Roads and Maritime Supplement to Austroads Guide to Pavement Technology

Part 2: Pavement Structural Design

Document No: RMS 11.050 Version 3.0 | August 2018

Supersedes: RMS 11.050 Version 2.2

THIS PAGE LEFT INTENTIONALLY BLANK

Introduction to this Supplement

Austroads has released the *Guide to Pavement Technology, Part 2: Pavement Structural Design* and all road agencies across Australasia have agreed to adopt the Austroads guides to provide a level of consistency and harmonisation across all jurisdictions. This agreement means that the new Austroads guides and the Australian Standards, which are referenced in them, will become the primary technical references for use within the Agency.

This supplement is issued to clarify, add to, or modify the *Austroads Guide to Pavement Technology, Part 2: Pavement Structural Design (2017)*.

Roads and Maritime Services accept the principles in the Austroads *Guide to Pavement Technology, Part 2: Pavement Structural Design (2017)* with variations documented in this supplement under the following categories:

- **Roads and Maritime enhanced practice:** Roads and Maritime practices which enhance the Austroads Guides.
- **Roads and Maritime complementary material:** Roads and Maritime reference material that complements the Austroads Guides. These documents include Roads and Maritime Manuals, Technical Directions or other reference material and are to be read in conjunction with the Austroads Guides.
- **Roads and Maritime departures:** Roads and Maritime that depart from the Austroads Guides.

This document supersedes the following Roads and Maritime publications:

- RMS 11.050 *Austroads Guide to Pavement Technology Part 2: Pavement Structural Design Version 2.2*

Note: In this Supplement the Austroads *Guide to Pavement Technology, Part 2: Pavement Structural Design (2017)* is referred to as the "Guide" and section numbering corresponds to the Guide. Variations to the Guide are detailed under the corresponding headings.

About this release

Title:	Roads and Maritime Supplement to Austroads Guide to Pavement Technology Part 2: Pavement Structural Design
Branch/Section/Unit:	Engineering Services/Pavements and Geotechnical/Pavements
Author:	Senior Pavement Engineer
Contributors:	Pavement Manager (Flexible Pavements), Pavement Manager (Rigid Pavements), Pavement Manager (Project Engineering), Pavement Manager (Asphalt Technology), Pavement Manager (Sprayed Seals), Pavement Manager (Pavement Performance)
Endorsed by:	Director Pavements and Geotechnical
Approvals:	Confer with Director of Engineering
Approved by:	Director of Engineering
Date of Approval and Effect:	August 2018
For:	Roads and Maritime Services and pavement design contractors
Next Review Date:	2019
RMS Publication No.:	RMS 11.050
Keywords:	pavement, base, subbase, subgrade, flexible, rigid, bound, asphalt, granular, concrete, design

Document history

Version	Date	Reason for amendment	Page No.	Editor
3.0	August 2018	Update to align with revised Guide to Pavement Technology Part 2: Pavement Structural Design (2017)	All	SPE
2.2	22/1/2015	Various updates. Changes detailed in V 2.2	All	GV
2.1	July 2013	Various updates. Changes detailed in V 2.1	8-9, 14	GV
2.0	May 2013	Various updates. Changes detailed in V 2.0		AN
1.0	January 2011	Initial document	All	

1. Introduction

Roads and Maritime enhanced practice, complementary material, or departures

1.1 Scope of the Guide and this Part

The terms for various pavement layers found in flexible and rigid pavements are shown in Figure 1. Rigid pavements may have a wearing surface as indicated in Section 9.2.3 in this Supplement.

The pavement structure consists of the base and subbase layers. The subgrade may contain a layer of selected subgrade material in the Selected Material Zone (SMZ) and other layer(s) on top of the natural subgrade. See Figure 2.

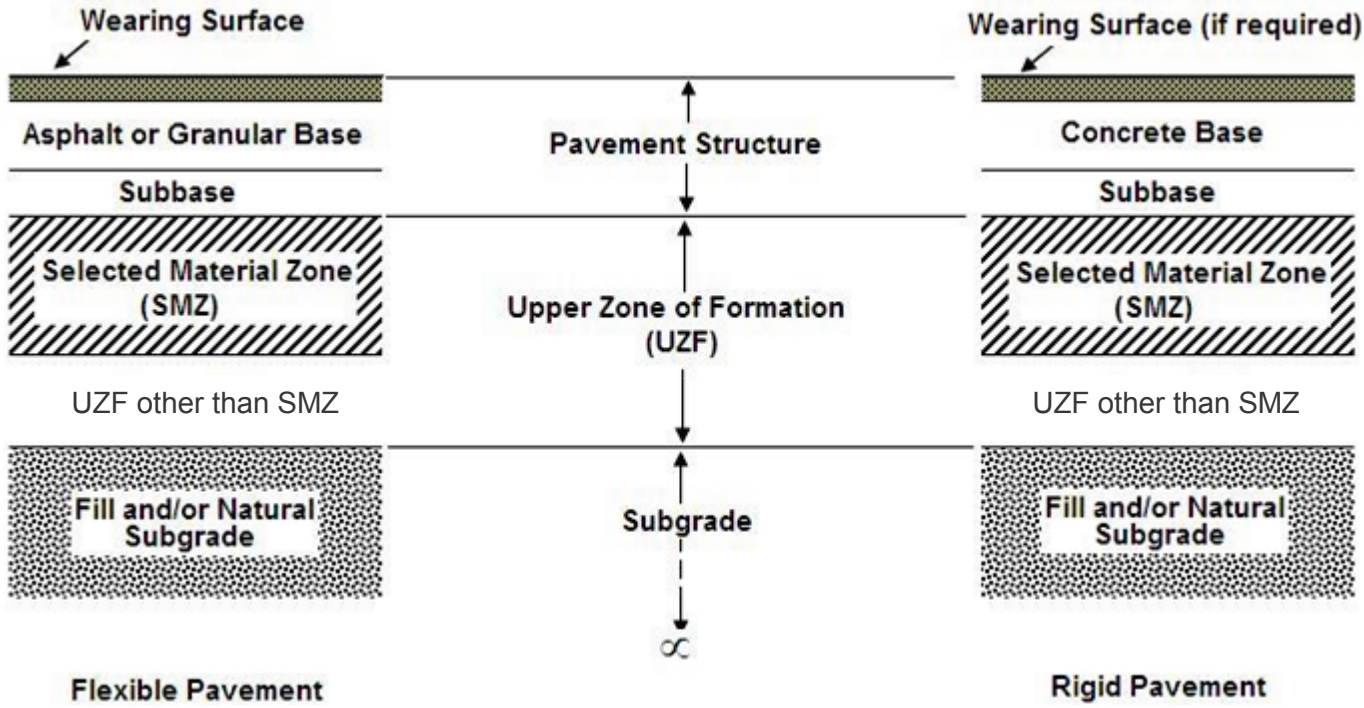

Figure 1: Typical layers of flexible and rigid pavements

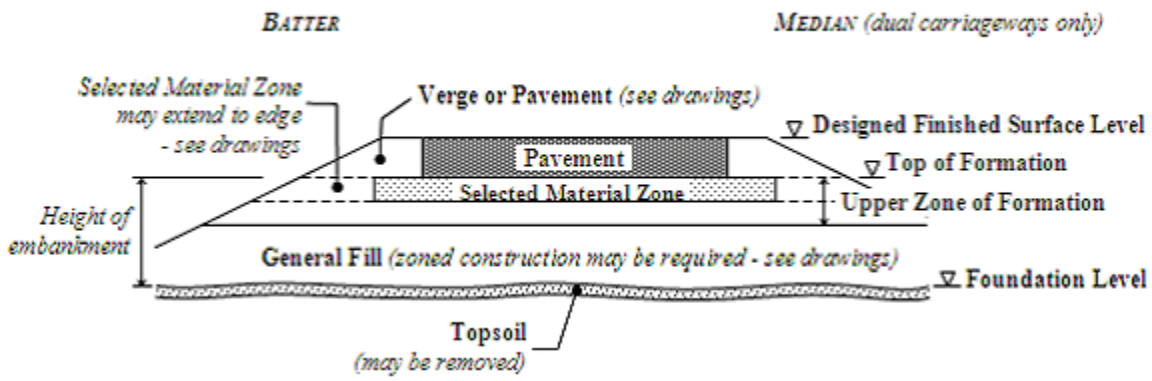

Figure 2: Typical layers of a road embankment according to specification IC-QA-R44

2. Pavement Design Systems

Roads and Maritime enhanced practice, complementary material, or departures

2.2 Common pavement types

2.2.1 General

In this Supplement, heavy duty pavements are defined as those roads having design traffic loading (DESA) of 10^7 ESA or greater in the design lane for the first 20 years of service. The design of new heavy duty pavements is based on a 40 year service life, excluding the post-cracking phase of the cemented layers.

Examples of heavy duty pavement configurations are shown in Figure 3 and Figure 4. Table 1 and Table 2 list additional requirements for these pavements and further information is included in the pavement standard drawings volume *Typical Pavement Profiles*.

