Pavement Design Supplement

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

June 2021

Queensland Government

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Feedback

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About this document

The Queensland Department of Transport and Main Roads adopts the fundamental pavement design principles in *Part 2: Pavement Structural Design* of the Austroads *Guide to Pavement Technology* (Austroads, 2017), hereafter referred to as AGPT02.

Transport and Main Roads has published this *Pavement Design Supplement* ('this supplement'), for use in departmental 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 Transport and Main Roads works must use this supplement in conjunction with AGPT02, as well as any other project-specific requirements.

This edition of the supplement replaces the 2018 *Pavement Design Supplement*. The supplement has been updated primarily to:

- include the new Austroads procedure for the design of pavements incorporating lightly bound materials
- include typical pavement structures for lightly bound base pavements
- define the depth of subgrade material to be considered in subgrade evaluation and pavement design as 1.5 m, aligning with the latest version of MRTS04 *General Earthworks*
- adopt a laboratory density ratio of 97.0% (standard compaction) for laboratory CBR testing of subgrade materials
- extend the mechanistic-empirical design procedure for flexible pavements to include subgrades with design CBR as low as 2% (replacing the previous limit of 3%)
- align with the most recent version of MRTS05 *Unbound Pavements* which incorporates unbound recycled materials
- provide guidance on the composition of granular pavements with thin asphalt surfacings
- extend the recommended traffic limits for the selection of foamed bitumen stabilised pavements with asphalt surfacing
- reduce the minimum thickness of foamed bitumen stabilised materials from 300 mm to 250 mm
- include a flexural modulus master curve and fatigue relationship for high modulus asphalt (EME2)
- align with the latest version of *Guideline: Structural Design Procedure for Lime Stabilised Subgrade* which increases the design modulus and removes the requirement for sublayering of lime stabilised subgrade materials, and
- include references to relevant technical documents on bridge deck wearing surfaces.

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 also 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 Transport and Main Roads, 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 construct only contracts. Further guidance on developing project design briefs is included in Section 1.2.

Due to differences between design inputs and whole-of-life actualities (for example, 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 Transport and Main Roads practice and experience to date, and current future directions, including:

- for the Transport and Main Roads-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 in the Department of Transport and Main Roads* (Transport and Main Roads, 2014).

How to use this document

This document must be read and applied together with AGPT02. You must have access to AGPT02 to understand what applies to Transport and Main Roads projects.

This document:

- sets out how AGPT02 applies to Transport and Main Roads projects
- has precedence over AGPT02 when applied to Transport and Main Roads projects, and
- has the same chapter and section numbering and headings as AGPT02.

The following table summarises the relationship between AGPT02 and this document:

Applicability	Meaning
Accepted	The AGPT02 section is accepted.
Accepted, with amendments	Part or all of the AGPT02 section has been accepted with additions, deletions or differences.
New	There is no equivalent section in AGPT02.
Not accepted	The AGPT02 section is not accepted.

Definitions

The following general amended definitions apply when reading AGPT02.

Reference to…	Means
Part 2, AGPT02 and this Part	AGPT02, as amended by this document. For example, a reference to “this Part” in AGPT02 means you must refer to AGPT02, **and** this *Pavement Design Supplement*.

Relationship table

Chapter	Section	Description	Applicability
1	**Introduction**		
	1.1	Scope of the Guide and this Part	Accepted, with amendments
	1.2	Project Scope and Background Data Requirements for Design	Accepted
	1.2.1	*Investigation and Design Proposal*	Accepted, with amendments
2	**Pavement Design Systems**		
	2.1	General	Accepted
	2.2	Common Pavement Types	–
	2.2.1	*General*	Accepted, with amendments
	2.2.2	*Granular Pavements with Sprayed Seal Surfacings*	Accepted, with amendments
	2.2.3	*Cemented Granular Bases with Sprayed Seal Surfacings*	Accepted, with amendments
	2.2.4	*Granular Pavements with Thin Asphalt Surfacings*	Accepted, with amendments
	2.2.5	*Asphalt over Granular Pavements*	Accepted, with amendments
	2.2.6	*Flexible Composite, Deep Strength and Full Depth Asphalt Pavements*	Accepted, with amendments
	2.2.7	*Concrete Pavements*	Accepted, with amendments
	2.2.8	*Asphalt over Heavily Bound (Cemented) Pavements*	New
	2.2.9	*Foamed Bitumen Stabilised Pavements*	New
	2.2.10	*Lightly Bound Base Pavements*	New
	2.3	Overview of Pavement Design Systems	Accepted
	2.3.1	*Input Variables*	Accepted, with amendments
	2.3.2	*Selecting a Trial Pavement Configuration*	Accepted
	2.3.3	*Structural Analysis*	Accepted
	2.3.4	*Distress Prediction*	Accepted
	2.3.5	*Comparison of Alternative Designs*	Accepted
	2.4	Shoulders with a Lower Structural Standard	New

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3	**Construction and Maintenance Considerations**		
	3.1	General	Accepted, with amendments
	3.2	Extent and Type of Drainage	Accepted, with amendments
	3.2.1	*Purpose and Details of Drainage Measures*	Accepted
	3.2.2	*Drainage of Pavement Materials*	Accepted, with amendments
	3.2.3	*Use of a Drainage Blanket*	Accepted, with amendments
	3.2.4	*Permeable Pavements on Moisture-sensitive Subgrades*	Accepted
	3.2.5	*Full Depth Asphalt Pavements on Moisture-sensitive Subgrades*	Accepted
	3.2.6	*Treatment of Stormwater Run-off*	Accepted
	3.3	Use of Boxed Construction	Accepted
	3.4	Availability of Equipment	Accepted
	3.5	Use of Staged Construction	Accepted
	3.6	Use of Stabilisation	Accepted, with amendments
	3.7	Pavement Layering Considerations	Accepted, with amendments
	3.8	Use of Strain Alleviating Membrane Interlayers	Accepted, with amendments
	3.9	Environmental and Safety Constraints	Accepted, with amendments
	3.10	Social Considerations	Accepted
	3.11	Construction under Traffic	Accepted, with amendments
	3.12	Maintenance Strategy	Accepted
	3.13	Acceptable Risk	Accepted
	3.14	Improved Subgrades	–
	3.14.1	*Soft Subgrades*	Accepted, with amendments
	3.14.2	*Improved Layers under Bound Layers*	Accepted, with amendments
	3.15	Surfacing Type	Accepted
	3.15.1	*Sprayed Seals*	Accepted, with amendments
	3.15.2	*Asphalt or Concrete Surfaces*	Accepted
	3.15.3	*Open-graded Asphalt*	Accepted, with amendments
	3.15.4	*Surfacings in Tunnels*	Accepted
	3.16	Pavement Widenings	Accepted
	3.17	Settlement	New
	3.18	Pavement Jointing Considerations	New
	3.19	Thickness of Bituminous Seals	New
	3.20	Temporary Pavements for High Traffic	New
	3.21	Construction Impacts on Buildings	New

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4	**Environment**		
	4.1	General	Accepted, with amendments
	4.2	Moisture Environment	Accepted, with amendments
	4.2.1	*Equilibrium Moisture Content*	Accepted
	4.3	Temperature Environment	Accepted, with amendments
5	**Subgrade Evaluation**		
	5.1	General	Accepted, with amendments
	5.2	Measures of Subgrade Support	Accepted
	5.3	Factors to be Considered in Estimating Subgrade Support	Accepted, with amendments
	5.3.1	*Subgrade Variability*	Accepted
	5.3.2	*Performance Risk*	Accepted
	5.3.3	*Sequence of Earthworks Construction*	Accepted
	5.3.4	*Compaction Moisture Content Used and Field Density Achieved*	Accepted
	5.3.5	*Moisture Changes during Service Life*	Accepted, with amendments
	5.3.6	*Pavement Cross-section and Subsurface Drainage*	Accepted
	5.3.7	*Presence of Weak Layers below the Design Subgrade Level*	Accepted
	5.3.8	*Lime-stabilised subgrades*	Accepted, with amendments
	5.4	Methods for Determining Subgrade Design CBR Value	Accepted
	5.5	Field Determination of Subgrade CBR	Accepted
	5.5.1	*In situ CBR Test*	Accepted
	5.5.2	*Cone Penetrometers*	Accepted, with amendments
	5.5.3	*Deflection Testing*	Accepted
	5.6	Laboratory Determination of Subgrade CBR and Elastic Parameters	Accepted, with amendments
	5.6.1	*Determination of Density for Laboratory Testing*	Accepted, with amendments
	5.6.2	*Determination of Moisture Conditions for Laboratory Testing*	Accepted, with amendments
	5.7	Adoption of Presumptive CBR Values	Accepted, with amendments
	5.8	Limiting Subgrade Strain Criterion	Accepted
	5.9	Subgrades with Design CBR less than 3%	New

Chapter	Section	Description	Applicability
6	**Pavement Materials**		
	6.1	General	Accepted, with amendments
	6.2	Unbound Granular Materials	–
	6.2.1	*Introduction*	Accepted, with amendments
	6.2.2	*Factors Influencing Modulus and Poisson's Ratio*	Accepted
	6.2.3	*Determination of Modulus of Unbound Granular Materials*	Accepted, with amendments
	6.2.4	*Permanent Deformation*	Accepted
	6.3	Modified Granular Materials	Accepted, with amendments
	6.4	Cemented Materials	–
	6.4.1	*Introduction*	Accepted, with amendments
	6.4.2	*Factors Affecting Modulus of Cemented Materials*	Accepted
	6.4.3	*Determination of Design Modulus*	Accepted, with amendments
	6.4.4	*Determination of Design Flexural Strength*	Accepted
	6.4.5	*Factors Affecting the Fatigue Life of Cemented Materials*	Accepted
	6.4.6	*Determining the In-service Fatigue Characteristics from Laboratory Fatigue Measurements*	Accepted
	6.4.7	*Determining the In-service Fatigue Characteristics from Laboratory Measured Flexural Strength and Modulus*	Accepted
	6.4.8	*Determining the In-service Fatigue Characteristics from Presumptive Flexural Strength and Modulus*	Accepted, with amendments
	6.5	Asphalt	–
	6.5.1	*Introduction*	Accepted
	6.5.2	*Factors Affecting Modulus of Asphalt*	Accepted
	6.5.3	*Definition of Asphalt Design Modulus*	Accepted
	6.5.4	*Determination of Design Modulus from Direct Measurement of Flexural Modulus*	Accepted, with amendments
	6.5.5	*Determination of Design Modulus from Measurement of ITT Modulus*	Accepted, with amendments
	6.5.6	*Design Modulus from Bitumen Properties and Mix Volumetric Properties*	Accepted, with amendments
	6.5.7	*Design Modulus from Published Data*	Accepted, with amendments
	6.5.8	*Poisson's Ratio*	Accepted

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	6.5.10	*Fatigue Criteria*	Accepted, with amendments
	6.5.11	*Means of Determining Asphalt Fatigue Characteristics*	Accepted, with amendments
	6.5.12	*Permanent Deformation of Asphalt*	Accepted, with amendments
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	6.6.2	*Subbase Concrete*	Accepted
	6.6.3	*Subbase Concrete for Flexible Pavements*	Accepted
	6.6.4	*Base Concrete*	Accepted, with amendments
	6.7	Foamed Bitumen Stabilised Materials	New
	6.8	Lightly Bound Granular Materials	New
7	**Design Traffic**		
	7.1	General	Accepted
	7.2	Role of Traffic in Pavement Design	Accepted
	7.3	Overview of Procedure for Determining Design Traffic	Accepted
	7.4	Procedure for Determining Total Heavy Vehicle Axle Groups	–
	7.4.1	*Introduction*	Accepted
	7.4.2	*Selection of Design Period*	Accepted, with amendments
	7.4.3	*Identification of Design Lane*	Accepted
	7.4.4	*Initial Daily Heavy Vehicles in the Design Lane*	Accepted, with amendments
	7.4.5	*Cumulative Number of Heavy Vehicles when Below Capacity*	Accepted, with amendments
	7.4.6	*Cumulative Number of Heavy Vehicles Considering Capacity*	Accepted, with amendments
	7.4.7	*Cumulative Heavy Vehicle Axle Groups*	Accepted
	7.4.8	*Increases in Load Magnitude*	Accepted
	7.5	Estimation of Traffic Load Distribution (TLD)	Accepted, with amendments
	7.6	Design Traffic for Flexible Pavements	–
	7.6.1	*Damage to Flexible Pavements*	Accepted
	7.6.2	*Pavement Damage in Terms of Equivalent Standard Axle Repetitions*	Accepted
	7.6.3	*Design Traffic for Mechanistic-empirical Design Procedure*	Accepted
	7.7	Design Traffic for Rigid Pavements	Accepted
	7.8	Example of Design Traffic Calculations	Accepted

