUND SUBBASES

Residential streets are generally not heavily trafficked by commercial vehicles and therefore do not require a bound subbase to resist erosion. Erosion is not a limiting factor with the performance of these pavements.

When bound subbases are used, a significant increase in the effective subgrade strength is achieved. For bound subbases a cemented, not just modified, material is required. The probable range of cement contents for a cement-bound material will be 4–6% by weight of the untreated granular subbase material. However, modified subbase materials may be used for lightly trafficked pavements. The probable range of cement contents for cement-modified material will be 2–4% by weight of the untreated granular subbase material (see *Recycling Pavements by Cement Stabilisation*[16]).

7.5 SUBBASE CONSTRUCTION

The subbase should be trimmed to crossfalls and surface tolerances as would apply in other pavements, to avoid undesirable fluctuations in the concrete base thickness. Finished surface level tolerances should be +0 mm to –10 mm to ensure the full base layer thickness is cast.

For bound subbases, the longitudinal jointing, if it occurs (not usual), should be arranged so the longitudinal joints in the subbase do not occur within 200 to 400 mm of longitudinal joints in the concrete base layer.

08 Concrete

8.1 GENERAL

The principal properties required by the concrete base are –

- flexural strength;
- skid resistance; and
- durability.

The designer is mainly interested in the properties of the hardened concrete. However, since concrete is in a plastic condition when placed; its placing, compaction, finishing and curing are of utmost importance in achieving the hardened concrete with the desired properties.

8.2 STRENGTH

The strength of concrete used in pavements is usually specified in one of two ways:

- Compressive – measured by crushing a cylinder along its vertical axis (AS 1012 Parts 8 and 9[17])
- Flexural – measured by breaking a beam in flexure (AS 1012 Parts 8 and 11[17])

When, under vehicular traffic, a concrete pavement is loaded to the point of fracture, the concrete fails in flexure rather than compression. For this reason, the concrete thickness design is based on flexural strength rather than compressive strength. Flexural strength grades in the range of F3.5 MPa to F4.25 MPa are typically specified for concrete pavements.

Compressive strength testing is usually used as an indirect measure of flexural strength.

A 28-day 4.25-MPa average flexural strength will typically be obtained by a 28-day characteristic compressive strength in the range of 32–40 MPa. Where no information is available the designer may, for the thicknesses given in this manual, conservatively assume either 4.25-MPa flexural and specify 40-MPa compressive; or 3.50-MPa flexural and specify 32-MPa compressive strength concrete.

TABLE 8.1 Recommended investigatory levels for skid resistance

Road situation	Investigatory SFC levels (VicRoads/RTA 1995)	Minimum Grip No.* (Max. vehicle speed km/h) (Transport SA 2001)
Difficult sites – steep grades, tight bends, traffic signal approaches, roundabouts	55	0.50–0.55 (60–80)
Urban arterial roads (undivided)	0.45	0.45 (60)
Rural arterial roads (undivided)	0.45	0.45 (110)
Urban lightly trafficked roads and bikeways	0.40	0.40 (60)

* *The approximate conversion from Grip No. to the British Pendulum No. SRV (Skid Resistance Value) is: SRV = 100 x Grip No.*

8.3 SKID RESISTANCE

8.3.1 Factors Affecting Skid Resistance

To reduce the risk of skidding, a suitable surface texture must be provided. The skid resistance of a surface is measured by various means, from truck-mounted devices to hand-operated portable devices.

Skid resistance is the ability of a surface to provide friction to a reference tyre or slider, usually measured wet. The units of skid resistance are measures of coefficient of friction (below unity) or an index representing the percentage of friction (index is below 100).

The surface texture is divided into a micro-texture and a macro-texture. At low speeds skid resistance is primarily provided by the micro-texture. By definition, a micro-texture has a wavelength of less than 0.5 mm and typically a smaller height or texture depth of less than 0.2 mm. Therefore, micro-texture is the 'roughness' felt by rubbing one's thumb across sandpaper, or in a pavement context, across the concrete mortar (surface).

At speeds of travel in excess of 40 km/h in wet weather, the next level of surface texture (macro-texture) becomes increasingly important in providing skid resistance, as tyres tend to aquaplane on a thin film of water. Macro-texture, the texture one feels by placing fingers in between stone chippings or over hessian-dragged concrete or a tyned concrete surface, provides channels for water to be squeezed from the surface to permit rubber to micro-texture contact, thereby providing some skid resistance.

For residential streets and bikeways where maximum operational speeds are typically 60 km/h and less, the micro-texture has the greater influence on skid resistance.

8.3.2 Other Factors which Influence Skid Resistance

Abrasion resistance of the surface slows the rate of decrease of skid resistance with time and trafficking. For heavily trafficked pavements with traffic of 3 tonnes or more[18], a minimum 32-MPa concrete is specified to enhance the abrasion resistance.

Sand and fine aggregate particles contribute the major 'roughness' component of the mortar matrix; the micro-texture. Sand with a high quartz (silica) content is an exceptionally hard-wearing material; crushed quartz sand generally has excellent durability and angularity.

Coarser aggregate particles have a significant effect on skid resistance only if they are exposed. If an exposed-aggregate surface is constructed, a coarse aggregate having a minimum Polished Stone Value (PSV) is required. The typical minimum PSV value of such aggregate is 48.

8.3.3 Skid Resistance Values

The most widely used skid resistance value is the Sideways Force Coefficient (SFC) produced by the Sideways Coefficient of friction Routine Investigation Machine (SCRIM). Recommended investigatory levels for road pavement surfaces are given in Table 8.1. Note that investigatory levels are greater values than threshold levels.

Another measure of skid resistance is shown in the right column, that given by the GripTester which produces a value not exactly the same as, but very similar to SCRIM's SFC value. If a portable British Pendulum test device (a hand-operated device), is used an approximate relationship of these values to the Grip No. is provided in the footnote to Table 8.1.

8.3.4 Typical Skid Resistance Values for Decorative Concrete Surfaces

Work carried out by the Cement & Concrete Association of Australia[19] on decorative finishes, based on meeting minimum skid resistance values, suggests the following generically described finishes are suitable for residential streets.

Finish	Comments
Rough cobblestone	May present problems for wheelchair users at road crossings and for cyclists in general
Coarse stencilled*	Depends on durability (abrasion resistance) of the finish
Broom	Transversely applied
Wood float	To produce fine macro-texture
Exposed aggregate	A crushed aggregate must be used

**Providing a homogenous and positive texture can be imparted to the surface.*

The above finishes are generically described. As the actual skid resistance of a surface is dependent on material types (sands, aggregates, etc) and how these are used (finishing process, exposure of aggregates, imparting of texture, etc) a wide range of skid resistance values could result for any given finish. Therefore it is not possible to provide a typical skid resistance value for these finishes.

Hints for Improved Skid Resistance for Residential Streets

- Use silica or crushed silica sand.
- Use crushed sand in preference to natural sand.
- Use aggregates with a minimum percentage of crushed faces where aggregate is likely to become exposed during the pavement's design life.
- Where an exposed aggregate surface is to be used, specify a minimum aggregate PSV of 48.
- Avoid the use of a steel float; use a wood float if no further texturing is to be imparted.
- Avoid overworking of the surface as this tends to bring more fines/slurry to the surface and may reduce the surface durability.
- Specify a minimum strength concrete; typically 32 MPa is specified for arterial pavements; the absolute minimum value is 25 MPa.
- Impart macro-texture to the surfacing; use wood float, brooming, hessian drag, etc.
- If a moulded stamped finish is used, additional micro-texture may need to be implemented by brooming or other surface application.

8.4 LUMINANCE

The procedure generally used for road lighting is to make the road bright by beaming light against the direction of the traffic. In this way, dark objects (nearly all, particularly pedestrians, have a low reflection factor) are contrasted against the brighter background of the road surface. This compares with lighting by vehicle headlights or by intense street lighting at for example, pedestrian crossings, where the objects themselves are illuminated.

Contrast, rather than discernment of detail is a key visibility requirement as in ambient night-light conditions, the human visual system loses sensitivity.

In providing the contrast, the pavement surface is important in reflecting light to the eye of an observer; both in wet and dry conditions. This luminance is dependent on the surface texture and the colour, with darker coloured surfaces absorbing more light than lighter coloured surfaces. Researchers report that:

- luminance levels of up to 30% greater can be achieved by selection of a light coloured surfacing[20]; and
- to gain a similar brightness to that of concrete roads, asphalt surfaces require a minimum of 15% of artificial brightener aggregates such as quartzite or labrodorite[21].

The top few millimetres of a concrete slab comprises cement mortar mixed with fine aggregate particles; usually sand-sized and less. Naturally occurring sands often contain quartz, a very light coloured mineral, which, with the light-coloured cement mortar, provides a very light coloured surface. Aggregates, which provide the bulk of the concrete mix, are, unless specifically exposed, buried just beneath the surface mortar and are not visible.

Other surfacings that have the aggregates exposed or containing bitumen binder tend to present as dark coloured unless, as mentioned previously, light coloured aggregates are used.

Road surface texture is important in wet weather to provide a diffusing effect on light rather than producing a mirror-effect—called specular reflection. The spectrality of different surfaces is dependent on the depth of texture and the degree of polish of exposed aggregates. Durable surfaces, those which retain their texture and resist polishing, will have better long-term wet-weather luminance.

8.5 DURABILITY

Concrete should have adequate durability to resist deterioration and wear under service conditions. To achieve this, concrete should have sufficient abrasion resistance and an adequate level of impermeability. Measures taken to maximise the design strength of the concrete will also enhance its durability. These include:

- good quality concrete;
- proper placing and compaction;
- proper curing (starting immediately after the concrete has been finished).

The choice of a coarse aggregate does not greatly influence the abrasion resistance of good quality concrete. It is the fine aggregate (sand) which is at the wearing surface.

The concrete pavement should comply with the durability requirements of AS 3600[18]; where limiting values are generally strength requirements for abrasion, ie pavements subject to:

- Light pneumatic-tyred traffic (vehicles up to 3 t gross mass) ≥25 MPa
- Medium or heavy pneumatic-tyred traffic (vehicles heavier than 3 t gross mass) ≥32 MPa

8.6 WORKABILITY

The workability of plastic concrete needs to be compatible with the method of construction to ensure that full-depth compaction of the concrete can be achieved.

Slump is used as a measure of workability. The method of construction influences the slump required. As a guide, the lowest slump consistent with adequate workability should be used. For fixed-form paving with manually operated vibratory equipment, slump values are in the range 50 to 60 mm. For slip-form construction with no side forms, slump values in the range of 30 to 50 mm are typical.

8.7 CHEMICAL ADMIXTURES

Chemical admixtures are commonly used to modify the properties of concrete, making it more suitable for a particular purpose. Chemical admixtures should not be regarded as a substitute for, but rather part of good mix design and good concreting practice.

8.8 CONSTRUCTION PRACTICES

The placing, compacting, finishing and curing of concrete have a major influence on its strength and durability.

Concrete should be thoroughly compacted, particularly around reinforcement and in corners of forms. If concrete is not adequately compacted (by surface and/or immersion vibrators) air voids in the hardened concrete will result in a pavement of less than optimum strength, and possibly in corrosion of reinforcement and/or spalling.

The strength of concrete falls rapidly as the percentage of air voids increases. For example, a 2% reduction below maximum density resulting from poor compaction, lowers the strength by about 10%. If concrete contains 5% of air voids, its strength is likely to be about 30% below that of fully compacted concrete[7].

When placing concrete during high evaporative conditions such as hot, dry and/or windy weather, the finishing operation will require additional attention. These conditions will reduce the time available for the sfinishing operation and may also result in plastic cracking due to the surface of the concrete drying rapidly, generally before the full depth of the concrete has had time to take its initial set. More information about evaporative conditions can be found in Chapter 12 of the *Guide to Concrete Construction*[6].

Loss of surface moisture due to evaporation can be minimised by the erection of sunshades or windbreaks. More particularly with concrete pavements, the application of an evaporation retardant to the surface of the concrete is required immediately after the initial screeding has been completed. The evaporation retardant forms a thin film over the surface of the wet concrete that reduces evaporation by up to 80% in windy conditions without interfering with subsequent finishing.