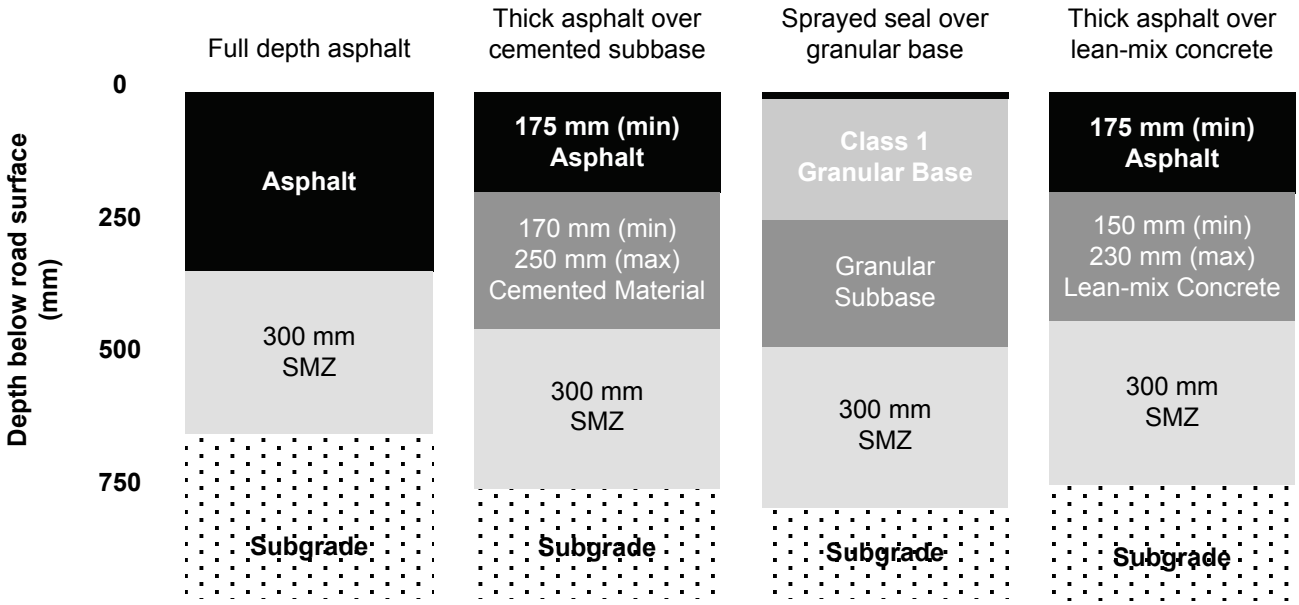

Figure 3: Examples of heavy duty flexible pavement configurations used in NSW

Table 1: Requirements for heavy duty flexible pavements (Notes to Figure 3)

Pavement Type/Layer	Requirements
Full depth asphalt (FDA)	• 7 mm low cutter seal must be placed on top of SMZ. • Typical asphalt thickness range up to 350 mm, compacted in several layers.
Thick asphalt over cemented subbase	• 7 mm sprayed seal must be placed on top of SMZ and a low cutter seal must be placed on top of cemented material layer. • Typical asphalt thickness ranges from 175 mm to 225 mm, compacted in several layers. • Cemented material is heavily bound (modulus E = 5000 MPa). • Minimum and maximum thickness of 170 mm and 250 mm respectively for cemented layer.
Thick asphalt over lean-mix concrete (LMC) subbase	• 7 mm sprayed seal must be placed on top of SMZ. • Lean-mix concrete curing membrane and bonding treatment in accordance with specification R82. • Typical asphalt thickness ranges from 175 mm to 225 mm, placed in several layers. • Lean-mix concrete must satisfy 5 MPa minimum compressive strength (modulus E = 10,000 MPa). • Minimum and maximum thickness of 150 mm and 230 mm respectively for lean-mix concrete layer.
Granular base (heavy duty application)	• Not suitable for climates with an annual average rainfall greater than 800 mm. • Not suitable for a design traffic loading greater than 5 x 10^7 ESA. • Base course must comprise a minimum of 200 mm Class 1 DGB placed in two layers and compacted to a minimum 100 per cent modified relative compaction • Consider granular base and subbase permeability and pavement drainage. • 7 mm sprayed seal on SMZ is optional.
Selected material zone (SMZ)	• Materials within this zone must meet the requirements of specification IC-QA-R44.
Upper zone of formation (UZF)	• Materials within this zone must meet the requirements of specification IC-QA-R44.
Subgrade	Natural subgrade and fill including any treatments for improving the design subgrade California bearing ratio (CBR).

Notes to Table 1:

- A sprayed seal is to be provided below open graded asphalt (OGA) wearing surfaces
- Stone mastic asphalt (SMA) wearing courses should be placed on an AC14 layer to assist in meeting level and ride requirements.

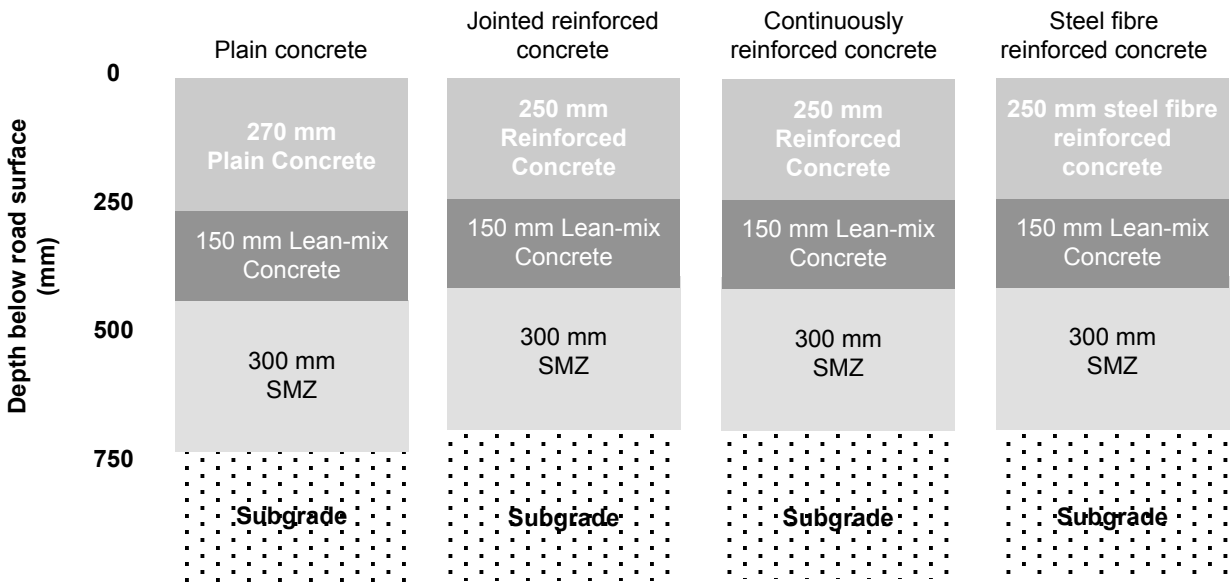

Figure 4: Examples of heavy duty rigid pavement configurations used in NSW

Table 2: Requirements for heavy duty rigid pavements (Notes to Figure 4)

Pavement Type/Layer	Requirements
Plain Concrete	• 7 mm sprayed seal must be placed on top of SMZ. • Curing and debonding treatment on top of lean-mix concrete (LMC) subbase. • For heavy duty applications, base concrete thickness ranges from 220 mm to 280 mm. • Transverse sawcut joints are typically 4.2 m apart with variation required to meet local geometrics.
Jointed Reinforced Concrete	• 7 mm sprayed seal must be placed on top of SMZ. • Curing and debonding treatment on top of LMC subbase. • For heavy duty applications, base reinforced concrete thickness ranges from 200 mm to 250 mm. • SL82 mesh reinforcement. • Dowelled contraction joints typically 8 m apart.
Continuously Reinforced Concrete	• 7 mm sprayed seal must be placed on top of SMZ. • Curing and debonding treatment on top of LMC subbase. • For heavy duty applications, base reinforced concrete thickness ranges from 200 mm to 250 mm with continuous 16 mm diameter longitudinal steel at a minimum proportion of steel of 0.67%.
Selected Material Zone (SMZ)	• Materials within this zone must meet the requirements of specification IC-QA-R44.
Upper Zone of Formation (UZF)	• Materials within this zone must meet the requirements of specification IC-QA-R44.
Subgrade	• Natural subgrade and fill including any treatments for improving the design subgrade CBR.

When selecting the pavement configuration, consider the following:

- Adjoining pavement types
- Construction and maintenance of pavement
- Total and differential settlement
- Works under traffic
- Safety in design
- Applicability of pavement types in tunnels
- Bridge decks.

Adjoining pavement types

Different pavement types should not be used in adjacent lanes unless structural incompatibility, interface drainage and safety issues are addressed.

Construction and maintenance of pavement

In the initial pavement design consider the type and frequency of pavement maintenance. For high volume roads, consider using pavement materials with low frequency of replacement or maintenance to reduce regular maintenance activity on these roads. The pavement should be designed to avoid failure in the lower layers so that future maintenance is confined to the upper layers.

Construction tolerance requirements are stipulated in clauses 8.1 and 9.4.1.

Total and differential settlements

When a pavement is constructed on an embankment or in a cut, design it to cope with the maximum anticipated pavement surface movement or settlement of the subgrade. Settlement variations may be attributed to one of the following conditions:

- Soft soils
- Mining subsidence
- Compressible fill material (for example waste tip areas)
- Underground structures such as culverts and pipes
- Soil stratifications, etc.

Where differential settlement is expected, a pavement type that can tolerate the anticipated movements is required. For rigid and flexible pavements, the subgrade settlement criteria must be specified in the project brief.

Works under traffic

When new pavements are constructed near existing roads or buildings, consider the following issues:

- Extent of vibration from the compaction of unbound and bound layers may affect the surrounding people and structures
- Use of stringlines for ride quality may not be permitted due to traffic flow limitations
- The temporary closure of intersections may influence the pavement materials and construction processes
- Underground services may limit the pavement depth.

Safety in design

The Work Health and Safety Act 2011 requires designs to take into consideration safe work practices for the construction, operation, maintenance and removal of pavements. Refer to the project brief or scope of works and technical criteria (SWTC) for more information.

Pavements in tunnels

The most common types of pavement configurations in tunnels involve continuously reinforced concrete pavements (CRCP) over a no fines concrete (NFC) subbase in unlined tunnels or lean-mix concrete subbase in lined tunnels.

The pavement wearing surfaces applicable to tunnels are:

- Dense graded asphalt
- Stone mastic asphalt
- Concrete with tyning or conventional diamond grinding.

Open graded asphalt (OGA) is not permitted for wearing courses in tunnels.

Lean-mix concrete (LMC) subbase is not permitted in unlined tunnels.

Design the base layer thickness to allow for the traffic loading during the design period of the pavement specified in the project brief or SWTC, trafficking the pavement as a temporary haul road during construction and any grinding required.

Asphalt surfaced concrete bridge decks

Asphalt surfaced concrete bridge decks are to include a quick dry primer (QDP) and sprayed bituminous waterproofing membrane (SBWM) in accordance with Roads and Maritime specification B344 overlaid by a protective asphalt correction course (where required) and the final asphalt wearing course.