Chapter	Section	Description	Applicability
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	8.2.2	*Procedure for Elastic Characterisation of Selected Subgrade and Lime-stabilised Subgrade Materials*	Accepted, with amendments
	8.2.3	*Procedure for Elastic Characterisation of Granular Materials*	Accepted
	8.2.4	*Procedure for Determining Critical Strains for Asphalt, Cemented Material and Lean-mix Concrete*	Accepted
	8.2.5	*Procedure for Determining Allowable Loading for Asphalt, Cemented Material and Lean-mix Concrete*	Accepted, with amendments
	8.2.6	*Consideration of Post-cracking Phase in Cemented Material and Lean-mix Concrete*	Accepted
	8.2.7	*Design of Granular Pavements with Thin Bituminous Surfacings*	Accepted
	8.2.8	*Minimum Support Conditions under Lightly Bound, Asphalt, Heavily Bound (Cemented) and Foamed Bitumen Stabilised Pavements*	New
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	8.3	Empirical Design of Granular Pavements with Thin Bituminous Surfacing	Accepted, with amendments
	8.3.1	*Determination of Basic Thickness*	Accepted, with amendments
	8.3.2	*Pavement Composition*	Accepted, with amendments
9	**Design of Rigid Pavements**		
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	9.2	Pavement Types	–
	9.2.1	*Base Types*	Accepted
	9.2.2	*Subbase Types*	Accepted, with amendments
	9.2.3	*Wearing Surface*	Accepted, with amendments
	9.3	Factors used in Thickness Determination	–
	9.3.1	*Strength of Subgrade*	Accepted, with amendments
	9.3.2	*Effective Subgrade Strength*	Accepted
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	9.4.1	*General*	Accepted, with amendments
	9.4.2	*Base Thickness Design Procedure*	Accepted
	9.4.3	*Minimum Base Thickness*	Accepted, with amendments
	9.4.4	*Example of the Use of the Design Procedure*	Accepted
	9.4.5	*Example Design Charts*	Accepted
	9.4.6	*Provision of Dowels*	Accepted
	9.4.7	*Provision of Tiebars*	Accepted
	9.5	Reinforcement Design Procedures	–
	9.5.1	*General*	Accepted
	9.5.2	*Reinforcement in Plain Concrete Pavements*	Accepted
	9.5.3	*Reinforcement in Jointed Reinforced Pavements*	Accepted
	9.5.4	*Reinforcement in Continuously Reinforced Concrete Pavements*	Accepted
	9.6	Base Anchors	Accepted
	9.7	Joint Types and Design	–
	9.7.1	*Introduction*	Accepted
	9.7.2	*Transverse Contraction Joints*	Accepted
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	9.7.6	*Joint Design*	Accepted
10	**Economic Comparison of Designs**		
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	10.2	Method for Economic Comparison	Accepted
	10.3	Construction Costs	Accepted
	10.4	Maintenance Costs	Accepted
	10.5	Salvage Value	Accepted
	10.6	Real Discount Rate	Accepted
	10.7	Analysis Period	Accepted, with amendments
	10.8	Road User Costs	Accepted
	10.9	Surfacing Service Lives	Accepted

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11	**Implementation of Design and Collection of Feedback**		
	11.1	Implementation of Design	Accepted
	11.2	Collection of Feedback	–
	11.2.1	*Need*	Accepted, with amendments
	11.2.2	*Benefits*	Accepted
	11.2.3	*Current Australian LTPP Program*	Accepted
	11.2.4	*Data Collection*	Accepted
12	**Design of Lightly-Trafficked Pavements**		
	12.1	General	Accepted
	12.2	Pavement Design Systems	–
	12.2.1	*Selecting a Trial Pavement Configuration*	Accepted
	12.3	Construction and Maintenance Considerations	Accepted
	12.3.1	*Extent and Type of Drainage*	Accepted
	12.3.2	*Use of Boxed Construction*	Accepted
	12.3.3	*Availability of Equipment*	Accepted
	12.3.4	*Use of Staged Construction*	Accepted
	12.3.5	*Environmental and Safety Constraints*	Accepted
	12.3.6	*Social Considerations*	Accepted
	12.3.7	*Maintenance Strategy*	Accepted
	12.4	Environment	–
	12.4.1	*General*	Accepted
	12.4.2	*Moisture*	Accepted, with amendments
	12.4.3	*Temperature*	Accepted
	12.5	Subgrade Evaluation	Accepted
	12.5.1	*Methods for Estimating Subgrade Support Value*	Accepted
	12.6	Pavement Materials	Accepted
	12.6.1	*Unbound Granular Materials*	Accepted, with amendments
	12.6.2	*Cemented Materials*	Accepted, with amendments
	12.6.3	*Asphalt*	Accepted
	12.6.4	*Concrete*	Accepted
	12.7	Design Traffic	Accepted
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	12.7.2	*Design Traffic for Flexible Pavements*	Accepted

Chapter	Section	Description	Applicability
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	12.8.2	*Empirical Design of Granular Pavements with Thin Bituminous Surfacing*	Accepted
	12.8.3	*Mechanistic-empirical Procedure – Example Charts*	Accepted
	12.9	Design of Rigid Pavements	–
	12.9.1	*General*	Accepted
	12.9.2	*Pavement Types*	Accepted
	12.9.3	*Factors Used in Thickness Determination*	Accepted
	12.9.4	*Base Thickness Design*	Accepted
	12.9.5	*Reinforcement Design Procedures*	Accepted
	12.9.6	*Joints*	Accepted
	12.10	Implementation of Design and Collection of Feedback	Accepted
13	**References**		
Appendices			
A	Australasian Road Agency Pavement Design Manuals or Supplements		Accepted
B	Weighted Mean Annual Pavement Temperature		Accepted
C	Calculating CGF for Non-Constant Annual Growth Rates		Accepted
D	Example Determination of Cumulative Number of Heavy Vehicles Considering Capacity		Accepted
	D.1	Calculation of Annual Number of Heavy Vehicles	Accepted
	D.2	Calculation of Maximum Annual Number of Heavy Vehicles	Accepted
	D.3	Adjusted Annual Number of Heavy Vehicles	Accepted
	D.4	Cumulative Number of Heavy Vehicles	Accepted
E	Characteristics of Traffic at Selected WIM Sites		Accepted
	E.1	Introduction	New
	E.2	Methods for Selecting or Deriving TLDs for Pavement Design	New
	E.3	Method 1: TLD from WIM Site at or near the Project Location	New
	E.4	Method 2: Class-specific TLDs from Relevant WIM Site Combined with Project-specific Classified Vehicle Count	New
	E.5	Method 3: Presumptive Class-specific TLDs Combined with Project-specific Classified Vehicle Count	New

Chapter	Section	Description	Applicability
	E.6	Upper Limit on WIM Loads	New
	E.7	Additional Notes on Method 1	New
F	Adjustment of Design Traffic for Anticipated Increases in Load Magnitude		Accepted
G	Traffic Load Distribution		Accepted
H	Pavement Damage in Terms of Equivalent Standard Axles		Accepted
	H.1	Evaluation of Number of Equivalent Standard Axle (ESA) Repetitions per Axle Group	Accepted
	H.2	Specification of Design Traffic Loading and its Calculation	Accepted
I	Example of Design Traffic Calculations		Accepted
	I.1	Total Number of Heavy Vehicle Axle Groups	Accepted
	I.2	Design Traffic for Flexible Pavements	Accepted
	I.2.1	*Estimating Equivalent Standard Axles per Heavy Vehicle Axle Group*	Accepted
	I.2.2	*Design Traffic Loading Calculation in ESA*	Accepted
	I.2.3	*Design Traffic Loading Calculation for Bound Materials*	Accepted
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J	Procedures for Evaluation of Pavement Damage Due to Specialised Vehicles		Accepted
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	J.2	Granular Pavements with Thin Bituminous Surfacings	Accepted
	J.3	Flexible Pavements which include Bound Materials	Accepted
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	J.5	Attachment – Example of the Use of Evaluation Procedures for Specialised Vehicles	Accepted
K	Effect of Asphalt Thickness on Fatigue Life of Asphalt-Surfaced Pavements		Accepted

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L	Examples of Use of the Mechanistic-Empirical Procedure for Flexible Pavements		Accepted, with amendments
	L.1	Sprayed Seal Surfaced Unbound Granular Pavement	Accepted
	L.2	Full Depth Asphalt Pavement	Accepted
	L.3	Asphalt Pavement Containing Cemented Material Subbase	Accepted
	L.4	Asphalt Over Lightly Bound Base Pavement (ALBB)	New
	L.5	Full Depth Asphalt Pavement with Lightly Bound Improved Layer and EME2 Base	New
M	Examples of Use of the Empirical Design Charts for Granular Pavements with Thin Bituminous Surfacings		Accepted
	M.1	Example 1: Utilising Unbound Granular Materials	Accepted
	M.2	Example 2: Utilising Crushed Rocks and Selected Subgrade Materials	Accepted
	M.3	Example 3: Utilising Crushed Rocks and Lime-stabilised Subgrade Materials	Accepted
N	Examples of Use of the Design Procedure for Rigid Pavements		Accepted
O	Traffic Load Distributions for Lightly-Trafficked Roads		Accepted

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1 Introduction

1.1 Scope of the Guide and this Part

Addition

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 Transport and Main Roads 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 Transport and Main Roads projects. Other components of the suite include the Austroads *Guide to Pavement Technology* (Parts 1 to 10) and the following Transport and Main Roads documents:

- Specifications and Technical Specifications
- *Pavement Rehabilitation Manual*
- *Geotechnical Design Standard*
- *Road Planning and Design Manual*
- *Materials Testing Manual*
- *Road Drainage Manual*
- *Transport Noise Management Code of Practice*
- *Skid Resistance Management Plan* (contact RoadAssetData@tmr.qld.gov.au to access)
- Standard Drawings
- *Transport Infrastructure Asset Management Policy*
- Engineering Policies, Technical Notes and Guidelines
- *Western Queensland Best Practice Guidelines*
- Supplementary Specifications and Test Methods
- *Risk Management Framework*
- *Risk Management Organisational Policy (contact* Risk_Advsory_Services_Team_Mailbox@tmr.qld.gov.au *to access)*
- Queensland Transport Strategy.

This supplement and AGPT02 do not specifically address the selection of pavement surfacings. In some cases, surfacings types have been included to illustrate common 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, 2009a), and
- Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments*.

1.2 Project Scope and Background Data Requirements for Design

1.2.1 Investigation and Design Proposal

<u>*Addition*</u>

For Transport and Main Roads 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 of AGPT02, and
- method of reporting alternatives and exceptions (such as departures from the 'typical' assumptions, methodology and standards in AGPT02 and this supplement) for Transport and Main Roads approval / acceptance, including:
    i. reasons for the departure
    ii. technical justification with supporting evidence
    iii. requirements for implementation (for example, modifications and/or additions to technical specifications)
    iv. estimated cost savings or additional costs, and
    v. 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 prompt clarification from Transport and Main Roads regarding any aspects of the design requirements that are unclear or missing from the design brief.

2 Pavement Design Systems

2.2 Common Pavement Types

2.2.1 General

<u>*Addition*</u>

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 specifications
- availability and adequacy of materials and costs of transporting materials
- adoption of standards higher than the minimums in the technical specifications (for example, when the standard of available materials is well in excess of the technical specifications) may reduce the performance risk for some pavement types
- availability and adequacy of construction equipment and expertise

- construction constraints (for example, construction under traffic may preclude the adoption of pavement materials that require long curing periods prior to trafficking)
- changes to the road network and/or function / classification of the road during the design period
- land development
- specific functional requirements (for example, 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 heavily bound (cemented) or rigid layers
- whole-of-life costs which may include both direct and indirect costs such as structural interventions, maintenance, rehabilitation, modifying drainage structures, increasing clearances, modifying 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 Transport and Main Roads projects based on traffic loading is provided in Table 2.2.1. This guide is intended to be used in conjunction with local practice and experience, and with the consideration of project-specific factors.