The continued presence of moisture for hydration of the cement binder, especially in the first few days after concrete is placed, is essential for the development of concrete strength and durability. If a concrete pavement is not properly cured, the surface will be weak and – since it is subject to abrasion – therefore prone to wear. Concrete pavements are relatively thin and have a high surface to volume ratio. Under most site conditions the potential for moisture loss immediately after placing is therefore quite high. Moisture loss must be controlled by appropriate curing. Methods of curing can be split into two groups:

- Those that offset water loss, eg fine continuous water spraying;
- Those that seal the surface and thus control water loss from the concrete, eg covering with plastic sheeting or coating the concrete with a membrane curing compound, such as water-based or wax emulsion which can be brushed, sprayed or rolled onto the surface of the pavement.

The relative performance of curing methods in controlling moisture loss from concrete is shown in Figure 8.1. AS 3799[22] sets out the characteristics and requirements for liquid membrane-forming curing compounds for concrete. Water-based curing compounds are commonly used with concrete pavements as they are considered to be efficient and user friendly.

The minimum periods for which concrete must be cured are set out in AS 3600[18]. These vary with the strength of the concrete and the conditions to which it is exposed. Plain or reinforced concrete pavements in contact with non-aggressive soils are to be initially cured continuously for at least three days under ambient conditions or at least seven days in tropical, industrial and near coastal environments.

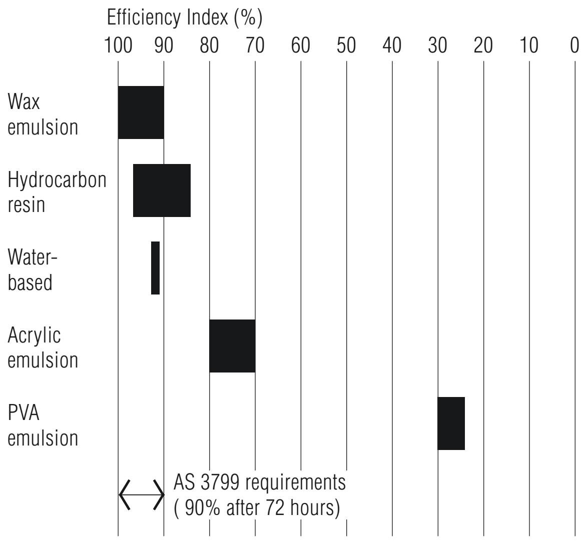


Figure 8.1 *Comparative efficiency of curing compounds*

Unlike other paving materials, the rate of strength gain in concrete is time-dependent and it must be protected from traffic until adequate strength has been achieved to resist the imposed load stresses. The appropriate time for opening the pavement to traffic will be dependent on the anticipated traffic (both volume and loads need to be considered), the strength grade of the concrete, and the elapsed time since placing.

As a general rule, it is suggested that the pavement should not be trafficked until it has gained 60% of its specified 28-day pavement-design strength. This is usually about seven days after placing. If earlier trafficking is necessary then there is a variety of techniques that can be used, solely or in combination, to attain the necessary strength in the required time. These techniques include using a higher strength of concrete, accelerators, thermal curing, heated mixing water, vacuum dewatering, etc. Alternatively the stress in the pavement can be reduced by temporarily covering with steel plates or planks. With these techniques pavements can be opened within 12 to 24 hours or even sooner.

09 Thickness Design

9.1 GENERAL

The selection of concrete pavement type and overall configuration for a given project is a decision for the designer. Some of the factors that might influence such a decision are:

- size of the project;
- availability of the appropriate equipment and skilled operators;
- effects of delays to street users;
- ease of site access when performing joint filling and other maintenance operations.

9.2 DESIGN CONCEPT

The design procedure for thickness design is based on the same method as that used in Austroads pavement design guide[2]. This method is based on the procedure developed by the PCA[23]. It involves the assessment of the:

- predicted traffic volume and composition over the design period;
- strength of the subgrade;
- strength of the concrete to be used in the pavement.

This manual gives pavement thicknesses for plain and reinforced concrete pavements.

9.3 FACTORS USED

- ***Subgrade strength*** The subgrade strength should be assessed in terms of CBR. Details of subgrade support and preparation are discussed in Section 6 *Subgrades*.
- ***Concrete strength*** The factors affecting concrete strength and durability are discussed in Section 8 *Concrete*.

  The thickness design tables given in this guide are based on concrete having a 28-day design characteristic flexural strength of 3.5 or 4.25 MPa.
- **Design Traffic** The evaluation of design traffic in CVAG is discussed in Section 5.3 *Traffic Estimation*.

9.4 CONCRETE SHOULDERS

The provision of a concrete shoulder with the pavement improves its performance. The design procedure takes this into account, enabling the adoption of a reduced base thickness. To permit this, a concrete shoulder should have at least the same strength as the concrete base and is defined as:

- a keyed and tied shoulder with a minimum width of 1.5 m from the edge of the trafficked lane; or
- a 600-mm integrally cast widening of a trafficked lane (this may include integral channel or kerb and channel).

Note: extruded kerb and channel, even if well tied to the base, is not considered equivalent to a shoulder for design purposes due to its lower strength. However, a compacted slip-formed kerb and channel can be considered as a shoulder.

The adoption of the with-shoulder case can also be justified if the majority of heavy vehicles travel at least 600 mm from the pavement edge (see Matthews and Mulholland[24]). This may occur in car parking areas or streets that provide for, or at least expect, roadside parking. Tables 9.1 to 9.4 cover thicknesses of pavements with or without concrete shoulders.

9.5 DETERMINATION OF BASE THICKNESS

The full procedure for the determination of the base thickness is detailed in Austroads pavement design guide[2].

Concrete base thicknesses have been developed using the full design procedure. For simplification, Tables 9.1 to 9.4 indicate the minimum thickness produced by each load spectrum for the particular load condition for design lives of 20 and 40 years.

9.6 STEEL REINFORCEMENT

9.6.1 General

The role of steel reinforcement in a concrete pavement is not to prevent cracking, but to control drying shrinkage cracking that may occur in slabs longer than those permitted in unreinforced pavements. The use of steel reinforcement does not increase the load

TABLE 9.1 Concrete base thickness (mm) **for Subgrade CBR 2%**

CBR 2%		NO SHOULDER Concrete flexural strength (MPa) 3.5		4.25		WITH SHOULDER Concrete flexural strength (MPa) 3.5		4.25	
		Design life (yr)		Design life (yr)		Design life (yr)		Design life (yr)	
Street type		20	40	20	40	20	40	20	40
Minor	single-lane	190	200	170	170	160	170	140	140
	two-way	190	200	170	170	160	170	140	150
Local access	no buses	200	210	170	190	170	180	150	150
	with buses	210	220	190	190	180	190	160	160
	Industrial area	210	210	180	180	170	180	150	150
Collector	no buses	230	240	200	200	190	200	170	170
	with buses	240	250	210	210	200	210	180	180

TABLE 9.2 Concrete base thickness (mm) **for Subgrade CBR 5%**

CBR 5%		NO SHOULDER Concrete flexural strength (MPa) 3.5		4.25		WITH SHOULDER Concrete flexural strength (MPa) 3.5		4.25	
		Design life (yr)		Design life (yr)		Design life (yr)		Design life (yr)	
Street type		20	40	20	40	20	40	20	40
Minor	single-lane	170	180	150	160	150	150	130	130
	two-way	180	180	150	160	150	150	130	130
Local access	no buses	180	190	160	160	160	160	140	140
	with buses	190	200	170	180	170	170	150	150
	Industrial area	180	190	160	170	160	160	140	140
Collector	no buses	200	210	180	180	180	180	150	160
	with buses	210	220	190	190	180	190	160	160

TABLE 9.3 Concrete base thickness (mm) **for Subgrade CBR 10%**

CBR 10%		NO SHOULDER Concrete flexural strength (MPa) 3.5		4.25		WITH SHOULDER Concrete flexural strength (MPa) 3.5		4.25	
		Design life (yr)		Design life (yr)		Design life (yr)		Design life (yr)	
Street type		20	40	20	40	20	40	20	40
Minor	single-lane	170	170	150	150	140	150	120	130
	two-way	170	170	150	150	140	150	130	130
Local access	no buses	180	180	150	160	150	150	130	130
	with buses	190	190	170	170	160	170	140	150
	industrial area	180	180	160	170	150	160	130	140
Collector	no buses	190	200	170	180	170	170	150	150
	with buses	200	210	180	180	180	180	150	160

TABLE 9.4 Concrete base thickness (mm) **for Subgrade CBR 15%**

CBR 15%		NO SHOULDER Concrete flexural strength (MPa) 3.5		4.25		WITH SHOULDER Concrete flexural strength (MPa) 3.5		4.25	
		Design life (yr)		Design life (yr)		Design life (yr)		Design life (yr)	
Street type		20	40	20	40	20	40	20	40
Minor	single-lane	160	170	140	150	140	140	120	120
	two-way	160	170	140	150	140	140	120	130
Local access	no buses	170	180	150	150	150	150	130	130
	with buses	180	180	160	160	160	160	140	140
	Industrial area	170	180	150	160	150	160	130	130
Collector	no buses	190	200	170	170	170	170	140	150
	with buses	200	200	180	180	170	180	150	150

capacity of the pavement and is independent of thickness design. Reduction in thickness is not permitted when pavements are reinforced.

9.6.2 Reinforcement Design

Table 9.5 provides typical steel reinforcement requirements for lightly trafficked residential streets and for slab lengths less than 15 metres (maximum slab length recommended).

9.6.3 Special Requirements for Unreinforced Pavements

In unreinforced pavements, reinforcement of certain slabs is recommended to control or minimise the effects of cracking. These include slabs:

- irregular in shape, or not square or near square (ie a slab with a width:length ratio exceeding 1:1.25);
- opposite a joint, ie mismatched joint (reinforce the full slab);
- containing pits or access holes (either internally, on one edge or in a corner – wholly within the slab).

For such slabs in pavements up to 230 mm thick, the reinforcement required is SL62 Fabric. Details of joint layout are shown in Section 10.6 *Joint Layout*.

9.6.4 Detailing of Steel Reinforcement

In order to perform as intended, the steel reinforcement should be:

- in the form of a single sheet located in the upper half of the pavement base, subject to a minimum top cover of 40 mm for pavements less than 150 mm thick and 50 mm for pavements greater than or equal to 150 mm thick;
- terminated 75 to 80 mm from transverse contraction joints and isolation joints, and 40 to 80 mm from longitudinal warping joints where joints are induced by sawing. Reinforcement may continue over the joint location, however greater care is required in the timing of the saw cut;
- located above dowel bars or tie bars;
- lapped so that the two outermost wires of one sheet of fabric overlap the outermost wire of the sheet being lapped (lapped portions should be tied with wire at a maximum spacing of 500 mm);
- handled so that sheets are free from undue distortions or kinks;

TABLE 9.5 Steel reinforcement for slabs up to 15 metres long

Concrete base thickness (mm)	**Steel reinforcing fabric** (to AS/NZS 4671)
125	SL62
150	SL72
175	SL82
200	SL82
225	SL92
250	SL92

- free from material which may affect bond with the concrete (a light coating of rust on the reinforcement will not impair its performance);
- supported on bar chairs in a regular grid not exceeding 1 m (it should neither be stamped down into the concrete nor laid on the ground and raised into the concrete);
- secured to the subbase in such a way as to resist displacement during concrete placing.

9.6.5 Continuously Reinforced Concrete Pavements

Continuously reinforced concrete pavements require a more complex reinforcement design procedure than that used for jointed pavements. For further information on this procedure refer to Austroads pavements design guide[2].

9.6.6 Steel Fibre Reinforced Pavements

The use of steel fibre reinforced concrete is appropriate to control cracking in irregular shaped slabs. This type of pavement is often used at roundabouts and bus bays.

Steel fibres are generally between 15 and 50 mm in length with either an enlarged end that acts as anchorage and/or crimping to improve bond. Typically, fibres 15 to 50 mm in length are added to the concrete at a rate of approximately 75 to 45 kg/m^3 respectively (referred to as 'fibre loading'). The steel fibre supplier's recommendations on concrete strengths, thickness and joint design should be obtained. For more information refer to *Fibres in Concrete*[25].

10 Joints

10.1 GENERAL

As has been previously stated in Section 4.6 *Joints,* the objectives of joint design are to develop a jointing system which will control transverse and longitudinal cracking, and provide enough load transfer across joints so that the pavement will have adequate riding qualities over its service life. Section 4.6 also provides definitions of the three types of joints that may be required in concrete pavements – contraction, construction and isolation.