The function of the dense graded asphalt correction course is to:

- Provide protection for the waterproofing membrane during future removal and replacement of the wearing course.
- Provide shape correction if required to the bridge deck in order to achieve final ride quality requirements on the wearing course.

Low cutter seals

Standard cutter proportions used in primerseals and cutback sprayed seals may soften the binder of an overlaying asphalt layer which will compromise asphalt performance. A low cutter seal is designed to prevent softening.

The design and application of a low cutter seal is as follows:

- Aggregate spread rate for 10 mm aggregate is to be between 170 - 190 m^2/m^3
- Aggregate spread rate for 7 mm aggregate is to be between 200 - 250 m^2/m^3
- A maximum of 2% cutter oil may be used
- Use 1% adhesion agent
- Double the amount of rolling for a sprayed seal
- For a 10 mm sprayed seal, the typical residual binder is 1.0 L/m^2
- For a 7 mm sprayed seal, the typical residual binder is 0.8 L/m^2
- The sprayed seal is to be placed in accordance with Roads and Maritime specification R106.

A prime and sprayed seal is preferable to a low cutter seal when placed between a thin (50 mm or less) asphalt layer and granular base. A prime is designed with high cutter content to provide penetration into granular material while the sprayed seal would provide waterproofing for the granular base and improve adhesion of the thin asphalt layer to the granular base.

For an asphalt layer (greater than 50 mm thick) over granular base, a low cutter seal is specified. The risk of asphalt delaminating is reduced as the thickness of asphalt increases, however the risk of asphalt failure from trapped cutter oil from a primerseal increases.

Seek advice from Roads and Maritime Pavements unit if a primerseal is to be used between an asphalt layer (greater than 50 mm thick) and a granular base.

2.3 Overview of pavement design systems

2.3.1 Input variables

Table 2.1 of the Guide lists typical project reliabilities for different road classes. The minimum values for Roads and Maritime road projects are shown in Table 3.

Table 3: Minimum project reliability levels for various Roads and Maritime projects

Road Type	Minimum Project Reliability (%)
Freeway, motorway, major highway or heavy duty pavement	95
Other than above where lane AADT > 2000	90
Other than above where lane AADT ≤ 2000	85

3. Construction and Maintenance Considerations

Roads and Maritime enhanced practice, complementary material or departures

3.2 Extent and type of drainage

Subsurface drainage must be considered by the designer for all pavements and provided as required. Where verge, UZF or general fill materials complying with Roads and Maritime specification IC-QA-R44 are placed adjacent to pavement layers, the pavement structure is to be classified as boxed construction.

Design pavement subsurface drainage to comply with the Roads and Maritime standard drawings *Standard Pavement Subsurface Drainage Details* and the Roads and Maritime technical guide *P-G-001 Standard Pavement Subsurface Drainage Details*.

Pavement failures in cuttings are commonly associated with the presence of groundwater. This problem is made worse by heavy traffic and poor drainage. Where geotechnical investigations have identified free water (eg springs), or where the excavation has produced an irregular rock floor or exposed an expansive or dispersive clay and/or soft subgrade, undertake preventative treatments to minimise future deformation in the pavement. See Section 3.14 of the Guide and this Supplement for treatment measures. Refer to Section 5.3.6 of this Supplement for the minimum requirements for pavements in wet cuttings, and Section 5.3.5 regarding expansive subgrades and their treatment.

3.14 Improved subgrades

3.14.1 Soft subgrades

If the insitu California bearing ratio (CBR) of the natural subgrade at the time of construction is less than 2%, provide a stable working platform, bridging layer or adequate treatments to enable the compaction of subsequent layers (eg upper zone of formation, selected subgrade material). Design any measures to satisfy Roads and Maritime specification IC-QA-R44 *Earthworks* and design assumptions.

A working platform complying with specification IC-QA-R50 *Stabilisation of Earthworks* can improve short-term construction issues over a subgrade with insitu CBR < 2%. However, consider the long-term durability of the working platform and the possibility of subsequent settlement of the pavement owing to consolidation of the subgrade.

Table 4 gives a presumptive semi-infinite subgrade design CBR value which may be used in pavement design for various working platforms. When such a working platform is used in pavement design, the requirements must also be shown on the construction plans and changes made to the project-specific specification R44. A working platform provided to overcome short term construction issues and constructed in accordance with specifications IC-QA-R44 and IC-QA-R50 is not considered to provide the same degree of subgrade improvement as those in Table 4.

Table 4: Presumptive design semi-infinite subgrade design CBR values over a working platform

Working platform type	Presumptive semi-infinite subgrade CBR
A minimum of 200 mm of bound material constructed in accordance with the following Roads and Maritime Specifications • Specification IC-QA-R73 Construction of Plant Mixed Heavily Bound Pavement Course or IC-QA-R75 Insitu Pavement Stabilisation Using Slow Setting Binders • IC-QA-3051 Granular Base and Subbase Materials for Surfaced Road Pavements	3%

While a working platform (bridging layer) is required for structural improvement, an impermeable capping layer is placed over the subgrade material to limit its moisture related movements. Refer to Table 5 for conditions that require a working platform and/or a capping layer to be provided. Section 5.3.5 includes additional capping layer requirements.

Table 5: Working platform and capping layer

Design Subgrade CBR	CBR Swell	
	< 2.5%	≥ 2.5%
< 2%	Working platform needed	Working platform and capping layer needed
≥ 2%	No working platform No capping layer	Capping layer needed

Road formations constructed on soft soils

Geotechnical investigations are required and should include the following information:

- Extent of soft ground under the embankment in both transverse and longitudinal directions
- Rate and magnitude of settlement predictions both in transverse and longitudinal directions for the various ground improvement options proposed. Settlement analysis should reflect the proposed construction sequence together with any preloading measures to reduce long term settlements
- Short and long term stability analysis of the road formation structure.

Road formations affected by mining subsidence

Ground subsidence due to longwall mining can be up to 2 m and impose tensile and compressive ground strains of up to 0.015 (ie 15 mm/m). Compressive strain can cause buckling failure of a stiff pavement layer (eg heavily bound subbase or concrete pavement). This may result in pavement stepping, which is a hazard to motorists. For more details, refer to the Roads and Maritime *Guide for design of concrete pavements in areas of settlement*.

Road formation constructed on compressible fill material

Increasingly in built up urban areas, new roads are being constructed over old fill sites (for example, old brick pits in-filled with waste materials). Ongoing settlement of landfill sites poses major concerns to any civil engineering construction at such locations.

Some materials, such as claystone and shale, are of low durability and may be prone to degradation and/or piping under certain moisture conditions. Such materials are not to be used in the upper zone of formation since they may cause excessive long-term settlement and/or differential settlement.

Geotechnical investigations and interpretation should define the extent of such compressible areas and determine the material composition, durability and volumetric stability. The geotechnical report should outline a range of methods to treat the site in order to limit settlements.

4. Environment

Roads and Maritime enhanced practice, complementary material or departures

4.1 General

The effects of climatic and geographic features on pavement design relate to pavement type selection, subgrade moisture conditions, drainage requirements, susceptibility to flooding and the selection of suitable subbase materials. The latter is important since under traffic loading excessive pore water pressure can develop at high saturation values, particularly when the material is prone to breakdown.

The project brief must specify the water level during flooding relative to the finished carriageway surface level.

Seasonal and diurnal temperature variations are important for pavements with asphalt layers. In addition, the effect of climate change should also be considered.

Roads and Maritime roadworks specifications place lower and upper limits on temperatures and weather conditions for placing asphalt, cemented or concrete pavement layers.

Roads and Maritime has defined 12 climatic zones shown in Figure 5. When designing new pavements, consider the rainfall areas and their impact on subgrade strength. Table 6 lists the different climatic zones along with their representative locations, and annual average temperature and rainfall levels.