Table 2.2.1 – Guide to the selection of pavement types based on traffic

Pavement Type	**Rural**					**Urban**				
	Average Daily Equivalent Standard Axles (ESA) in Design Lane in Year of Opening									
	< 100	**100 to < 500**	**500 to < 1000**	**1000 to < 3000**	**≥ 3000**	**< 100**	**100 to < 500**	**500 to < 1000**	**1000 to < 3000**	**≥ 3000**
SG	✓✓	✓✓	✓✓	✓	××	✓#	✓#	✓#	××	××
SG(HD)	×	×	✓	✓	××	×	×	✓#	××	××
SLBB	✓✓	✓✓	✓✓	✓	××	✓#	✓#	✓#	××	××
SFB	✓✓	✓✓	✓✓	✓	××	✓#	✓#	✓#	××	××
AG(B)	×	✓*	××	××	××	✓*	✓*	××	××	××
ALBB	×	✓✓	✓✓	✓	××	✓✓	✓✓	✓✓	✓	××
AFB(B)	×	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓
AG(A)	×	✓	✓	✓	××	×	✓✓	✓✓	✓	××
ASt(A)	×	✓	✓	✓	××	×	✓✓	✓✓	✓	××
ASt(B)	×	✓	✓	✓	××	×	✓	✓	✓	××
FC	×	×	×	✓	✓	×	×	×	✓	✓

Pavement Type	Rural					Urban				
	Average Daily Equivalent Standard Axles (ESA) in Design Lane in Year of Opening									
	< 100	100 to < 500	500 to < 1000	1000 to < 3000	≥ 3000	< 100	100 to < 500	500 to < 1000	1000 to < 3000	≥ 3000
DSA	×	×	×	✓✓	✓✓	×	×	×	✓✓	✓✓
AFB(A)	×	×	×	✓✓	✓✓	×	×	×	✓✓	✓✓
FDA	×	×	×	✓✓	✓✓	×	×	×	✓✓	✓✓
Rigid	×	×	×	✓✓	✓✓	×	×	×	✓✓	✓✓

	Notes and Abbreviations
✓✓	Typically suitable
✓*	Typically suitable when selected according to Table 6.5.10
✓#	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
SG	Unbound granular pavement with sprayed seal surfacing (Table 2.2.2)
SG(HD)	Heavy duty unbound granular pavement with sprayed seal surfacing (Table 2.2.2)
SLBB	Lightly bound granular base with sprayed seal surfacing (Table 2.2.10(a))
SFB	Foamed bitumen stabilised pavement with sprayed seal surfacing (Table 2.2.9(c))
AG(B)	Unbound granular pavement with thin asphalt surfacing (Table 2.2.4)
ALBB	Lightly bound granular base with asphalt surfacing (Table 2.2.10(b))
AFB(B)	Asphalt over foamed bitumen stabilised base pavement (Table 2.2.9(b))
AG(A)	Asphalt over granular pavement (Table 2.2.5)
ASt(a)	Asphalt over heavily bound (cemented) pavement (Table 2.2.8(a))
ASt(B)	Heavily bound (cemented) base with thin asphalt surfacing (Table 2.2.8(b))
FC	Flexible composite pavement (Table 2.2.6(a))
DSA	Deep strength asphalt pavement (Table 2.2.6(b))
AFB(A)	Asphalt over foamed bitumen stabilised subbase pavement (Table 2.2.9(a))
FDA	Full depth asphalt pavement (Table 2.2.6(c))
Rigid	Concrete pavement (Table 2.2.7)

2.2.2 Granular Pavements with Sprayed Seal Surfacings

Addition

The typical structure of a granular pavement with a sprayed seal surfacing (SG and SG(HD)) is as shown in Table 2.2.2.

Table 2.2.2 – 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 6.2.1. Thicknesses are typically determined from Figure 8.4 of AGPT02 or Figure 12.2 of AGPT02. Further guidance on SG(HD) pavements is provided in Transport and Main Roads Technical Note TN171 *Use of High Standard Granular (HSG) Bases in Heavy Duty Unbound Granular Pavements*.

Notes:

1. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.

2.2.3 Cemented Granular Bases with Sprayed Seal Surfacings

Addition

Pavements comprised of a heavily bound (cemented) granular base with sprayed seal surfacing are, at times, adopted by Transport and Main Roads for floodways in remote areas where more resilient concrete pavements are determined to be uneconomical on a whole-of-life basis. The typical structure of such a pavement is as shown in Table 2.2.3. 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.

Table 2.2.3 – Typical structure of heavily bound (cemented) base with sprayed seal

Course	Description (typical)
Surfacing[1,2]	Prime plus sprayed seal
Base	Minimum 150 mm Cat 1 or Cat 2 heavily bound (cemented) material (thickness determined by mechanistic-empirical design)
Subbase	If required, minimum 150 mm Type 2.3 unbound granular material or lightly bound improved layer (refer to Section 3.14.2 for further details).

Notes:

1. Where improved resistance to reflective cracking is required, a strain alleviating membrane (SAM-S or SAM-R) or a geotextile seal (GRS-S/S or GRS-D/D) should be considered. In locations susceptible to flooding, additional measures to reduce the risk of geotextile separation from the pavement should be implemented as detailed in the Transport and Main Roads *Pavement Rehabilitation Manual*.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.

2.2.4 Granular Pavements with Thin Asphalt Surfacings

Addition

The typical structure of a granular pavement with thin asphalt surfacing (AG(B)) is as shown in Table 2.2.4.

Table 2.2.4 – Typical structure of granular pavement with thin asphalt surfacing (AG(B))

Course	Description (typical)	
Surfacing[1]	AC10M, AC10H, AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate	N/A	AC10M, AC10H, AC14M or AC14H
Prime and seal	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Base and subbase	Unbound granular material selected using tables 6.2.1 and 6.5.10. Thicknesses are typically determined from Figure 8.4 of AGPT02 or Figure 12.2 of AGPT02.	

Notes:

1. Refer to tables 6.5.10 and 6.5.12 for guidance on the selection of asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.

2.2.5 Asphalt over Granular Pavements

Addition

The typical structure of an asphalt over granular pavement (AG(A)) is as shown in Table 2.2.5.

Table 2.2.5 – Typical structure of asphalt over granular pavement (AG(A))

Course	Description (typical)	
Surfacing[1]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[1]	N/A	AC14M or AC14H
Base[1]	AC14M, AC14H, AC20M, AC20H or EME2 with thickness determined by mechanistic-empirical design	
Prime and seal[4]	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Subbase (improved layer)	Minimum 150 mm Type 2.3 unbound granular material or lightly bound improved layer. Where the traffic in the design lane at opening is 1000 ESA/day or more, minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
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

Addition

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 2.2.6(a), 2.2.6(b) and 2.2.6(c).

Transport and Main Roads has limited experience with the use of flexible composite pavements.

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

Table 2.2.6(a) – Typical structure of flexible composite pavement (FC) for heavy-duty applications

Course	Description (typical)	
Surfacing[1]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[1]	AC14M or AC14H	
Base[1]	AC20M or AC20H with thickness determined by mechanistic-empirical design and to provide at least 175 mm of asphalt (excluding open graded asphalt) in the total pavement structure	
Curing compound and seal	Bitumen emulsion plus a SAMI seal[3,4]	
Subbase	150 to 230 mm lean-mix concrete	
Prime and seal[5]	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Improved layer	Minimum 150 mm lightly bound improved layer. Where the traffic in the design lane at opening is 1000 ESA/day or more, minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
4. The SAMI seal can be substituted with a 7 mm C170 S/S seal where an increased risk of future reflective cracking is accepted by the Transport and Main Roads project representative.
5. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

Table 2.2.6(b) – Typical structure of deep strength asphalt pavement (DSA) for heavy-duty applications

Course	Description (typical)	
Surfacing[1]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[1]	AC14M or AC14H	
Base[1]	AC20M or AC20H with thickness determined by mechanistic-empirical design and to provide at least 175 mm of asphalt (excluding open graded asphalt) in the total pavement structure	
Prime and seal	Prime plus a SAMI seal[3]	
Subbase	150 to 200 mm Cat 1 or Cat 2 heavily bound (cemented) material	
Prime and seal[4]	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Improved layer	Minimum 150 mm lightly bound improved layer. Where the traffic in the design lane at opening is 1000 ESA/day or more, minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
4. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

Table 2.2.6(c) – Typical structure of full depth asphalt pavement (FDA) for heavy-duty applications

Course	Description (typical)	
Surfacing[1]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[1]	AC14M or AC14H	
Base[1]	AC20M, AC20H or EME2 with thickness determined by mechanistic-empirical design	
Prime and seal[4]	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Improved layer	Minimum 150 mm lightly bound improved layer. Where the traffic in the design lane at opening is 1000 ESA/day or more, minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
4. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

2.2.7 Concrete Pavements

Addition

The typical structure of concrete pavement used in heavy-duty applications is as shown in Table 2.2.7.

Guidance on the design of bridge deck wearing surface (DWS), based on deck type, is provided in the Transport and Main Roads *Design Criteria for Bridges and Other Structures* (Part B). The guidance includes:

a) minimum DWS thickness to accommodate the corrector course (where required), waterproofing membrane and surfacing

b) waterproofing membrane requirements, including its position within the DWS, and

c) corrector course requirements.

MRTS77 *Bridge Deck* and MRTS84 *Deck Wearing Surface* specify requirements for texturing the concrete deck, including the minimum texture depth to be achieved on the concrete surface. Requirements for preparing and priming the concrete deck prior to placement of the corrector course (where required) or waterproofing membrane are also provided.

Table 2.2.7 – Typical structure of concrete pavement for heavy-duty applications

Course	Description (typical)
Base[1,2]	• 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-mix concrete
Prime and seal[3]	Prime plus 10 or 14 mm nominal size C170 S/S seal
Improved layer	Minimum 150 mm lightly bound improved layer. Where the traffic in the design lane at opening is 1000 ESA/day or more, minimum support conditions also apply. Refer to sections 3.14.2 and 9.3.1 for further details.

Notes:

1. The base course typically also functions as the pavement surfacing if it meets surface property requirements; however, in some cases, an additional asphalt surfacing is provided over CRCP (refer to Section 9.2.3).
2. Diamond grinding may be required to meet surface property requirements.
3. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

2.2.8 Asphalt over Heavily Bound (Cemented) Pavements

New

There are two general design approaches typically adopted for asphalt over heavily bound (cemented) pavements. These are:

a) Asphalt base over heavily bound (cemented) subbase (ASt(A)) – this pavement type comprises an asphalt surfacing, asphalt intermediate course (where relevant) and asphalt base, as shown in Table 2.2.8(a). A minimum of 175 mm of asphalt (excluding open graded asphalt) and a SAMI are typically provided to inhibit cracks in the subbase reflecting through the asphalt; however, even with these provisions, cracking of the heavily bound (cemented) material and subsequent reflection into overlying asphalt layers should be anticipated.

b) Asphalt surfacing over heavily bound (cemented) base (ASt(B)) – this pavement type comprises an asphalt surfacing and asphalt intermediate course (where relevant) over a heavily bound (cemented) base, as shown in Table 2.2.8(b). The total asphalt thickness (excluding open graded asphalt) 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 heavily bound (cemented) granular base with sprayed seal surfacing pavement type detailed in Section 2.2.3. This pavement type is typically only adopted for temporary pavements or where the need for future maintenance interventions has been carefully considered and accepted.

Table 2.2.8(a) – Typical structure of asphalt over heavily bound (cemented) pavement (ASt(A))

Course	Description (typical)	
Surfacing[1]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[1]	N/A	AC14M or AC14H
Base[1]	AC14M, AC14H, AC20M or AC20H with thickness determined by mechanistic-empirical design and to provide at least 175 mm of asphalt (excluding open graded asphalt) in the total pavement structure.	
Prime and seal	Prime plus a SAMI seal[3,4]	
Subbase	150 to 200 mm Cat 1 or Cat 2 heavily bound (cemented) material	
Prime and seal[5]	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Improved layer	Minimum 150 mm Type 2.3 unbound granular material or lightly bound improved layer. Where the traffic in the design lane at opening is 1000 ESA/day or more, minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
4. As an alternative to a SAMI seal, a geotextile reinforced sprayed seal (GRS-S/S) 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 2.2.8(b) – Typical structure of asphalt surfacing over heavily bound (cemented) base pavement (ASt(B))

Course	Description (typical)	
Surfacing[1,2,3]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Intermediate[1,3]	AC14M or AC14H (if required)	AC14M or AC14H
Prime and seal	Prime plus a SAMI seal[4,5]	
Base	Heavily bound (cemented) material. The thickness of the base is determined by mechanistic-empirical design (using the pre-cracking phase only).	
Prime and seal[6]	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Improved layer	150 to 300 mm unbound granular material or lightly bound improved layer, or an appropriate selected fill material (refer to Section 3.14.2 for further details).	

Notes:

1. Refer to Table 6.5.12 for guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Section 3.7 for guidance on the use of waterproofing seals.
3. The total thickness of asphalt (excluding open graded asphalt) 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. For temporary pavements, the total thickness of asphalt (excluding open graded asphalt) is typically 100 mm for design traffic greater than or equal to 3000 ESA/day in the design lane in the year of opening, and 50 mm for traffic less than 3000 ESA/day in the design lane in the year of opening.
4. As an alternative to a SAMI seal, a geotextile reinforced sprayed seal (GRS-S/S) may be provided to further inhibit crack reflection.
5. At locations subject to significant horizontal loads (as detailed in Section 8.2.7 of AGPT02), it may be necessary to adopt an alternative treatment to enhance bonding and/or increase the overlying asphalt thickness to reduce the risk of shearing at the SAMI/GRS layer interface.
6. Refer to Section 3.14.2 for further guidance on priming and sealing the improved layer.