When contraction joints are spaced and sealed as recommended, expansion joints will not be required in residential street pavements. When joints are not sealed, some expansion joints will be required. Unsealed, tied, longitudinal, contraction joints should be kept to 3 mm or less in width to minimise the risk of spalling.

10.2 CONTRACTION JOINTS

10.2.1 Classification

When viewed in the direction of paving, contraction joints fall into two categories, namely transverse and longitudinal as shown in Figure 10.1, commonly known as; transverse contraction joints and longitudinal warping joints.

Both are constructed either by early-age power sawing or by placing an insert in the fresh concrete. This locally reduces the concrete thickness, inducing cracking at these locations whilst limiting it elsewhere.

10.2.2 Transverse Contraction Joints

Transverse contraction joints should:

- provide for adequate load transfer across the joint;
- permit longitudinal movement at the joint;
- incorporate a reservoir for a joint sealant.

The recommended detailing of transverse contraction joints is shown in Figure 10.2. Note that the specified depth of the saw cut or insert must be at least one-quarter, and not more than one-third, the concrete thickness to ensure that cracking will be induced at these locations and that there is adequate load transfer across the joint by the action of aggregate interlock. The depth of the saw cut may be reduced when early saw cutting of plastic concrete is made using purpose designed equipment such as a Soff-cut saw. In this latter case, the depth of the saw cut should be to the manufacturer's recommendations.

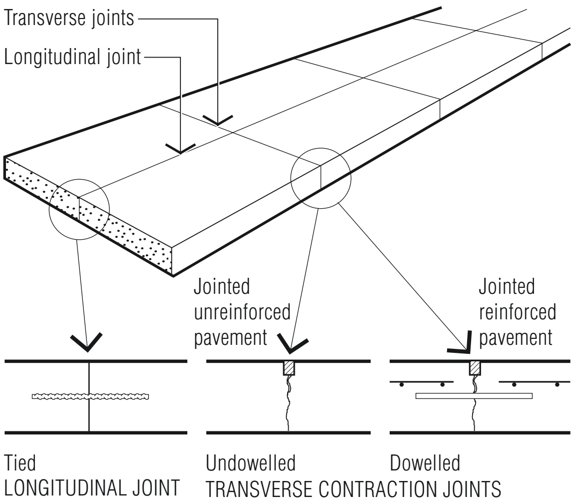


Figure 10.1 *Contraction joints*

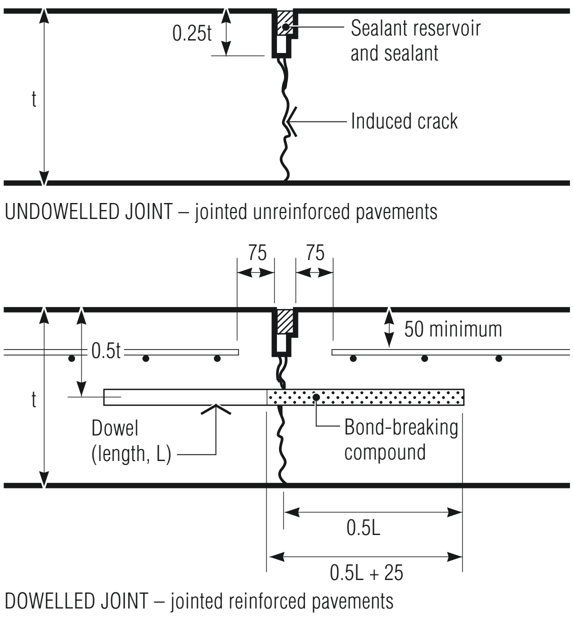


Figure 10.2 *Transverse contraction joint details*

TABLE 10.1 Recommended maximum slab dimensions for jointed unreinforced pavements

Concrete base thickness (mm)	**Contraction joint spacing** (m)	**Nominal longitudinal joint spacing***(m)
125–150	3.5	4.0
150–175	4.0	4.5
175–200	4.25	5.0

**May be increased marginally to suit carriageway widths.*

TABLE 10.2 Recommended dowel diameters (from Austroads[2])

Slab thickness (mm)	**Dowel diameter** (mm)
125–140	20
141–160	24
161–190	28
191–220	33
221–250	36

The joint spacings shown in Table 10.1 are such as to ensure load transfer by aggregate interlock at the fractured joint face. To supplement load transfer in heavily trafficked pavements, a bound subbase may be used (see Section 7.4).

For reinforced pavements, transverse contraction joints can be spaced at suitable intervals up to a recommended maximum of 15 metres. For practical and economic reasons, a slab length of 12 metres is typically specified. Since these joints will open and close to the extent that load transfer by aggregate interlock will not be effective, smooth steel dowels are installed to provide the necessary load-transfer capacity. A joint of this type will also be required at the connection of a jointed reinforced pavement to a jointed unreinforced pavement.

To permit joint movement, the dowels must be:

- sawn not cropped at least on one end;
- straight, smooth and free of burrs;
- effectively de-bonded over at least half their length;
- placed orthogonal to the joint direction and parallel to the pavement surface.

Proper field supervision of the placing of the dowels is crucial to good performance as failure to meet all of these requirements can cause the joint to 'lock', leading to distress at the joint and spalling. Dowels should be Grade 250R steel bars, 450 mm long and placed at 300-mm centres. Dowel diameters are shown in Table 10.2.

Dowels should be placed in assemblies and firmly secured to the subbase to avoid disturbance during concrete placing. The dowel-assembly support frame should not pass through the joint. The insertion of dowels during the placing of concrete is not acceptable. A typical dowel assembly is shown in Figure 10.3.

10.2.3 Longitudinal Warping Joints

Longitudinal joints are provided to control longitudinal cracking which can occur after construction as a result of slab warping combined with traffic loading. The detail of this type of joint is shown in Figure 10.4. Note that the specified depth of the saw cut or insert must be at least one-third the concrete thickness to ensure that cracking will be induced at this location. These joints can also serve as construction joints.

For unreinforced pavements, the intervals between longitudinal joints should not exceed 1.25 times the maximum transverse contraction joint spacing. For reinforced pavements, the spacing should not exceed 5 metres, except in pavements with a uniform one-way crossfall, where a maximum spacing of 6 metres is permissible.

Since longitudinal joints are not intended to open and close, load transfer between adjacent slabs is

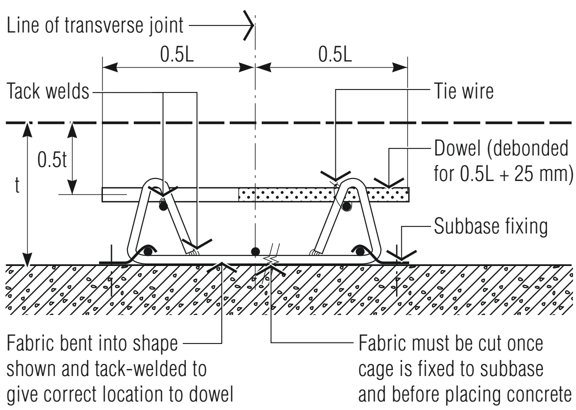


***Figure 10.3** Suggested concrete road pavement dowel assembly*

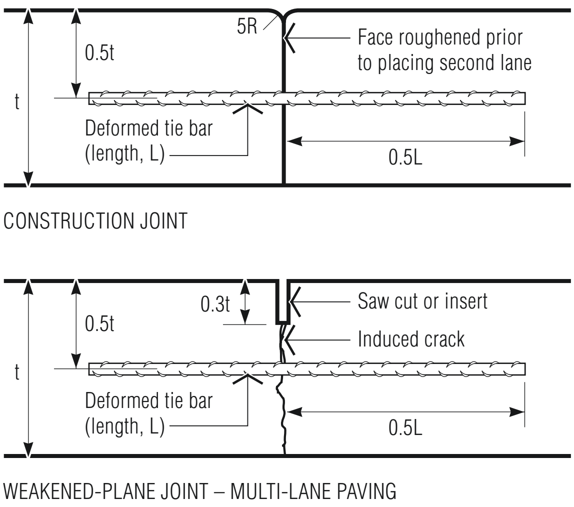


Figure 10.4 *Longitudinal warping joint details*

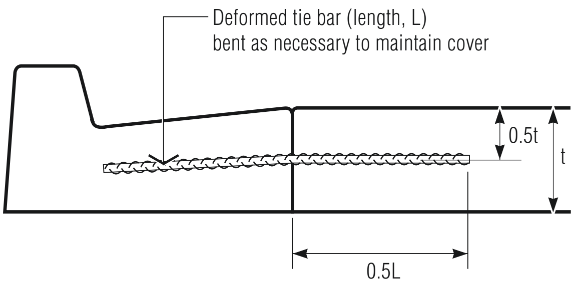


Figure 10.5 *Longitudinal joint with kerb and channel*

provided by tying them together with deformed reinforcing bars. Tie bars should consist of 12-mm-diameter Grade 500Y deformed steel bars 1 m long and placed at 800-mm centres. The accurate alignment of these bars is not critical.

Where concrete pavement is placed against separately hand-formed or slip-formed kerb and channel, the resulting formed longitudinal joint should be tied as shown in Figure 10.5. Extruded kerb and channel cannot be effectively tied (due to poor bond in the low-slump extruded concrete) to the adjacent slab which therefore needs to be designed as a 'no shoulder' pavement.

The total width of tied pavement (ie across numerous longitudinal warping joints) including tied kerb and channels is 13 m to 15 m. Pavements wider than this require a longitudinal isolation joint to limit the tied width. This is generally only applicable to multi-lane (ie very wide pavements).

10.2.4 Difference Between Dowel and Tie Bars

There is often confusion between these two steel elements in pavement joints. Dowel bars transfer shear load across a contraction or expansion joint while allowing for horizontal movement. They must therefore be de-bonded over one-half of their length and be free to move to permit opening and closing of the joint, while providing a load transfer connection. Tie bars are designed to hold a joint tightly closed whilst permitting a small amount of rotation (hinging) or warping. They must therefore be firmly anchored in the concrete. For this reason, tie bars are relatively thin and are deformed to provide the necessary anchorage; dowel bars are relatively larger in diameter and are plain.

10.3 CONSTRUCTION JOINTS

10.3.1 Classification

Construction joints can be classified in accordance with the direction of paving, namely transverse and longitudinal.

10.3.2 Transverse Construction Joints

These may be planned or unplanned. They are typically formed by a header board placed on the subbase (or subgrade where no subbase is provided) at right angles to the pavement centre line.

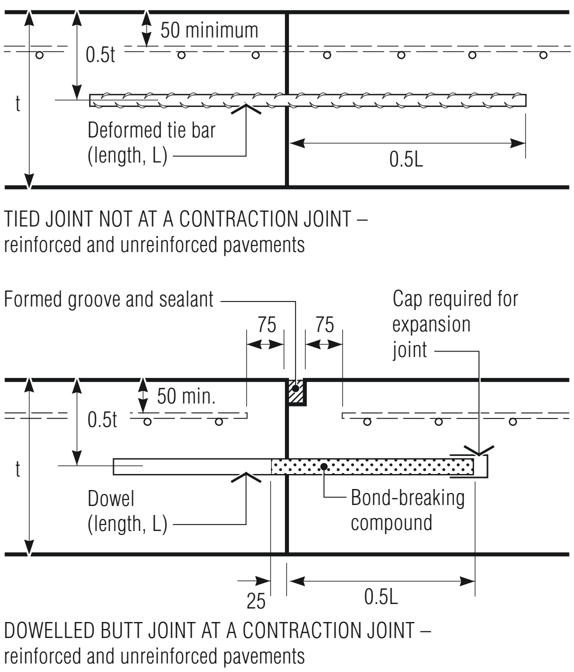


Figure 10.6 *Transverse construction joint details*

Transverse construction joints should be located either at the end of a slab (at the location of and to replace a transverse contraction joint) or in the slab's middle third. For unreinforced pavements, the alternative locations are equally suitable. For reinforced pavements, the preferred location is at the end of a slab.

Details of mid-slab and end-of-slab transverse construction joints are shown in Figure 10.6.

10.4 ISOLATION JOINTS

These joints are provided to isolate adjacent pavements at intersections or at the junction between an existing pavement, including pits or access holes within the pavement or where it abuts a fixed structure such as a wall.

Edge thickening is appropriate where pavement is designed as a 'with-shoulder' condition and trafficking is possible adjacent or over the joint. Alternatively, a subgrade beam (400 mm W x 200 mm D) should be provided below the subbase to provide edge support.