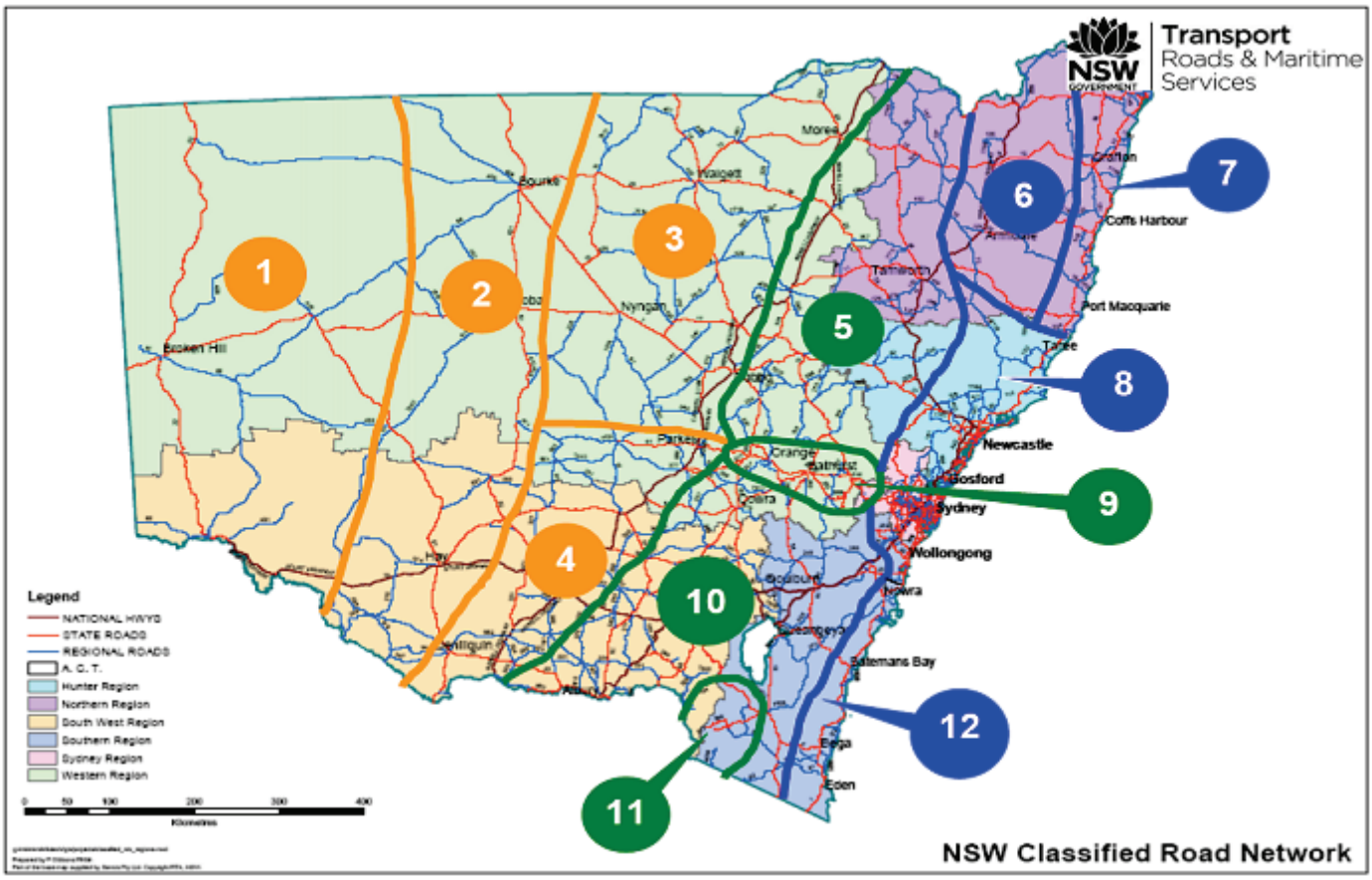

Figure 5: NSW climatic zones defined by Roads and Maritime

Table 6: Average rainfall and monthly temperatures for the 12 NSW climatic zones

Climatic zone №	Description	Min. Avg Temp (ºC)	Max Avg Temp (ºC)	Avg Annual Rainfall (mm)
1	Arid desert Wilcannia	12.1	26.5	261
2	Western plain Cobar	12.7	25.1	408
3	Northern plains Gilgandra	9.9	24.7	561
4	Southern plains Narrandera	9.9	23.2	487
5	Northern hills Gunnedah SCS	10.8	25.9	616
6	Northern ranges Glen Innes	7.2	20.1	857
7	North coast South West Rocks	15.6	23.1	1493
8	Central coast (Sydney) Lucas Heights	12.3	21.4	1036
9	Blue mountains Lithgow	16.5	16.5	1072
10	Cool ranges Yass	7.2	20.6	649
11	Humid mountains Perisher Valley	0.6	10.3	1947
12	South coast Moruya Heads	11.3	20.4	963

5. Subgrade Evaluation

Roads and Maritime enhanced practice, complementary material or departures

5.3 Factors to be Considered in Estimating Subgrade Support

5.3.5 Moisture Changes during Service Life

Expansive subgrades and treatment

Expansive subgrades are highly moisture sensitive. To confirm the appropriate pavement type and composition, and decide whether to place a capping layer over the subgrade material, a combination of insitu field testing, laboratory soaked CBR, CBR swell and field proof rolling are often required. A capping layer can limit moisture changes and the resulting change in pavement shape. See Table 5 for conditions where a capping layer is required.

Where the UZF is placed over a soft or expansive subgrade, material in the UZF must have a permeability < $5x10^{-9}$ m/s. Material in the UZF, other than the selected material zone, must have a CBR > 8% and swell < 1.0% unless otherwise detailed in the project-specific specification R44, the project brief or SWTC. The swell is determined in accordance with test method T117. See Figure 6.

Where the pavement design is based on earthworks requirements that differ to those in the Roads and Maritime specification IC-QA-R44, include the design requirements on the pavement construction plans and in the pavement design report together with clauses for inclusion in the project-specific specification R44.

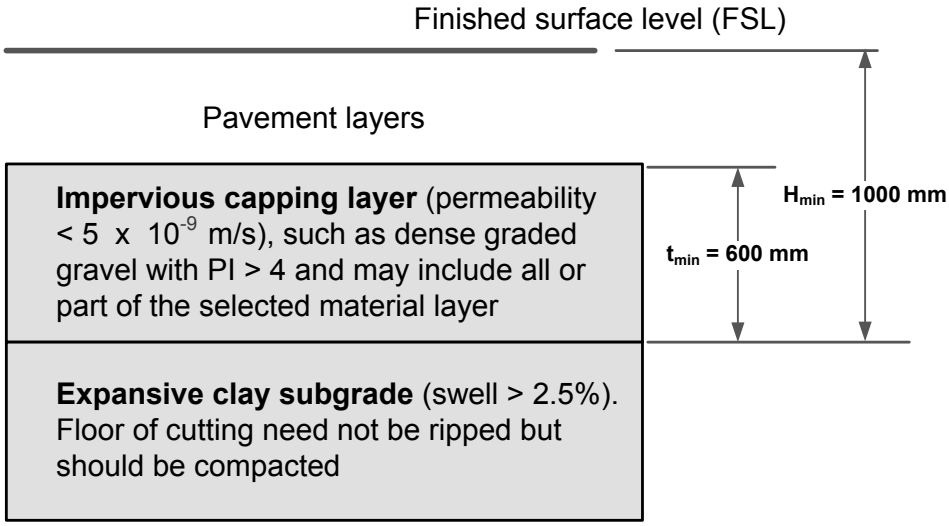

Figure 6: Treatment for expansive clay subgrades

5.3.6 Pavement Cross-section and Subsurface Drainage

Rock or wet cuttings

In rock and wet cuttings where free water has been identified, provide the recommended treatment as detailed in specification IC-QA-R44.

Selected material zone

The selected material zone (SMZ) consists of material in accordance with specification IC-QA-R44 and a minimum thickness of 300 mm. If materials subject to breakdown under compaction and/or wetting and drying cycles are proposed, pre-treatment as detailed in test methods T102 and T103 is to be carried out prior to strength testing. Shale is not permitted for use in the selected material zone.

Provide a 7 mm sprayed seal on the top of the SMZ of all heavy duty pavements except for full depth asphalt pavements where the sprayed seal is to be a low cutter seal: See Table 1. This sprayed seal acts as a construction expedient and minimises the risk of long-term wetting-up of the top of the SMZ at the pavement support interface. The sprayed seal may only be omitted where a granular pavement layer is being constructed on the SMZ and the SMZ is not affected by rain before placing the granular pavement material during construction.

The variety of pavement treatments available for cuttings requires geotechnical consideration on each project, with incorporation of the preferred treatment in design cross sections.

Where the pavement design takes into consideration the strength of specific subgrade treatments nominated in specification IC-QA-R44 or specified for the pavement, nominate the treatment on the plans and amend the project specific specification R44 to suit the pavement design assumptions.

5.6 Laboratory Determination of Subgrade CBR and Elastic Parameters

In agreement with the Guide, the design modulus of subgrade and selected subgrade materials (including SMZ) is capped at a maximum vertical value of 150 MPa.

5.6.2 Determination of Moisture Conditions for Laboratory Testing

Fine-grained materials wet up through capillary action in high rainfall areas. For this reason, use a soaked CBR for design in these areas with a 10-day soaked period in accordance with test method T117 for cohesive soils, unless the rainfall and testing conditions shown in Table 7 support 4-day soaking.

For dry inland regions of NSW prepare the sample at the field moisture content (or the equilibrium moisture content (EMC) where applicable) and test with no soaking period unless the road is subject to inundation or located adjacent to irrigation channels. This approach is to be used in lieu of Table 7.

Table 7: Typical moisture conditions for laboratory CBR testing

Median annual rainfall (mm)	Specimen compaction moisture content	Testing condition	
		Excellent to good drainage	Fair to poor drainage
< 600	OMC	Unsoaked	4-day soak
600 – 800	OMC	4-day soak	10-day soak
> 800	OMC	10-day soak	10-day soak

Table 8 lists published equilibrium moisture content (EMC) and optimum moisture content (OMC) data on pavement and subgrade moisture conditions.

Table 8: Typical ratio of EMC to OMC at modified compaction

Layer	Conditions		EMC/OMC		
			Normal moisture state	Unusually moist state	Wet saturated state
Base	Unbound granular		0.60	0.80	> 1.0
	Post-cracking cemented	1% cement	0.70	0.85	> 1.0
		2% cement	0.80	0.90	> 1.0
Subbase	Arid climate		0.70	0.85	> 1.0
	Moderate climate		0.75	0.90	> 1.1
	Wet climate		0.85	0.95	> 1.1
Subgrade	Arid climate		0.75	0.9	> 1.1
	Moderate climate		0.92	1.05	> 1.1
	Wet climate		1.00	1.1	> 1.15

Table 8 source:

- EMERY, S.J. (1985) Prediction of moisture content for use in pavement design. PhD thesis, University of Witwatersrand, Johannesburg

- MRWA (2009) Reid Highway trials to Dec 2008. Report 2009/5M. Main Roads Western Australia.

5.7 Adoption of Presumptive CBR Values

Presumptive values as listed in Table 9 should only be used when no other relevant information exists.

Table 9: Presumptive subgrade design CBR values

Description of subgrade		Presumptive design CBR values (%)	
Material	**Unified soil classification (USC)**	**Favourable condition (i)**	**Unfavourable condition (ii)**
Highly plastic clay	CH	5	2
Silt	ML	4	2
Silty clay	CL	5	3
Sandy clay	SC	5	3
Sand	SW, SP	10	5

Notes to Table 9:

(i) Favourable condition – good construction conditions, low water table

(ii) Unfavourable condition – poor construction conditions, high water table, flood plain.

6 Pavement Materials

Roads and Maritime enhanced practice, complementary material or departures

6.2 Unbound Granular Materials

6.2.1 Introduction

Material characteristics and requirements

Requirements for unbound granular and modified materials are given in specification IC-QA-3051.

Granular pavement layers are constructed in accordance with relevant roadworks specifications, such as IC-QA-R71.

6.2.3 Determination of Modulus of Unbound Granular Materials

Determination of modulus of top granular sublayer

The Guide permits the assignment of modulus for layered elastic analysis using either direct measurement or presumptive values.

Direct measurement

The measured (designed) moduli of unbound granular materials for pavement analysis based on direct measurement cannot exceed 350 MPa for standard compaction and 500 MPa for modified compaction.

Presumptive values

The maximum presumptive moduli of unbound granular materials are detailed in Table 10 when using specifications IC-QA-3051 and IC-QA-R71.