2.2.9 Foamed Bitumen Stabilised Pavements

New

Foamed bitumen stabilised pavements include the following general types:

a) Asphalt over foamed bitumen stabilised subbase (AFB(A)). This pavement type comprises asphalt surfacing, intermediate and base courses over foamed bitumen stabilised granular material in the subbase (upper and lower), as shown in Table 2.2.9(a).

b) Asphalt over foamed bitumen stabilised base (AFB(B)). This pavement type comprises asphalt surfacing and an asphalt intermediate course (where required) over foamed bitumen stabilised granular material in the base and subbase, as shown in Table 2.2.9(b).

c) Foamed bitumen stabilised pavement with sprayed seal surfacing (SFB). This pavement type comprises sprayed seal surfacing over foamed bitumen stabilised granular material in the base and subbase, as shown in Table 2.2.9(c).

Table 2.2.9(a) – Typical structure of asphalt over foamed bitumen stabilised subbase (AFB(A))

Course	Description (typical)	
Surfacing[1]	AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[1]	AC14M or AC14H	
Base[1]	AC20M, AC20H or EME2	
Seal[2]	7 or 10 mm nominal size with C170, or bituminous emulsion	
Subbase[4]	Minimum 250 mm foamed bitumen stabilised granular material with thickness determined by mechanistic-empirical design	
Improved layer[5,6]	Minimum 100 mm unbound granular or fill material. Minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details. Cementitious materials must not be used.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
4. A 7 or 10 mm nominal size seal (with C170, or bituminous emulsion) between successive plant-mixed foamed bitumen stabilised granular layers may be required. Refer to Section 3.14.2 for guidance on sealing between foamed bitumen stabilised granular layers.
5. The improved layer is typically omitted where the subgrade design CBR ≥ 7%.
6. Where the expansive nature of the subgrade is very high (as defined in Table 5.3.5), a subgrade geo-composite layer (MRTS58 *Subgrade Reinforcement using Pavement Geosynthetics*) is typically provided at subgrade level (in addition to any other treatments determined from Figure 5.3.5 and/or recommended in the geotechnical assessment detailed in Section 5.3.5).

Table 2.2.9(b) – Typical structure of asphalt over foamed bitumen stabilised base pavement (AFB(B))

Course	Description (typical)	
Surfacing[1]	AC10M, AC10H, AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A[3]	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate[4]	AC10M, AC10H, AC14M or AC14H (if required)	AC10M, AC10H, AC14M or AC14H
Seal[2]	7 or 10 mm nominal size with C170, or bituminous emulsion	
Base[5]	Minimum 250 mm foamed bitumen stabilised granular material with thickness determined by mechanistic-empirical design	
Improved layer[6,7]	Minimum 100 mm unbound granular or fill material. Minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details. Cementitious materials must not be used.	

Notes:

1. Refer to Table 6.5.12 for further guidance on the selection of dense graded asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. The waterproofing seal under dense graded asphalt and stone mastic asphalt is typically omitted where the asphalt contractor has demonstrated a history of conformance with the in situ air voids requirements. Refer to Section 3.7 for details.
4. Where the surfacing is dense graded or stone mastic asphalt, the intermediate course is typically omitted where the average daily traffic in the design lane in the year of opening is less than 1000 ESA.
5. A 7 or 10 mm nominal size seal (with C170, or bituminous emulsion) between successive plant-mixed foamed bitumen stabilised granular layers may be required. Refer to Section 3.14.2 for guidance on sealing between foamed bitumen stabilised granular layers.
6. The improved layer is typically omitted where the subgrade design CBR ≥ 7%.
7. Where the expansive nature of the subgrade is very high (as defined in Table 5.3.5), a subgrade geo-composite layer (MRTS58 *Subgrade Reinforcement using Pavement Geosynthetics*) is typically provided at subgrade level (in addition to any other treatments determined from Figure 5.3.5 and/or recommended in the geotechnical assessment detailed in Section 5.3.5).

Table 2.2.9(c) – Typical structure of foamed bitumen stabilised pavement with sprayed seal surfacing (SFB)

Course	Description (typical)
Surfacing[1]	Sprayed seal
Seal[1]	7 or 10 mm nominal size with C170, or bituminous emulsion
Base[2]	Minimum 250 mm foamed bitumen stabilised granular material with thickness determined by mechanistic-empirical design
Improved layer[3,4]	Minimum 100 mm unbound granular or fill material. Minimum support conditions also apply. Refer to sections 3.14.2 and 8.2.8 for further details. Cementitious materials must not be used.

Notes:

1. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
2. A 7 or 10 mm nominal size seal (with C170, or bituminous emulsion) between successive plant-mixed foamed bitumen stabilised granular layers may be required. Refer to Section 3.14.2 for guidance on sealing between foamed bitumen stabilised granular layers.
3. The improved layer is typically omitted where the subgrade design CBR ≥ 7%.
4. Where the expansive nature of the subgrade is very high (as defined in Table 5.3.5), a subgrade geo-composite layer (MRTS58 *Subgrade Reinforcement using Pavement Geosynthetics*) is typically provided at subgrade level (in addition to any other treatments determined from Figure 5.3.5 and/or recommended in the geotechnical assessment detailed in Section 5.3.5).

2.2.10 Lightly Bound Base Pavements

New

Lightly bound base pavements include the following general types:

a) Lightly bound base pavement with sprayed seal surfacing (SLBB). This pavement type comprises a sprayed seal surfacing over lightly bound material in the base, and lightly bound or unbound granular material in the subbase, as shown in Table 2.2.10(a).

b) Asphalt over lightly bound base pavement (ALBB). This pavement type comprises asphalt surfacing and an asphalt intermediate course (where required) over lightly bound material in the base, and lightly bound or unbound granular material in the subbase, as shown in Table 2.2.10(b).

Table 2.2.10(a) – Typical structure of lightly bound base pavement with sprayed seal surfacing (SLBB)

Course	Description (typical)
Surfacing[1]	Prime plus sprayed seal
Base[2]	Lightly bound base (refer to Section 8.2.9 for minimum thickness)
Subbase[2]	Minimum 150 mm unbound granular material or lightly bound subbase. Minimum support conditions apply as detailed in Section 8.2.8. Unbound granular material selected using Table 6.2.1.

Notes:

1. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
2. Thicknesses of the base and subbase are determined using mechanistic-empirical design.

Table 2.2.10(b) – Typical structure of asphalt over lightly bound base pavement (ALBB)

Course	Description (typical)	
Surfacing[1]	AC10M, AC10H, AC14M, AC14H, SMA10 or SMA14	OG10 or OG14
Seal[2]	N/A	10 or 14 mm waterproofing seal under asphalt (WP-A)
Intermediate	N/A	AC10M, AC10H, AC14M or AC14H
Prime and seal	Prime plus 10 or 14 mm nominal size C170 S/S seal	
Base[3]	Lightly bound base (refer to Section 8.2.9 for minimum thickness)	
Subbase[3]	Minimum 150 mm unbound granular material or lightly bound subbase. Minimum support conditions apply as detailed in Section 8.2.8. Unbound granular material selected using Table 6.2.1.	

Notes:

1. Refer to tables 6.5.10 and 6.5.12 for guidance on the selection of asphalt mix type and binder class.
2. Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.
3. Thicknesses of the base and subbase are determined using mechanistic-empirical design.

2.3 Overview of Pavement Design systems

2.3.1 Input Variables

Addition

Project reliability

The project reliability levels typically adopted by Transport and Main Roads are listed in Table 2.3.1.

Table 2.3.1 – Typical project reliability levels

Road Category	Typical Project Reliability Levels (%)
Freeways (Motorways) (includes connections between motorways)	95
All other roads (includes motorway ramps, highways and main roads)	90

2.4 Shoulders with a Lower Structural Standard

New

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 lower risk of 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).

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

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 / layers 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 included at the interface of the shoulder pavement and the 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 included 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.

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 excavating into the in situ subgrade materials should be considered in determining the thickness of the shoulder (for example, consider the risks of exposing low strength materials).

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 for trafficked lanes
- 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 (for example, curves, end of tapers, narrow through lanes, access points, intersections and/or no edge lines).

3 Construction and Maintenance Considerations

3.1 General

<u>*Addition*</u>

It is assumed that Transport and Main Roads standards for construction and maintenance will be adopted.

3.2 Extent and Type of Drainage

<u>*Addition*</u>

In addition to the drainage provisions discussed in Part 10: *Subsurface Drainage* of the Austroads *Guide to Pavement Technology* (Austroads, 2009b), 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:
    a. seal the shoulder and verge, and maintain the seal in a sound condition, and/or
    b. provide appropriate subsoil drainage to intercept water seepage before it reaches the pavement or subgrade.
3. In cuttings:
    a. provide table drains where an unbound granular pavement is used
    b. provide table drains or subsurface pavement drains where a bound or rigid pavement is used, and
    c. where rock floors are present, use a heavily bound (cemented) 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.
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:
    a. located away from the formation (typically minimum 5 m) in flat or lightly undulating country or excluded altogether
    b. directed away from the formation
    c. appropriately shaped (refer to the Transport and Main Roads *Road Drainage Manual*), and
    d. 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 top of subgrade (or bottom of a drainage blanket, where present).
8. Compact pavement materials right up to the edge of the pavement to the specified compaction standard, and remove any excess, poorly compacted paving material beyond the seal edges.
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 (for example, 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.
11. Pavement drains (MRTS38 *Pavement Drains*) at interfaces between pavements comprising different structures and/or materials.

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

<u>*Addition*</u>

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, 1987a) 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

Addition

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 (MRTS27 Geotextiles (Separation and Filtration)) and covered by a 150 mm thick heavily bound (cemented) material or lightly bound improved layer 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.

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 affect future pavement performance including:

- potential for moisture ingress (for example, from inundation) and ability for moisture to drain freely from the material
- maintenance activities that may affect 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, and
- suction potential of the overlying materials.

3.6 Use of Stabilisation

Addition

Guidance on the design of pavements with lime stabilised subgrades is provided in Transport and Main Roads Guideline *Structural Design Procedure for Lime Stabilised Subgrade*.

Use of multi-layer construction for heavily bound (cemented) material courses is not typically adopted when the design traffic is 1000 ESA/day or more at opening due to the performance risk associated with these layers not remaining fully bonded throughout the pavement's life (even when bonding treatments are used).

Accelerated loading tests at Beerburrum (NAASRA, 1987a) clearly illustrated the consequences of inadequate bonding between layers. Measures to improve the bond between layers are detailed in the relevant technical specifications. The report *Cement Slurry Applications to CTB Layer Bonding* (Main Roads, 1988) describes the use of these measures in more detail.

Where multi-layer construction is adopted, only the bottom layer may be 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

<u>*Addition*</u>

To achieve adequate bonding of asphalt to the underlying layer, preparatory treatment including, but not limited to, texturing the underlying surface and/or use of a proprietary bond coat may be required at locations:

a) subject to high shear stresses (for example, from heavy braking and/or tight cornering), such as intersections, roundabouts and approaches, and/or

b) where the surface of a lower asphalt layer is trafficked prior to construction of the overlying layer.

In pavements with multiple asphalt layers, and where the surfacing is open graded asphalt, a waterproofing seal (WP-A) between the asphalt surfacing and the intermediate layer is typically provided.

In pavements with multiple asphalt layers, and where the surfacing is dense graded asphalt or stone mastic asphalt, a 10 or 14 mm waterproofing seal (WP-A) between the asphalt surfacing and the underlying asphalt should be provided as a provisional (if ordered) item. The waterproofing seal should be incorporated into the works until such time that the asphalt contractor has demonstrated a history of compliance with the in situ air voids requirements in MRTS30 *Asphalt Pavements* for the specific asphalt mixes used, after which time, the layer may be omitted from the works, pending ongoing conformance with the air voids requirements of MRTS30 *Asphalt Pavements*.

On contracts where a schedule of rates is not adopted, the same principle should apply, with the waterproofing seal being incorporated into the works until such time that the contractor has demonstrated a history or compliance with the air voids requirements of MRTS30 *Asphalt Pavements*.

The guidance in the preceding paragraphs should be included in Annexure MRTS30.1 *Asphalt Pavements* and also be noted on the design drawings.

Asphalt pavements should be designed to minimise the potential for AC20M and AC20H layers to be exposed to wet weather for prolonged periods during construction. Where the construction program dictates that exposure of such layers to wet weather cannot be avoided, an AC14M or AC14H mix should be used for the exposed layer to minimise the potential for moisture ingress and subsequent stripping of the asphalt.

3.8 Use of Strain Alleviating Membrane Interlayers

<u>*Addition*</u>

SAMI seals are typically applied to the surface of heavily bound (cemented) layers to inhibit crack reflection into overlying pavement layers.