Details of isolation joints are provided in Figure 10.7.

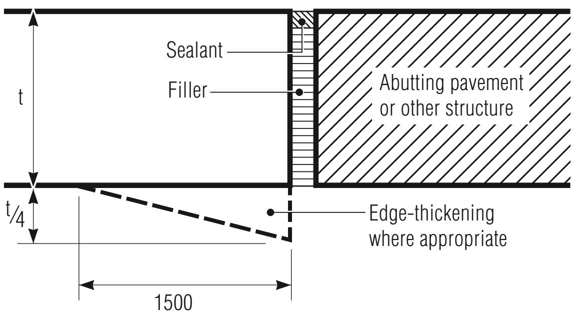


Figure 10.7 *Isolation joint details*

10.5 EXPANSION JOINTS

These joints are provided to permit expansion of the concrete pavement without inducing high point stresses, and in extreme cases, buckling up of slabs. Provided the pavement has been cast in typical ambient temperatures (ie not abnormally low), aggregates of low thermal expansion are used and wide transverse joints are sealed, these joints are not usually required in Australian road pavements.

In detail, these joints are very similar to isolation joints but with the inclusion of dowels. The dowels used in expansion joints must be capped (at one end) with compressible material to accommodate expansion. Refer to Figure 10.8.

Expansion joints are more common in footpaths and cycle-paths, as contraction joints are typically not sealed. For light pavements, load transfer may not be important. However, if soil movements are possible, the use of dowels will maintain vertical alignment. Refer also to Section 11.3.4 *Load Transfer across Contraction Joints*.

10.6 JOINT SEALING

10.6.1 General

It is recommended that pavement joints designed to accommodate movement should be properly sealed. The width of the joint needs to be designed for the particular sealant used and may require saw cutting to the correct width.

Joint sealants are designed to withstand repeated cycles of tension and compression as the joint opens and closes. To be effective, sealants must resist the intrusion of incompressible material, such as sand or gravel and other foreign objects, into the joint. They should minimise water entering the joint and reaching the subbase or subgrade.

If contraction joints are not sealed then some allowance should be made for expansion. Expansion joints could be installed, which can be constructed either as an isolation joint with a subgrade beam (400 mm W x 200 mm D – placed within the subgrade aligned with the joint) or as shown in Figure 10.8.

10.6.2 Sealant Types

Joint sealants are usually divided into two classes: field-moulded sealants and pre-formed sealants. Pre-formed sealants are currently not widely used for sealing joints in concrete pavements.

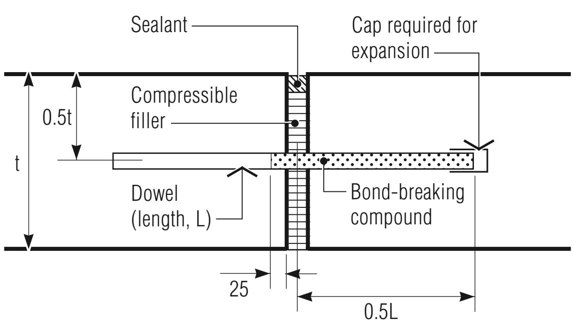


Figure 10.8 *Expansion joint details*

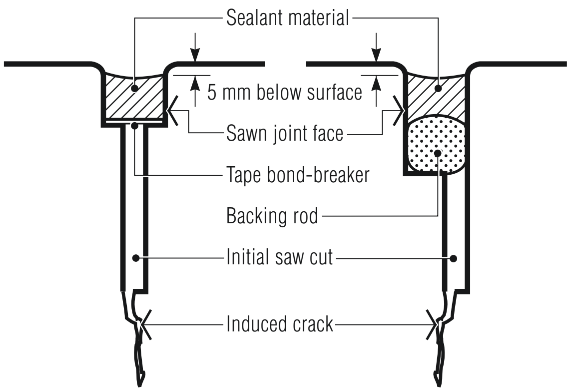


Figure 10.9 *Typical joints with field-moulded sealants*

Field-moulded sealants are either poured or gunned into the joint above the backing rod in a semi-liquid form. They include thermosetting or chemically cured compounds such as polysulphide, silicone and polyurethane. Current experience suggests that silicone sealants perform best. It is important that sealants are installed in accordance with the manufacturer's recommendations.

Typical details of joints with field-moulded sealants are shown in Figure 10.9.

All sealants must be suitable for the expected slab movement and manufacturer's recommendations should be followed.

10.7 JOINT LAYOUT

10.7.1 General

The principal aim is to develop a simple joint layout to maximise the use of uniform slab dimensions.

In developing layouts, intersections, turning areas and cul-de-sacs require particular attention. Joint layouts for concrete roundabouts in residential streets together with design and construction details are given in the RTA's roundabouts publication[11].

10.7.2 Schematic Layouts

In the joint layouts prepared for typical intersections and cul-de-sacs shown in Figure 10.10 the following points should be noted:

- Suggested layouts are provided for both reinforced and unreinforced (plain) pavements. The selection of pavement type is a matter for the designer. The decision may depend on the required simplicity of construction and relative construction costs.
- The joint layouts at intersections are shown for T intersections and two-lane carriageways. These can be adapted for four-lane carriageways and four-way intersections. For wide pavements, the total width of tied slabs and kerb and channel is limited to 13 m to 15 m as discussed in Section 10.2.3 *Longitudinal warping joints*.

Schematic joint layouts, for typical turning areas in private rights-of-way, are shown in Figure 10.11. The layouts may need to be adjusted to suit specific site conditions and geometric standards.

10.7.3 Construction Programming

To assist in developing a simple, economical construction program, the joint layout should take in consideration the desirability of :

- maximising the potential length of individual paving runs;
- minimising the number of construction joints; and
- minimising the need for special forms or tools.

The development of a paving sequence will be influenced by :

- the requirement for early access to particular building lots in new projects, eg construction of display houses or to parking areas; and
- the need to maintain traffic flow when reconstructing an existing street.

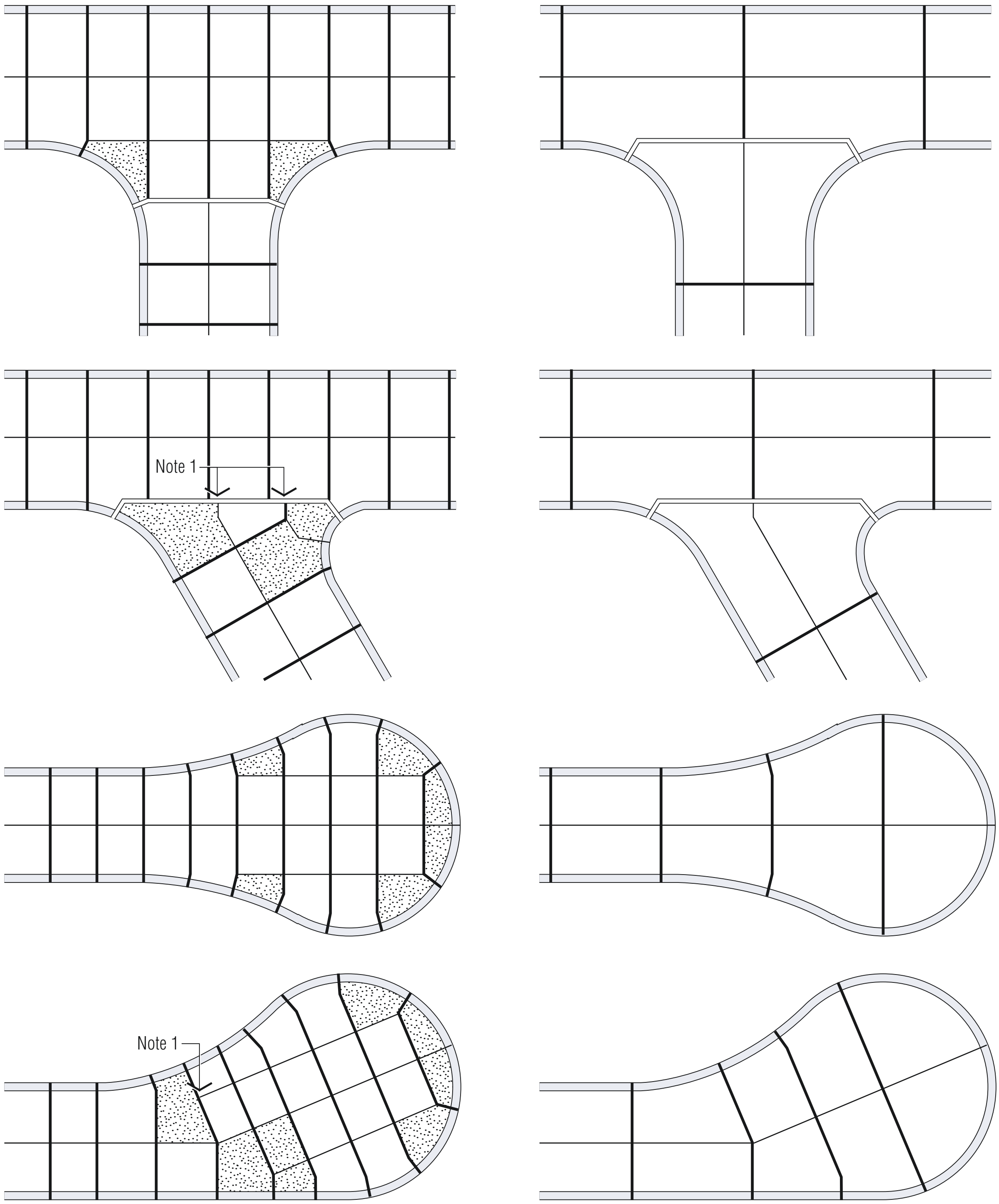
10.8 SETTING OUT OF JOINTS

10.8.1 General

The plans should have sufficient details to enable the joints to be set out in the field.

Joint locations can be marked on the side forms for fixed-form paving or recovery marks can be located near the pavement perimeter. The location of sawn joints can be marked on the pavement by crayon after the concrete has taken its initial set.

When some slabs, within an otherwise unreinforced pavement, are to be reinforced, they must be clearly identified on the drawings.



UNREINFORCED (PLAIN) CONCRETE PAVEMENTS

REINFORCED CONCRETE PAVEMENTS

NOTES

1 Avoidance of mismatched joints depends on actual street dimensions

2 Transverse construction joints are not indicated in these diagrams as their location is a result of construction considerations or circumstances

LEGEND

- Longitudinal joint
- Transverse contraction joint
- Isolation joint
- Slabs to be reinforced (see text for details)

Figure 10.10 *Schematic joint layouts at intersections and cul-de-sacs*

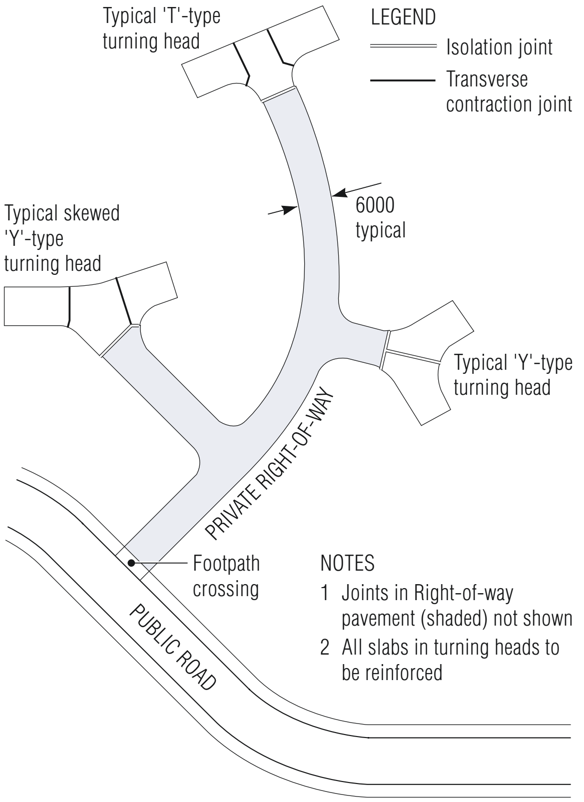


Figure 10.11 *Schematic joint layouts for turning areas*

10.8.2 Continuity at Joints

Wherever possible, joints should be continuous either across the length or width of the pavement.

