Pavement Design Supplement

Supplement to 'Part 2: Pavement Structural Design' of the Austroads Guide to Pavement Technology

November 2013

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Foreword

The Queensland Department of Transport and Main Roads (TMR) adopts the fundamental pavement design principles in *Part 2: Pavement Structural Design* of the Austroads *Guide to Pavement Technology* (Austroads, 2012), hereafter referred to as AGPT02.

TMR has published this *Pavement Design Supplement* ("this supplement"), for use in TMR projects, to complement the design guidance provided by Austroads, such as for Queensland's local materials, environment, loadings and pavement performance. Therefore, this supplement generally does not repeat the guidance already provided in AGPT02, and pavement designers completing designs for TMR works should use this supplement in conjunction with AGPT02, as well as any other project-specific requirements.

This supplement replaces the *Pavement Design Manual* (Main Roads, 2009).

For ease of reference, section numbers in this supplement align with the applicable section numbers in AGPT02. References to section numbers, tables, figures, equations and appendices are to be read as references to both this supplement and AGPT02. Where additional sections, tables, figures, equations and appendices are included in this supplement, these are numbered with a prefix of Q.

This supplement is not a prescriptive standard, rather it is intended to be a guide for professional, trained, experienced and knowledgeable pavement designers who:

- work within the confines of government policies, guidelines and road network requirements
- are aware of, assess and apply risk management and budgetary constraints to the road system as a whole and its various components
- apply engineering principles and data to a design, construction or production activity
- take into account local area or project-specific issues, including when the typical assumptions and standards in this supplement are being considered, and
- optimise initial designs and in-service treatments to suit budget and whole-of-life cost issues.

As this supplement is not a prescriptive standard, reference to it in contract documents will typically require project-specific requirements appropriate for the contract to be included in a pavement design brief. A pavement design brief is essential for projects where the designer is external to TMR, particularly where the contract is a type where the designer is employed or engaged by a third party such as a construction contractor or developer. A more detailed brief is likely required for these types of contracts, as compared to an RCC-style (AS2124) contract. Further guidance on developing project design briefs is included in Section 1.2.

Due to differences between design inputs and whole-of-life actualities (e.g. traffic growth, enforcement of and changes to legislation relating to heavy vehicle loading, variability in construction, accuracy of design models, environmental considerations and ongoing maintenance and rehabilitation) the guidance contained in AGPT02 and this supplement can provide only an indication of future pavement performance. Specifically, the guidance provided for typical design assumptions and standards is based on TMR practice and experience to date, and current future directions, including:

- for the TMR controlled road network, historically the pavement design imperative has been for low cost all-weather connections through the adoption of lower initial standards in order to favour maximum length constructed. This has provided an adequate level of service over the whole network within the context of budgetary constraints and the comparatively large geographical area of Queensland with a relatively low population density

- reducing high cost maintenance interventions and associated user disruptions on highly trafficked urban roads remains a priority
- vehicle load intensities are increasing, causing increased vertical loading and associated increases in horizontal shear loading
- expectations about safety requirements, and
- delivering value for money, including working within the constraints of limited initial budgets.

Alternatives and exceptions to AGPT02 and this supplement's typical design assumptions and standards may be necessary for the designer's project-specific engineering design. In making these professional engineering decisions, designers are implicitly evaluating the engineering risks and benefits to the project based on application of the pertinent engineering technology. Professional engineers will recognise that there may be compounding and interconnected risks and/or opportunities when multiple changes to typical values are applied in determining a design solution.

Where innovations are being considered, designers and project managers should refer to *Engineering Innovation within TMR* (TMR, 2013a).

Contents

Appendix B

Tables

Figures

1 Introduction

1.1 Scope of the guide

This supplement is for the design of pavements that are within the scope of AGPT02. Limitations of AGPT02 in terms of its scope also apply to this supplement.

Pavements are assumed to be constructed to TMR quality requirements and standards.

This supplement and AGPT02 are part of a suite of technical documents which are relevant to the design and construction of pavements on TMR projects. Pavement designers and project managers are referred to other components of the suite which include the Austroads *Guide to Pavement Technology* (Parts 1 to 10) and the following TMR documents:

- *Specifications and Technical Standards Manual*
- *Pavement Rehabilitation Manual*
- *Road Planning and Design Manual*
- *Materials Testing Manual*
- *Road Drainage Manual*
- *Road Traffic Noise Management: Code of Practice*
- *Skid Resistance Management Plan*
- *Standard Drawings Roads Manual*
- *Asset Maintenance Guidelines*
- *Busway Planning and Design Manual*
- *Engineering Notes, Policy Statements and Technical Notes*
- *Supplementary specifications and test methods*
- *Risk Management Framework*
- *Guide to Risk Management*
- *Guidelines for Strategic Road Network Planning*

This supplement and AGPT02 do not specifically address the selection of pavement surfacings. In some cases, typical surfacings have been included to illustrate typical design outcomes. For project-specific selection, designers and project managers are referred to:

- *Part 3: Pavement Surfacings* of the Austroads *Guide to Pavement Technology* (Austroads, 2009)
- *Update of Double / Double Design for Austroads Sprayed Seal Method,* AP-T236-13 (Austroads, 2013a) and
- *Update of the Austroads Sprayed Seal Design Method*, AP-T68-06 (Austroads, 2006).

1.2 Project scope and background data requirements for design

1.2.1 Investigation and design proposal

For TMR projects, the proposal (often referred to as the pavement design brief) details the required outcomes of pavement design including:

- assumptions regarding design inputs and level of acceptable risk
- project scope requirements listed in Table 1.1, and
- method of reporting alternatives and exceptions (such as departures from the "typical" assumptions, methodology and standards in AGPT02 and this supplement) for TMR approval/acceptance, including:
  - i) reasons for the departure
  - ii) requirements for implementation (for example, modifications and/or additions to standard specifications)
  - iii) estimated cost savings or additional costs, and
  - iv) anticipated and/or potential impacts, including those on road users, serviceability, durability, whole-of-life performance, construction program, functional performance, maintenance requirements and safety.

Designers are expected to seek clarification from TMR regarding any aspects of the design requirements that are unclear or missing from the design brief.

2 Pavement design systems

2.1 Common pavement types

2.2.1 General

The choice of pavement type requires consideration of project-specific factors which may include:

- horizontal shear stresses on grades, curves and intersections (for example, granular pavements with sprayed seal surfacing may not be suitable in some locations; and, for granular pavements with thin asphalt surfacings, it may be necessary to increase the thickness of asphalt in these areas)
- likely in-service moisture conditions may limit the suitability of unbound granular materials
- heavy vehicle loads and/or pavement contact stresses higher than those used in the development of the current pavement design models and technical standards
- availability and adequacy of materials and costs of transporting materials
- adoption of standards higher than the minimums in the technical standards (e.g. when the standard of available materials is well in excess of the technical standards) may reduce the performance risk for some pavement types
- availability and adequacy of construction equipment and expertise
- construction constraints (e.g. construction under traffic may preclude the adoption of pavement materials that require long curing periods prior to trafficking)
- changes to the function/classification of the road during the design period

- changes to the road network during the design period
- specific functional requirements (e.g. safety, noise)
- current and future traffic characteristics including anticipated changes to vehicle mass limits and tyre pressures during the design period
- subgrade settlement and/or water-induced volume change which may impact on pavements with stabilised or rigid layers
- whole-of-life costs which may include both direct and indirect costs such as structural interventions, maintenance, rehabilitation, raising drainage structures, increasing clearances, raising safety barriers, providing temporary access, maintaining alternative routes, delays and disruptions to road users
- sustainability requirements such as local laws, policies and regulations
- current and future budget considerations, and
- local environmental conditions.

A guide to the selection of pavement types for TMR projects based on traffic loading is provided in Table Q2.1. This guide is intended to be used in conjunction with local practice and experience, and with the consideration of project-specific factors. For busway pavements, reference should also be made to the TMR *Busway Planning and Design Manual*.

Table Q2.1 – Guide to the selection of pavement types based on traffic (ESA)

Pavement Type	Rural				Urban			
	Average daily ESA in design lane in year of opening							
	< 100	100 to < 1000	1000 to < 3000	≥ 3000	< 100	100 to < 1000	1000 to < 3000	≥ 3000
SG	✓✓	✓✓	✓	××	✓#	✓#	××	××
SG(HD)	×	✓	✓	××	×	×	××	××
CMB	✓✓	✓✓	✓	××	✓✓	✓	✓	××
AG(B)	×	✓*	××	××	✓✓	✓*	××	××
AG(A)	×	✓	✓	××	×	✓✓	✓	××
ASt(A)	×	✓	✓	××	×	✓✓	✓	××
ASt(B)	×	✓	✓	××	×	✓	✓	××
FC	×	×	✓	✓	×	×	✓	✓
DSA	×	×	✓✓	✓✓	×	×	✓✓	✓✓
FDA	×	×	✓✓	✓✓	×	×	✓✓	✓✓
Rigid	×	×	✓✓	✓✓	×	×	✓✓	✓✓

	Notes
✓✓	Typically suitable
✓*	Typically suitable where the asphalt fatigue life is acceptable
✓#	Typically suitable where a sprayed seal surfacing is acceptable
✓	May be suitable following project-specific assessment (for example, to consider relatively high initial cost and/or performance risk)
×	Not typically adopted due to relatively high initial cost
××	Typically unsuitable due to anticipated poor or uncertain performance
	Abbreviations
SG	Unbound granular pavement with sprayed seal surfacing (Table Q2.2)
SG(HD)	Heavy-duty unbound granular pavement with sprayed seal surfacing (Table Q2.2)
CMB	Cementitiously modified base with sprayed seal or asphalt surfacing (refer to Section 6.3 for further details)
AG(B)	Unbound granular pavement with thin asphalt surfacing (Table Q2.4)
AG(A)	Asphalt over granular pavement (Table Q2.5)
ASt(A)	Asphalt over cementitiously stabilised granular pavement (Table Q2.10)
ASt(B)	Cementitiously stabilised granular base with thin asphalt surfacing (Table Q2.11)
FC	Flexible composite pavement (Table Q2.6)
DSA	Deep strength asphalt pavement (Table Q2.7)
FDA	Full depth asphalt pavement (Table Q2.8)
Rigid	Concrete pavement (Table Q2.9)

2.2.2 Granular pavements with sprayed seal surfacings

The typical structure of a granular pavement with a sprayed seal surfacing (SG and SG(HD)) is as shown in Table Q2.2.

Table Q2.2 – Typical structure of granular pavement with sprayed seal surfacing (SG and SG(HD))

Course	Description (typical)
Surfacing[1]	Prime plus sprayed seal
Base and subbase	Unbound granular material selected using Table Q6.1. Thicknesses are typically determined from Figure 8.4 or Figure 12.2.

Notes:

1. Refer to Appendix A of AP-T236/13 (Austroads, 2013a) for guidance on specific treatment selection.

2.2.3 Cemented granular bases with sprayed seal surfacings

Pavements comprised of a cemented granular base with sprayed seal surfacing are at times adopted by TMR for floodways in remote areas where more resilient concrete pavements are determined to be uneconomical on a whole-of-life basis. Due to the significant maintenance/performance issues associated with this pavement type, it should only be adopted after a rigorous pavement selection process has been undertaken that compares it to other alternatives. The typical structure of such a pavement is as shown in Table Q2.3.

Table Q2.3 – Typical structure of cementitiously stabilised granular base with sprayed seal

Course	Description (typical)
Surfacing	Prime plus a 14 mm C170, PMB or geotextile seal[1]
Base	Minimum 150 mm Cat 1 or Cat 2 cementitiously stabilised granular material (design thickness determined by mechanistic design)
Subbase	If required, minimum 150 mm Type 2.3 unbound granular material. Cementitious treatment is sometimes adopted for this course (refer to Section 3.14.2 for further details).

Notes:

1. Where improved resistance to reflective cracking is required, a SAM (PMB) or geotextile seal should be considered.

2.2.4 Granular pavements with thin asphalt surfacings

The typical structure of a granular pavement with thin asphalt surfacing (AG(B)) is as shown in Table Q2.4.

Table Q2.4 – Typical structure of granular pavement with thin asphalt surfacing (AG(B))

Course	Description (typical)	
Surfacing[1,2]	DG10[4] or DG14[3]	OG10 or OG14
Seal	N/A	10 or 14 mm waterproofing seal with S4.5S binder
Intermediate	N/A	DG10[3] or DG14[3]
Prime and seal	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Base and subbase	Unbound granular material selected using Table Q6.1. Thicknesses are typically determined from Figure 8.4, Figure 12.2 or mechanistic design.	