Table 10: Maximum presumptive moduli of unbound granular materials conforming to specification IC-QA-3051 and specificationIC-QA-R71 (standard) compaction requirements

Maximum presumptive modulus (MPa)			
Based on Table 3051.1		Based on Table 3051.4	
Base	Subbase	Base	Subbase
Class 1 and 2 DGB	DGS20 and DGS40	Class 2 DGB	DGS20 and DGS40
350	250	300	200

Note to Table 10:

- The maximum presumptive modulus for Class 1 DGB material produced in a pugmill with controlled fines and placed in accordance with specification IC-QA-R71 modified compaction requirements is 500 MPa and where a pugmill is not used is 450 MPa.

The vertical modulus (MPa) of the top sublayer for granular material overlain by bound material is defined in Tables 6.4 and 6.5 of the Guide for normal-standard and high-standard base material, with a maximum presumptive modulus of 350 MPa and 500 MPa, respectively. For granular materials with different maximum presumptive moduli to those provided in the guide, the modulus of the top granular layer is defined by:

$E_{Top} = E_{max} \times (1.377 - 3.804 \times 10^{-4} \times T \times E_e^{1/3})$

Where:

E_{Top} = modulus of the top layer (rounded to the nearest 10 MPa)

E_{max} = maximum presumptive modulus of unbound granular material (MPa)

T = thickness of overlying material (mm)

E_e = modulus of cover material (MPa).

For material conforming to specifications IC-QA-3051 and IC-QA-R71, the minimum presumptive design modulus of the top granular sublayer is the greater of 150 MPa and the maximum presumptive value (Table 10) divided by 2.35 (rounded to the nearest 10 MPa).

6.3 Modified Granular Materials

The vertical modulus (MPa) of the top sublayer (E_{Top}) for modified granular material overlain by bound material is limited in accordance with the relationship included in 6.2.2 with E_{max} = 1000 MPa. A minimum of 430 MPa applies.

6.4 Cemented Materials

6.4.1 Introduction

Cemented materials are assumed to be isotropic (that is, the modulus in the vertical direction is the same as the modulus in the horizontal direction) and have a Poisson's ratio of 0.20.

Requirements for materials to be bound are also given in specification IC-QA-3051.

6.4.3 Determination of design modulus

Definition of design modulus

The Guide states that the assigned modulus of a cemented material is an estimate of insitu flexural modulus after 90 days curing in the road bed. Provided the density requirements of the specifications IC-QA-R73 and IC-QA-R75 are met, the modulus is assumed to be constant for the full layer thickness.

6.4.8 Determining the In-service Fatigue Characteristics from Presumptive Flexural Strength and Modulus

In the design of heavily bound pavement course constructed in accordance with specifications IC-QA-R73 and IC-QA-R75 the allowable number of repetitions N is to be determined by the relationship in equation 10 of the Guide with a presumptive constant K of 263. The maximum presumptive pre-cracking modulus value is 5000 MPa for such heavily bound stabilised materials.

6.5 Asphalt

6.5.1 Introduction

Asphalt pavement courses are constructed in accordance with relevant roadworks specifications, such as IC-QA-R116.

An asphalt pavement course may consist of multiple layers in which case each layer must comply with the limits in Table 11.

Table 11: Allowable asphalt layer thickness range

Asphalt type	Allowable layer thickness for different nominal asphalt size (mm)				
	5 mm	7 mm	10 mm	14 mm	20 mm
Dense graded asphalt (AC)	15 - 25	21 - 35	30 – 50	42 - 70	60 - 100
Stone mastic asphalt (SMA)	-	-	30 – 50	42 - 70	-
Open graded asphalt (OGA)	-	-	25 – 40	35 - 56	-
High modulus asphalt (EME 2)	-	-	-	70 - 130	-

AC20 dense graded asphalt is not to be used as a wearing course due to a higher probability of deformation and permeability. Stone mastic asphalt (SMA), open graded asphalt (OGA) or a smaller stone sized dense graded asphalt may be used as the wearing course.

Open graded and stone mastic asphalt surfacing must not be placed directly over dense graded asphalt with nominal size greater than 14 mm. Use of underlying asphalt with nominal size greater than 14 mm may result in out of specification for roughness and finished surface levels as well as an increased permeability and stripping potential.

The risk of variability and segregation increases with the increase in the nominal size of asphalt. Therefore, AC28 dense graded asphalt must be avoided unless specific safeguards such as full width augers and material transfer vehicles are mandated.

6.5.2 Factors Affecting Modulus of Asphalt

Asphalt/binder options

Asphalt containing plastomer polymer modified binder (eg EVA, EMA) should only be used where all underlying asphalt layers contain the same polymer. Plastomers are stiffer than other binders and if asphalt containing a plastomer is placed over less stiff asphalt, early fatigue failure may occur. A cemented subbase should be used under this type of asphalt.

Polymer binders used in open graded and stone mastic asphalt surfacing must be elastomers and not plastomers.

While stone mastic asphalt (SMA) containing elastomeric polymer modified binder can have reasonably high modulus values, its use is limited to wearing surfaces on Roads and Maritime roads. An SMA modulus is highly sensitive to mix design and can be adversely affected by water penetration in the field.

Consistent with the French pavement design catalogue, use of high modulus asphalt (EME2) in pavements containing a cementitiously bound layer below is not recommended due to concerns regarding reflective

cracking. Use of EME2 over a modified granular layer (with unconfined compressive strength less than 1.0 MPa at 28 days) is acceptable.

6.5.3 Definition of Asphalt Design Modulus

The Guide allows the use of either laboratory determined design modulus or modulus derived from the Shell nomographs.

The design modulus must be determined from either the Shell nomographs in the Guide or resilient modulus measured using standard indirect tensile test (ITT) in accordance with AS 2891.13.1 or flexural modulus obtained from four-point bending tests in accordance with Austroads test method AGPT-274-16.

The design modulus is to be rounded to two significant figures and must be calculated at the in-service pavement temperature (WMAPT), the heavy vehicle design speed (Table 13) and the in-service air voids (Table 12). Except for EME2 the adjusted design modulus is limited to a maximum of 4000 MPa and minimum of 1000 MPa.

6.5.4 Determination of Design Modulus from Direct Measurement of Flexural Modulus

This method has limited application under a competitive tender arrangement where multiple asphalt suppliers may be tendering and have not characterised their asphalt mixes.

6.5.5 Determination of Design Modulus from Measurement of ITT Modulus

Modulus determined from ITT must use the procedure described in Section 6.5.5 of the Guide. Correct the measured modulus to an air voids content of 6%. List all the items mentioned in Section 9.1 of AS 2891.13.1 in the test report.

6.5.6 Design Modulus from Bitumen Properties and Mix Volumetrics

The modulus of asphalt, except EME2, may be determined from the Shell nomographs in the Guide (see Figures 6.11 and 6.12 in the Guide) provided the following conditions are met:

- The value determined does not exceed that calculated using Roads and Maritime's asphalt modulus calculator available from Roads and Maritime Pavements unit
- The coarse aggregate size is in the range of 10 mm to 28 mm
- The material property values in Table 12 are used
- The heavy vehicle speeds in Table 13 are used in the determination of the design modulus for various posted speed limits and longitudinal grades
- In-service temperature (WMAPT) for NSW is based on values in Appendix B of the Guide
- Modulus values for asphalts containing polymer modified binder are estimated from asphalt with Class 450 bitumen and adjusted for binder type in accordance with Table 6.13 of the Guide.

Table 12: Presumptive values for asphalt and bitumen properties

Asphalt properties	AC10	AC14	AC20	SMA10	SMA14
Bitumen content by mass (%)	5.7	5.2	4.9	6.7	6.5
Bitumen absorption (%)	0.3	0.3	0.3	0.3	0.3
Insitu air voids (%)	6	6	6	6	6
Combined aggregate density (t/m³)	2.65	2.65	2.65	2.65	2.65
Bitumen properties	AR450				
Rolling thin film oven (RTFO) viscosity (Pa.s)	970				
RTFO penetration (0.1 mm)	31				
Binder density (t/m³)	1.043				

Table 13: Recommended heavy vehicle speeds to be used in the determination of the design modulus for various posted speed limits and longitudinal grades

Posted speed limit (km/h)	Speeds for asphalt characterisation		
	Less than 3% grade	3 to 5% grade	Over 5% grade
60	60	50	20
70	70	60	20
80	80	70	20
100 or greater	100	80	20

Notes to Table 13:

- For urban roads subject to peak hour traffic conditions, the speed for asphalt characterisation is the lesser of that determined from the table and that determined by the posted speed limit less 20 km/h.
- For roundabouts and signalised intersection the use of a polymer modified binder should be considered for rut resistance.

6.5.7 Design Modulus from Published Data

Published data including the values published in Table 6.14 of the Guide are not to be used.

If the structural contribution of open graded asphalt (OGA) is to be taken into account in the pavement design, a maximum moduli of 300 MPa (as a wearing surface) and 500 MPa (as a drainage interlayer) cannot be exceeded.

The presumptive design modulus and binder volume of EME2 at 80 km/h is set out in Table 14.

Table 14: Presumptive design modulus value for EME2

Asphalt Mix Type	Binder Type	Volume of binder (%)	Modulus at 28°C and 80 km/h design speed (MPa)
EME2	EME Binder (15/25 pen)	13.5	6000

Note to Table 14:

- Note: Temperature and speed corrections are to be made using the following equation:

$$E_{WMAPT,V} = E_{28^\circ\ C,80km/h} \times e^{(-0.08(WMAPT-28))} \times (\frac{V}{80})^{0.365}$$

This modulus value is based on an analysis of indirect tensile stiffness modulus test results from:

- Currently available Australian EME2 mixes and
- A French EME2 mix, that was produced in France and tested in Australia.

6.5.12 Permanent Deformation of Asphalt

To design pavements containing asphalt at intersections and other places where vehicles are required to slow down, the mix should be assessed by wheel tracking testing. When conducted, wheel tracking testing must be carried out according to the Austroads test method AGPT-T231-06. The recorded deformation after 10,000 cycles should not exceed the maximum values for various roads (see Table 15).