Where either a kerb or a kerb and channel is provided and is tied to or cast integrally with the pavement, joints in these should coincide with pavement joints. At typical pavement slab lengths (4 m), a separately formed kerb and channel will normally also require an intermediate contraction joint. The weakened plane or construction joint in the kerb should be of sufficient depth to ensure positive crack induction at the desired location. Dummy-type kerb joints will not usually be effective.

Mismatched joints should be avoided where possible. If a mismatched joint is unavoidable, a portion of the slab opposite the mismatched joint should be reinforced as shown in Figures 10.12 and 10.13, except where the mismatched joint occurs at an isolation joint.

10.8.3 Acute Angles in Slabs

At kerb returns on intersections or curved edges in cul-de-sacs, joints may form acute angles in the corners of slab. In these cases the potential for a crack to occur across the acute angle can be avoided by offsetting the joint, desirably over 600 mm but 300 mm as a minimum from the inside of the kerb, to remove the acute angle; refer to Figure 10.14.

10.8.4 Access Holes and Pits

Joints at access holes and pits (within the pavement and at pavement edges) must not only be of the appropriate type but must also be carefully detailed to control unplanned cracking in the pavements.

The preferred arrangement for access holes and pits located other than at pavement edges is shown in Figure 10.15. It is important to note that:

- the access hole/pit surround should be completely isolated from the pavement by an isolation joint.
- in a jointed unreinforced pavement, the adjacent slabs do not need to be reinforced if no re-entrant angles result – as shown in Figure 10.15.

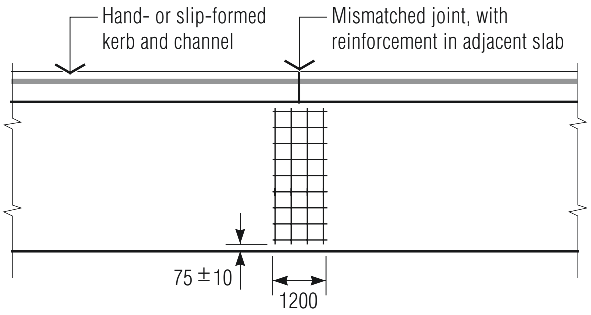


Figure 10.12 *Treatment of slab opposite mismatched kerbing joint*

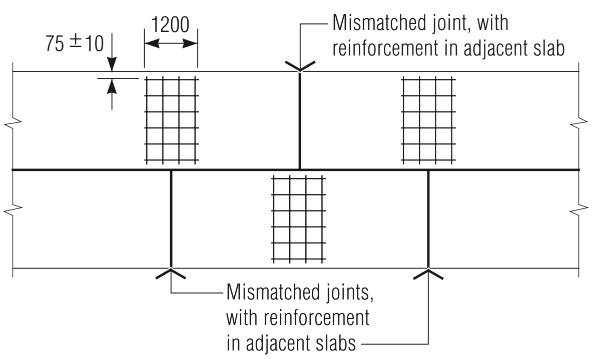


Figure 10.13 *Treatment of slabs opposite mismatched joints*

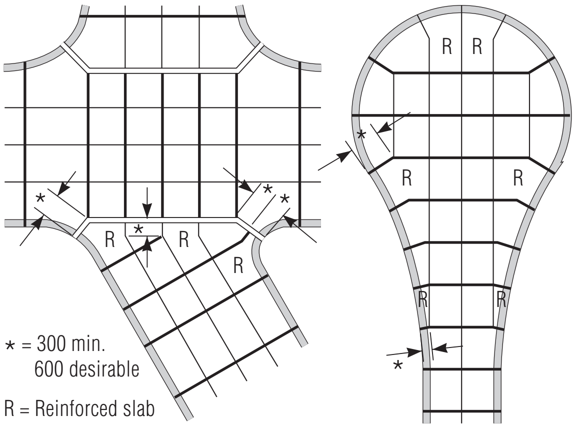


Figure 10.14 Detailing to avoid acute angles in slabs

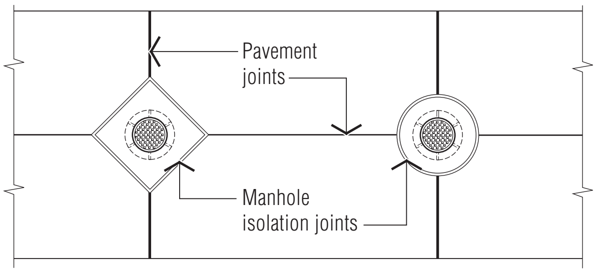


Figure 10.15 Access holes and pits not at pavement edges

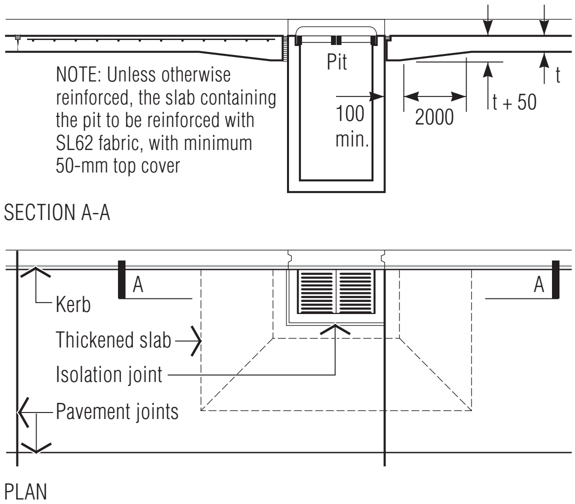


Figure 10.16 Access holes and pits at pavement edges

The detailing recommended for access holes/pits located other than at pavement edges can also be used for columns, light stanchions, etc associated with parking areas.

The preferred arrangement for pits located at pavement edges is shown in Figure 10.16. The access hole/pit should be surrounded by an isolation joint and the slab containing the access hole/pit should be reinforced.

If the above procedures are not followed, it should be anticipated that unplanned cracking would ultimately occur, starting at the pit corners.

10.8.5 Steep Grades

When longitudinal grades exceed 9%, reinforced concrete anchor blocks should be provided to prevent the pavement sliding down the slope. The reinforced concrete anchor blocks should be constructed for the full width of the pavement. An example of an anchor block is shown in Figure 10.17.

10.8.6 Surface Finishes

When surface finishes with patterns are used, the impact of joints on the finish should be considered. This may necessitate the modification of joint layout and/or surface finish.

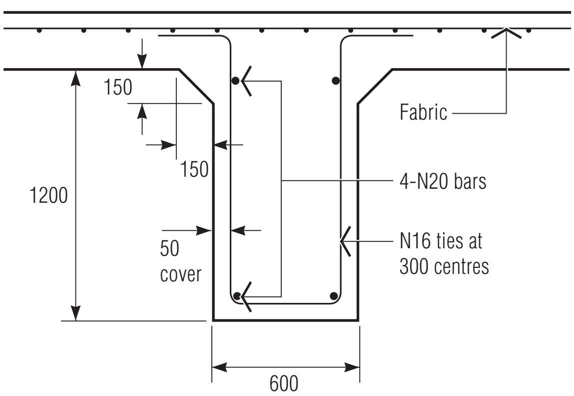


Figure 10.17 Example of reinforced concrete anchor blocks

11 Bikeways and Footpaths

11.1 GENERAL

The generical term 'bikeway' is used to cover exclusive-use paths for cyclists or a shared use path for pedestrians and cyclists (including skaters, boarders, etc).

The procedure for the structural design of bikeways is similar to that for road pavements; assessments of the foundation strength, traffic loading and material properties are required.

Of the three key design parameters, often the most difficult to estimate is the traffic loading, as in many cases the full extent of the use of the bikeway by service- and other road-vehicles is difficult to foresee or is more usually, inadvertently not considered.

11.1.1 Design Traffic Loading

Three loading regimes of traffic are adopted as follows:

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

Selecting the appropriate loading from one of these three categories can fast-track the pavement design process for most situations. However, if better information is available for a particular bikeway project, it should be used to calculate the design traffic, then selection of the design base thickness determined from Tables 9.1 to 9.4.

11.1.2 Foot and Bicycle Traffic

The foot and bicycle traffic category assumes similar limited loadings at all times. 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 (police, ambulances, etc) as well as for normal maintenance of the path and environs.

In practice, selection of this loading regime for design is rarely appropriate and should be made only 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 traffic the facility, then this loading category would be appropriate.

11.1.3 Light Truck Loading

The light truck-loading category is based on the (average) passage of one light commercial vehicle of a maximum gross mass of 3 tonnes per day over the design life of the path. This vehicle equates to a small truck capable of traversing a bikeway that has restricted clearance.

A typical road patrol vehicle with full-sized dual tyres on the rear axle does not meet this light truck definition, as even unladen, it exceeds 3 t mass.

If passenger cars and utilities frequently access the path, the light truck loading is also applicable.

11.1.4 Heavy Truck Loading

The heavy truck-loading regime is based on an (average) daily one-way passage of one commercial vehicle comprising a rigid body with single axle dual tyres at the rear and a single steer axle. The typical road-patrol truck would characterise this loading.

Designs are prepared based on a heavy vehicle loaded to about 70% of its gross vehicle mass (GVM) trafficking the path for a daily (one-way) passage over 40 years. A rigid-body 2-axle 'road-patrol truck' would therefore be restricted to a maximum GVM of approximately 10 tonnes.

If the bikeway is likely to sustain more frequent or heavier axle loadings, it is recommended that the design be undertaken in accordance with the APRG design guide[13].

11.1.5 Colour

For the standard bikeways, the concrete strength should be as shown in Table 11.1. When introducing colour (either integrally or by the dry-shake method), 32-MPa concrete should always be specified.

11.1.6 Summary

Table 11.2 summarises the traffic loading categories used in designs.

Table 11.3 provides the actual design traffic loadings used to generate the pavement designs.

TABLE 11.1 Concrete bikeway designs

Soil strength	Foot/bike traffic	Light truck 0 CVAG	Heavy truck (and crossovers) 3×10^4 CVAG
Poor (CBR ≥2%)	100 mm concrete (20 MPa) 50 mm granular bedding **150 mm**	125 mm concrete (25 MPa) 100 mm crushed rock **225 mm**	190 mm concrete (32 MPa) 100 mm crushed rock **290 mm**
Moderate (CBR ≥5%)	75 mm concrete (20 MPa) 50 mm granular bedding **125 mm**	125 mm concrete (25 MPa) 100 mm crushed rock **225 mm**	170 mm concrete (32 MPa) 100 mm crushed rock **270 mm**
High strength (CBR ≥10%)	75 mm concrete (20 MPa) 50 mm granular bedding **125 mm**	120 mm concrete (25 MPa) 100 mm granular bedding **220 mm**	170 mm concrete (32 MPa) 100 mm granular bedding **270 mm**

Note: For foot/bike traffic and light-truck crossovers, use heavy-truck base thicknesses with 25-MPa concrete. For coloured or decorative concrete finishes a minimum of 32-MPa concentrate should be used for all traffic.

TABLE 11.2 Indicative loadings for bikeway traffic categories (Transport SA[26])

Design traffic Category	User or vehicle type: Bicycle	Motor car	Utility	Light truck < 3 tonne	Heavy-tipper 2 axle	Very heavy-tipper > 2 axles
Foot and bicycle	✓	?	?	X	X	X
Light truck (< 3 t)	✓	✓	✓	✓	X	X
Heavy truck (< 11 t)	✓	✓	✓	✓	✓	X

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

TABLE 11.3 Recommended design traffic loadings for bikeway structural designs

Loading	Characterised by	Rigid pavement 40-year design life
Foot and bicycle	Foot and bicycle loading only	NA
Light truck	0.9 passes/day of truck with 3 t GMV	0 CVAG*
Heavy truck	1 pass/day of heavy vehicle	3×10^4 CVAG*

**Commercial Vehicle Axle Groups*

11.2 BIKEWAY PAVEMENT DESIGN

11.2.1 Jointed Concrete Pavements

Table 11.1 shows the structural composition for bikeways comprising concrete base for the range of loading and most common soil strength categories.

Where applicable, designs given in Table 11.1 are derived from the procedure given in APRG[13]. Interpolation of these designs based on different bearing capacity is not applicable due to the general insensitivity of thickness to this parameter. Where different traffic loadings to those given in Table 11.1 are expected, it is recommended that the design procedure in APRG[13] be followed.

11.2.2 Continuously Reinforced Concrete Pavements

Where constructed on expansive soils or where tree root damage is likely, a continuously reinforced concrete (CRC) bikeway is unsurpassed for long-term performance in providing a smooth surface with minimum maintenance costs.