Notes:

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for guidance on the selection of binder type in the asphalt layers.
3. The fatigue life of the asphalt should be assessed using mechanistic design.
4. Refer to Section 8.2.5 for guidance on the design of asphalt surfacings less than 40 mm thick. DG10 is typically limited to locations with design traffic less than 100 ESA/day at opening when C320 binder is used and 300 ESA/day at opening when A5S binder is used.

2.2.5 Asphalt over granular pavements

The typical structure of an asphalt over granular pavement (AG(A)) is as shown in Table Q2.5.

Table Q2.5 – Typical structure of asphalt over granular pavement (AG(A))

Course	Description (typical)	
Surfacing[1,2]	DG14	OG10 or OG14
Seal[3]	10 or 14 mm waterproofing seal with S4.5S binder	
Intermediate[2]	N/A	DG14
Base[2]	DG14 or DG20 are typically adopted with either C320 or C600 binder. DG28 may be suitable in some situations but carries greater risk in relation to segregation. Thickness is determined by mechanistic design.	
Prime and seal[4]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Subbase	Minimum 150 mm Type 2.3 unbound granular material. Cementitious treatment is sometimes adopted for this course (refer to Section 3.14.2 for further details).	

Notes:

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for further guidance on the selection of binder type in the asphalt layers.
3. Refer to Section 3.7 for further guidance on the inclusion of the waterproofing seal.
4. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer/subbase.

2.2.6 Flexible composite, deep strength and full depth asphalt pavements

These pavements are typically heavy-duty pavements which incorporate heavy-duty asphalt. Typical structures of flexible composite (FC), deep strength asphalt (DSA) and full depth asphalt (FDA) pavements used in heavy-duty applications are as shown in Tables Q2.6, Q2.7 and Q2.8.

TMR has limited experience with the use of flexible composite pavements.

Cracking of cemented materials, and subsequent reflection into overlying asphalt layers, should be anticipated in deep strength asphalt pavements.

Table Q2.6 – Typical structure of flexible composite pavement (FC) for heavy-duty applications

Course	Description (typical)	
Surfacing[1,2]	DG14HS or DG14HP[4]	OG10 or OG14
Seal[3]	10 or 14 mm waterproofing seal with S4.5S binder	
Intermediate[2]	DG14HS or DG14HP[4]	
Base[2]	DG20HM with thickness determined by mechanistic design and to provide at least 175 mm of dense graded asphalt in the total pavement structure.	
Curing compound and seal	Bitumen emulsion plus a SAMI seal (incorporating S4.5S polymer modified binder)[5]	
Subbase	150 to 230 mm lean concrete	
Prime and seal[6]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Improved layer	Minimum 150 mm Type 2.3 unbound granular material that has been cementitiously treated (refer to Section 3.14.2 for further details).	

Notes:

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for further guidance on the selection of binder type in the asphalt layers.
3. Refer to Section 3.7 for further guidance on the inclusion of the waterproofing seal.
4. DG14HP is typically only adopted in free flowing traffic conditions (e.g. it may not be suitable for use at the approach to signalised intersections).
5. The SAMI seal can be substituted with a 7 mm Class 170 bitumen seal where an increased risk of future reflective cracking is accepted.
6. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

Table Q2.7 – Typical structure of deep strength asphalt pavement (DSA) for heavy-duty applications

Course	Description (typical)	
Surfacing[1,2]	DG14HS or DG14HP[4]	OG10 or OG14
Seal[3]	10 or 14 mm waterproofing seal with S4.5S binder	
Intermediate[2]	DG14HS or DG14HP[4]	
Base[2]	DG20HM with thickness determined by mechanistic design and to provide at least 175 mm of dense graded asphalt in the total pavement structure.	
Prime and seal	Prime plus a SAMI seal (incorporating S4.5S polymer modified binder)	
Subbase	150 to 200 mm Cat 1 or Cat 2 cementitiously stabilised granular material	
Prime and seal[5]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Improved layer	Minimum 150 mm Type 2.3 unbound granular material that has been cementitiously treated (refer to Section 3.14.2 for further details).	

Notes:

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for further guidance on the selection of binder type in the asphalt layers.
3. Refer to Section 3.7 for further guidance on the inclusion of the waterproofing seal.
4. DG14HP is typically only adopted in free flowing traffic conditions (e.g. it may not be suitable for use at the approach to signalised intersections).

5, Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer

Table Q2.8 – Typical structure of full depth asphalt pavement (FDA) for heavy-duty applications

Course	Description (typical)	
Surfacing[1,2]	DG14HS or DG14HP[4]	OG10 or OG14
Seal[3]	10 or 14 mm waterproofing seal with S4.5S binder	
Intermediate[2]	DG14HS or DG14HP[4]	
Base[2]	DG20HM with thickness determined by mechanistic design	
Prime and seal[5]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Improved layer	Minimum 150 mm Type 2.3 unbound granular material that has been cementitiously treated (refer to Section 3.14.2 for further details).	

Notes:

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for further guidance on the selection of binder type in the asphalt layers.
3. Refer to Section 3.7 for further guidance on the inclusion of the waterproofing seal.
4. DG14HP is typically only adopted in free flowing traffic conditions (e.g. it may not be suitable for use at the approach to signalised intersections).
5. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer

2.2.7 Concrete pavements

The typical structure of concrete pavement used in heavy-duty applications is as shown in Table Q2.9.

Table Q2.9 – Typical structure of concrete pavement for heavy-duty applications

Course	Description (typical)
Base[1]	Jointed and unreinforced Plain Concrete Pavement (PCP), Jointed Reinforced Concrete Pavement (JRCP), Continuously Reinforced Concrete Pavement (CRCP) or Steel Fibre reinforced Concrete Pavement (SFCP)
Curing and debonding	Curing and debonding treatment
Subbase	Minimum 150 mm lean concrete
Prime and seal[2]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal
Improved layer	Minimum 150 mm Type 2.3 unbound granular material that has been cementitiously treated (refer to Section 3.14.2 for further details).

Notes:

1. The base course typically also functions as the pavement surfacing. However, in some cases an additional asphalt surfacing is provided over CRCP (refer to Section 9.2.3).
2. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

Q2.2.8 Asphalt over cementitiously stabilised granular pavement

There are two general design approaches typically adopted for asphalt over cementitiously stabilised granular pavements. These are:

a) Asphalt base over cementitiously stabilised granular subbase (ASt(A)) – this pavement type comprises an asphalt surfacing, asphalt intermediate course (where relevant) and asphalt base, as shown in Table Q2.10. A minimum of 175 mm of dense graded asphalt is typically provided to inhibit cracks in the stabilised subbase reflecting through the asphalt. However, even with this provision, cracking of the cemented material and subsequent reflection into overlying asphalt layers should be anticipated.

b) Asphalt surfacing over cementitiously stabilised granular base (ASt(B)) – this pavement type comprises an asphalt surfacing and asphalt intermediate course (where relevant) over a cementitiously stabilised base, as shown in Table Q2.11. The total dense graded asphalt thickness is typically less than 175 mm, meaning reflection of cracks through the asphalt should be expected relatively early in the life of the pavement. This pavement type carries similar performance risks as the cemented granular base with sprayed seal surfacing pavement type detailed in Section 2.2.3. This pavement type is typically only adopted where the need for future maintenance interventions has been carefully considered and accepted.

Table Q2.10 –Typical structure of asphalt over cementitiously stabilised granular pavement (ASt(A))

Course	Description (typical)	
Surfacing[1,2]	DG14	OG10 or OG14
Seal[3]	10 or 14 mm waterproofing seal with S4.5S binder	
Intermediate[2]	N/A	DG14
Base[2]	DG14 or DG20 is typically adopted with either C320 or C600 binder. The thickness of the base is determined by mechanistic design and to provide at least 175 mm of dense graded asphalt in the total pavement structure. DG28 may be suitable in some situations but generally carries greater risk in relation to segregation.	
Prime and seal	Prime plus a SAMI seal (incorporating S4.5S polymer modified binder)[4]	
Subbase	150 to 200 mm Cat 1 or Cat 2 cementitiously stabilised granular material	
Prime and seal[5]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Improved layer	Minimum 150 mm Type 2.3 unbound granular material. Cementitious treatment is sometimes adopted for this course (refer to Section 3.14.2 for further details).	

Notes:

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for further guidance on the selection of binder type in the asphalt layers.
3. Refer to Section 3.7 for further guidance on the inclusion of the waterproofing seal.
4. As an alternative to the SAMI seal, a geotextile reinforced sprayed seal may be provided to further inhibit crack reflection.
5. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

Table Q2.11 – Typical structure of asphalt surfacing over cementitiously stabilised granular base pavement (ASt(B))

Course	Description (typical)	
Surfacing[1,2,3]	DG14[4]	OG10 or OG14
Intermediate[2]	DG14 (if required)[4]	DG14[4]
Prime and seal	Prime plus a SAMI seal (incorporating S4.5S polymer modified binder)[5]	
Base[6]	Cementitiously stabilised granular material typically specified with an appropriate project-specific technical standard with provisions to reduce the risk of cracking. The thickness of the base is determined by mechanistic design.	
Prime and seal[7]	Prime plus 10 or 14 mm nominal size Class 170 bitumen seal	
Improved layer	150 to 300 mm unbound granular or stabilised granular material, or an appropriate selected fill material (refer to Section 3.14.2 for further details).	

1. SMA may also be considered, subject to a project-specific assessment of its suitability.
2. Refer to Table Q6.7 for guidance on the selection of binder type in the asphalt layers.
3. Refer to Section 3.7 for guidance on the use of waterproofing seals.
4. The total thickness of dense graded asphalt (surfacing plus intermediate course) is typically 100 mm for design traffic between 1000 and 3000 ESA/day in the design lane in the year of opening, and 50 mm for traffic less than 1000 ESA/day in the design lane in the year of opening.
5. As an alternative to the SAMI seal, a geotextile reinforced sprayed seal may be provided to further inhibit crack reflection.
6. For temporary pavements, the base typically comprises a minimum 150 mm Cat 1 or Cat 2 cementitiously stabilised granular material (thickness determined by mechanistic design).
7. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

2.3 Overview of pavement design systems

2.3.1 Input variables

Project reliability

The project reliability levels typically adopted by TMR are listed in Table Q2.12.

Table Q2.12 – Typical project reliability levels

Road Category	Typical Project Reliability Levels (%)
Freeways (Motorways)	95
All other roads (includes highways and main roads)	90

Q2.4 Shoulders with a lower structural standard

There are two broad design alternatives for shoulders:

1. Continue all layers of the pavement for the adjacent trafficked lane across the shoulder. This approach is typically adopted as it is generally more practical to construct with a lower risk of construction variability and/or moisture issues.
2. Design and construct the shoulder to a lower structural standard than the adjacent trafficked lane to reduce the initial pavement capital cost.

In both cases, the pavement in the trafficked lane should extend at least 200 mm beyond the delineated edge of the trafficked lane for heavy-duty pavements, and at least 100 mm for other pavements. In some instances it may be beneficial to extend the pavement for the trafficked lane a greater distance into the shoulder to facilitate future widening (for example, to accommodate portable concrete barriers and/or lane realignments).

Where a shoulder of a structural standard lower than that of the adjacent trafficked lane of the pavement is adopted, the following should be provided:

- The total pavement thickness of the shoulder should be the same as the adjacent trafficked lane.
- Where the adjacent trafficked lane of the pavement is asphalt over granular, full depth asphalt, deep strength asphalt, flexible composite, or similar, the shoulder should have the same asphalt surfacing, seal and intermediate courses as the adjacent trafficked lane. Beneath this, the thickness of asphalt or sealed unbound granular base, should be designed to ensure that the asphalt has acceptable fatigue life. The balance of material down to the top of the granular subbase or improved layer would then typically be a granular subbase material. A pavement drain is typically provided at the interface of the shoulder pavement and adjacent trafficked lane pavement.
- Where the adjacent trafficked lane of the pavement is a granular pavement with a sprayed seal or thin asphalt surfacing, the shoulder should have the same asphalt layers and seal as the adjacent trafficked pavement. The shoulder should also have the same granular base layer(s) and materials as the adjacent trafficked pavement. The balance of the thickness of the shoulder to the level of the lowest pavement layer can be a select fill material. General fill may not be appropriate if its permeability is low relative to the adjacent trafficked pavement, as this may inhibit drainage of the pavement layers.
- Where the adjacent trafficked lane of the pavement is concrete, a minimum asphalt thickness of 50 mm is typically provided in the shoulder. Where the adjacent concrete pavement also includes an asphalt surfacing, all bituminous layers (such as the surfacing, seal and intermediate course) are typically also included in the shoulder. Beneath this, the thickness of asphalt or sealed unbound granular base should be designed to ensure that the asphalt has acceptable fatigue life. The balance of material down to the top of the improved layer would then typically be a granular subbase material. A concrete edge drain is typically provided at the interface of the two pavements.
- In all cases, it is typical practice to continue the seal to the outside edge of any verge, or if a verge does not exist, to the outside edge of the shoulder.