Testing of the asphalt is only required for the wearing course and any asphalt layer immediately under the wearing course.

Table 15: Maximum wheel tracking deformation depths for various road sites

Description of road site	Maximum tracking depth (mm)
Intersections (within 50 m)	3.5
Roundabouts	3.5
Heavy duty pavements	8
Channelisation of narrow lanes	5
Other sites	13

6.6 Concrete

6.6.3 Subbase Concrete for Flexible Pavements

The performance relationship for a lean-mix concrete subbase is as indicated by equation 27 of the Guide using fatigue constant K of 223.

No increase in modulus and fatigue performance is permitted for higher strength lean-mix concretes as these concretes usually exhibit wider shrinkage cracks.

Maximum presumptive pre-cracking modulus values for lean rolled (roller compacted) and lean-mix concrete are 7000 and 10,000 MPa respectively when supplied to pavement specifications. These modulus values are low when compared with laboratory values but account for the effects of shrinkage cracking and construction variability. In a post-cracking phase, these materials will be considered as non-cemented with the design properties in Table 16.

Table 16: Presumptive post-cracking phase modulus of leaned rolled and lean-mix concrete

Cracked material	Modulus	EV/EH	Poisson's Ratio	Sublayered[(i)]
Lean rolled concrete (cracked by normal traffic)	500 MPa	2.0	0.35	Yes
Lean rolled concrete (cracked by construction traffic)	350 MPa	2.0	0.35	Yes
Lean-mix concrete	700 MPa	1.0	0.20	No

Note to Table 16:

- (i) Sublayering for CIRCLY analysis

If a no fines concrete subbase is used in a flexible pavement, model it as either an additional SMZ layer or a layer that contributes no strength to the pavement.

7. Design Traffic

Roads and Maritime enhanced practice, complementary material or departures

7.4 Procedure for Determining Total Heavy Vehicle Axle Groups

7.4.1 Introduction

For heavy-duty applications, both flexible and rigid pavements are designed for a 40 year design period. Rural highways with medium traffic levels are typically designed for a minimum 20 year design period. See Section 2 of this Supplement.

Considering the possible traffic variations throughout their design periods, all flexible and rigid pavements should be designed with traffic loadings and growth rate based on traffic modelling for heavy vehicle volumes or as specified in the project brief or SWTC. Where the modelled growth rate is less than 1%, use a minimum growth rate of 1%.

Traffic count data is often presented in terms of the number of vehicles or axle pairs. Figure 7 shows a general relationship between the number of axle pairs per vehicle and percent of heavy vehicles for use to calculate AADT from an axle pair count and percent heavy vehicles.

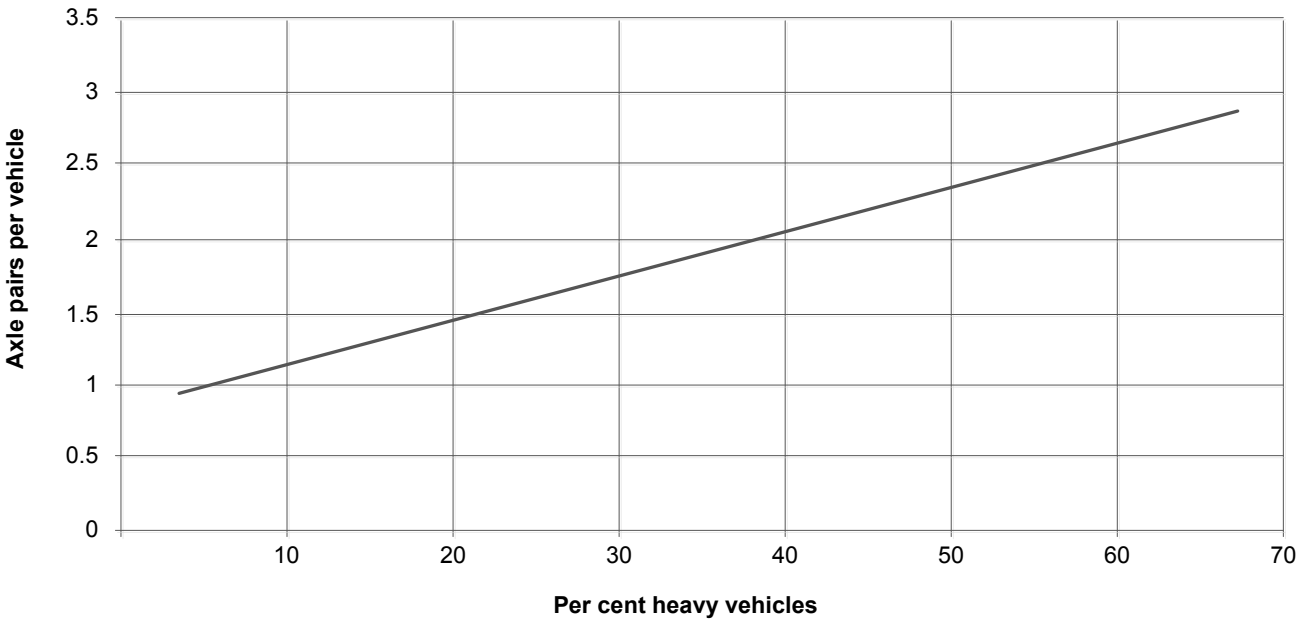

Figure 7: Variation of axle pairs per vehicle with per cent heavy vehicle

7.4.4 Initial Daily Heavy Vehicles in the Design Lane

Method 3 of the Guide is not suitable for the purposes of matching a TLD to the design lane as required in section 7.5 of the Guide.

7.4.7 Cumulative Heavy Vehicle Axle Groups

Calculate the Nhvag from the NSW TLD matched to the pavement design site or, where a NSW TLD was not matched use the appropriate presumptive TLD in section 7.5 of this Supplement.

7.5 Estimation of Traffic Load Distribution (TLD)

The Guide no longer provides presumptive TLDs for urban and rural roads. Traffic load distributions can be obtained by analysing at least three months of WIM data for a road carrying traffic similar to that expected on the road being designed. For traffic design advice, contact the Roads and Maritime Pavements unit.

Matters to be considered in choosing a similar traffic spectrum are:

- Type or class of road
- Rural or urban environment
- Average heavy vehicle axle groups per heavy vehicle (HVAG/HV)
- Axle group proportions
- Expected changes in traffic profile and volume
- Percentage of the design traffic which will travel in the design lane.

If an adjacent WIM site is available, select the TLD from this WIM site.

Where there is no adjacent WIM site, select a NSW TLD to match the design lane's traffic distribution and load distribution where information is available.

Where no classification information exists, select a presumptive TLD from Table 17 or Table 18. Note that using these presumptive TLDs will result in a pavement thickness design based on the 90th percentile of NSW WIM sites.

Table 17: Urban presumptive TLD

Axle group load (kN)	Axle group type %					
	SAST	SADT	TAST	TADT	TRDT	QADT
10	0	1.6515	0	0.0231	0	0
20	0.3561	4.004	0	0.3002	0.015	0.0111
30	13.3571	12.9448	0.0994	0.8502	0.0543	0
40	12.7317	19.902	0.2239	2.4396	0.2766	0.0111
50	21.098	16.829	1.101	4.5192	0.8964	0.0222
60	37.5276	14.0346	4.4791	6.8	2.0169	0.1441
70	14.159	10.8988	11.8182	8.5507	3.639	0.8646
80	0.6755	8.4266	17.1939	8.9734	5.1633	2.2611
90	0.067	6.1059	18.02	7.9581	6.4251	5.1984
100	0.028	3.4667	17.6748	6.3826	6.629	8.3906
110	0	1.2478	13.865	5.3969	5.9452	9.8647
120	0	0.3592	7.4612	5.1905	4.9118	9.2552
130	0	0.1064	3.0661	5.5013	4.4113	6.2625
140	0	0.0227	1.8617	6.2101	4.193	3.9459
150	0	0	1.8641	6.8837	4.3453	3.9348
160	0	0	1.2716	7.285	4.5746	3.6134
170	0	0	0	7.177	4.8813	3.1368
180	0	0	0	5.4063	5.2969	3.2698
190	0	0	0	2.7516	5.7355	3.4915
200	0	0	0	0.9769	6.2336	4.09
210	0	0	0	0.2961	6.465	4.4779
220	0	0	0	0.0899	6.0455	4.7218
230	0	0	0	0.0294	4.825	4.0789
240	0	0	0	0.0082	3.2879	3.0814
250	0	0	0	0	1.9568	2.3055
260	0	0	0	0	1.0135	2.1281
270	0	0	0	0	0.4719	2.0727
280	0	0	0	0	0.1916	2.1392
290	0	0	0	0	0.0806	1.8843
300	0	0	0	0	0.0181	1.8732
310	0	0	0	0	0	1.1527
320	0	0	0	0	0	0.7537
330	0	0	0	0	0	0.6096
340	0	0	0	0	0	0.4323
350	0	0	0	0	0	0.4101
360	0	0	0	0	0	0.1108
370	0	0	0	0	0	0
380	0	0	0	0	0	0
390	0	0	0	0	0	0
400	0	0	0	0	0	0
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000
Group proportions	0.3474	0.1665	0.0214	0.3116	0.1515	0.0016