CRC bikeway pavements comprise a 32-MPa concrete base of thickness the same as for a jointed base given in Table 11.1, with longitudinal reinforcing bars added to control shrinkage cracking. The bar diameter and spacing is calculated to satisfy the need to resist tension developed by the shrinking concrete. Typically, the reinforcing bars will comprise 0.65% to 0.8% of the total cross-sectional area.

The quantity of reinforcement is dependent upon many factors, which include the steel yield strength, the concrete tensile strength and coefficient of friction between the base slab and subbase. Hence, each pavement should be designed and detailed by an experienced pavement engineer using the design method given in Austroads[2], Section 9.5.4. However, for costing purposes, estimates of quantities can be derived from Table 11.1 and the estimated steel reinforcement percentages given above.

Due to physical limitations of reinforcing-bar size, fixing and misalignments, and the need to preserve minimum cover requirement, it is recommended that the minimum thickness of CRC bikeway be not less than 130 mm.

11.2.3 Reinforcement

Reinforcement may be provided in jointed (unreinforced) pavements where the jointing layout results in an odd shaped slab, ie a slab being very narrow compared to its length, or having a re-entrant angle or a sharp external angle (typically < 80°). In these situations, the reinforcement assists in tightly holding together any cracking resulting from the slab shape. SL72 reinforcement mesh would be appropriate.

11.3 BIKEWAY CONSTRUCTION

11.3.1 General

Recommended procedures require that the concrete mix should be compacted with double-beam vibrating screeds. A slipform concrete paver with internal vibration may also be used.

The development of advanced concrete construction techniques and products has resulted in significant improvements in rider comfort. It is highly desirable that such techniques are employed. They include:

- Pre-formed or saw-cut contraction joints. As a consequence, bullfloating, trowelling and broom finishing can be extended right up to the joints, resulting in a considerably improved riding surface. In particular, wet-formed contraction joints made using a grooving tool should be avoided as discussed in Section 11.3.5 *Hand-formed Transverse Contraction Joints*.
- The use of extended bullfloats (up to 4 m wide) to reduce the frequency and height of transverse corrugations that affect cyclists travelling at speed.

11.3.2 Concrete Joints

Joints in rigid bikeways comprise the same range as for road pavement construction. Particular differences in the application of these joints for bikeways as compared to road pavements are discussed below.

11.3.3 Contraction Joints

Contraction joints should be no more than 3 mm wide, extend into the slab by about a quarter of the slab thickness, and be placed at maximum intervals of less than 20 times the slab thickness; ie generally no more than about 3-m intervals. The narrow joints provide excellent ride-quality, required for small-wheeled items such as in-line-skates and skateboards, but it is difficult to effectively seal such narrow joints. Unless the bikeway is subject to particular conditions such as blowing sand, etc, it is recommended that the contraction joints not be sealed.

11.3.4 Load Transfer across Contraction Joints

Where movement due to expansive soils is expected or if tree roots are likely to deform the jointed-concrete bikeway, consideration should be given to incorporating steel dowels across the concrete joints. This will increase construction costs, as the dowels also need to be accurately aligned and securely restrained against movement during the concrete pouring process. Dowels are generally unsuitable for concrete thicknesses of less than 125 mm, due to the increased risk of causing spalling at the joint.

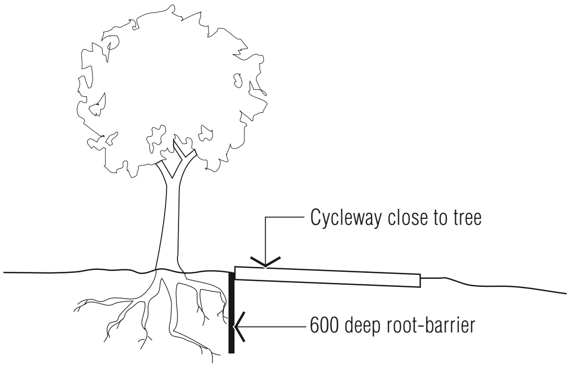


Figure 11.1 *Root-barrier to direct root growth away from pavement*

11.3.5 Hand-formed Transverse Contraction Joints

The traditional grooving tool usually forms a very wide joint at the surface (greater than 3 mm) 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 adjacent 50 mm of concrete either side 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.

11.3.6 Expansion Joints

Expansion joints should be provided in jointed-concrete bikeways, due to the recommended practice of not sealing the 3-mm-wide contraction joints. Small incompressible particles that lodge in open joints prevent expansion of the concrete. The resulting forces that occur in the horizontal direction cause spalling of the joints and in extreme cases, upward arching of the slabs at the joint. Figure 10.8 shows expansion joint details. For light-traffic loading, the dowel bar may be omitted.

Expansion joints should be 10 mm wide, extend the full depth of the slab, be filled with compressible filler, and be formed at a minimum of 12-m intervals.

11.3.7 Isolation Joints

Isolation joints are typically needed at intersections with kerb and channel.

11.3.8 Anchor Blocks

Where the slope of the path exceeds 10%, the use of anchor blocks should be considered to prevent slippage of the slab. The blocks are similar to that shown in Figure 10.18 but measure 600 mm high (including base thickness) by 300 mm wide cast integrally and transverse to the path. A spacing of about 40 m is recommended.

Reinforcing mesh is placed in the slab containing the anchor block to prevent transverse cracking at the leading edge of the anchor block.

11.3.9 Vehicle Crossovers

Where pavements designed for foot/bike and light trucks are subject to vehicular crossings, it is strongly recommended that the design be locally changed to the base thickness for heavy-truck design (Table 10.1). The same 25-MPa concrete can be used for the crossover but reinforced with SL72 steel fabric to control unplanned cracking.

11.3.10 Surface Finish

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

11.3.11 Protection from Landscaping

Where trees are planted such that their canopies extend to the bikeway edge, consideration should be given to providing vertical root barriers as shown in Figure 11.1. These are effective in preventing the development of large roots directly beneath the pavement, a major cause of longitudinal roughness.

11.3.12 Subbase

Sand should not be used as a subbase layer, as the small mineral particles will eventually enter the joint spaces and restrict the slab expansion/contraction cycle.

11.4 FOOTPATHS

Footpaths, located or planned such that the use of and level of loading is restricted to pedestrians, cyclists etc are considered in this section. Where service vehicles may access lengths of footpath or vehicles cross footpaths, a 'bikeway' design (Section 11.2) will be required.

TABLE 11.4 Footpath thicknesses

Environment	Thickness (mm)
Firm foundation	75
Service trenches with questionable reinstatement—localised thickening	100
Very soft foundation	100
Over poorly or un-compacted soils or fills	100
In location where vehicles mount kerb; eg where footpath is adjacent to kerbing and parking provision on road pavement is nil or limited	100

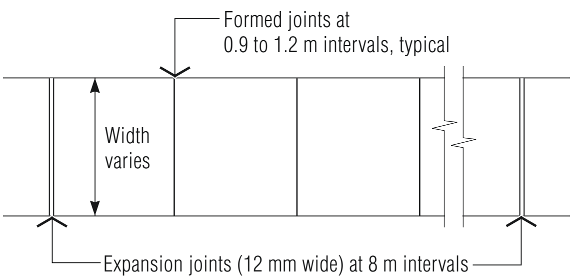


Figure 11.2 Layout of footpath

11.4.1 Footpath Design

Jointed concrete pavements Table 11.4 shows recommended thickness for concrete footpaths.

Concrete For standard footpaths, 20-MPa concrete having a maximum 20-mm aggregate size should be specified. For hand placing, an 80-mm slump is recommended. When introducing colour (either integrally or by the dry-shake method), 32-MPa should be specified. For footpaths subject to high volumes of pedestrian movements, particularly stiletto heels, it may be necessary to increase the strength to 32–40 MPa for increased abrasion resistance.

Subbase It is recommended that a granular subbase or bedding layer be placed to provide:

- greater uniformity of support for the thin concrete slab, particularly over back-filled ground or service trenches;
- a layer which, when compacted, will resist pumping up into the transverse contraction or expansion joints thereby allowing the slabs to move freely; and
- a good working platform on which to place concrete; as the slab is relatively thin, it is highly desirable to have a firm surface, one that will retain its level during construction, to ensure a uniform slab thickness.

A minimum of 50 mm of compacted crushed or recycled granular material is required for the subbase. Where soft ground is present, a thicker compacted layer of 75 to 100 mm will assist in strengthening the subgrade and keeping very soft material from pumping through during the construction process.

Jointing Figure 11.2, 11.3 and 11.4 show the layout and cross-section details of transverse contraction and expansion joints—which for footpaths are typically induced by wet-forming, rather than by saw cutting as for high-ride-quality bikeways and road pavements.

Rules for Jointing

- Keep transverse contraction joint spacing at less than 20 times the slab thickness;
- Keep slab width to length dimensions at a ratio of less than 1:1.4;
- Transverse contraction joints should be formed to a depth of D/4 where D is the slab depth.

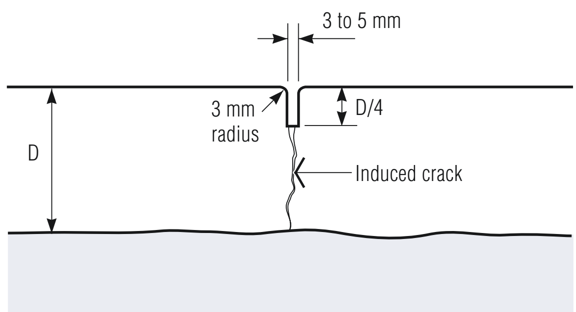


Figure 11.3 Formed transverse contraction joint

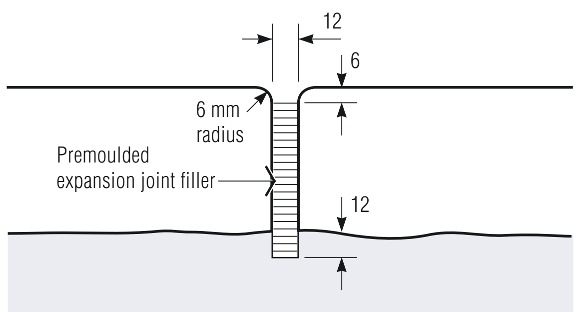


Figure 11.4 Expansion joint

TABLE 11.5 Formed and extruded kerb and channel comparison

	Formed	Extruded
Method of placing	By hand between fixed formwork or by slip-form machine (no fixed formwork)	By purpose-built extruding machine
Concrete slump	Typically 80 mm for hand-formed work Typically 40 mm for slip-formed	Zero
Strength requirement	A minimum of 20 MPa, to 32 MPa	Not applicable
Surface finish	Steel-trowelled	Additional rendering of fine-aggregate, cement and water mix, placed to a max. 3 mm thickness; steel-trowelled
Suitability for edge-support for concrete pavement	Yes (tie-bars embedded in fully compacted concrete)	No (full compaction around tie-bars not achievable).

Reinforcement Reinforcement is not typically required in footpath construction provided the above 'rules for jointing' are observed. Where these rules cannot be met, place SL62 mesh should be placed in the upper half of the slab, taking care to commence and finish the mesh placement close to (approximately 35 mm) from the formed joint. Reinforced slabs should be at least 100 mm thick.

Step-faulting Where step-faulting of the footpath is likely to occur (this may be due to nearby large shrubs and trees), the ideal solution is to isolate the footpath from the roots by placing a 600-mm-deep vertical root-barrier alongside the footpath as shown in Figure 11.1.

Another solution to assist in preserving the vertical slab-to-slab alignment is to use shear connecting forming devices such as keyed joints, which are available commercially from numerous suppliers. These systems are, however, restricted to slab 100 mm or more in thickness.

Dowels may offer some relief from step-faulting; however, the remaining cover thickness to dowels is such that spalling may occur during differential movement of the thin footpath slabs. Reinforcing mesh may provide a superior solution against step-faulting for thin slabs; however, typical shrinkage of concrete used in footpath slabs, even when jointed at close spacing, is sufficient to permit eventual rusting of the longitudinal reinforcing wires. Due to minimum cover requirements of 40 mm, minimum slab thickness to accommodate the mesh is 100 mm.