A lower standard shoulder is not typically used on the high side of one-way crossfalls as this could result in moisture entering the pavement.

Where a shoulder of a structural standard lower than that of the trafficked lanes is constructed as a widening to an existing pavement, the effect of disturbing in situ subgrade materials should be considered in determining the thickness of the shoulder.

There are some limitations to the use of shoulders of a structural standard lower than that of the trafficked lanes. These limitations include applications where:

- construction may be more difficult because of increased complexity and narrow working widths
- future widening may be more difficult
- with concrete pavements, a thicker base course is typically required
- temporary trafficking of the shoulder during construction and future maintenance of the through lanes may be restricted, and/or
- some shoulders may experience regular trafficking because of the nature of the road alignment (e.g. curves, end of tapers, narrow through lanes, access points, intersections and/or no edge lines).

3. Construction and maintenance considerations

3.1 General

It is assumed that TMR standards for construction and maintenance will be adopted. At the time of publication of this supplement, project-specific technical standards are required for some of the included materials, such as high standard granular material, cementitiously modified granular material, plant-mixed foamed bitumen stabilised material, stone mastic asphalt and multigrade bitumen binder.

3.2 Extent and type of drainage

In addition to the drainage provisions discussed in Part 10: *Subsurface Drainage* of the Austroads *Guide to Pavement Technology* (Austroads, 2009), the following cross-sectional provisions should be considered to reduce the exposure of the pavement and subgrade materials to moisture infiltration:

1. Seal over the full width of the formation (traffic lanes and shoulders)
2. On the high side of one-way cross-falls:
   - provide a low permeability verge (which would typically extend at least an additional 100 m beyond either end from where the transition to a crowned pavement commences);
   - seal the shoulder and verge, and maintain in a sealed condition, and/or
   - provide appropriate subsoil drainage to intercept water seepage before it reaches the pavement or subgrade.
3. In cuttings:
   - provide table drains where an unbound granular pavement is used
   - provide table drains or subsurface pavement drains where a bound or rigid pavement is used, and
   - where rock floors are present, use a stabilised infill, or dental concrete, with surface cross-fall so that water ponding does not occur.
4. In wet regions, the formation should be kept as high as economically possible over flat terrain so as to improve moisture contents.
5. Maximise cross-fall within the permissible range for geometric design.
6. Design divided roads with two-way cross-fall (where possible).
7. Longitudinal drainage, such as table drains (where used), should be:

- located away from the formation (typically minimum 5 m) in flat or lightly undulating country or excluded altogether
- directed away from the formation
- appropriately shaped (refer to the *TMR Road Drainage Manual*), and
- such that the invert level is lower than subgrade level in cuttings, to intercept seepage before it reaches the pavement or subgrade. Typically the invert is located at least 200 mm below the lowest pavement layer and improved layer.

8. Compact pavement materials right up to the edge of the pavement to the specified compaction standard, and any excess, poorly compacted paving material beyond the seal edges should be removed.
9. In drier areas (that is, arid and semi-arid areas), particularly if design traffic volumes are less than 10^6 ESAs, low permeability paving materials may have benefits in relation to reducing moisture infiltration into the subgrade. However, such materials may have lower strength than standard materials so their suitability should be considered on a case-by-case basis.
10. In situations where the shoulder is narrow and the verge is not sealed, the runoff flow path may be hindered (e.g. by a grassed verge) resulting in moisture entry into the pavement over time. In such situations, consideration should be given to the likely impact on the pavement, in particular unbound pavements.

Moisture from seepage, infiltration through the surfacing and from water table fluctuations, can be controlled by the installation of properly designed pavement and subgrade drains. However, drains are only effective when subgrade moisture is subject to hydrostatic head (positive pore pressures). It is common for fine grained subgrade materials (silts and clays) to have equilibrium moisture contents above optimum moisture content, yet, because pore pressures are not positive, they cannot be drained. While subsurface drainage does play an important role in moisture control, unrealistic assumptions about the effect of subsurface drainage on subgrade moisture condition should not be made.

In some circumstances, subsurface drainage or other types of drainage may need to be constructed well before the pavement to help drain wet subgrades and aid in pavement construction.

The time required to drain a wet subgrade will depend on the permeability of the subgrade material, type and spacing of drains and the extent of additional water in flows. If it is not possible to provide subgrade drainage, or an adequate drainage time, the design should allow for wet conditions, and material types and construction methods should be selected accordingly.

Where pavement or subgrade drainage measures are proposed, the construction sequence should ensure that drainage is installed early enough to prevent a build up of water in the pavement and/or subgrade due to rain during construction.

Consideration should be given to the construction sequence to ensure that drainage installations are not rendered ineffective, even temporarily, by later construction activities. Careful planning in this area can minimise delays to construction caused by wet weather as well as ensure that future pavement performance is not compromised.

Maintenance of drainage provisions is essential, particularly for unbound granular pavements. This may include routine checking and flushing of subsoil drains, and cleaning of surface drains.

3.2.2 Drainage of pavement materials

Cemented materials can be quite permeable and water has been found to travel long distances within a layer of cemented material. In addition, shrinkage cracks within these materials can become avenues of rapid moisture movement. Boundaries between layers inadequately bonded together have also been found to allow rapid water movements.

The results of accelerated loading tests (NAASRA, 1987b) as well as observations of field performance have shown that rapid water movement in cemented layers can cause erosion, weakening and subsequent failure of these layers. Thus, if cemented materials are proposed in the pavement structure, consideration should be given to providing effective drainage for these layers.

3.2.3 Use of a drainage blanket

An alternative to an open-graded 20 mm crushed rock is a larger size (typically 125 mm nominal size and 300 mm thick) rock fill. Rock fill is particularly suited to locations with soft subgrades, or where a high drainage capacity is required. The rock fill is typically wrapped in a suitable geotextile and covered by a 150 mm thick cementitiously stabilised granular material to provide a stable platform for pavement construction.

For the purpose of pavement thickness design, crushed rock and rock fill drainage blankets are typically modelled as selected subgrade material with presumptive vertical modulus limited to a maximum of 150 MPa.

3.6 Use of stabilisation

Guidance on the design of pavements with lime stabilised subgrades is provided in *TMR Technical Note 74 Structural Design Procedure of Pavements on Lime Stabilised Subgrades* (TMR, 2012).

Use of multi-layer construction for cemented material courses is not typically adopted for heavy-duty pavements due to the performance risk associated with these layers not remaining fully bonded throughout the pavement’s life.

Accelerated loading tests at Beerburrum (NAASRA, 1987b) clearly illustrated the consequences of inadequate bonding between layers. Measures that have been used to improve the bond between layers in lower traffic situations include:

- application of a cement slurry (water cement ratio 0.6 to 0.7) at a rate equivalent to 2 kg of cement per square metre placed immediately before laying subsequent layers, or
- using a set retarder in the lower layer and applying the upper layer within approximately 6 hours.

The report *Cement Slurry Applications to CTB Layer Bonding* (Main Roads, 1988a) describes the use of these measures in more detail.

Where multi-layer construction is adopted, the second and subsequent layers should not be stabilised using in situ stabilisation methods, even if the first layer is constructed in situ. Additionally, the first layer should be kept as thick as possible (at least 150 mm) in order to avoid damage to the lower layer by construction traffic placing subsequent layers.

3.7 Pavement layering considerations

Asphalt is typically permeable and therefore significantly more susceptible to moisture ingress and damage when the air void contents achieved in construction are greater than 6% for SM14 mixes, 7% for SM10, DG14, DG20 and DG28 mixes and 8% for DG7 and DG10 mixes. It may take several weeks or months of trafficking, even for dense graded asphalt, before the asphalt surfacing becomes relatively impermeable. Even after this early traffic, any areas of segregation, and particularly areas around construction joints, often remain permeable. To mitigate the risk of moisture ingress, it is typical practice to provide a waterproofing seal under all asphalt surfacings. For unbound granular pavements, a bitumen or lightly modified polymer modified binder is typically used.

Where the layer beneath the asphalt surfacing is also asphalt, the waterproofing seal typically contains an S4.5S polymer modified binder and cover aggregate with a nominal size of 10 mm or larger. The seal should be designed to suit the site conditions and to provide effective waterproofing. The waterproofing seal is typically not required where the following minimum characteristic compaction standards are achieved in the asphalt base, intermediate and surface courses: 94.0% for SM14 mixes, 93.0% for SM10, DG14, DG20 and DG28 mixes, and 92.0% for DG7 and DG10 mixes.

At locations subject to high shear stresses (for example, from heavy braking and/or tight cornering), such as intersections, roundabouts and approaches, the spray rate may need to be adjusted due to the increased risk of shearing. In some atypical situations it may be appropriate to omit the waterproofing seal to reduce the risk of shearing, while accepting increased risk of moisture ingress. Additional preparative treatment including, but not limited to, texturing the underlying surface and/or use of a propriety bond coat (to bond the asphalt surfacing to the underlying pavement) would typically be required in these circumstances.

Where DG14 is used in surfacing and/or intermediate course in AG(A), ASt(A) and ASt(B) pavements, a minimum compacted layer thickness of 50 mm is typically adopted for the DG14 to aid in achieving adequate compaction and hence inhibit moisture ingress.

DG20 and DG28 layers are particularly prone to moisture ingress when the achieved relative compaction is less than 93.0%. Where this occurs, these layers are typically covered with the next layer of asphalt or a sprayed seal as soon as possible and within 10 calendar days of placement, to reduce the risk of moisture ingress.

3.8 Use of strain alleviating membrane interlayers

SAMI seals are typically applied to the surface of cementitiously stabilised layers to inhibit crack reflection into overlying pavement layers.

3.9 Environmental and safety constraints

Unbound granular pavements are particularly susceptible to damage caused by the infiltration of water during construction, such as from ponded water, seepage and inundation.

Austroads (2003a) provides guidance on the control of moisture in pavements during construction. These factors should be considered during:

- selection of pavement type
- design of the pavement structure (including cross-sectional details)
- programming of works and development of construction methodology, and
- developing contract provisions for the work.

Typically, construction of unbound granular layers includes provisions such that:

- the construction program minimises the potential for exposure of the pavement to rainfall events and/or inundation
- the construction program makes allowance for drying out of pavement layer(s) to below the material's degree of saturation limit, and
- the options, responsibility and liability for any rectification/rework caused by water infiltration and/or inundation during pavement construction is clearly established in the construction contract.

For concrete pavements, the time from commencement of base paving to completion of base paving to the full carriageway width is typically limited to one month, to minimise any problems relating to differential movements. Likewise, for flexible composite pavements the lean concrete subbase is typically covered within one month to assist in limiting the width of shrinkage cracks.

3.11 Construction under traffic

Pavement damage, resulting from temporarily trafficking pavement layers below the final surfacing (including excessive construction traffic), should be included in the pavement design calculations. This may include fatigue damage to asphalt, foamed bitumen stabilised and cemented layers.

3.14 Improved subgrades

3.14.1 Soft subgrades

The selection and design of soft subgrade treatment measures necessitates consideration of project-specific factors including expected construction traffic and the subgrade strength at the time of construction. The subgrade strength at the time of construction may differ to the design subgrade strength used in pavement thickness determination as the design subgrade strength is typically determined on the basis of long-term equilibrium moisture and density conditions, rather than the conditions at the time of construction.

One of the most common soft subgrade treatments is to cover the soft material with a geotextile wrapped granular fill. The granular fill typically comprises a well-graded coarse gravel or crushed rock, or rock fill which has good inter-particle friction. The minimum thickness of material typically required is as shown in Table Q3.1. Rock fill is typically covered by a 150 mm cementitiously stabilised granular material to provide a stable platform for construction of the pavement, including the improved layer (if present).