Table 18: Rural presumptive TLD

Axle group load (kN)	Axle group type %					
	SAST	SADT	TAST	TADT	TRDT	QADT
10	3.2524	16.4151	2.899	0.1572	0.0071	0
20	7.6949	30.342	2.0029	0.5451	0.031	0
30	3.1258	13.3169	0.6796	0.6241	0.0541	0.069
40	3.7531	8.7761	0.6081	0.8996	0.2116	0.2758
50	16.9342	8.1179	2.468	1.1759	1.2353	0.3792
60	52.4934	7.4348	6.6877	2.58	3.8528	0.8274
70	10.2776	5.8528	11.3725	4.8833	5.7266	1.2758
80	1.7075	4.5056	15.3777	6.5131	5.7878	3.2066
90	0.5852	2.3832	17.2731	6.7622	5.0538	4.3094
100	0.1759	1.1701	17.276	7.4089	5.0639	4.1035
110	0	0.7909	11.446	8.8279	5.5024	4.4825
120	0	0.4358	5.1858	8.2671	5.1903	3.8277
130	0	0.3069	2.8255	8.0064	5.3248	4.3789
140	0	0.1519	1.6811	8.0873	5.2651	4.7926
150	0	0	1.2873	8.9493	5.4725	4.2067
160	0	0	0.9297	9.7239	6.0876	4.7585
170	0	0	0	7.3061	6.4428	4.8964
180	0	0	0	4.4557	7.392	4.8958
190	0	0	0	2.2787	7.8481	5.0688
200	0	0	0	1.1198	6.8469	4.552
210	0	0	0	0.6558	5.0767	4.6559
220	0	0	0	0.4006	2.8196	5.312
230	0	0	0	0.2618	1.4952	4.5176
240	0	0	0	0.1102	0.8706	5.6896
250	0	0	0	0	0.4962	4.1378
260	0	0	0	0	0.3567	3.9315
270	0	0	0	0	0.2215	3.3106
280	0	0	0	0	0.1391	2.4485
290	0	0	0	0	0.0998	1.5518
300	0	0	0	0	0.0281	1.3104
310	0	0	0	0	0	1.1038
320	0	0	0	0	0	0.6206
330	0	0	0	0	0	0.3103
340	0	0	0	0	0	0.3103
350	0	0	0	0	0	0.4137
360	0	0	0	0	0	0.069
370	0	0	0	0	0	0
380	0	0	0	0	0	0
390	0	0	0	0	0	0
400	0	0	0	0	0	0
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000
Group proportions	0.3044	0.0670	0.0020	0.2781	0.3465	0.0020

7.6 Design Traffic for Flexible Pavements

7.6.2 Pavement Damage in Terms of Equivalent Standard Axle Repetitions

Where a TLD has not been selected from an adjacent WIM site or by matching classification information, calculate the ESA/HVAG using a presumptive TLD from Table 17 or Table 18 as appropriate.

7.6.3 Design Traffic for Mechanistic-empirical Design Procedure

Where a TLD has not been selected from an adjacent WIM site or by matching classification information, use a presumptive TLD from Table 17 or Table 18 as appropriate.

8. Design of New Flexible Pavements

Roads and Maritime enhanced practice, complementary material or departures

8.1 General

Roads and Maritime requires a construction tolerance to be added to the design thickness of the critical pavement layer. The critical pavement layer is defined as the layer that controls the design life of the pavement through its fatigue resistance or, in the case of granular pavement, is the unbound granular base layer.

The tolerance for granular base, asphalt, lean-mixed concrete and bound material is 10 mm based on the use of automated level control. Where non-automated level control systems are used for construction, an additional 10 mm tolerance may be required (see specifications R71, R73, R75 and R76).

Pavement layer thicknesses are to be rounded up to the nearest 5 mm.

Constructed shoulders of equal thickness and composition as pavement layers allows for:

- Better traffic flow
- Emergency stopping lane for vehicles
- Operation of certain vehicles for vegetation management
- Better confinement of pavement layers
- Moisture protection and drainage of pavement layers.

Design structural shoulders for 100% of the traffic in the design lane. The minimum structural shoulder width for flexible pavements if no kerb and gutter is present is 0.5 m, except for granular pavements with a thin surfacing where the minimum width is 1.0 m. The kerb and gutter must be at least the same depth as the combined pavement base layer and wearing surface thickness. The minimum structural shoulder width applies for both the outer and inner lanes for dual carriageway pavements.

When designing sealed granular shoulders adjoining new pavement and extending beyond the minimum structural width, ‘daylight’ each pavement layer at the edge of the formation on the low side of the pavement in fills to promote pavement drainage, or design as boxed construction. When designing for boxed construction, provide subsurface drainage to prevent saturation of layers within the pavement structure during construction and during the pavement life. The minimum total thickness of granular shoulder material is not to be less than that obtained from Figure 8.4 of the Guide, using a design traffic value for the shoulders of 2% to 5% of the pavement design traffic value, as appropriate. If the shoulder pavement thickness varies from the travelled pavement thickness then consider moisture movement and potential moisture barriers.

Where the sealed shoulder is full lane width, an emergency stopping lane, or is likely to be frequently trafficked, 100% of the design traffic is to be adopted unless otherwise specified in the project brief or SWTC.

The minimum thickness of a cemented or bound pavement course is 170 mm. Construct the full course thickness in one layer to minimise the possibility of early fatigue cracking due to partial slippage of layers following delamination of constructed layers or lifts. With the exception of self-cementing materials, the placement and compaction of cemented or bound material in multiple layers or lifts that involves compaction of the first placed layer or lift prior to spreading a subsequent layer or lift is not permitted under specification IC-QA-R73.

The maximum thickness of any cemented or bound pavement course in a new pavement is 250 mm to ensure full compaction. For rehabilitation treatments where reduced compaction criteria apply such as deep lift insitu stabilisation and temporary connections, thicker layers should be used only as a single layer.

Design the binder content in cemented or bound material to control erosion of interfaces, under surfaces and at shrinkage cracks.

For asphalt thicknesses of 50 mm or less over bound or cemented layers (including lean mix concrete), use an asphalt modulus of 1000 MPa in the analysis and the fatigue life of the asphalt does not need to be considered in the design analysis.

For asphalt thicknesses in excess of 50 mm, consider the modulus and fatigue life of each individual layer (eg AC14, AC20) in the design.

8.2 Mechanistic-empirical Procedure

Calculate strains for use in the mechanistic-empirical design procedure using the computer program CIRCLY (version 5.0 or later).

Mechanistic design with asphalt layers

The information in this section of the Supplement must be read in conjunction with Section 2 and Section 6 of this Supplement.

Sprayed seals must be considered as non-structural pavement layers. Their thickness, based on the ALD nominated in the Roads and Maritime standard drawings *Typical Pavement Profiles*, is not to be included in measured pavement course thicknesses used in the assessment of thickness and level conformance in construction.

Minimum asphalt thickness

The minimum total asphalt thickness over various types of cemented or bound subbases is 175 mm excluding sprayed seals and OGA layers. This thickness is required to minimise the effects of load-induced and thermally-induced movements of the cemented or bound subbases. The thicker the asphalt overlay, the longer the time before reflective cracking becomes evident. This is because structural movement in the subbase is reduced by load spreading and its thermal movement is reduced by the insulating asphalt thickness.

Section 3.8 of the Guide noted that strain alleviating membrane interlayers (SAMIs) can also be used over cement-stabilised bases where future cracking is likely to reflect through the asphalt surfacing. The use of SAMIs in this case can defer the onset of reflective cracking. If the minimum asphalt thickness is provided, SAMIs will not normally be required.

8.2.2 Procedure for Elastic Characterisation of Selected Subgrade and Lime-stabilised Subgrade Materials

Nominate the subgrade design CBR used for pavement analysis and the design CBR of the material in the SMZ. Where the selected subgrade material extends below the SMZ layer, also nominate the design CBR used for pavement analysis of the UZF other than SMZ layer.

The modulus assigned to the UZF other than SMZ layer must not exceed ten times the CBR value nominated in specification IC-QA-R44. Where lime stabilisation is proposed to improve the modulus of the UZF other than SMZ , the improved modulus is not to be considered unless a laboratory investigation is undertaken to determine the required binder application rate and that the rate is sufficient to achieve enhanced long term strength and that the project specific specification R44 is revised accordingly.

8.2.5 Procedure for Determining Allowable Loading for Asphalt, Cemented Material and Lean-mix concrete

A presumptive value of 6 is to be used for the shift factor (SF) in equation 44.

The allowable number of repetitions for cemented materials is to be determined in accordance with equation 45 and a K value in accordance with section 6.4.8 of this Supplement.

8.2.6 Consideration of Post-cracking Phase in Cemented Material and Lean-mix Concrete

The Guide allows for the design of cemented materials in the post-cracked phase. However, Roads and Maritime does not permit the post-cracking phase of cemented material in the subbase layer to be included in the design life of heavy duty pavements. The approach for heavy-duty pavements is to design the cemented material in the subbase layer such that it will not fatigue during the design period. For lighter traffic roads however, it would be acceptable for pavements to incorporate the post-cracking phase as described in the Guide.

8.3 Empirical Design of Granular Pavements with Thin Bituminous Surfacing

8.3.1 Determination of Basic Thickness

Where a pavement configuration consists of a thin wearing surface on a granular base and the design traffic exceeds 10^6 ESA, design the pavement using the mechanistic-empirical design method.

9. Design of Rigid Pavements

Roads and Maritime enhanced practice, complementary material or departures

9.1 General

The design procedure assumes that the base and subbase are structurally debonded by applying a debonding layer such as a bituminous sprayed seal over a wax emulsion curing compound (see specification IC-QA-R82).

The Guide does not offer any guidance on the impact of settlement on pavement thickness. This issue is explained in the Roads and Maritime *Guide for design of concrete pavements in areas of settlement*.

9.2 Pavement Types

9.2.1 Base Types

Roundabout pavements

Some aspects of thickness design for roundabout pavements are detailed in Roads and Maritime *Concrete Roundabout Pavements: A Guide to their Design and Construction*. Concrete pavements offer better performance than flexible pavements under such loading conditions.

9.2.2 Subbase Types

Lean-mix concrete as specified in Roads and Maritime specification IC-QA-R82 must be used as a subbase on all concrete pavement base types except for CRCP in unlined tunnels in rock where no fines concrete (NFC) and an asphalt interlayer is placed in accordance with specification IC-QA-R81. The minimum thickness for lean-mix subbases for heavy duty rigid pavements is 150 mm. The thickness of NFC subbase in unlined tunnels is 220 mm.

9.2.3 Wearing Surface

Where SMA or OGA is specified over CRCP, the minimum asphalt wearing surface thickness is 30 mm. For low speed roads, the minimum thickness of dense graded asphalt over CRCP is 30 mm or as specified in the project brief. In lieu of adding a maintenance tolerance to the CRCP base thickness to allow for removal and replacement of the asphalt surfacing, a dense graded asphalt layer may be included under the wearing surface.

Thin asphalt wearing surfaces must not be used over plain concrete pavement and jointed reinforced concrete pavement as reflective cracking in these thin layers is difficult to maintain, even with a pre-treatment over the transverse contraction joints. See Section 8.2 of this Supplement.