3.9 Environmental and Safety constraints

<u>*Addition*</u>

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 (2003) 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
- development of 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 (for example, sealing the pavement as soon as possible)
- 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-mix concrete subbase is typically covered within one month to assist in limiting the width of shrinkage cracks.

3.11 Construction under Traffic

Addition

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 heavily bound (cemented) layers.

3.14 Improved Subgrades

3.14.1 Soft Subgrades

Addition

This section applies to soft subgrade treatments used to provide a stable construction platform (when the in situ CBR of the subgrade at the time of construction is less than 3%). This is distinguished from when the design subgrade CBR is less than 2% (at the design moisture and density conditions), which is addressed in Section 5.9.

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.

Provision of a soft subgrade treatment alone is generally not sufficient to ensure the required compaction standard can be achieved in overlying bound layers. An improved layer is also typically provided, as detailed in Section 3.14.2.

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 unbound granular material (for example, Type 2.5 material in dry conditions, or Type 2.4 material in wet conditions) or rock fill which has good inter-particle friction. The minimum thickness of granular fill material typically required is as shown in Table 3.14.1.

Rock fill is typically covered by a 150 mm heavily bound (cemented) material or lightly bound improved layer to provide a stable platform for construction of the pavement. Where rock fill is used to treat soft subgrades, the issues listed in Section 3.2.3 which may affect future pavement performance should also be considered.

Table 3.14.1 – Typical minimum cover to provide a stable construction platform

In situ Subgrade CBR at Time of Construction (%)	Typical Minimum Cover of Granular Fill 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.

The characterisation of the coarse granular materials and rock fill used in soft subgrade treatments for pavement design purposes is typically consistent with the guidance provided in Section 5.9

3.14.2 Improved Layers under Bound Layers

<u>*Addition*</u>

An improved layer is typically included in pavements with asphalt, heavily bound (cemented), and/or concrete layers. An improved layer is also typically included under foamed bitumen stabilised material where the subgrade design CBR is less than 7%. The improved layer is in addition to the soft subgrade treatments detailed in sections 3.14.1 and 5.9.

The improved layer:

- provides access for construction traffic and minimises the potential for rainfall to cause subgrade instability and excessive construction delays
- provides a sound platform on which to construct the overlying pavement layers (to achieve compaction), and
- protects the subgrade and supports the other pavement layers for the life of the pavement structure.

Asphalt, heavily bound (cemented) and concrete pavements

For asphalt, heavily bound (cemented) and concrete pavements with design traffic of 1000 ESA/day or more at opening, the improved layer typically consists of a 150 mm (minimum) thick layer of lightly bound material with an unconfined compressive strength of 1.0 to 2.0 MPa at seven days (MRTS10 *Plant-Mixed Lightly Bound Pavements*).

For these pavements, a minimum support condition also applies, which is detailed in Section 8.2.8 for asphalt and heavily bound (cemented) pavements, and Section 9.3.1 for concrete pavements.

In lower-trafficked pavements, a Type 2.3 unbound granular material improved layer is typically adopted.

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 1×10^3 ESA, and/or
- required by the contractor for the particular site and construction procedures used (for example, if the improved layer is to be loaded excessively with heavy construction equipment).

For unbound and lightly bound improved layers, it is typical practice to prime and seal (10 mm, C170) the improved layer in the following situations:

- where rainfall during construction of the improved layer and/or pavement is likely
- where part of the curing strategy for a lightly bound improved layer
- where the improved layer is exposed to the environment (that is, not covered within a few days of construction) and/or trafficked for an extended period of time
- where the overlying layer is concrete or lean-mix concrete, 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 effect of its inclusion in the design on the construction program
- the need for an alternative curing method for the improved layer prior to covering
- damage to the improved layer by construction traffic and the environment
- infiltration of moisture into the subgrade, and
- the program risk and costs associated with construction delays and rework.

Where sealing of the improved layer is omitted, a prime is typically still included except where the pavement is constructed in a single shift to meet traffic management constraints.

An initial seal (formerly known as a primerseal) may also suffice in some circumstances, where this has been determined to provide a suitable surface for trafficking and waterproofing for construction operations; however, the effect of cutter in the initial seal on subsequent pavement layers needs to be considered.

Refer to Transport and Main Roads Technical Note TN175 *Selection and Design of Sprayed Bituminous Treatments* for further guidance.

The improved layer is included in the mechanistic-empirical pavement design. Further details on design inputs are included in tables 6.2.3(b) and 6.8 for unbound and lightly bound improved layer materials.

Foamed bitumen stabilised pavements

For pavements comprising foamed bitumen stabilised granular material, an improved layer of unbound granular material (minimum 100 mm) or earth fill material (minimum thickness as specified in MRTS04 *General Earthworks*) is typically provided where the design subgrade CBR is less than 7%.

For these pavements, a minimum support condition also applies, which is detailed in Section 8.2.8.

The improved layer, in this case, provides a platform on which to construct the foamed bitumen stabilised granular layers, and assists in protecting the subgrade; however, at the typical design configurations shown in tables 2.2.9(a) to 2.2.9(c), this treatment may provide only limited access for construction traffic and limited protection from rainfall during construction. These functions are typically achieved with the first foamed bitumen stabilised granular layer placed above the improved layer (or above the subgrade where there is no improved layer).

It is typical practice to seal (with no prime) between foamed bitumen stabilised granular layers in the following situations:

- where rainfall during construction of the foamed bitumen stabilised granular layers is likely
- where the lower foamed bitumen stabilised granular layer is exposed to the environment (that is, not covered within a few days of construction) and/or trafficked for an extended period of time, and/or
- the lower foamed bitumen stabilised granular layer is permeable and/or the layer(s) below it are sensitive to the effects of moisture ingress.

Where foamed bitumen stabilised granular layers are exposed to an extended period of construction traffic and/or public traffic, fatigue damage due to the traffic must be taken into consideration in the pavement design, as detailed in Section 3.11.

The improved layer is included in the mechanistic-empirical pavement design. Refer to Section 6.7 for guidance on design inputs for the foamed bitumen stabilised granular layers.

3.15 Surfacing Type

3.15.1 Sprayed Seals

Addition

Wherever possible, a prime and seal is typically adopted, rather than an initial seal (formerly known as a primerseal), due to the likelihood of enhanced bonding with the underlying pavement. An exception to this is over foamed bitumen stabilised material where an initial seal should be used. An initial seal may also be used in some other 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

Addition

A 10 mm or 14 mm dense graded asphalt intermediate course is typically provided under 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.

3.17 Settlement

New

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 (for example, drainage and/or surcharge of the formation) may be required to reduce the magnitude and extent of settlement after the pavement is constructed.

Settlement criteria for maximum total in-service settlement and maximum differential settlement are included in the Transport and Main Roads *Geotechnical Design Standard – Minimum Requirements*.

3.18 Pavement Jointing Considerations

New

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, longitudinal construction joints are typically located away from wheel paths; however, where a longitudinal joint is skewed (which may occur between new and existing pavements on projects involving both lane realignment and widening), it may be preferable for the longitudinal joint in the base course to diagonally cross the wheel paths over short lengths. This can maximise the reuse of the existing pavement and facilitate continuous compaction runs rather than introducing additional transverse joints.

Additionally, construction joints in flexible pavement layers are typically offset from the construction joints in underlying layers using a step-type arrangement.

3.19 Thickness of Bituminous Seals

New

For the purpose of determining design levels, the thickness of seals and initial seals (formerly known as 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.

3.20 Temporary Pavements for High Traffic

New

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

Unbound granular pavements are considered to be very high risk for temporary pavements in high traffic situations (where both the following are true at opening: design traffic greater than 1000 ESA/day and one-way traffic greater than 5000 vehicles per day) 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 heavily bound (cemented) base with asphalt surfacing. An improved layer is typically provided below the heavily bound (cemented) base where the subgrade design CBR is less than 5%, and/or where required to facilitate construction of overlying pavement layers.

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

3.21 Construction Impacts on Buildings

New

Construction close to buildings may lead to building damage if vibration is not appropriately managed. Requirements for managing vibration during construction are detailed in MRTS51 *Environmental Management*. Where required, designs can facilitate management of vibration during construction by adopting pavement configurations which are suited to construction in thinner layers (enabling less compaction energy during construction) and/or without vibration (potentially with heavier rollers and/or more roller passes); for example, smaller nominal size asphalt mixes can be placed in thinner layers than larger nominal size mixes.

4 Environment

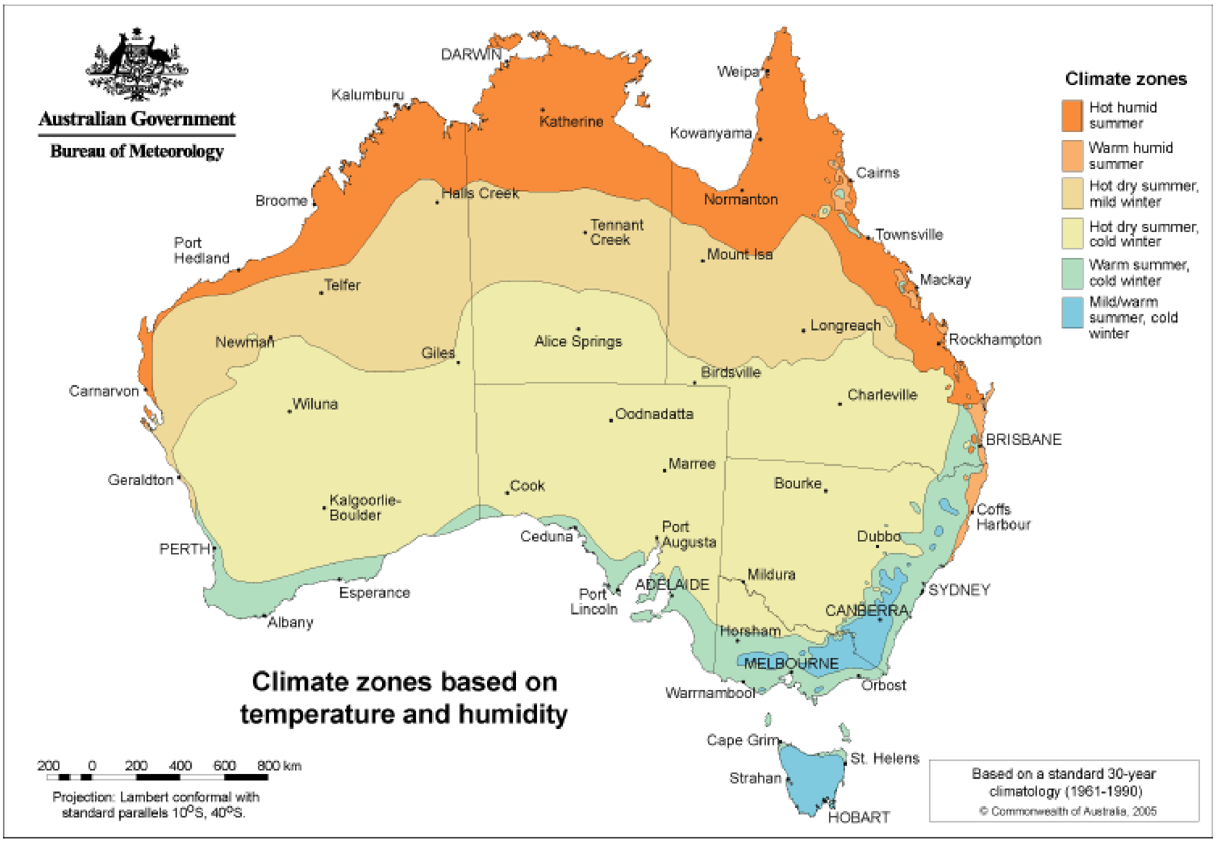
4.1 General

Addition

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 Australian Bureau of Meteorology at www.bom.gov.au.

Figure 4.1 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 4.1 – Australian climatic zones (www.bom.gov.au)



4.2 Moisture Environment

Addition

The moisture environment will affect 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 4.2(a) illustrates Australian seasonal rainfall zones, based on median annual rainfall and seasonal incidence. Figure 4.2(b) provides more detail for Queensland, illustrating median annual isohyets. Rainfall intensity may also affect moisture conditions within the pavement and subgrade.