Table Q3.1 – Typical minimum cover to provide a stable construction platform

In situ subgrade CBR at time of construction (%)	Typical minimum cover to provide a stable construction platform (mm)
1.0 – 1.4	400
1.5 – 1.9	300
2.0 – 2.4	200
2.5 – 2.9	150

Note: Cover thicknesses in this table assume a typical level of construction traffic required for the sole purpose of constructing the overlying pavement layers.

Measures to improve constructability may improve other subgrade characteristics including strength, workability, and/or swelling potential. Where a soft subgrade treatment is undertaken, the pavement thickness design typically makes allowance for the contribution of the treatment to pavement support.

For design subgrade strengths of 3% or more, the treatment is typically accounted for as an additional selected subgrade material in the pavement thickness determination. This approach is also applicable when the design subgrade strength is less than 3% and the pavement thickness is determined using Figures 8.4 or 12.2.

For flexible pavements that are designed mechanistically, and where the pavement design subgrade strength is less than 3%, a presumptive subgrade design CBR is typically adopted for an assumed semi-infinite layer which accounts for the combined strength of the soft subgrade and treatment. This is necessary as the standard mechanistic pavement design procedure is based on materials having an elastic response to load, whereas materials with CBR less that 3% are unlikely to behave elastically when loaded.

The presumptive design CBR should be determined by considering the treatment and the likely long-term condition of the materials and subgrade. For example, a presumptive subgrade design CBR of 3% for the assumed semi-infinite layer (that is, from the top of the treatment and extending infinitely below) is typically adopted for the following treatments:

- a minimum thickness of coarse granular or rock fill wrapped in geotextile, determined using Table Q3.2
- a minimum 200 mm of Category 1 or 2 cemented material over subgrade material with a design CBR of 2 to 3%
- a minimum 150 mm of mass concrete (either lean concrete or no fines concrete with geotextile) or sand/cement (12:1) mix over subgrade material with a design CBR of 2 to 3%

Table Q3.2 – Minimum thickness of coarse granular or rock fill required for the adoption of a presumptive design CBR of 3%

Subgrade CBR (%) (at design density and moisture conditions)	Minimum thickness (mm) of coarse granular or rock fill required for the adoption of a presumptive design CBR of 3%
1.0	400
1.5	300
2.0	200
2.5	150
3.0	0

An example of the application of this approach to mechanistic design of a flexible pavement is shown in Figure Q.31.

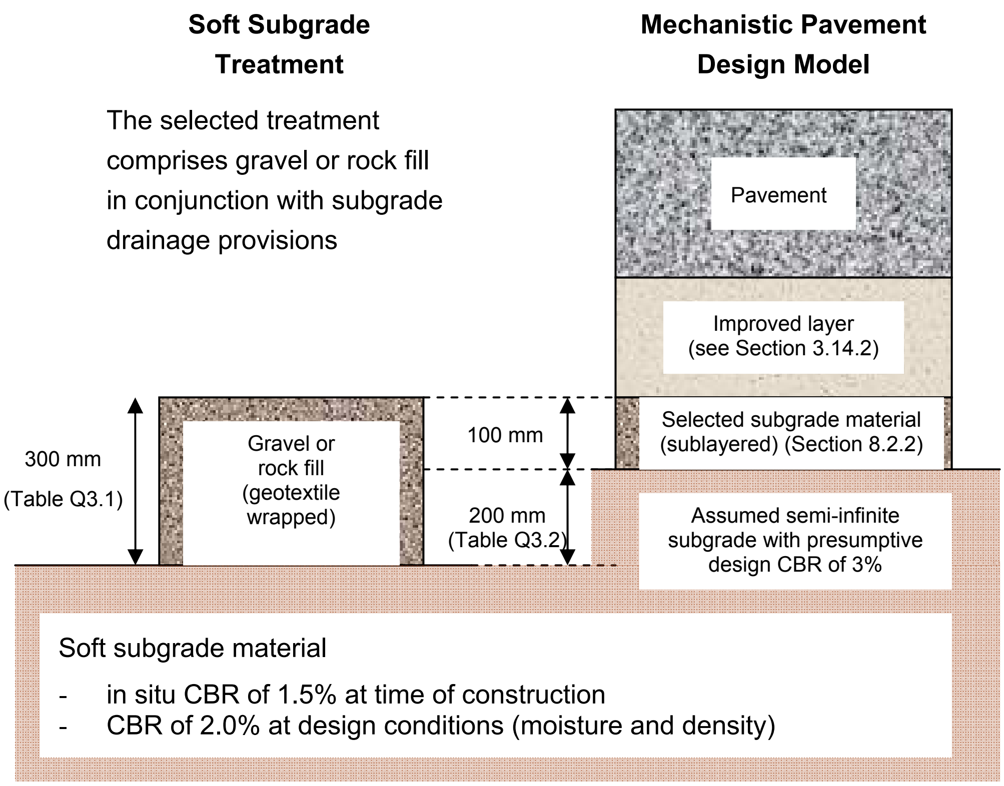

Figure Q3.1 – Example of mechanistic model for a soft subgrade treatment where the CBR of the in situ material at the design conditions is less than 3%

For rigid pavement design, the contribution of a soft subgrade treatment to subgrade strength can be accounted for by applying Equation 25.

In assigning design parameters (for both flexible and rigid pavement design) to the materials used in the soft subgrade treatment, consideration should be given to the impacts of construction traffic and long-term service, recognising that the long-term condition of such materials is likely to be significantly degraded from their initial condition. Typically the materials (including granular, rock fill, and cemented materials) are modelled as sublayered selected subgrade materials with design parameters not exceeding those of a CBR 10% selected fill material.

Where rock fill is used, including in drainage blankets, it is important that the material and cross-section is designed to be free draining throughout the service life of the pavement, taking into consideration issues which may impact on future pavement performance including:

- potential for moisture ingress and ability for moisture to drain freely from the material
- maintenance activities that may impact on drainage (for example, inhibiting drainage as a result of grading of drains, shoulders and batters)
- heavy vegetation growth and associated maintenance
- shrink/swell potential of the underlying subgrade material
- suction potential of the overlying materials.

The soft subgrade treatments in this supplement do not address longer term settlement (refer to Section Q3.17).

3.14.2 Improved layers under bound layers

An improved layer is typically included under pavements with asphalt, cemented, foamed bitumen stabilised and/or concrete layers. This is in addition to the soft subgrade treatments detailed in Section 3.14.1.

In heavy-duty pavements this layer has historically been referred to by TMR as the working platform. Such an improved layer:

- provides access for construction traffic and minimises the potential for rainfall at critical stages in the construction process to cause subgrade instability and excessive construction delays
- provides a sound platform on which to construct the pavement layers
- protects the subgrade for the life of the pavement structure.

The improved layer in heavy-duty pavements typically consists of a 150 mm (minimum) thick layer of Type 2.3 unbound pavement material that is treated with a cementitious stabilising agent to achieve an unconfined compressive strength of 1.0 to 2.0 MPa at 7 days. In lower-trafficked pavements, an unbound layer is typically adopted. Adoption of an unbound pavement or select fill material under heavy duty pavements is not typically adopted due to its increased risk in relation to moisture sensitivity, which may lead to construction delays and rework.

A more substantial treatment may be needed where:

- the in situ strength of the underlying material is less than CBR 7% (at the time of construction)
- traffic using the improved layer prior to placement of the next structural layer exceeds 1 x 10^3 ESA, and/or
- required by the contractor for the particular site and construction procedures proposed.

It is typical practice to prime and seal (10 mm Class 170 bitumen) the improved layer in the following situations:

- Where the probability of rainfall during construction of the improved layer and/or pavement is significant
- Where the improved layer is exposed to the environment (ie not covered within a few days of construction) and/or trafficked for an extended period of time, and/or
- The improved layer is permeable and/or the layer(s) below the improved layer are sensitive to the effects of moisture ingress.

For other situations the designer should consider the merits of priming and sealing the improved layer giving due consideration to the following:

- The cost of the treatment and impact of its inclusion in the design on the construction program, and
- The program risk and costs associated with construction delays and rework.

A primerseal may also suffice in some circumstances, where this has been determined to provide adequate trafficability and waterproofing for construction operations. However, the effect of cutter in the primerseal on subsequent pavement layers needs consideration.

The improved layer is included in the mechanistic pavement design. Further details on design inputs are included in Table Q6.3.

3.15 Surfacing type

3.15.1 Sprayed seals

Wherever possible, a prime and seal is typically adopted, rather than a primerseal, due to the likelihood of enhanced bonding with the underlying pavement. However, a primerseal may be used in some situations, such as where this risk is considered less important than the imperative that the pavement be opened to traffic soon after construction or that the pavement be constructed under traffic.

3.15.3 Open-graded asphalt

Initial construction

A 10 mm or 14 mm dense graded asphalt intermediate course is typically provided under all new pavements that are surfaced with open graded asphalt. Provision of this course enables the open graded asphalt to be fully removed without unduly disturbing the underlying pavement when resurfacing is required.

Q3.17 Settlement

Neither AGPT02 nor this supplement contain provisions for settlement of materials below the pavement layers. Where required, additional geotechnical investigations and assessments should be carried out to determine if and how much settlement may occur. The amount of settlement permissible typically varies for different pavement types and maintenance strategies. If unacceptable settlement is likely, pre-treatment (e.g. drainage and/or surcharge of the formation) may be required to reduce the extent of settlement after the pavement is constructed.

Q3.18 Pavement jointing considerations

The structural competency of the pavement at longitudinal construction joints is often not as sound as in other areas. As a result, pavements tend to be weaker and more permeable at longitudinal construction joints. Load induced deformation and/or cracking can occur in these areas.

To reduce the risk of premature distress, construction joints are typically located away from wheel paths. Additionally, construction joints in flexible pavement layers are typically offset from the construction joints in underlying layers using a step-type arrangement.

Q3.19 Thickness of bituminous seals

For the purpose of determining design levels, the thickness of seals and primerseals should be taken as the average least dimension (ALD) of the cover aggregate. If the ALD is not known at the time of design, the ALD can be estimated as 6 mm for 10 mm nominal size cover aggregate and 9 mm for 14 mm nominal size cover aggregate.

Q3.20 Temporary pavements in high traffic situations

In order to facilitate traffic management, it may be necessary to utilise temporary pavements during construction.

Unbound granular pavements are considered to be very high risk for temporary pavements in high traffic situations (1000 ESA/day or more in the design lane), and are therefore not typically adopted in such situations. A number of projects have suffered failures of unbound granular pavements within the first day of trafficking, resulting in significant interruptions to road users and the project program. Therefore, temporary connections for pavements in high traffic situations typically comprise, as a minimum, a cemented granular base with asphalt surfacing. An improved layer is typically provided below the stabilised base where the subgrade CBR is less than 5%.

Other temporary pavement alternatives that have been successfully used in high traffic situations include asphalt over granular (AG(A)), asphalt over cementitiously stabilised granular (ASt(A)) and full depth asphalt.

4 Environment

Historical climate data is used to assist with site classification, including the likely moisture and temperature conditions the pavement will experience in service. Further information on climate zones and average conditions is available from the Commonwealth Bureau of Meteorology at www.bom.gov.au.

Figure Q4.1 illustrates Australian climatic zones on the basis of temperature and humidity. Most of coastal Queensland is classified as having hot humid summers. Western areas have hot summers with either mild or cold winters.