9.3 Factors used in Thickness Determination

9.3.3 Base Concrete Strength

A minimum 28-day concrete flexural strength of 4.5 MPa is required for PCP, JRCP and CRCP pavements. Steel fibre reinforced concrete for roundabouts is typically designed to a minimum 28-day flexural strength of 5.5 MPa.

9.3.5 Concrete Shoulders

A concrete shoulder must be incorporated in the design. In this case, the Guide defines the structural requirements for channel gutter, or kerb and gutter, to function as shoulders. Refer to Roads and Maritime Pavement Standard Drawings for Rigid Pavement – Standard Details – *Construction*.

9.4 Base Thickness Design

9.4.1 General

Roads and Maritime requires a construction tolerance of 10 mm to be added to the design base thickness.

In addition to the construction tolerance, an allowance of 10 mm must also be added to the design base thickness for rigid pavements with a concrete wearing surface for future surface grinding. This additional thickness is a provision for grinding the concrete surface within the pavement life cycle to:

- Re-establish surface texture
- Reduce dynamic loading and improve ride quality.

The additional 10 mm of thickness provides for the possibility of two scheduled grinding operations during a 40 year pavement life.

In addition to the construction tolerance, an allowance of 10 mm must also be added to the designed base thickness for CRCP pavements with an asphaltic wearing course if a sacrificial dense graded asphalt layer is not provided between the CRCP and asphaltic wearing course. This additional thickness is a provision for removing the wearing course by cold milling without reducing the CRCP thickness.

The design approach detailed in the Guide is based on highway traffic loading. Appendix J of the Guide has a procedure for evaluation of pavement damage due to specialised vehicles. The effect of such heavy loads, together with the effect of temperature variation, should be analysed using a numerical method such as the finite element method (FEM).

9.4.3 Minimum Base Thickness

Determine the minimum rigid pavement base thickness as the greater of:

- The design thickness determined in accordance with section 9.4.2 of the Guide and increased by the construction tolerance and where necessary the grinding/milling tolerance as per section 9.4.1 of this Supplement, and
- The minimum thickness in accordance with Table 9.7 of the Guide.

The minimum base thickness in Table 9.7 of the Guide assumes a design concrete flexural strength of 4.5 MPa for plain and reinforced concrete, and 5.5 MPa for steel fibre reinforced concrete, and joint spacing as detailed in Section 9.2.1 of the Guide.

9.4.5 Example Design Charts

These charts are graphical solutions of pavement thicknesses based on the example traffic load distribution in Appendix G of the Guide. They will be of assistance in establishing a trial thickness for a given effective subgrade CBR and design traffic in the initial design stage.

9.5 Reinforcement Design Procedures

9.5.3 Reinforcement in Jointed Reinforced Pavements

Jointed reinforced concrete slabs are usually 8 m to 15 m long, but lengths in range of 8 m to 10 m are recommended on the basis of economy and pavement performance. In addition, slabs longer than about 12 m are likely to provide noticeably lower ride quality because of wider transverse joints.

In steel fibre reinforced concrete pavements, slab lengths must be limited to 6 m in the case of undowelled joints (the limiting factor being shear transfer at joints) and 10 m for dowelled joints (the limiting factor being flexural capacity of the slab).

9.5.4 Reinforcement in Continuously Reinforced Concrete Pavements

The Guide shows that the proportion of longitudinal reinforcing steel (p) in a cross section, or steel ratio, is initially determined using Equation 61. For example, in a typical continuously reinforced concrete pavement using N16 bars, assuming a crack width of 0.3 mm, and a total shrinkage and temperature strains of 500 $\mu\varepsilon$ (ie 500 x 10^{-6}), the minimum longitudinal steel proportion is 0.67%.

9.7 Joint Types and Design

Joints and rigid pavement detailing must be in accordance with specifications IC-QA-R82, IC-QA-R83 and the following Roads and Maritime standard drawings for new construction:

- Pavement Standard Drawings, Rigid Pavement, Volume CP - Plain Concrete Pavement
- Pavement Standard Drawings, Rigid Pavement, Volume CC - Continuously Reinforced Concrete Pavement
- Pavement Standard Drawings, Rigid Pavement, Volume CP – Jointed Reinforced Concrete Pavement
- Pavement Standard Drawings, Rigid Pavement, Steel Fibre Reinforced Concrete Pavement (SFCP) for Roundabouts
- Pavement Standard Drawings, Rigid Pavement, Bicycle Path Design.

The design methodology for rigid pavements takes into consideration assumed heavy vehicle wheel spacing along the axle and within the group, and wander of the vehicle within the lane. Figure 8 provides the nominal spacing of wheels to be adopted in design joint layout when specified.

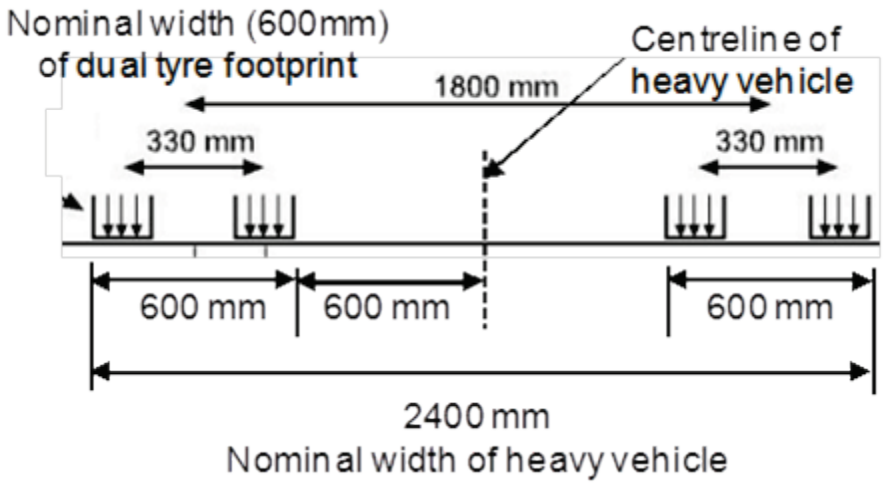

Figure 8: Location of wheels for a dual tyre axle group configuration

10. Comparison of Design

Roads and Maritime enhanced practice, complementary material or departures

10.2 Method for Economic Comparison

The present worth of costs method is the preferred option. It effectively allows both uniform series and sporadic events (which are applied through the life of the pavement) to be simultaneously accommodated in the analysis.

10.5 Salvage Value

Roads and Maritime favours a nil residual benefit or salvage value for roads at the end of the analysis period (unless the plan for a particular option is to have rehabilitation or reconstruction through the period). However certain long lasting pavements would still be functional after 40 years (or even have substantial value as suitable to take an overlay). These pavements should be assigned a residual value in the analysis but not more than 25% of the initial construction cost.

10.6 Real Discount Rate

Based on the *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives – Transport Economic Appraisal Guidelines*, the analysis must be carried out using a central real discount rate of 7%, with sensitivity tests performed at 4% and 10%.

10.7 Analysis Period

For heavy duty pavements, an analysis period of 40 years from the year of opening to traffic should be used. This applies for both flexible and rigid pavements.

10.8 Road user costs

Road users costs are not applied for pavement costs comparisons unless specified in the project brief.

References

Concrete Roundabout Pavements: A Guide to their Design and Construction, NSW Roads and Maritime Services

Guide for design of concrete pavements in areas of settlement, NSW Roads and Maritime Services

Guide to Pavement Technology, Part 2: Pavement Structural Design (2017) Austroads

P G 001 Standard Pavement Subsurface Drainage Details, NSW Roads and Maritime Services

Prediction of moisture content for use in pavement design, Emery, S.J. (1985) PhD thesis, University of Witwatersrand, Johannesburg

Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives – Transport Economic Appraisal Guidelines, Transport for NSW

Reid Highway trials to Dec 2008, Report 2009/5M, Main Roads Western Australia

TPP 07-5 *NSW Government Guidelines for Economic Appraisal,* 2007, NSW Treasury

Roads and Maritime specifications

IC-QA-R44 *Earthworks*

IC QA R50 *Stabilisation of Earthworks*

IC-QA-106 *Sprayed Bituminous Surfacing (with Cutback Bitumen)*

IC QA 3051 *Granular Base and Subbase Materials for Surfaced Road Pavements*

IC-QA-75 *Insitu Pavement Stabilisation Using Slow Setting Binders*

IC-QA-76 *Insitu Pavement Stabilisation Using Foamed Bitumen*

IC-QA-82 *Lean-Mix Concrete Subbase*

IC-QA-83 *Concrete Pavement Base*

IC QA B344 *Sprayed Bituminous Waterproofing Membrane*

IC QA R106 *Sprayed Bituminous Surfacing (with Cutback Bitumen)*

IC QA R116 *Heavy Duty Dense Graded Asphalt*

IC-QA-R71 *Unbound and Modified Pavement Course*

IC-QA-R73 *Construction of Plant Mixed Heavily Bound Pavement Course*

IC-QA-R81 *No Fines Concrete Subbase*

Test methods

AS/NZS 2891.13.1:2013 *Methods of sampling and testing asphalt - Determination of the resilient modulus of asphalt - Indirect tensile method*, SAI Global

T117 *California bearing ratio of remoulded specimens of road construction material*, NSW Roads and Maritime Services

AGPT-T231-06 *Deformation Resistance of Asphalt Mixtures by the Wheel Tracking Test,* Austroads

AGPT-T274-16 *Characterisation of Flexural Stiffness and Fatigue Performance of Bituminous Mixes*, Austroads

Roads and Maritime pavement standard drawings:

Typical Pavement Profile

Standard Pavement Subsurface Drainage Details

Rigid Pavement, Volume CP - *Plain Concrete Pavement*

Rigid Pavement, Volume CC - *Continuously Reinforced Concrete Pavement*

Rigid Pavement, Volume CP – *Jointed Reinforced Concrete Pavement*

Rigid Pavement, *Steel Fibre Reinforced Concrete Pavement (SFCP) for Roundabouts*

Rigid Pavement, *Bicycle Path Design*

www.rms.nsw.gov.au/

13 22 13

Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

August 2018
RMS 11.050