Construction To assist in the curing and durability of these thin slabs:

- the subbase should be thoroughly moistened prior to placing concrete (resulting in reduced loss of moisture);
- as soon as the texturing via either a decorative finish, wood float or brooming has been done, curing should be initiated by covering with damp hessian or well-secured plastic sheeting, or applying a curing compound at the rate of 0.3 litres/m^2, and
- water should not be added to the as-delivered mix; this will lower the concrete strength, cause greater shrinkage and may cause chalkiness and dusting of the surface.

11.5 SLIP RESISTANCE OF CONCRETE SURFACES

Slip resistance is described as the ability of a surface to substantially reduce the risk of a person slipping. It generally refers to those textured flooring and paving materials that perform well in preventing slipping in both wet and dry conditions. There is an expectation that surfaces will provide sufficient slip resistance and this is increasingly being incorporated into legislation.

The outcome of work carried out by the Cement & Concrete Association of Australia on the slip resistance qualities of decorative concrete finishes and can be found in *Road Note 64*[10].

11.6 KERB AND CHANNELS

Dimensions of kerbing, channel, and kerb and channel sections (termed 'kerb and channel' in this document) are usually detailed on standard drawings to which local infrastructure authorities require conformity. Typically, details such as bedding or support material, concrete specification and finishing are also included on these drawings. The principles described elsewhere in this document also apply to kerb and channel construction and curing. Some important differences are described.

Formed versus extruded kerb and channel
Table 11.5 lists important differences between formed and extruded kerb and channel.

Support for kerb and channels It is important to provide adequate and uniform edge-support for kerb and channel to resist outwards rotation and resist fatigue in beam-action when loaded by heavy commercial vehicles.

Edge support should extend a minimum of 300 mm from the back of kerb and channel as shown in Figure 11.5 and Figure 11.6.

Where a separate compacted thickness of a granular bedding layer is less than 75 mm, the depth of the section to be cast or extruded should be extended as shown in Figure 11.6.

Where pavement material is 'boxed' between kerb and channel and no pavement layer extends beneath the kerb and channel, the minimum support/bedding layer is 150 mm as shown in Figure 11.7.

Jointing of kerb and channel Transverse contraction joints are usually wet-formed (guillotined in extruded or slip-formed work and by withdrawal of templates for hand-formed work) at intervals not exceeding 2.5 m. The resultant slot is then neatly tooled to form a 5-mm-wide, 20-mm-deep groove. Some authorities then require sawing within the groove of the hardened concrete to form a 50-mm-deep cut.

Where separately formed (not extruded) kerb and channel is tied to a concrete pavement, the transverse contraction joints should be aligned. As the transverse contraction jointing interval of the kerb and channel is less than that of the pavement base, any intermediate joints can be omitted and trench mesh placed in the kerb and channel (as shown in Figure 10.13), up to 75 mm from the contraction joints.

Expansion joints are required at fixed objects such as bridge abutments, see Figure 11.4.

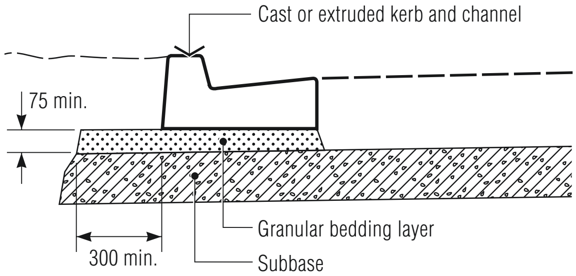


Figure 11.5 *Support layer extension and minimum bedding layer thickness*

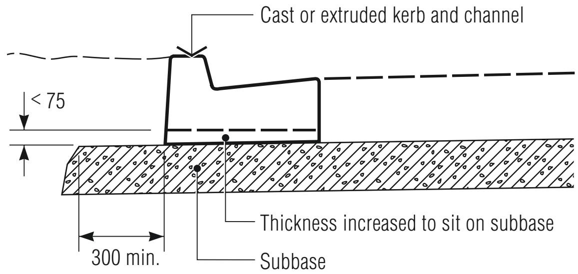


Figure 11.6 *Depth of section extended where bedding would be less than 75 mm thick.*

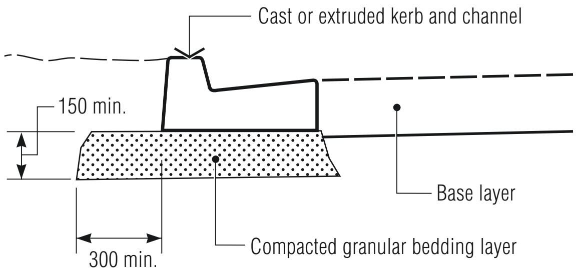


Figure 11.7 *Minimum total thickness of support layer/bedding*

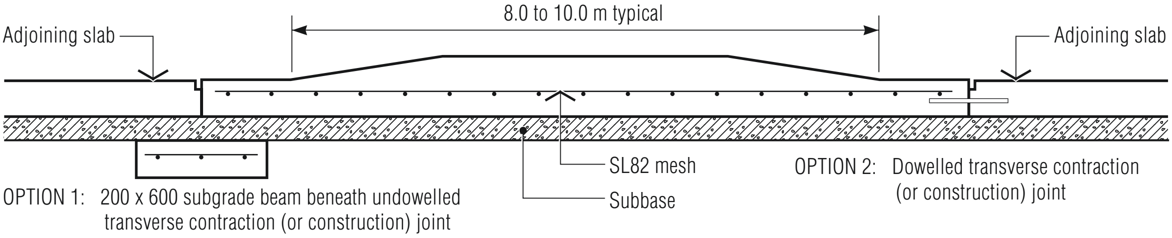


Figure 11.8 Raised pavement profile cast into a single slab.

11.7 THRESHOLDS

11.7.1 General

Thresholds, typically occurring at the intersection between one road and another are often given special treatment to:

- indicate of different road function, status or hierarchy
- improve the appearance of an intersection
- deter or calm entering traffic
- make a subdivision entry statement—usually with other architectural landscaping features.

11.7.2 Treatments

Various devices are used in the threshold treatments to achieve these functions, viz:

- Visual relief and differentiation by colour, texture and pattern
- Tactile differentiation introducing a contrasting texture, by use of different materials or different forms of the same material
- Physical impediment or relief—a raised surface or a restricted width of passage with associated landscaping.

Implementation of some of the above elements within a concrete pavement is considered in the following section.

11.7.3 Elements

Raised pavement A raised pavement profile cast integrally into the pavement will typically be longer than a typical plain (unreinforced) slab. Figure 11.8 shows a slab with a raised profile cast as a single reinforced slab. To preserve shear load transfer, either a dowelled transverse joint or a transverse joint supported by a subgrade beam is required.

To obviate the need for dowels and subgrade beams, transverse contraction joints at intervals shown in Table 10.1 can be provided. The reinforcement should be retained throughout individual slabs over the extent of pavement as shown in Figure 11.8. A crushed rock subbase with a minimum compacted thickness of 100 mm should be provided beneath, as a minimum, the full approach slab, the raised profile and the departure slab.

Splitter Islands and super-imposed kerbing Where splitter islands are constructed over an existing concrete pavement, the integrity of the joints should not be compromised by inadvertently 'locking' together adjacent slabs by either spiked- or cast-in-place kerbing. Active joint lines through splitter islands and overlaid kerbing should be maintained as shown in Figure 11.9.

Pavement narrowing Pavement narrowing requires consideration of the jointing 'rules' to achieve a design—free of unplanned shrinkage cracking. The basic 'rules' are:

- No acute angles at corners
- Reduce mis-matched joints (where this can not be avoided, reinforce the adjacent slab)
- Maintain a width to length ratio of less than 1:1.4 (where this can not be avoided reinforce the slab)
- Desirable minimum slab side length is 600 mm, the absolute minimum is 300 mm.

Figure 11.10 shows the acceptable jointing layouts of a wide and a narrow pavement being further restricted.

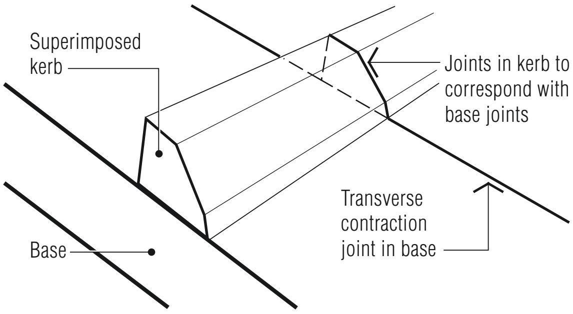


Figure 11.9 *Maintain jointing in super-imposed kerbs and islands*

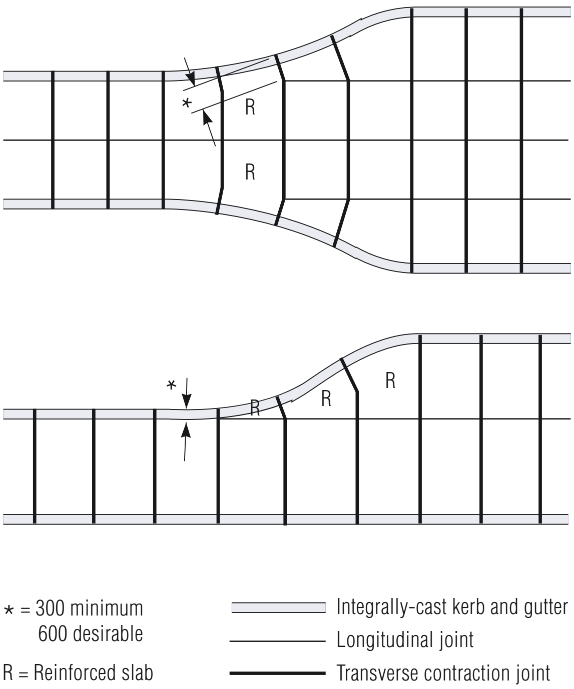


Figure 11.10 *Jointing layouts for pavement narrowing*

11.8 PARKING BAYS

11.8.1 Design

Parking bays may be designed using bikeway design thicknesses for Light Truck or Heavy Truck depending upon the likely traffic loading. Sub-surface drainage should be provided at the junction of the parking bay and pavement as shown in Figure 11.11, unless both pavements are constructed with uniform thicknesses and the junction does not form a drainage invert.

11.8.2 Jointing

For small parking bays, such as 2-car bays, no transverse contraction joint will be required as the slab is fully reinforced with an appropriate size mesh as shown in Figure 11.12. For longer parking bays, it is recommended that reinforced slabs be relieved of shrinkage stresses at a maximum interval of 15 m.

If no reinforcement is used, transverse contraction joints should be provided at the intervals shown in Table 10.1.

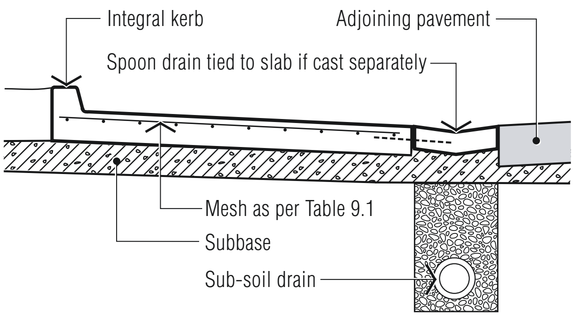


Figure 11.11 *Cross-section of parallel parking bay*

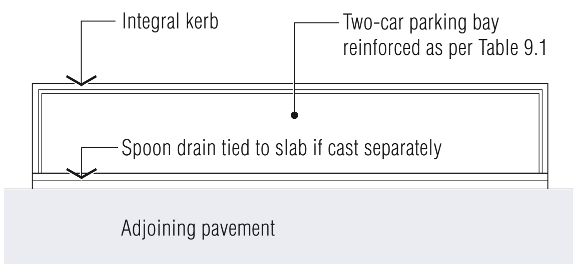


Figure 11.12 *Plan of parallel parking bay*

Appendix A
Glossary of Terms

The following terms are typically used in the description of pavement for residential streets and many have been used in this guide. For further information or other terms, refer to *Cement and Concrete Terminology*[27] or *Dictionary of Concrete*[28].

TERM/DEFINITION

Base The main structural slab of a concrete pavement laid on ground or a subbase.

Bleeding The rising to the free surface of mixing water within newly placed concrete caused by the settlement of the solid material within the mass.

Bond The adhesion of concrete to the surface of hardened concrete or other material such as reinforcement.

Bound material Granular material to which cement or similar binders are added to produce structural stiffness.

Bull float A flat, broad-bladed steel hand tool used in the final stages of finishing operations to impart a smooth surface to concrete pavements and other unformed concrete surfaces.