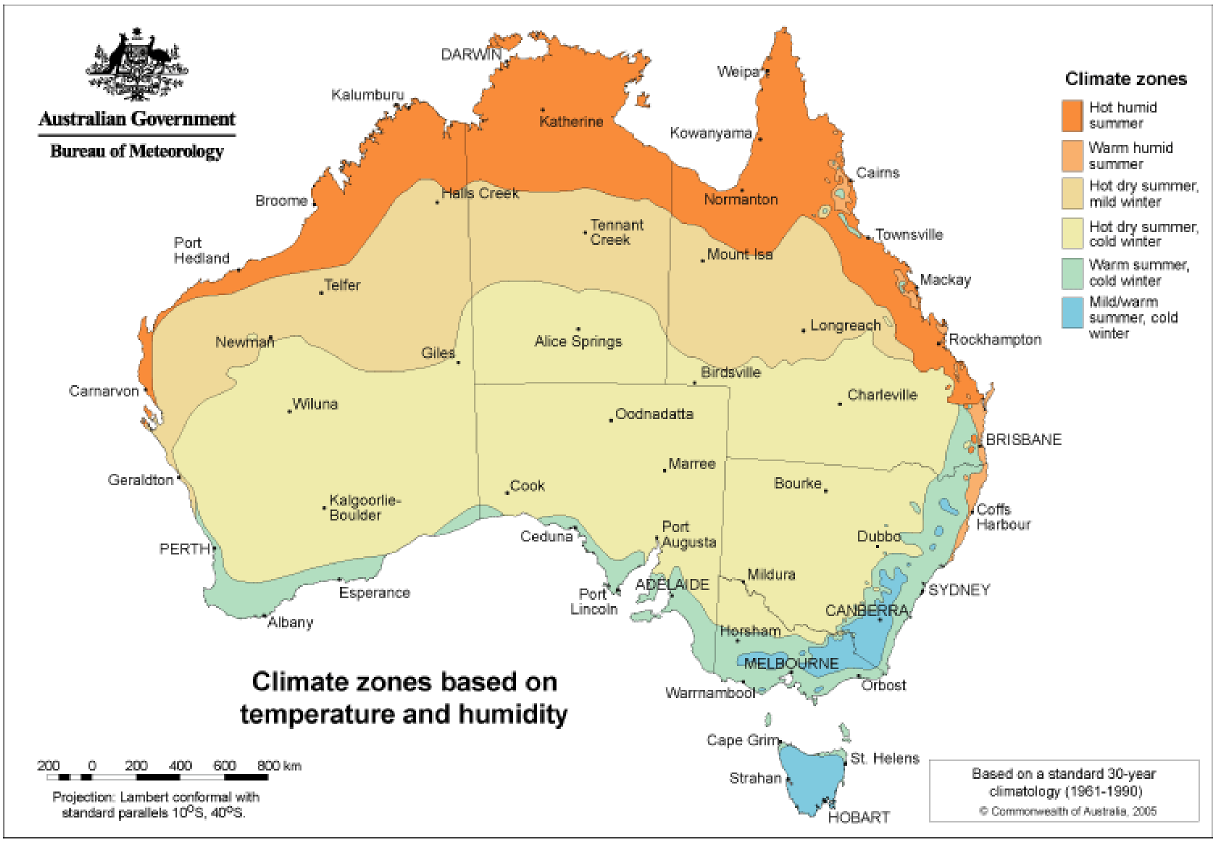

Figure Q4.1 – Australian Climatic Zones (www.bom.gov.au)

4.2 Moisture environment

The moisture environment will have an impact on subgrade moisture conditions, drainage requirements and the selection of pavement materials. Volume changes and material strength variations caused by moisture content changes can lead to cracking and, when loaded, shear failures in subgrades and paving materials.

Figure Q4.2 illustrates Australian seasonal rainfall zones, based on median annual rainfall and seasonal incidence. Figure Q4.3 provides more detail for Queensland, illustrating median annual isohyets. Rainfall intensity may also impact on moisture conditions within the pavement and subgrade.

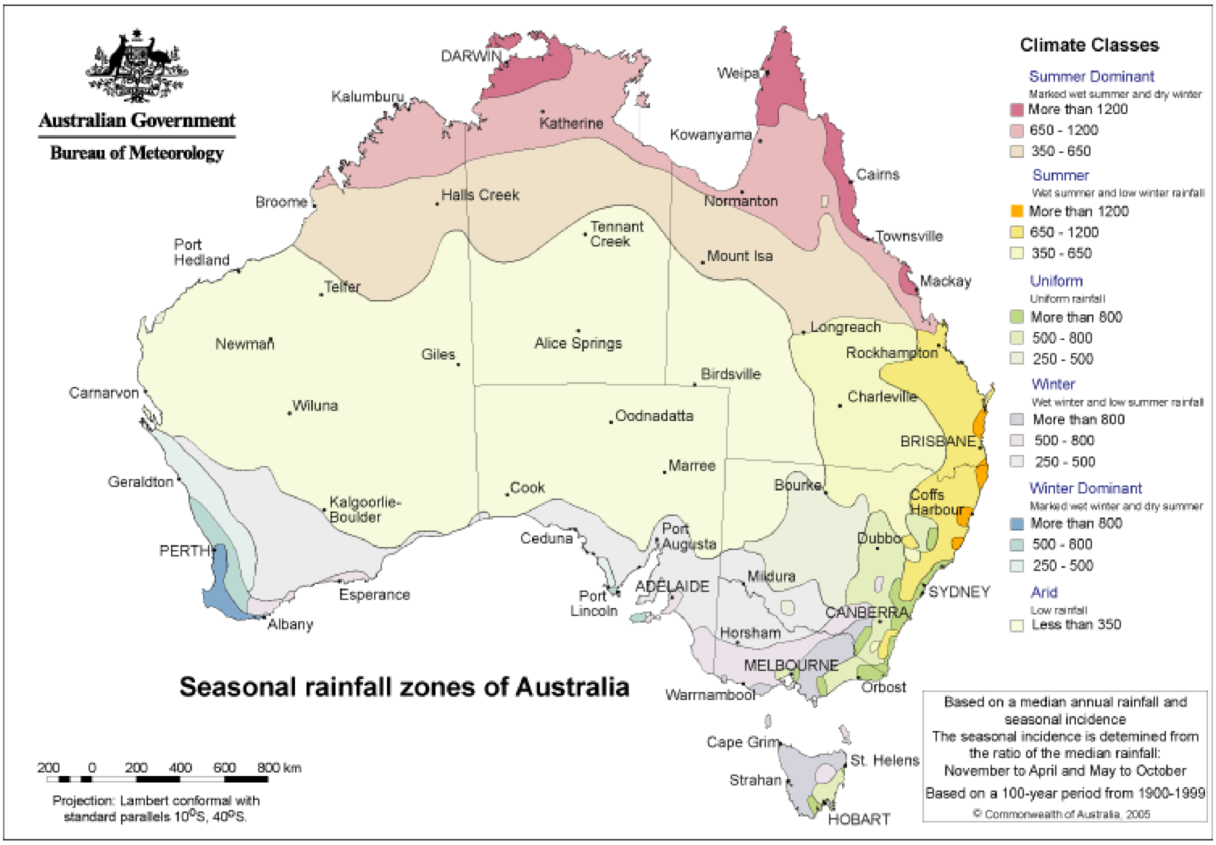

Figure Q4.2 – Australian seasonal rainfall zones (www.bom.gov.au)

4.3 Temperature environment

WMAPTs for additional sites in Queensland are listed in Appendix B of this supplement.

TMR technical standards place limits on temperatures and weather conditions for placing asphalt, seals, cementitiously stabilised and concrete pavement layers. These requirements limit the detrimental effects that adverse weather conditions can have on the quality and/or performance of the constructed pavement.

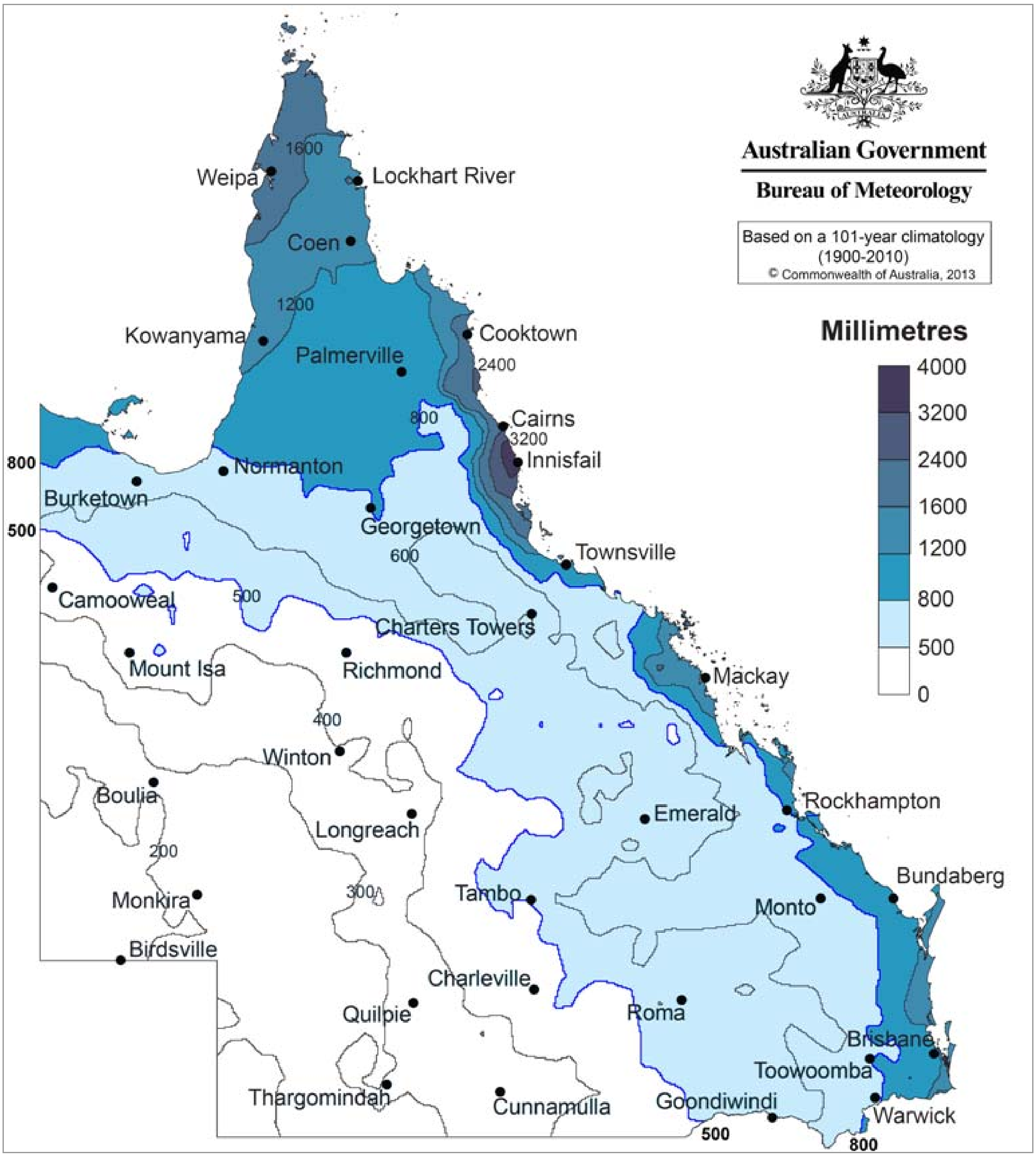

Figure Q4.3 – Median Annual Isohyets for Queensland

5 Subgrade evaluation

5.1 General

In addition to assessing subgrade strength, evaluation of the expansive nature of subgrade materials is also important.

5.3 Factors to be considered in estimating subgrade support

The subgrade should be assessed as early as possible, typically in the planning and design phase of the project. Subgrade assessment can be made difficult by highly variable natural materials and changes to the subgrade material during construction. Accordingly, the subgrade materials should be reassessed immediately prior to pavement construction, in addition to any prior assessments.

Typically the designer will need to include detailed requirements for this reassessment as part of the pavement design solution so that the design can be validated prior to construction.

Subgrade materials are typically assessed using the following measures:

- soil description and classification
- plasticity (plastic limit, liquid limit, and plasticity index)
- moisture content in situ
- particle size distribution
- weighted plasticity index (WPI), which is the plasticity index multiplied by the percent passing the AS 0.425 mm sieve
- laboratory CBR and swell determined at the design density and moisture conditions, and
- field CBR tested with a dynamic cone penetrometer (DCP).

When stabilisation of the subgrade material is being considered, additional testing may also be required such as lime demand, sulphate content and UCS. Further guidance on the evaluation of materials for stabilisation is provided in the TMR *Pavement Rehabilitation Manual* (TMR, 2012).

5.3.5 Moisture changes during service life

Expansive soils

As a consequence of changes in water content, subgrades with expansive soils (including embankments where expansive soils have not been excluded), can experience considerable volume change that can disrupt the pavement in a number of ways, including:

- surface deformation, causing roughness and potential ponding of water
- pavement deformation, that can cause loss of density and loss of strength, and
- cracking that can allow the infiltration of contaminants (such as water and incompressible material) and also loss of strength.

The magnitude of volume change depends on factors such as:

- potential swell of the subgrade and/or embankment material
- extent (width and depth) of expansive material
- effectiveness of adopted treatments
- material density and permeability, and
- exposure to, and magnitude of, changes in moisture content (current and future).