Figure 4.2(a) – Australian seasonal rainfall zones (www.bom.gov.au)

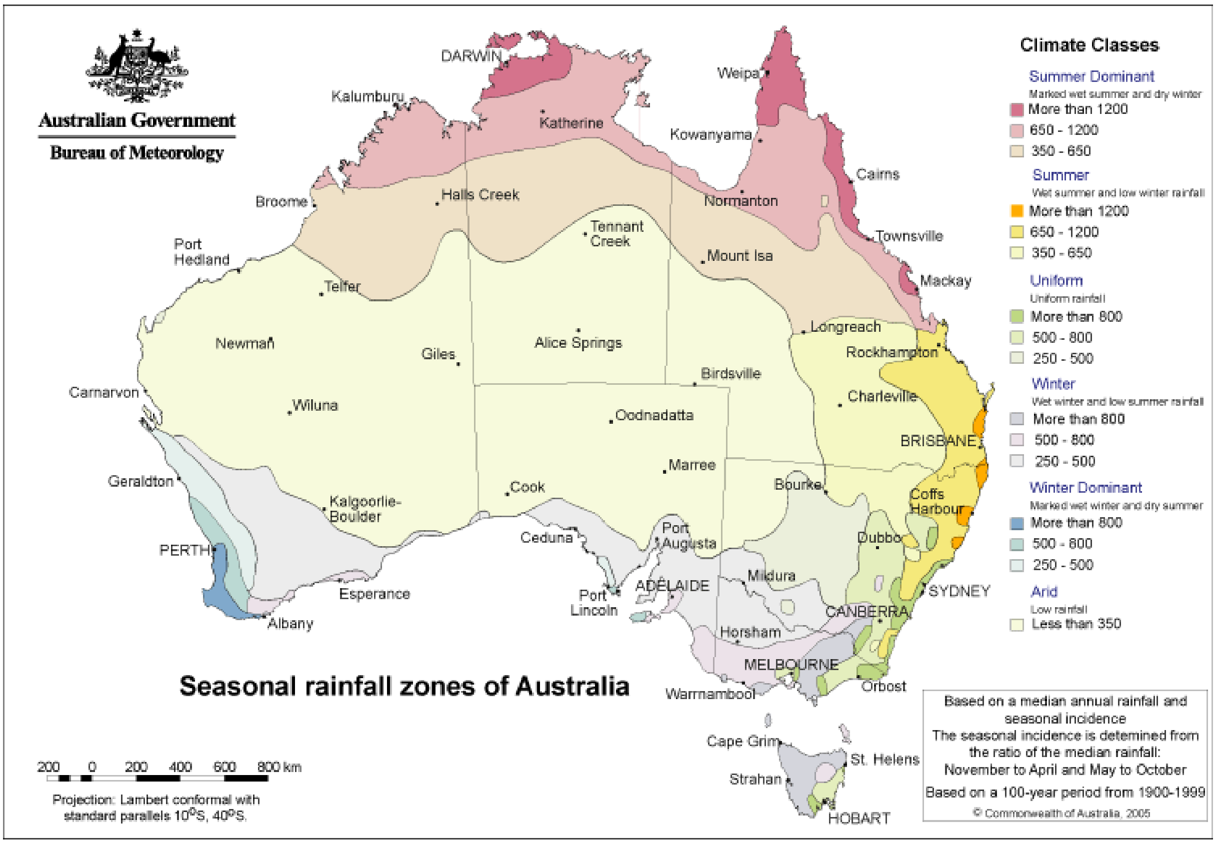
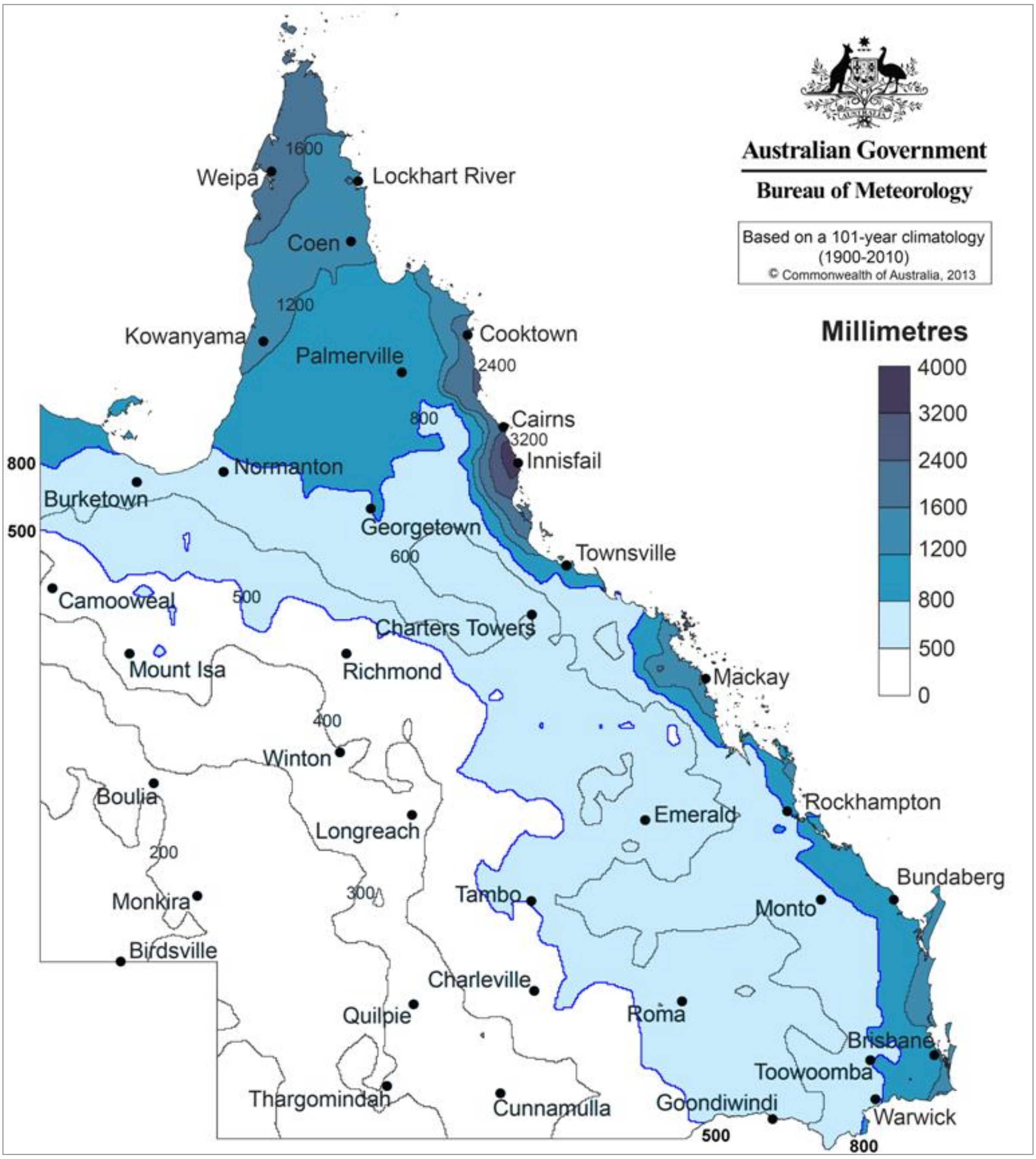


Figure 4.2(b) – Median annual isohyets for Queensland



4.3 *Temperature Environment*

<u>*Addition*</u>

Transport and Main Roads technical specifications place limits on temperatures and weather conditions for placing pavement layers. These requirements limit the detrimental effects that adverse weather conditions can have on the quality and/or performance of the constructed pavement.

5 Subgrade Evaluation

5.1 General

Addition

Subgrade materials, including existing subgrade materials and fill materials, are typically assessed to a depth of 1.5 m below subgrade level.

MRTS04 *General Earthworks* includes requirements for verification of the subgrade design inputs at the time of construction. The principles of MRTS04 *General Earthworks* are also typically followed during the design development stages of a project to determine the pavement design inputs.

All subgrade sampling and testing is to be undertaken by laboratories accredited by the National Association of Testing Authorities (NATA) for the appropriate procedures and registered under the Transport and Main Roads Construction Materials Testing (CMT) Supplier Registration System (SRS).

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

Addition

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).

The applicable test methods are defined in MRTS04 *General Earthworks*.

When stabilisation of the subgrade material is being considered, additional testing may also be required such as lime demand, sulfate content and UCS. Further guidance on the evaluation of materials for stabilisation is provided in MRTS04 *General Earthworks*, the Transport and Main Roads *Pavement Rehabilitation Manual* and the Transport and Main Roads *Materials Testing Manual* (Part 2).

5.3.5 Moisture Changes during Service Life

Addition

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:

- expansive nature of the subgrade and/or embankment material
- extent (width and depth) of expansive material
- changes in moisture content related to climatic conditions, which are often expressed in terms of the depth of design soil suction change
- effectiveness of adopted treatments
- material density and permeability, and
- changes in moisture content related to local site conditions (such as drainage provisions).

For the classification of expansive soils, Table 5.2 in AGPT02 is replaced by Table 5.3.5. Where CBR swell and Weighted Plasticity Index (WPI) on the same material indicate different classifications, the CBR swell should take precedence.

Table 5.3.5 – Guide to classification of expansive soils

Expansive Nature	Weighted Plasticity Index (WPI) (PI x % < 0.425 mm)	CBR Swell (%)[1]
Extreme	> 4200	> 10.0
Very high	> 3200–4200	> 5.0–10.0
High	> 2200–3200	> 2.5–5.0
Moderate	> 1200–2200	> 0.5–2.5
Low	≤ 1200	≤ 0.5

Notes:

1. Swell at OMC, 97% MDD (standard compactive effort), four-day soaked, and using 4.5 kg surcharge.

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
- effects 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 depth of design soil suction change is very high and/or the expansive nature of the soil is extreme (as defined in Table 5.3.5).

Providing a minimum cover of material over expansive soil is one of the most common techniques used to minimise volume change effects on the pavement (NACOE, 2018). The required thickness of cover is an output of the geotechnical assessment.

Fox (2000 and 2002) defines the relationship between the depth of design soil suction change and six climatic zones in Queensland: wet coastal, wet temperate, temperate, dry temperate, semi-arid and arid. The depth of design soil suction change is considered to be very high in dry temperate, semi-arid and arid areas. In these areas, providing a minimum cover of material over expansive soil is not typically economical as substantial thicknesses of cover are required. In these areas, other treatments are typically adopted and these are selected and designed in accordance with local practice (for example, lime stabilisation).

For pavements over embankment fill materials that are expansive in nature, cover and zoning requirements should meet the requirements of MRTS04 *General Earthworks*.

For pavements over existing in situ subgrade material (such as in cuttings, at grade, or under low / near grade embankments) with an expansive nature which is high or very high (as defined in Table 5.3.5), and where a geotechnical assessment is not undertaken, the following guidance should be used to determine the cover thickness:

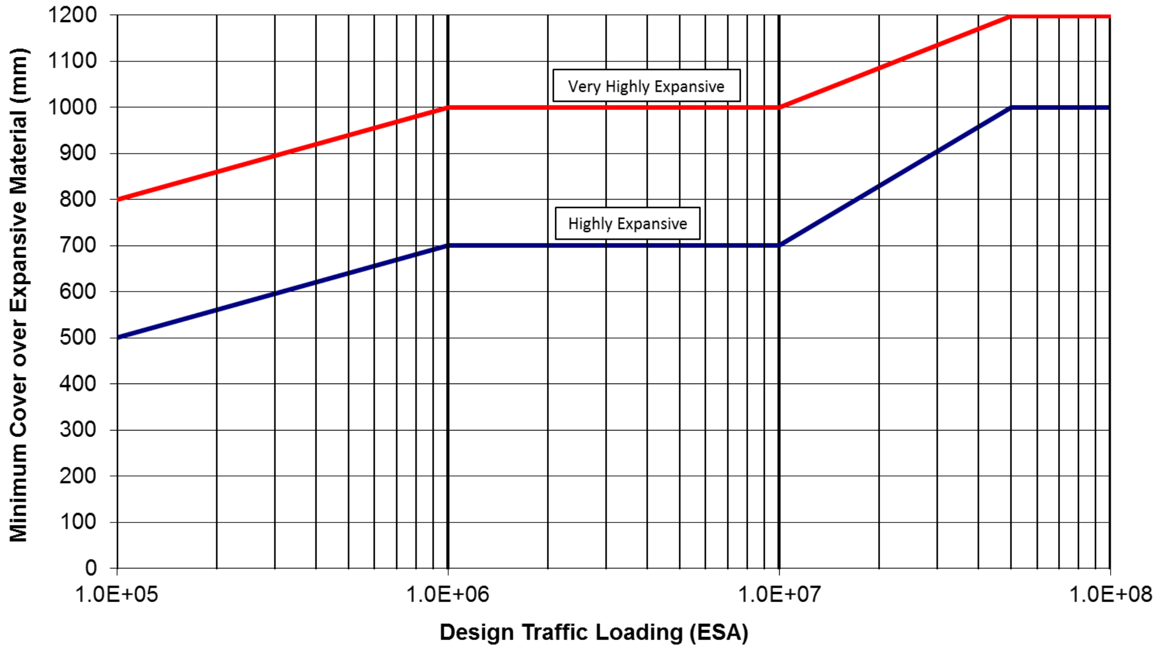
- for flexible pavements, the thickness as determined from Figure 5.3.5 (which includes the thickness of the pavement and other courses such as select fill, rock fill, treated material and improved layers). Figure 5.3.5 assumes that a minimum 150 mm layer of low-permeability subbase, improved layer or select fill is included in the overall structure, and
- for rigid pavements, a minimum cover of 600 mm over highly expansive subgrades and 800 mm over very highly expansive subgrades (to the underside of the subbase), including a minimum 150 mm of low permeability material.