Compaction The process of inducing a closer packing of the solid particles in freshly mixed concrete during placing by the reduction of the volume of voids.

Construction Joint The location where two successive placement of concrete meet.

Contraction Joint A formed, sawn or tooled joint provided to relieve tensile stress in the pavement due to contraction.

Control joint A joint provided in a concrete pavement to prevent stress due to expansion, contraction or warping.

Controlled low-strength material (CLSM)
A cementitious backfill material that flows like a liquid, self-levels and support like a solid without compaction.

Crack inducer A strip of material placed within the pavement so as to induce a crack at a desired location.

Crazing Fine, random cracks on the concrete surface.

Curing Maintenance of humidity and temperature of freshly placed concrete during some definite period following placing, casting or finishing, to ensure satisfactory hydration of the cementitious materials and proper hardening of the concrete.

Curing membrane A proprietary coating applied to the surface of a concrete pavement to reduce loss of moisture and promote curing.

Curling Warping of a concrete pavement whereby the edges curl up because of differential shrinkage or temperature through its depth.

Dowel bar A smooth steel bar, coated with a de-bonding agent over half its length, placed horizontally across a joint to transfer vertical loads from one panel to another while permitting longitudinal movement between panels.

Edging tool A tool similar to a float, but has a form suitable for rounding the edge of freshly placed concrete.

Expansion joint A joint, normally filled with a resilient material, provided to separate a panel from adjoining panels or structures to prevent stress due to expansion.

Finish The texture and smoothness of a surface.

Finished pavement level The level of the wearing surface of the pavement.

Finishing Levelling, smoothing, or otherwise treating surfaces of freshly or recently placed concrete to produce the desired appearance and characteristics.

Float (see also Power float) A flat-faced wood or metal hand tool, for evening or flattening concrete.

Float finish A rather rough surface texture obtained by finishing with a float.

Floating The use of a float during finishing operations to impart a relatively even (but not smooth) texture to an unformed fresh concrete surface.

Hardened concrete Concrete that has attained an appreciable strength.

In-fill In alternate bay or lane construction, the bays or lanes cast between the previously laid and hardened bays or lanes to complete the pavement.

Initial Set Bleed water has disappeared leaving a matt finish surface; concrete has no appreciable strength; (see also **Set**).

Isolation joint A joint between a panel and an immoveable structure to prevent stress due to expansion or contraction or other structural movements.

Joint filler A strip of compressible and/or elastic material used to fill and expansion or isolation joints.

Joint sealant A material used to prevent ingress of water or solid foreign material into a joint.

Lean-mix concrete Concrete that is designed to have a low-strength.

Longitudinal joint The joint parallel to the direction of the pavement.

Modified material The improvement of the properties of a material by the addition of small quantities of cement or similar binder.

Pavement Traffic carrying structural element comprising a base and/or subbase.

Panel (Syn. with **Slab**) A unit of concrete pavement laid in one piece and bounded on all sides by free edges or joints.

Placing The deposition and compaction of freshly mixed mortar or concrete in the place where it is to harden.

Power float A motor-driven revolving disc that flattens and compacts the surface of concrete pavements.

Sawn joint A transverse or longitudinal groove, cut by a special circular saw to between one-quarter and one-third of the depth of the hardened concrete pavement to create a contraction joint when shrinkage causes a crack between the bottom of the groove and the bottom of the base.

Screed A layer of mortar or other plastic material laid over a pavement and brought to a defined level.

Screed board A straight edge of wood or metal moved over guides to strike off or finish the surface of concrete or a screed layer.

Seal The prevention of ingress of water or foreign solid material into a joint or crack.

Sealant A material used to form a seal in a joint or crack.

Set The condition of cement paste or concrete when it can no longer be moulded but has not attained any appreciable strength.

Shrinkage The reduction in volume caused by drying, thermal and chemical changes.

Side form A form used along one side of a pavement to retain the concrete and act as a datum for finishing the surface.

Slab (Syn. with **Panel**) A unit of concrete pavement laid in one piece and bounded on all sides by free edges or joints.

Subbase A layer of imported material or modified subgrade provided between the subgrade and the base.

Subgrade The upper strata of the existing, imported or improved soil under a pavement.

Tie bar A steel bar (usually a deformed bar) used across longitudinal joints and primarily designed to prevent opening of the joint, rather than as a means of vertical load transfer (as does a dowel bar).

Trowel A tool (usually of highly tempered steel) with a hand grip and made in a variety of patterns to be used to give a particular finish to the surface.

Wearing surface The surface which comes in contact with traffic using the pavement.

Appendix B
Design Example

A concrete pavement is to be designed for a local access road that carries no buses. The pavement is to have a stencilled wearing surface to complement the streetscape and is to be 5 m wide with a roll kerb along one side. No data is available on the average daily heavy vehicle traffic. The design life of the pavement is to be 40 years and a geotechnical investigation has established that the subgrade is sandy clay with a CBR of 6%. A typical cross section of the pavement is shown in Figure B1.

STEP 1 PROJECT INVESTIGATION

1.1 From the geotechnical investigation the subgrade has a CBR of 6%.

1.2 There is no data available for the average daily heavy vehicle traffic. Therefore use the values in Table 5.2 (page 13).

The design commercial vehicle axle groups (CVAG) for a local access street with no buses and a 40-year design life is 3.0×10^5. As the thickness design tables are being used, this value is noted for interest only.

1.3 Carry out a site survey, including locating existing service utilities. Check requirements for proposed service utilities and provide conduits where required.

1.4 A one-way crossfall with be satisfactory for a pavement width of 5 metres. This will minimise storm-water drainage infrastructure.

Sub-surface drainage may not be required to the pavement due to the low heavy vehicle volumes. If a subbase is installed, sub-surface drainage will definitely be unnecessary.

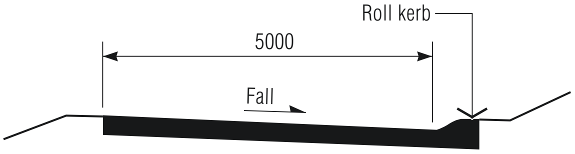


Figure B1 *Typical cross section of pavement*

STEP 2 SUBGRADE

2.1 Check the geotechnical investigation to determine if the subgrade may provide continuous and uniform support for the pavement.

2.2 The subgrade is to be compacted for the full width of the formation (to rear face of kerb) at optimum moisture content.

Refer to Section 6 *Subgrades.*

STEP 3 SUBBASE

3.1 A subbase may not required due to the light traffic loading and future serviceability of the pavement. The geotechnical investigation suggests that the sandy clay subgrade may provide a satisfactory working platform. However, the joints in the concrete must be sealed.

Should any doubt exist as to the ability of the subgrade to sustain construction activity at that time, place a minimum thickness granular subbase (75 mm of 20-mm crushed rock). This is the preferred option.

STEP 4 CONCRETE

4.1 Adopt a concrete base having a flexural strength of 4.25 MPa. The relationship between flexural strength and compressive strength is not known from the local batch plant that will supply the project. Therefore, specify a 28-day characteristic compressive strength of 40 MPa.

STEP 5 THICKNESS DESIGN

5.1 A roll kerb and gutter is along one edge of the pavement; however, there is no guarantee that heavy vehicles will not drive close to the other free edge. Therefore design the pavement thickness for a no-shoulder condition.

5.2 From Table 9.2 (page 24) we can assume the following:

CBR 5 (closest to and *below* CBR value of 6%)

CVAG of 3.0×10^5	40 year design life
Subgrade CBR	6
Concrete base thickness	160 mm

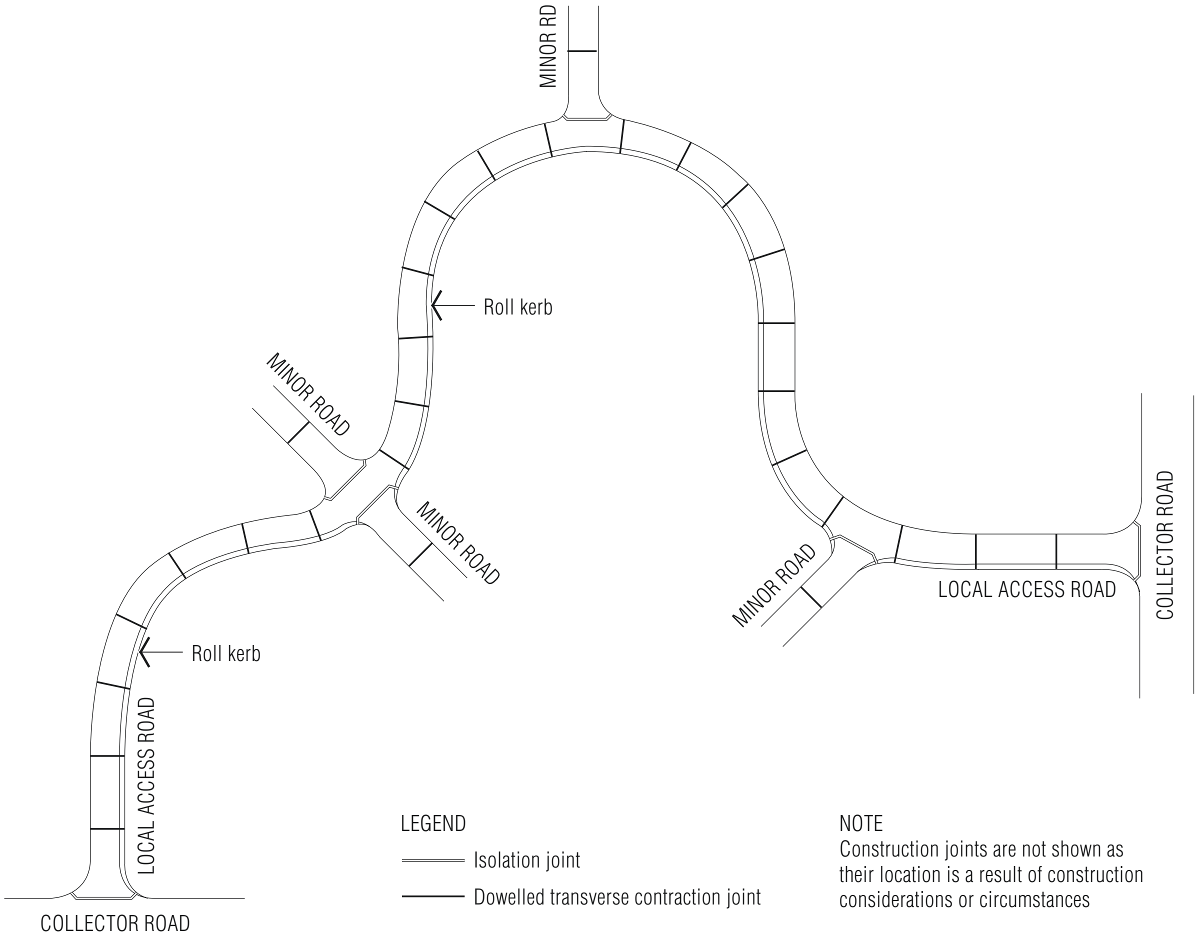


***Figure B2** Pavement joint layout*

5.3 The pavement will be designed as a reinforced pavement to minimise the number of joints. From Table 9.5 (page 26) the pavement is to be reinforced with a layer of RF82 fabric having a 50 mm minimum top cover.

STEP 6 JOINTS

6.1 The maximum spacing for transverse contraction joints is 15 metres. However, adopt a spacing of 12 metres as this permits the use of two standard fabric sheets with suitable lapping and eliminates any end cutting.

6.2 The transverse contraction joints will require dowels to provide load transfer at the joint.

From Table 10.2 (page 28) adopt 20-mm-diameter dowels, 450 mm long and placed 300-mm centres.

6.3 A longitudinal warping joint is not required in the pavement.

Spacing of longitudinal warping joints should not exceed 5 m, except in pavements with a one-way crossfall where a maximum spacing of 6 m is permissible.

6.4 Provide isolation joints to isolate adjacent pavements at intersections and to isolate the pavement from pits or access holes within the pavement.

6.5 The joint layout for the street can now be prepared to achieve a simple layout. Joint layouts at intersections and turning heads may be adapted from Figure 10.10 (page 32). The completed joint layout is shown in Figure B2.

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FURTHER READING

A full list of publications, both downloadable and for sale can be found at www.concrete.net.au.