The degree to which volume change is addressed in the design solution depends on a number of project-specific factors such as:

- cost of initial treatment alternatives
- impact of initial treatment alternatives on function and serviceability
- availability of materials
- tolerance for future maintenance interventions to correct loss of shape and/or cracking in the pavement, and

- project constraints such as time and traffic management.

Where expansive subgrades are present, a geotechnical assessment is typically required to determine the appropriate mitigation strategy, particularly where the expansive nature of the soil is very high (as defined in Table 5.2).

Providing a minimum cover of material over expansive soil is one of the most common techniques used to minimise volume change impacts on the pavement. The required thickness of cover is an output of the geotechnical assessment.

For pavements over subgrades with an expansive nature which is high (as defined in Table 5.2), and where a geotechnical assessment is not undertaken, the following cover thicknesses are typically adopted:

- for flexible pavements, the thickness as determined from Figure Q5.1 (which includes the thickness of the pavement and other courses such as select fill, rock fill, treated material and improved layers). Figure Q5.1 assumes that a minimum 150 mm layer of low-permeability subbase, improved layer or select fill is included in the overall structure
- for rigid pavements, a minimum cover of 600 mm to the underside of the subbase, including a minimum 150 mm of low permeability material.

These thicknesses are intended to mitigate the risk based on the importance of the road (for example, low risk for heavily trafficked pavements, and higher risk for lower trafficked pavements). However, it may not always be economic to provide these cover thicknesses, particularly for pavements with low traffic and where suitable fill materials are not readily available. In such circumstances, a design solution that accepts the potential impacts and addresses these through appropriate maintenance may be necessary.

For pavements over subgrades with a low or moderate expansive nature (as defined in Table 5.2), additional cover beyond that provided by the pavement and support layers is not typically required.

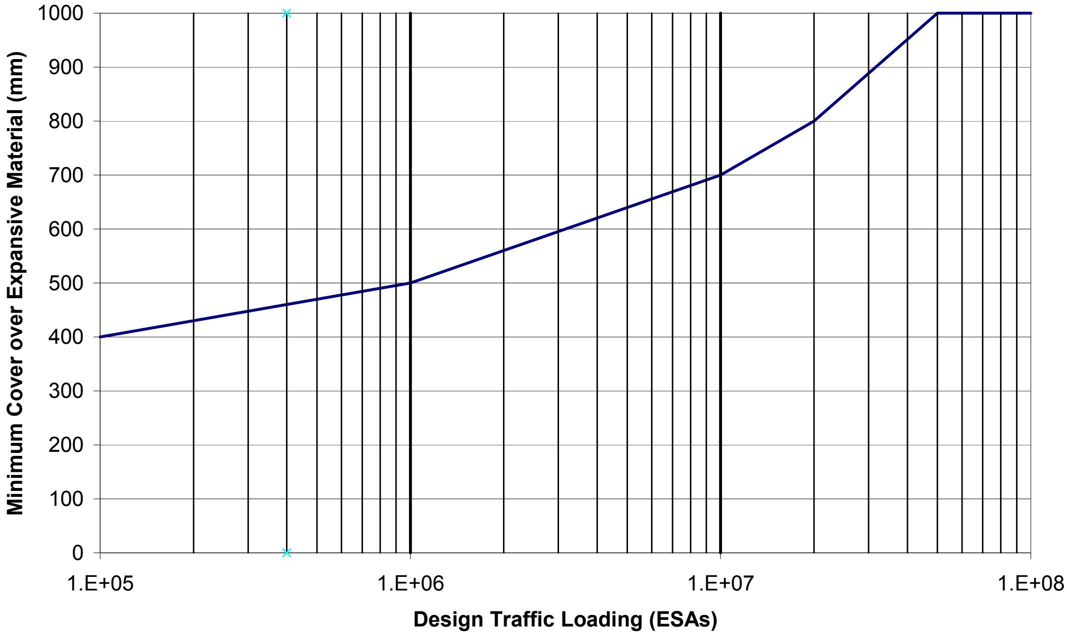

Figure Q5.1 – Typical Cover Thickness Over Highly Expansive Material for Flexible Pavements (thickness includes the pavement) (VicRoads, 2010)

The following additional strategies may also be adopted, as appropriate, to aid in minimising volume change in expansive soils:

- in embankments, limit the use of highly expansive materials to the core zone (ie use zoned embankments)
- control the moisture content of the top 300 mm of the untreated subgrade prior to and during the placement of overlying layers, so that the moisture content after placement of the pavement is as near as possible to the equilibrium moisture content
- direct water away from the formation by adopting appropriate geometric design (for example, maximising gradient and crossfall), and/or by adopting drainage provisions that avoid pondage of water within 5 m of the formation
- make provision for drying back and re-compacting water-affected subgrades
- in arid and semi-arid environments:
  - provide flat embankment batters using low permeability materials (1 on 4 or flatter) and low formation height, wherever possible, as it has been found that shoulder and pavement edge cracking and deformation are more prone to occur as fill height increases and where batters are steeper
  - maintain positive formation height above the surrounding terrain (say 300 – 500 mm at the top of pavement at formation edge with subgrade level being at least 100 mm above the surrounding terrain), and
  - provide 300 mm deep table drains where positive drainage is possible.

Geotechnical Assessment

A geotechnical assessment typically involves consideration of the following information:

1. Test results for the following material properties:
   - Liquid limit, plasticity index, grading (including determining the percentage of material passing the 2 μm sieve) and weighted plasticity index
   - Shrink-swell index
   - Moisture content (including variations in moisture content with depth)
   - Suction and
   - Clay type (typically determined using x-ray diffraction).

   Samples are typically obtained using shallow boreholes with continuous undisturbed sampling.
2. Maintenance history and condition of existing pavements and structures located where similar soils and moisture conditions are present.
3. Moisture conditions expected at the site, including potential for the material to wet up and dry out during construction and throughout the life of the pavement.
4. TMR performance expectations for the pavement.

Based on the above information, a geotechnical engineer can provide guidance on an appropriate thickness of cover noting:

- unbound granular, full depth asphalt and CRCP are less susceptible to structural damage due to subgrade movements than other pavement types
- asphalt shape correction treatments typically are not suitable for jointed pavements (PCP and JRCP)
- recompacted clays may have a higher potential for movement (in the first few years of wetting and drying cycles) than undisturbed clay subgrades and
- procedures for estimating surface movement such as those outlined in AS2870 and Van der Merwe (1964).

5.6 Laboratory determination of subgrade CBR and elastic parameters

Typical pretreatment for materials that breakdown under environmental and service conditions due to weathering (such as shales, claystones, siltstones and other soft laminated or jointed rocks), is to precondition by artificial weathering (10 cycles of soaking for at least 16 hours followed by drying on a hot plate without baking).

For material susceptible to breakdown due to construction procedures and weathering, typical pretreatment involves artificial weathering followed by repeated cycles of compaction.

5.6.1 Determination of density for laboratory testing

Consideration of the compaction requirements in the earthworks technical standard will typically be fundamental in the determination of the compaction standard for CBR testing. Compaction standards for subgrade materials of between 90 and 97% of maximum dry density (MDD) (standard compactive energy) are typically adopted by TMR. Where MRTS04 *Earthworks* is used, 97% of maximum dry density (MDD) is typically appropriate for Class A and B material at subgrade level, and 95% of maximum dry density (MDD) is typically appropriate for all other situations.

5.6.2 Determination of moisture conditions for laboratory testing

Site specific information and/or local knowledge is preferred for determining the moisture content to be used. A guide to typical moisture conditions for laboratory CBR testing of subgrade materials is provided in Table Q5.1.

Table Q5.1 – Guide to Moisture Conditions for Laboratory CBR Testing

Location / Circumstances	Testing Condition
Locations where all the following are true: • Median annual rainfall ≤ 800 mm • Excellent surface drainage and waterproofing • Excellent subsurface drainage • Subgrade not significantly affected by the water table, standing water, or ponded water • Subgrade not affected by inundation regularly and/or for extended periods • Experience indicates that unsoaked conditions should apply	Unsoaked
Locations where any of the following are true: • Floodways, causeways and other pavements likely to be inundated regularly and/or for extended periods • Cuttings at or below the water table level that existed prior to the cutting and/or where seepage is likely • Situations where experience indicates that 10 day soaked conditions should apply	10 day soaked
Locations with circumstances not described above, and where experience indicates that 4 day soaked conditions should apply	4 day soaked

Where unsoaked CBR testing is adopted, an investigation into the sensitivity of the material strength to moisture content variations is typically undertaken. For moisture sensitive materials, this typically includes CBR testing at a range of moisture contents and densities. The results of such testing may indicate the need to adopt a CBR that differs from the reported test results (multi-point CBR test results are typically reported at OMC and MDD).

The following points are provided as a guide to the moisture sensitivity of various materials:

- sandy (SW, SP) soils – small fluctuations in water content produce little change in volume or strength/stiffness.
- silty (SM, SC, ML) soils – small fluctuations in water content produce little change in volume, but may produce large changes in strength/stiffness. Typically these soils attract and retain water through capillary action, and do not drain well.
- CL or CH clay – small fluctuations in water content may produce large variations in volume, and there may be large changes in strength/stiffness, particularly if the moisture content is near or above optimum. Typically these soils attract and retain water through matrix suction.

5.7 Adoption of presumptive CBR values

Use of presumptive values typically involves the assessment of subgrades on the basis of geological, topographic and drainage information, routine soil classification tests and performance for similar soils in similar conditions. Once these factors are assessed, it may be possible to assign a presumptive design CBR. Use of presumptive values is typically limited to lightly-trafficked pavements.

6 Pavement Materials

6.2 Unbound granular materials

6.2.1 Introduction

Material characteristics and requirements

The quality and strength characteristics required of unbound granular paving materials depend upon a combination of factors including:

- traffic (both number and loading of axles)
- climate and
- pavement configuration and drainage.

The performance of unbound pavements is heavily influenced by the moisture content, or more specifically, the degree of saturation of the material. Where the degree of saturation limit of the material is exceeded, the permanent deformation resistance of the material reduces significantly, often resulting in rapid failure under traffic. For this reason it is essential that unbound materials be dried back to a moisture content less than the material's degree of saturation limit prior to sealing, and maintained such that the degree of saturation limit is not exceeded during service.

Table Q6.1 provides a guide to the selection of standard materials for use in unbound granular pavements with thin bituminous surfacings, based on traffic loading and median annual rainfall. Selection and specification of unbound materials also requires consideration of project-specific factors such as:

- Site conditions such as perched water tables, flat terrain, restricted surface drainage, weather conditions, inundation etc may cause a greater exposure to water than represented by the median annual rainfall category
- availability of materials
- drainage provisions, recognising it is essential for all unbound materials to be adequately drained, including surface, side and subsurface drainage
- quality control provisions, in particular source rock selection and other quarry management practices; and aggregate production testing regimes and associated use of control measures such as statistical control charts
- contract administration arrangements, in particular auditing and surveillance in relation to source material and product quality
- the need to protect moisture sensitive or expansive subgrades by specifying materials with low permeability
- coarse graded materials, particularly those with low clay contents, are permeable and prone to segregation
- gap graded materials are more permeable and prone to segregation than coarse graded materials but can be used with additional care
- well graded material with appropriate fine material properties may provide the best overall service but may be more expensive

- fine graded materials and/or materials with excess fines have less permeability and are less prone to segregation but may require additional attention to achieve their specified CBR requirement, and
- pavement performance and maintenance expectations.

Table Q6.1 – Typical application of standard materials (MRTS05 Type) in sealed unbound granular pavements

Average daily traffic in design lane in year of opening (ESA)	**Typical Material Type [2,3]**		
	Median Annual Rainfall (mm)		
	≥ 800 mm / year	**≥ 500 mm/year to < 800 mm/year**	**< 500 mm/year**
Base			
≥ 1000 to < 3000	HSG[1]	HSG[1]	HSG[1]
≥ 100 to < 1000	2.1 or 1.1	2.1 or 3.1	3.1
10 to < 100	2.1	2.1 or 3.1	3.1
< 10	2.2	2.2 or 3.2	3.2
Upper Subbase			
≥ 1000 to < 3000	1.2 or 2.3	2.3 or 2.4	2.3, 2.4, 3.3 or 3.4
≥ 100 to < 1000	2.3	2.3, 2.4, 3.3 or 3.4	3.3 or 3.4
< 100	2.4	2.4 or 3.4	3.4
Lower Base			
All	2.5	2.5 or 3.5	3.5

Notes:

1. High Standard Granular (HSG) material is specified through an appropriate project-specific technical standard.
2. Where material type alternatives are given, the first is the preferred and typically adopted option, with other materials listed in order of preference.
3. The standard specification for Type 3 materials does not include any minimum durability requirements, and therefore site specific moisture conditions should be carefully considered in addition to median rainfall.