These thicknesses only apply in wet coastal, wet temperate and temperate locations where the depth of design soil suction change is 2.3 metres or less (corresponding to locations with Thornthwaite Moisture Index of -15 or greater). In dry temperate, semi-arid and arid locations, where the depth of design soil suction change is greater than 2.3 metres (corresponding to Thornthwaite Moisture Index less than -15), a project-specific geotechnical assessment is recommended. Refer to AS 2870 *Residential slabs and footings* and Fox (2000 and 2002) for further guidance.

Additionally, 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 economical 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 effects and addresses these through appropriate maintenance may be necessary.

For pavements over existing in situ subgrade material with a low or moderate expansive nature (as defined in Table 5.3.5), additional cover beyond that provided by the pavement and support layers is not typically required.

Figure 5.3.5 – Typical cover thickness over highly and very highly expansive material for flexible pavements (thickness includes the pavement)



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 (that is, use zoned embankments as detailed in MRTS04 *General Earthworks*)
- 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 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 (samples are typically obtained using shallow boreholes with continuous undisturbed sampling):
   - 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)
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, and
4. Transport and Main Roads performance expectations for the pavement.

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

- unbound granular, full depth asphalt and CRCP are better able to withstand 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 AS 2870 and Van der Merwe (1964).

5.3.8 Lime-stabilised Subgrades

Difference

The mix design procedure for lime-stabilised subgrades is detailed in the Transport and Main Roads *Materials Testing Manual* (Part 2).

Guidance on the design of pavements with lime-stabilised subgrades is provided in the Transport and Main Roads Guideline *Structural Design Procedure for Lime Stabilised Subgrade*.

5.5 Field Determination of Subgrade CBR

5.5.2 Cone Penetrometers

Difference

Cone penetrometer testing is to be carried out in accordance with Test Method Q114B rather than AS 1289.6.3.2 *Methods of testing soils for engineering purposes, Method 6.3.2: Soil strength and consolidation tests – Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test*.

5.6 Laboratory Determination of Subgrade CBR and Elastic Parameters

Addition

Consistent with the requirements of MRTS04 *General Earthworks*, laboratory CBR testing of existing subgrade material and earth fill material is to be carried out in accordance with AS 1289.6.1.1 *Methods of testing soils for engineering purposes, Method 6.1.1: Soil strength and consolidation tests – Determination of the California Bearing Ratio of a soil – Standard laboratory method for a remoulded specimen.*

The typical pre-treatment for materials that break down under environmental and service conditions due to weathering (such as shales, claystones, siltstones and other soft laminated or jointed rocks) is to pre-condition the materials 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 pre-treatment involves artificial weathering, followed by repeated cycles of compaction.

5.6.1 Determination of Density for Laboratory Testing

Addition

For existing subgrade (as defined in MRTS04 *General Earthworks*) and fill material, a laboratory density ratio of 97.0% (standard compaction) is typically adopted for CBR testing. This laboratory density ratio aligns with the compaction requirements in MRTS04 *General Earthworks* for the upper portion of the subgrade. While MRTS04 *General Earthworks* includes a lower compaction standard for lower subgrade layers, a laboratory density ratio of 97.0% is still typically used for laboratory CBR testing. The use of this higher laboratory density ratio for lower subgrade layers is appropriate to account for the omission of any allowance for the higher confining stresses at depth (as a surcharge load of 4.5 kg is typically used for all laboratory CBR testing) (NACOE, 2021a).

5.6.2 Determination of Moisture Conditions for Laboratory Testing

Addition

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 5.6.2.

Table 5.6.2 – Guide to moisture conditions for laboratory CBR testing

Location / Circumstances	Testing Condition
Default testing condition, except for situations as described below	4 day soaked
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 • experience indicates that 10 day soaked conditions should apply	10 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 optimum moisture content (OMC) and maximum dry density (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

Addition

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.

5.9 Subgrades with Design CBR less than 2%

New

This section applies when the design subgrade CBR is less than 2% (at the design moisture and density conditions) (NACOE, 2021b). This is distinguished from when the in situ CBR of the subgrade at the time of construction is less than 3%, which is addressed in Section 3.14.1.

Subgrades which are soft at the time of construction are likely to require treatments additional to those detailed in this section. For locations identified as having an appreciable risk of the subgrade material being soft at the time of construction (such as where the subgrade material has a low design CBR and exposure to moisture ingress during construction is likely), the pavement designer should detail in the design documentation any additional subgrade treatments to be undertaken if the subgrade is soft at the time of construction.

For unbound granular pavements, a design subgrade CBR less than 2% may be used as an input into figures 8.4 and 12.2 of AGPT02.

For flexible pavements with one or more bound layers, and for rigid pavements, a soft subgrade treatment that results in a presumptive subgrade design CBR of at least 2% is typically provided where the subgrade design CBR would otherwise be less than 2%. A presumptive subgrade design CBR is then adopted in the pavement design calculations which accounts for the combined strength of the soft subgrade and the soft subgrade treatment.

In addition to the treatments detailed in this section, an improved layer under bound layers is also typically provided, as detailed in Section 3.14.2.

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 2% for the assumed semi-infinite layer (that is, from the top of the treatment and extending infinitely below) is typically adopted for geotextile wrapped granular material, comprising either coarse unbound granular material (for example, Type 2.5 material in dry conditions, or Type 2.4 material in wet conditions) or rock fill (MRTS04 *General Earthworks*), with thickness determined using Table 5.9.

Table 5.9 – Minimum thickness of coarse granular or rock fill required for the adoption of a presumptive design CBR of 2%

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 2%
1.0	250
1.5	150
2.0	0

In assigning design parameters (for both flexible and rigid pavement design) to the materials used in soft subgrade treatments, consideration should be given to the effects 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 heavily bound (cemented) materials) are modelled as selected subgrade materials with design parameters not exceeding those of a selected fill material with CBR of 15%.

Rock fill is typically covered by a 150 mm heavily bound (cemented) material or lightly bound improved layer to provide a stable platform for construction of the overlying pavement layers. Where rock fill is used to treat soft subgrades, the issues listed in Section 3.2.3 which may affect future pavement performance should also be considered.

6 Pavement Materials

6.1 General

Addition

Recycled materials may be used as a substitute for new materials in unbound, lightly bound, heavily bound (cemented), asphalt and foamed bitumen stabilised pavement layers, as detailed in the relevant technical specifications.

Technical Note TN193 *Use of recycled materials in road construction* provides further guidance on the use of recycled materials in road construction using Transport and Main Roads Technical Specifications.

6.2 Unbound Granular Materials

6.2.1 Introduction

Addition

Material characteristics and requirements

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

- traffic loading
- 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 granular 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.

Tables 6.2.1 and 6.5.10 provide guidance on the selection of standard materials for use in unbound granular pavements with thin bituminous surfacings, based on traffic loading and median annual rainfall. Table 6.2.1 also applies to the selection of materials under lightly bound base and lightly bound subbase.

Selection and specification of unbound granular 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 and so on 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 granular 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 6.2.1 – Typical application of unbound materials in unbound granular pavements and below lightly bound layers

Average Daily Traffic in Design Lane in Year of Opening (ESA)	**Typical Material Type (MRTS05)[1,2,3]**		
	Median Annual Rainfall (mm)		
	≥ 800 mm / Year	**≥ 500 mm / Year to < 800 mm / Year**	**< 500 mm / Year**
Base			
≥ 1000 to < 3000	1 (HSG)[4]	1 (HSG)[4]	1 (HSG)[4]
≥ 500 to < 1000	2.1	2.1 or 3.1	3.1
10 to < 500	2.1	2.1 or 3.1	3.1
< 10	2.2	2.2 or 3.2	3.2
Upper Subbase			
≥ 1000 to < 3000	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 Subbase			
All	2.5	2.5 or 3.5	3.5

(shaded)	Shading indicates where recycled materials can be used[5,6]

Notes:

1. Where material type alternatives are given, the first is the preferred and typically adopted option, with other materials listed in order of preference.
2. A Type 2 material of the same subtype may be used in lieu of a Type 3 material.
3. The requirements for Type 3 materials in MRTS05 *Unbound Pavements* do not include any minimum durability requirements, and therefore site specific moisture conditions should be carefully considered in addition to median rainfall.
4. The decision to use Type 1 (HSG) material is typically based on a project-specific assessment. Refer to Transport and Main Roads Technical Note TN171 *Use of High Standard Granular (HSG) Bases in Heavy Duty Unbound Granular Pavements* for further guidance.
5. An asphalt surfacing must be provided where a recycled material is used in the base course (unless use is in a temporary pavement with design period not exceeding two years).
6. There are no restrictions to the use of recycled materials in other applications, for example non-trafficked shoulders, subbases, improved layers, or subgrade treatments.

6.2.3 Determination of Modulus of Unbound Granular Materials

Addition

Presumptive values

The following may be used as a guide when assigning maximum design modulus values to typical unbound granular materials:

a) under thin bituminous surfacings – Table 6.2.3(a)

b) under bound (asphalt, foamed bitumen and heavily bound) layers – Table 6.2.3(b)

c) under lightly bound layers – Table 6.2.3(b) and Table 6.2.3(c).

Table 6.2.3(a) – Presumptive values for elastic characterisation of unbound granular base materials under thin bituminous surfacings

MRTS05 Material Type	Maximum Vertical Modulus of Top Sublayer (MPa)
1 (HSG)	500
2.1, 3.1	350
2.2, 3.2	300

Table 6.2.3(b) – Presumptive values for elastic characterisation of unbound granular materials under bound (asphalt, foamed bitumen and heavily bound) and lightly bound pavement layers

MRTS05 Material Type	Maximum Vertical Modulus of Top Sublayer (MPa)	
	Under Bound Material	Under Lightly Bound Material
1 (HSG)	Table 6.5 of AGPT02	N/A
2.1, 3.1	Table 6.4 of AGPT02	Table 6.2.3(c)
2.2, 3.2	Table 6.4 of AGPT02 but not exceeding 300	Table 6.2.3(c)
2.3, 3.3	Table 6.4 of AGPT02 but not exceeding 210	Table 6.2.3(c) but not exceeding 210
2.4, 2.5, 3.4, 3.5	150	150

Table 6.2.3(c) – Maximum vertical modulus of top sublayer of normal standard base material under lightly bound material

Thickness of Overlying Bound and Lightly Bound Material (mm)	Equivalent Modulus[1,2] of Overlying Bound and Lightly Bound Material (MPa)	
	600	**1000**
200	260	220
225	230	180
250	200	150
275	170	150
≥ 300	150	150

Note:

1. Equivalent modulus (E_e) is determined using Equation 5 of AGPT02.
2. If the equivalent modulus of overlying material exceeds 1000 MPa, Table 6.4 from AGPT02 should then be used.

6.3 Modified Granular Materials

Addition

Modified granular materials as defined in AGPT02 (with a maximum 28 day UCS of 1.0 MPa) are not commonly used on Transport and Main Roads projects. Where small amounts of stabilising agents are used, typically these are specified with a UCS between 1.0 and 2.0 MPa and are referred to as lightly bound materials. Further detail on lightly bound granular materials is provided in Section 6.8.

6.4 Cemented Materials

6.4.1 Introduction

Addition

Main characteristics

Guidance on lightly bound materials (with UCS of 1.0 to 2.0 MPa) is included in Section 6.8.

The typical characteristics of heavily bound (cemented) materials supplied to Transport and Main Roads technical specifications 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 granular materials in the heavily bound (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 heavily bound (cemented) material.

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

6.4.3 Determination of Design Modulus

Addition

Presumptive values

Presumptive values for the design modulus of heavily bound (cemented) materials typically adopted for standard Transport and Main Roads materials are provided in Table 6.4.3.

Table 6.4.3 – Presumptive values for elastic characterisation of standard heavily bound (cemented) materials

Material Category	Material to be Bound (MRTS05 Type)	UCS (28 Day) (MPa)	Presumptive Design Modulus (MPa)[1]
Category 1	2.1	3.0 to 6.0	4000
Category 2	2.1, 2.2, 3.1[2], 3.2[2]	2.0 to 4.0	3000

Notes:

1. These design modulus values assume seven days initial curing with negligible trafficking.
2. Type 3 materials are only suitable for use in relatively dry environments (refer to Table 6.2.1).

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

Addition

Presumptive fatigue constants for heavily bound (cemented) materials typically adopted for standard Transport and Main Roads materials are provided in Table 6.4.8. These presumptive fatigue constants are for use with Equation 10 in AGPT02 (instead of Equation 15 in AGPT02) and the reliability factors in Table 6.8 of AGPT02.