6.2.3 Determination of modulus of unbound granular materials

Presumptive values

Table Q6.2 may be used as a guide when assigning maximum values to typical granular materials under thin bituminous surfacings. Table Q6.3 may be used as a guide when assigning maximum values to typical granular materials when used in improved layers under bound pavements.

Table Q6.2 – Presumptive values for elastic characterisation of unbound granular base materials under thin bituminous surfacings

MRTS05 Material Standard	Presumptive Vertical Modulus (MPa)
HSG[1]	500
1.1, 2.1, 3.1	350
2.2, 3.2	300

Notes:

1. High Standard Granular (HSG) material is specified through an appropriate project-specific standard.

Table Q6.3 – Presumptive values for elastic characterisation of unbound granular materials used as subbase/improved layer (working platform) under bound pavement layers

MRTS05 Material Standard	Presumptive Vertical Modulus (MPa)	Additional Information
1.2, 2.3, 3.3[1]	210[2]	Material treated with cementitious stabilising agent to achieve a UCS of 1.0 to 2.0 MPa at 7 days. This material is typically adopted as the improved layer (working platform) under heavy-duty pavements, and other pavements where reduced moisture sensitivity is desired (refer to Section 3.14.2).
2.3, 2.4, 3.3[1], 3.4[1]	150	Unbound material, typically adopted as the improved layer (subbase) in AG(A) and ASt(A) pavements.

Notes:

1. Type 3 materials are only suitable for use in relatively dry environments (refer to Table Q6.1)
2. The material is typically modelled in mechanistic design as an unbound granular material.

6.3 Modified granular materials

While AGPT02 defines modified materials as having a maximum 28 day UCS of 1.0 MPa, TMR experience in base courses has been with stiffer materials that typically have a UCS between 1.0 and 2.0 MPa at 28 days (plant-mixed materials). While this approach may result in a material that is more prone to fatigue and/or shrinkage cracking, it has a number of benefits which include:

- reduced moisture sensitivity
- higher strength and stiffness
- reduced permeability
- reduced erodability
- reduced sensitivity to variations in grading and plasticity and
- higher binder content is more readily and consistently achieved.

To alleviate some of the concerns relating to cracking when used in base courses, TMR typically adopts additional controls such as SAM/SAMI seals, minimum layer thicknesses and/or minimum support conditions. In addition, use of modified materials has typically been to overcome other issues in relation to unbound granular pavements.

Some TMR regions have been active in developing regional-specific requirements. However, further research and performance monitoring is required to better understand the performance of modified granular materials across a range of conditions, and develop a more reliable technical standard and pavement design procedure that are suitable for more widespread use.

The use of modified granular materials requires the adoption of appropriate project-specific standards. Further guidance on the use of modified materials has been reported in *Considerations for the Selection, Design and Construction of CMB using ET05C* (TMR, 2012).

When using modified granular materials, the risks of both shrinkage and fatigue cracking should be recognised and accepted, and associated maintenance interventions over the life of the pavement should be anticipated.

6.4 Cemented materials

6.4.1 Introduction

Main characteristics

The typical characteristics of cemented materials supplied to TMR technical standards are as follows:

- Category 1 materials typically produce wider shrinkage cracks, which will be more prone to reflection into overlying layers, than cracks in Category 2 materials
- higher standard unbound materials (such as Type 1.1) in the cemented layer should produce narrower and more closely spaced shrinkage cracks, which will be less prone to reflection through overlying layers, and
- Category 1 materials may be less prone to erosion and crushing than Category 2 materials. Erosion resistance becomes increasingly important for pavements which are subjected to higher traffic volumes and/or higher rainfall.

The presence of high traffic volumes and/or high moisture ingress can cause rapid erosion of material around cracks in the cemented material.

Rocks which are likely to breakdown further in service, such as decomposed fine grained igneous, metamorphic and sedimentary rocks, are not typically included in cemented materials.

Cracking of cemented materials, and reflection of cracks into overlying layers, should always be anticipated when cemented materials are adopted.

6.4.3 Determination of design modulus

The preferred approach for determination of design modulus is by laboratory flexural beam testing.

Presumptive values

Presumptive values for the design modulus of cemented materials typically adopted for standard TMR materials are provided in Table Q6.4.

Table Q6.4 – Presumptive values for elastic characterisation of standard cemented materials

Category	Presumptive Design Modulus (MPa)[1,2]	Material to be Stabilised (MRTS05 Type)	Typical minimum UCS (28 day) (MPa)[3]
Category 1	3,500	1.1, 2.1	3.5 to 4.5
Category 2	2,500	1.1, 2.1, 2.2, 3.1[4] or 3.2[4]	2.5 to 3.5

Notes:

1. These design modulus values assume seven days initial curing with negligible trafficking.
2. Design modulus values are based on the specified compaction standard being achieved over the full depth of the layer.
3. The minimum 28 day UCS values shown are based on a cementitious blend of 75% cement and 25% flyash. These values are typically converted to 7 day values for construction compliance testing.
4. Type 3 materials are only suitable for use in relatively dry environments (refer to Table Q6.1).

6.5 Asphalt

6.5.3 Determination of asphalt design modulus and Poisson's ratio

Determination of design modulus from measured modulus

Where the measured modulus for a specific mix is to be adopted, the following is typically adopted:

- Adequate tests are undertaken, including modulus, density and binder volume, to assess variability and select a design modulus to provide 90% confidence, and
- Sufficient additional controls are established in production and construction to ensure the properties are consistently achieved.

Design modulus from published data

Presumptive values of design modulus that are typically adopted for standard asphalt mixes are provided in Table Q6.5 for a WMAPT of 32ºC. These values were generally derived from indirect tensile test (ITT) results of TMR registered mix designs. For mix types where limited or no data was available, the presumptive design values were determined based on relationships with other mixes.

Except for open graded asphalt, design moduli for locations with a WMAPT other than 32ºC are calculated using Equation Q6.1, rounded to the nearest multiple of 100 MPa.

$$E_{WMAPT} = \max\left(1000, E_{32^o C} \times e^{(-0.08 \times [WMAPT - 32])}\right) \qquad \text{(Q6.1)}$$

Where:

E_{WMAPT} = asphalt modulus at the desired WMAPT (MPa)

$E_{32ºC}$ = asphalt modulus at WMAPT 32ºC (MPa)

WMAPT= desired WMAPT (ºC)

A modulus of 800 MPa is typically used for open graded asphalt for all WMAPTs and design speeds.

Table Q6.5 – Presumptive values for elastic characterisation of asphalt mixes at a WMAPT of 32ºC

Asphalt Mix Type	**Binder Type**	**Volume of binder (%)**	**Asphalt modulus at heavy vehicle operating speed (MPa)**			
			10 km/h	**30 km/h**	**50 km/h**	**80 km/h**
OG10	A5S	N/A	800	800	800	800
OG14	A5S	N/A	800	800	800	800
SM14	A5S	13.0	1000* (600)	1000* (900)	1100	1300
DG10	C320	11.5	1000* (900)	1300	1600	1900
DG10	A5S	11.5	1000* (600)	1000* (800)	1000	1200
DG14	C320	11.0	1100	1700	2000	2400
DG14	C600	11.0	1400	2000	2400	2900
DG14	A5S	11.0	1000* (700)	1000	1300	1500
DG14HP	A5S	11.0	1000* (700)	1000	1300	1500
DG14HS	A5S	11.0	1000* (700)	1000	1300	1500
DG20	C320	10.5	1200	1800	2200	2600
DG20	C600	10.5	1500	2200	2600	3100
DG20HM	C600	10.5	1500	2200	2600	3100
DG28	C320	10.0	1200	1800	2200	2600
DG28	C600	10.0	1500	2200	2600	3100

Notes:

* Indicated values have been limited to a value of 1000 MPa. When adjusting these moduli to another WMAPT using Equation Q6.1, $E_{32ºC}$ should be taken as the value in brackets.

In the absence of more reliable information about the heavy vehicle operating speed, presumptive operating speeds that are typically adopted for various designated speed limits are given in Table Q6.6.

Table Q6.6 – Presumptive heavy vehicle operating speeds

Project Location	Presumptive heavy vehicle operating speeds (km/h)	
	Flat to ≤ 5% Grade	**> 5% Grade**
Speed limit > 80 km/h	80	50
Speed limit 50 – 80 km/h	50	30
Roundabouts, signalised intersections and approaches	30	10

6.5.4 Factors affecting asphalt fatigue life

Effect of binder type

Asphalt containing plastomeric polymer modified binder (e.g. A2V) should only be used where there is sufficient support to avoid premature fatigue of the layer. Such support can be provided by including a cemented subbase and/or using stiff underlying asphalt layers.

Guidance on the selection of asphalt binders is included in Table Q6.7.

6.5.7 Permanent deformation of asphalt

Guidance on the selection of asphalt binders is included in Table Q6.7.

Table Q6.7 – Guide to the selection of dense graded asphalt binders

Application	Traffic Conditions (average daily ESA in design lane in year of opening)		Typical Binders
	Free Flowing	High Shear[1]	
Surfacing	< 1000	< 300	C320 [2, 3]
	1000 to < 3000	300 to < 1000	A5S [2]
	≥ 3000	≥ 1000	A5S [4]
Intermediate course	< 1000	< 300	C320 [2, 3]
	1000 to < 3000	300 to < 1000	A5S [5]
	≥ 3000	≥ 1000	A5S [4]
Base course	All	< 3000	C320, C600 [2]
	All	≥ 3000[6]	C600 [2]

Notes:

1. High shear areas include signalised intersections and approaches, and other areas with very slow moving heavy vehicles.
2. M1000/320 and A0.6S could also be considered. However, there has been limited experience with these binder types in these applications on TMR projects.
3. A5S if required for improved fatigue resistance.
4. A10S or A2V could also be considered based on a project-specific engineering assessment. A10S should provide additional fatigue resistance to A5S but may be more difficult to place, while A2V should provide improved deformation resistance (refer to Section 6.5.4).
5. M1000/320, A0.6S and C600 could also be considered. However, there has been limited experience with these binder types in these applications on TMR projects.
6. A minimum of 100 mm cover (combined thickness of surfacing and intermediate course) is typically adopted in high shear locations with average daily ESA in the design lane in year of opening > 3000.

6.5.8 Recycled asphalt

The design parameters included in this supplement are based on up to 15% reclaimed asphalt pavement (RAP) being incorporated into dense graded asphalt with conventional bitumen or multigrade bitumen binders.

6.6 Concrete

6.6.3 Base concrete

A design flexural strength of 4.5 MPa (at 28 days) is typically adopted for pavement quality base concrete. This design value is less than the specified value (minimum characteristic value of 4.8 MPa at 28 days) in the TMR technical standard for concrete base to account for the actual strength gains beyond 28 days being typically less than what is assumed in the AGPT02 thickness design procedure (Austroads, 2013b).

For steel-fibre reinforced concrete, a design flexural strength of 5.5 MPa (at 28 days) is typically adopted.

Q6.7 Foamed bitumen stabilised materials

TMR experience with foamed bitumen stabilised material has historically been associated with in situ construction methods used to rehabilitate existing unbound granular pavements. However, recently the specialised mixing plant required to manufacture plant-mixed foamed bitumen stabilised material has become locally available, thereby creating the possibility for use of foamed bitumen stabilised material in new pavements.

Guidance on material requirements, material characterisation and mix design of foamed bitumen stabilised materials is provided in the TMR *Pavement Rehabilitation Manual* (TMR, 2012) and *Part 5: Pavement Evaluation and Treatment Design* of the Austroads *Guide to Pavement Technology* (Austroads, 2011),

7 Design Traffic

7.4 Procedure for determining total heavy vehicle axle groups

7.4.2 Selection of design period

The design periods typically adopted by TMR are as detailed in Table Q7.1.

Table Q7.1 – Typical Design Periods

Annual Average Daily Traffic (AADT) (total in two directions)	Typical Design Period (Years)
≥ 30,000	30
< 30,000	20

The design period may be optimised for project-specific requirements, which would typically involve consideration of whole-of-life costs and the infrastructure investment strategy current at the time of the design.

7.4.4 Initial Daily Heavy Vehicles in the Design Lane

Designers are referred to the Traffic Surveys and Data Management (TSDM) web reporting tool as a source of traffic data such as Traffic Analysis and Reporting System (TARS) and Weigh in Motion (WIM) reports. TMR officers can access TSDM at http://tsdm/tsdm.

The traffic volume in the year of opening may be determined by multiplying traffic volumes from a previous year (for example, the year the traffic survey was undertaken) by a growth factor (GF) as shown in Equation Q7.1.

$$GF = (1 + 0.01 \times R)^x \qquad \text{(Q7.1)}$$

where:

R = heavy vehicle growth rate per annum (%)

X = time period (years) between the year of the traffic survey and year of opening.

The average daily ESA in the design lane in the year of opening (ESA/day) can be calculated using Equation Q7.2.

$$ESA/day = AADT \times DF \times \frac{\%HV}{100} \times LDF \times N_{HVAG} \times ESA/HVAG \qquad \text{(Q7.2)}$$

where:

ESA/HVAG = average number of equivalent standard axles per heavy vehicle axle group (refer Section 7.6.2)

AADT, DF, %HV, LDF and N_{HVAG} are as detailed in Section 7.4.1.

7.4.5 Cumulative traffic volumes

The heavy vehicle growth rate is typically estimated based on project-specific traffic counts, historic trends and, in some cases, traffic modelling.

An additional source of information is Report 121 of the Department of Infrastructure and Transport, *Road freight estimates and forecasts in Australia: interstate, capital cities and rest of state* (BITRE, 2010). This report includes estimates of growth based on a comprehensive study of historic growth, and expected economic and population growth. The growth rates in Table Q7.2 were calculated using the information published in Report 121 and provide an indication of the likely growth, based on freight forecasts, for various general types of freight routes. These values are for indicative purposes only and are not intended to replace sound project-specific information.

Table Q7.2 – Indicative growth rates for below capacity traffic flow based on freight forecasts

Road	Indicative Annual Growth (2013 to 2020) (%)	Indicative Annual Growth (2021 onwards) (%)
Highways, motorways and other interstate routes	5	3
Urban roads in and around Brisbane, other than interstate routes	4	2
Other state controlled roads	3	2

Where guidance in this supplement is based on the average daily ESA in the design lane in the year of opening, it is assumed that heavy vehicle growth rates are not excessive when compared to typical historic rates. In this regard, growth rates exceeding about 10% per annum may be considered excessive.

7.5 Estimation of Traffic Load Distribution (TLD)

Available WIM data is published in the TSDM web reporting tool. Prior to using WIM data in pavement design, the relevance, accuracy and reliability of the data should be confirmed.

8 Design of flexible pavements

8.1 General

Layer thicknesses should be rounded up to the nearest 5 mm.

To allow for variations in construction thickness, a construction tolerance is typically added to the design thickness of the pavement as follows:

i) For unbound granular and modified granular pavements, a thickness of 20 mm is typically added to the design thickness.

ii) For full depth asphalt, deep strength asphalt, flexible composite, AG(A) and ASt(A) pavements, 10 mm is typically added to the pavement course that governs the overall allowable loading.

iii) For ASt(B) temporary pavements, 20 mm is typically added to the design thickness of the stabilised base course.

8.2 Mechanistic procedure

Mechanistic design is typically undertaken using the latest version of CIRCLY.

Thin interlayers and surfacing, such as sprayed seals and geosynthetics, are considered to be non-structural and therefore are not typically included in the design model.

For the thickness design of pavements comprising foamed bitumen stabilised materials in the base and/or subbase, reference should be made to the procedure detailed in the TMR *Pavement Rehabilitation Manual* (TMR, 2012) *and Part 5: Pavement Evaluation and Treatment Design* of the Austroads *Guide to Pavement Technology (*Austroads, 2011). This thickness design procedure is also applicable to pavements comprising plant-mixed foamed bitumen stabilised materials.

8.2.2 Procedure for elastic characterisation of selected subgrade materials

For lime stabilised subgrade materials which have been designed for both lime demand and unconfined compressive strength requirements, the procedures for elastic characterisation are as detailed in TMR Technical Note 74 (TMR, 2012).

8.3 Empirical design of granular pavements with thin bituminous surfacing

To reliably achieve an asphalt surfacing thickness less than 40 mm, the specified layer thickness would typically be 35 mm or less. This requires adoption of a 10 mm or smaller nominal size asphalt mix which may not be suitable in high speed situations. Where such an asphalt surfacing is provided and the average daily ESA in the design lane in the year of opening exceeds 100, consideration should be given to adopting a minimum compaction standard of 102% in the unbound base course to reduce the potential for asphalt fatigue.

8.3.1 Determination of basic thickness

The thickness design charts (Figures 8.4 and 12.2) are based on the premise that pavement roughness at the end of the design period (the terminal roughness) will be three times the initial roughness. This is the standard typically adopted by TMR. For example, a terminal roughness of approximately 150 NAASRA counts / km can be expected, assuming that the initial roughness is 50 NAASRA counts / km.

However, if a higher ratio of terminal to initial roughness is accepted, a thinner pavement can be designed by adjusting the design traffic using Figure Q8.1 which is based on NAASRA (1987). Such an adjustment should only be considered following a project-specific assessment of the impacts of reduced pavement performance. This assessment should consider the consequences of premature distress, poor pavement performance, whole-of-life and road user costs, topographical factors and availability of pavement materials.

This procedure uses only roughness as an indicator of the effect of the reduced standard. For instance, it does not include other elements such as rut depth, volume change, or durability, which need to be independently assessed.

This reduced design standard procedure is typically only adopted in a very limited number of situations. Examples, subject to project-specific assessment, may include:

- stage construction
- special maintenance works which will be subsequently overlaid
- parking lanes

- low volume roads (e.g. average daily ESA in the design lane in the year of opening < 100)
- pavements where environmental effects dictate performance, and
- temporary connections.

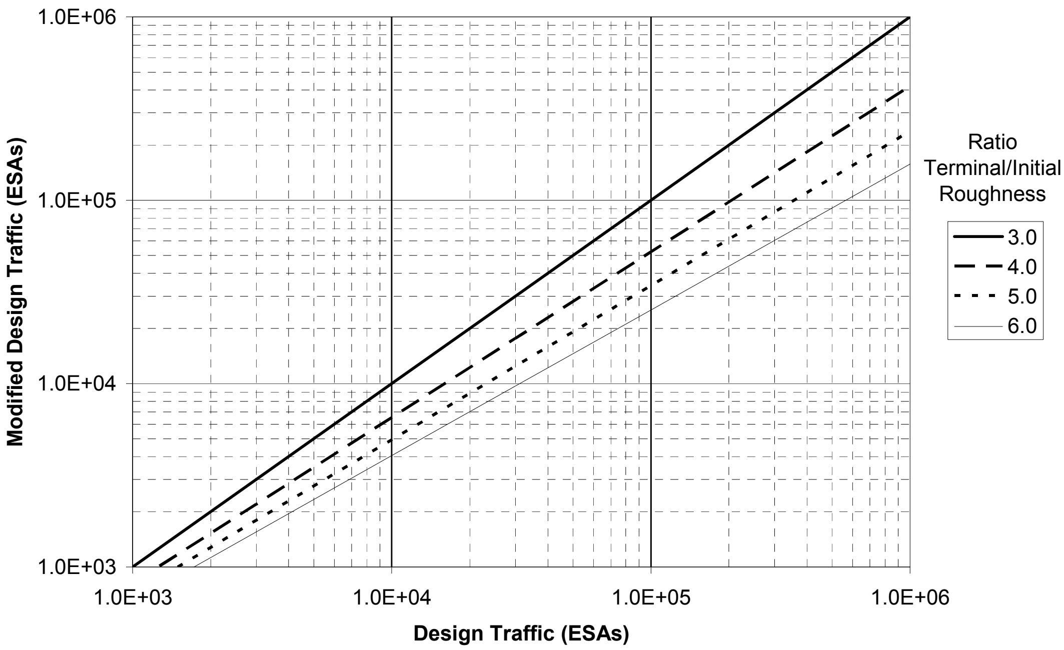

Figure Q8.1 – Modified Design Traffic for an Increased Terminal Roughness Condition

9 Design of new rigid pavements

9.2 Pavement types

9.2.2 Subbase types

Due to its proven ability to provide uniform support and erosion resistance, TMR has typically adopted lean concrete subbase, even at traffic levels less than 1 x 10^7 HVAG. TMR has limited experience with other subbase types such as bound materials. These typically require a project-specific risk assessment (including whole-of-life cost comparison) and development of project-specific technical standards.

In tunnels, project-specific requirements are typically required.

9.2.3 Wearing surface

The use of asphalt wearing surfaces over PCP and JRCP is not typically adopted as reflective cracking in the asphalt is likely from the underlying joints.

Where an asphalt wearing surface is required, CRCP in conjunction with a proprietary concrete surface primer, is typically used. In this case, future maintenance requirements should be considered, in particular the ability to mill the asphalt without unduly impacting on the concrete base.

9.4 Base thickness design

9.4.1 General

To allow for variations in the constructed layer thicknesses within the specified tolerances, a construction tolerance of 10 mm is typically added to the design base thickness.

An additional 10 mm should also be added to the base thickness in the following situations:

- for asphalt surfaced concrete, an additional 10 mm allowance should be provided to account for future fine milling and replacement of the asphalt surfacing. An alternative to this is the provision of an additional asphalt layer under the wearing surface so that future milling does not impact on the concrete base;
- where concrete base is also the trafficked surface, an additional 10 mm allowance should be included to account for future surface grinding which may be necessary to improve functional characteristics such as ride quality, noise and texture. This allowance is not typically applied when future grinding is unlikely (for example, on roundabouts where vehicle speeds are relatively low and the geometry is such that grinding is not practical).

Project-specific requirements for fine milling and surface grinding are typically adopted to ensure suitable tolerances for these treatments are specified.

10 Economic comparison of designs

10.1 General

For heavy-duty pavements, further guidance on comparison of alternative pavement types and configurations is provided in *A Guide to the Whole-of-Life Costing of Heavy Duty Pavements* (Main Roads, 1998).

10.7 Analysis period

An analysis period of 40 years is typically adopted by TMR.

11 Implementation of design and collection of feedback

11.2 Collection of feedback

Users of this supplement are encouraged to provide feedback on pavement performance, particularly where atypical solutions are adopted, or where typical designs produce unsatisfactory performance. Feedback should be sent to the Principal Engineer (Pavement Design) for consideration in future updates.

12 Design of lightly-trafficked pavements

12.4 Environment

12.4.2 Moisture

Unsealed shoulders

Unsealed shoulders are sometimes adopted on lightly-trafficked pavements where the consequences of moisture under the edge of the trafficked pavement can be tolerated. Where unsealed shoulders are to be considered, the following measures are typically adopted:

- extend the seal at least 200 mm beyond the delineated edge of the trafficked lane and
- in the shoulder provide material with low permeability, low swell and sufficient strength to support limited traffic during periods of wet weather, ensuring that an undrained boxed condition does not result.

12.6 Pavement materials

12.6.1 Unbound granular materials

In drier parts of Queensland where traffic volumes are low, marginal or non-standard materials (also typically referred to as Type 4 materials) have been used extensively and many have performed satisfactorily. Use of such materials typically requires project-specific standards be developed. These standards should be based on local experience with the particular material, including its construction and handling requirements, historic performance and future performance expectations for the project. The use of laboratory methods, such as the repeated load triaxial test, may assist in predicting the likely performance of these materials over a range of moisture conditions relative to standard materials.

12.6.2 Cemented materials

Where non-standard unbound materials (such as Type 4) are incorporated into stabilised layers, their use is typically restricted to applications such as floodways on lightly-trafficked roads in relatively dry environments (where some additional resistance to moisture is desired). Controls on grading and plasticity index (or linear shrinkage) are typically required to reduce the potential for shrinkage cracking and improve uniformity.

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APPENDIX B WEIGHTED MEAN ANNUAL PAVEMENT TEMPERATURE

The table below provides additional sites that are not already listed in AGPT02.

Queensland	
Town	**WMAPT**
Ayr	35
Baralaba	35
Barcaldine	36
Beaudesert	31
Biloela	32
Birdsville	37
Blackall	36
Bollon	33
Boulia	38
Bundaberg	33
Camooweal	39
Cardwell	36
Charters Towers	36
Clermont	35
Cloncurry	39
Cooktown	38
Gayndah	33
Gladstone	34
Goondiwindi	32
Herberton	30

Queensland	
Town	**WMAPT**
Hughenden	37
Isisford	36
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