Table 6.4.8 – Presumptive fatigue constants for standard heavily bound (cemented) materials

Property	Category 1 Material	Category 2 Material
Presumptive design modulus (MPa)	4000	3000
Presumptive flexural strength (MPa)	1.2	1.0
Presumptive in-service fatigue constant K	233	261

6.5 Asphalt

6.5.4 Determination of Design Modulus from Direct Measurement of Flexural Modulus

Addition

Transport and Main Roads Technical Note TN167 *A New Approach to Asphalt Pavement Design* provides further detail on the methodology for determining design modulus from direct measurement of flexural modulus for a specific asphalt mix.

Where the design modulus for a specific mix has been determined, it is used in conjunction with the fatigue model for the same mix, determined as detailed in Section 6.5.11.

6.5.5 Determination of Design Modulus from Measurement of ITT Modulus

Addition

A design modulus for a specific asphalt mix that has been determined from indirect tensile testing is not typically used on Transport and Main Roads projects. Determination of design modulus for a specific asphalt mix is typically undertaken using flexural modulus testing, as detailed in Section 6.5.4.

6.5.6 Design Modulus from Bitumen Properties and Mix Volumetric Properties

Addition

A design modulus for a specific asphalt mix that has been determined from bitumen properties and mix volumetric properties is not typically used on Transport and Main Roads projects. Determination of design modulus for a specific asphalt mix is typically undertaken using flexural modulus testing, as detailed in Section 6.5.4.

6.5.7 Design Modulus from Published Data

Addition

Presumptive values of design modulus that are typically adopted for standard asphalt mixes are provided in Table 6.5.7(a) for a WMAPT of 32ºC. These values were generally derived from Indirect Tensile Test (ITT) results of Transport and Main Roads 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.

For dense graded asphalt and stone mastic asphalt, design moduli for locations with a WMAPT other than 32ºC are calculated using Equation 6.5.7(a), rounded to the nearest multiple of 100 MPa.

Equation 6.5.7(a) – Design moduli for locations with a WMAPT other than 32ºC

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

where:

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

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

WMAPT= desired WMAPT (ºC), as detailed in Appendix B of AGPT02.

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

Table 6.5.7(a) – 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	A15E	9.5	800	800	800	800
OG14	A15E	8.5	800	800	800	800
SMA10	A15E	14.0	1000* (600)	1000* (900)	1100	1300
SMA14	A15E	13.0	1000* (600)	1000* (900)	1100	1300
AC10M	C320	11.5	1000* (900)	1300	1600	1900
AC10M AC10H	A15E	11.5	1000* (600)	1000* (800)	1000	1200
AC14M	C320	11.0	1100	1700	2000	2400
AC14M AC14H	C600	11.0	1400	2000	2400	2900
AC14M AC14H	A15E	11.0	1000* (700)	1000	1300	1500
AC20M	C320	10.5	1200	1800	2200	2600
AC20M AC20H	C600	10.5	1500	2200	2600	3100
AC20M AC20H	A15E	10.5	1000* (800)	1100	1400	1600
EME2	EME2 binder	–	To be determined using the presumptive flexural modulus master curve in Table 6.5.7(b)			

Notes:

1. Indicated values (*) have been limited to a value of 1000 MPa. When adjusting these moduli to another WMAPT using Equation 6.5.7(a), E32ºC should be taken as the value in brackets.

For high modulus asphalt (EME2), the design modulus is determined at the required WMAPT and design speed using the presumptive flexural modulus master curve fitting parameters provide in Table 6.5.7(b). These parameters were derived from flexural modulus test results for Transport and Main Roads-registered EME2 mixes (NACOE, 2021c).

Table 6.5.7(b) – Presumptive flexural modulus master curve parameters

Asphalt Mix Type	Binder Type	T_{ref} (°C)	Design air voids (%)	Master Curve Fitting Parameters					
				α	β	γ	δ	a	b
EME2	EME2 binder	25	4.5	2.759	-1.295	-0.409	1.563	7.049×10^{-4}	-0.143

The following steps are used to determine the design modulus from the presumptive flexural modulus master curve fitting parameters:

a) Determine the temperature shift (a_T) at the design temperature (WMAPT) using Equation 21 in AGPT02.

b) Determine the flexural modulus test frequency (f_{T274}) equivalent to the load frequency under a heavy vehicle travelling at the design heavy vehicle speed (V) using Equation 18 in AGPT02.

c) Determine the reduced frequency (f_r) at the design temperature and heavy vehicle speed using Equation 20 in AGPT02.

d) Determine the design flexural modulus (E*) at the design temperature and heavy vehicle speed using Equation 19 in AGPT02.

Design moduli determined using this procedure are shown in Table 6.5.7(c) for a WMAPT of 32°C. Use steps a) to d) shown previously to determine design moduli at other WMAPTs.

Table 6.5.7(c) – Presumptive EME2 design moduli at a WMAPT of 32ºC

Asphalt Mix Type	Binder Type	Design Air Voids (%)	Asphalt Modulus at Heavy Vehicle Operating Speed (MPa)			
			10 km/h	30 km/h	50 km/h	80 km/h
EME2	EME2 binder	4.5	3700	4700	5200	5700

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 6.5.7(d). In selecting presumptive values from Table 6.5.7(d), consideration should be given to the likely effect of overall site geometry on heavy vehicle speeds. This includes considering the length of graded sections, grade direction (uphill / downhill), location and radii of curves, and expected queue lengths.

Table 6.5.7(d) – Presumptive heavy vehicle operating speeds

Project Location	Presumptive Heavy Vehicle Operating Speed (km/h)	
	Grade ≤ 5%	Grade > 5%
Speed limit > 80 km/h	80	50
Speed limit 50 – 80 km/h	50	30
Roundabouts, signalised intersections and approaches	30	10

6.5.9 Factors Affecting Asphalt Fatigue Life

<u>*Addition*</u>

Effect of binder type

Asphalt containing plastomeric polymer modified binder (for example, A35P) could be considered where improved deformation resistance is required, based on a project-specific engineering assessment. A35P provides improved deformation resistance when compared to A15E but is more prone to cracking; therefore, A35P should only be used where the increased risk of cracking is accepted.

Where A35P is used, it is important to ensure sufficient support is provided to inhibit premature fatigue of the layer. Such support can be provided by including a heavily bound (cemented) subbase and/or using stiff underlying asphalt layers.

6.5.10 Fatigue Criteria

Addition

Transport and Main Roads Technical Note TN167 *A New Approach to Asphalt Pavement Design* provides a methodology for determining a mix-specific fatigue relationship for use in pavement design. The mix-specific fatigue relationship can be used in place of the Shell laboratory model (Equation 25 in AGPT02).

For EME2, the fatigue relationship provided in Equation 6.5.10 is to be used instead of Equation 25 in AGPT02. The relationship was developed from laboratory test results for Transport and Main Roads registered EME2 mixes (NACOE, 2021c).

Equation 6.5.10 – EME2 general fatigue relationship

$$N = \frac{SF}{RF}\left[\frac{57{,}500}{E^{0.36}\mu\varepsilon}\right]^{5.5}$$

where:

N, SF, RF, E and $\mu\varepsilon$ are as defined for Equation 25 in AGPT02.

Unbound and lightly bound pavements with thin asphalt surfacings

Asphalt fatigue does not need to be assessed for unbound and lightly bound granular pavements with thin asphalt surfacings when selected according to Table 6.5.10. These pavements are those with a single layer of asphalt (dense graded asphalt or stone mastic asphalt), or two layers of asphalt where the top layer is open graded asphalt. Table 6.5.10 provides guidance on the selection of base and surfacing materials for these pavements in free-flowing traffic conditions (NACOE, 2020).

Table 6.5.10 – Guide to the composition of asphalt surfaced granular pavements

Base Material	**Maximum Allowable Traffic for Various Surfacing Types[1] (Average Daily ESAs in the Design Lane in the Year of Opening)**		
	AC10[2] or AC14 with C320 bitumen	**AC10[2] or AC14 with A15E binder**	**SMA**
Type 2.2 or Type 3.2	10	10	10
Type 2.1 or Type 3.1	125	200	250
Type 1 (HSG)	150	250	300
Lightly bound base	250	1000 (3000)[3]	1000 (3000)[3]

Note:

1. An OG10 or OG14 surfacing, including WP-A seal, may be included above the dense graded asphalt options when required.
2. AC10 is not typically used where the design traffic exceeds 300 ESA/day at opening.
3. Typically suitable up to 1000 ESA/day at opening. May be suitable up to 3000 ESA/day at opening following project-specific assessment.

6.5.11 Means of Determining Asphalt Fatigue Characteristics

Addition

Transport and Main Roads Technical Note TN167 *A New Approach to Asphalt Pavement Design* provides a methodology for determining fatigue characteristics for a specific asphalt mix over a range of temperatures.

6.5.12 Permanent Deformation of Asphalt

Addition

Guidance on the selection of dense graded asphalt mix types and binders is included in Table 6.5.12.

As noted in Table 6.5.12, EME2 may be considered in base layers instead of dense graded asphalt, at all traffic levels as detailed in tables 2.2.1, 2.2.5, 2.2.6(c) and 2.2.9(a).

Table 6.5.12 – Guide to the selection of dense graded asphalt (AC) mix type and binder class

Application	**Traffic Volume (Average Daily ESAs in the Design Lane in the Year of Opening)**		**Typical Binders**
	Free Flowing	**High Shear[2]**	
Surfacing layer	< 1000	< 300	C320
	< 3000	< 1000	M1000[3]
	All	All	A15E[4]
Layer below surfacing	< 3000	< 1000	C320
	All	< 3000	C600, M1000[3]
	All	All	A15E[4]
Layers covered by at least two layers of asphalt	All	< 3000	C320
	All	All	C600, M1000[3], A15E[4]

Notes:

1. EME2 may be considered in base layers instead of dense graded asphalt, at all traffic levels as detailed in tables 2.2.1, 2.2.5, 2.2.6(c) and 2.2.9(a).
2. High shear areas include signalised intersections and approaches, roundabouts and approaches, and other areas with very slow moving and/or stationary heavy vehicles. For bus stops, busways and bus-only lanes, specialist advice should be sought from the Principal Engineer (Asphalt and Surfacings).
3. M1000 typically has a shorter oxidation life than C320 and A15E binders. More frequent resurfacing should be anticipated where M1000 binder is used in surfacing layers. Presumptive design parameters for Transport and Main Roads registered mixes with M1000 binder have not been established. For these reasons, M1000 is not typically used unless approved by the Transport and Main Roads project representative.
4. A15E binder is typically used in situations where enhanced deformation and/or fatigue resistance is desired.

6.6 Concrete

6.6.4 Base Concrete

Addition

A design flexural strength of 4.5 MPa (at 28 days) is typically adopted for pavement quality base concrete. For steel-fibre reinforced concrete, a design flexural strength of 5.5 MPa (at 28 days) is typically adopted.

6.7 Foamed Bitumen Stabilised Materials

New

Guidance on material requirements, material characterisation (for pavement design) and mix design of foamed bitumen stabilised materials is provided in the Transport and Main Roads *Pavement Rehabilitation Manual*, Transport and Main Roads *Materials Testing Manual* (Part 2) and relevant technical specifications.

The following points also apply in relation to determination of the design modulus of the foamed bitumen stabilised material:

a) The full thickness of the foamed bitumen stabilised material is assigned the same design modulus according to the aforementioned documents (the design modulus is mix-dependent and is between 1800 MPa and 2500 MPa at 25ºC prior to temperature correction. A presumptive design modulus of 1800 MPa, prior to temperature correction, is typically used when the details of the mix design are unknown).

b) Where the overlying asphalt thickness is greater than or equal to 100 mm, temperature correction does not apply.

c) Where the overlying asphalt thickness is less than 100 mm, temperature correction applies using the factors in Table 6.7.1(a).

Table 6.7.1(a) – Temperature correction factors for determination of foamed bitumen stabilised material design modulus

WMAPT (ºC)[1]	Temperature Correction Factor (F_t)	
	< 50 mm Overlying Asphalt	50 to < 100 mm Overlying Asphalt
≤ 25	1.00	1.00
30	0.90	0.95
32	0.86	0.93
35	0.80	0.90
40	0.70	0.85

Notes:

1. For intermediate temperatures, linear interpolation is used to determine the temperature correction factor.

The design binder volume (V_b) is also mix-dependent and is selected from Table 6.7.1(b). A presumptive design binder volume of 7.0% is typically used when the details of the mix design are unknown.

Table 6.7.1(b) – Design binder volume for foamed bitumen stabilised materials

Mix design nominated bitumen content (% by mass of dry material to be stabilised)	Design binder volume (V_b) (%)
3.0	7.0
3.25	7.5
3.5	8.0

6.8 Lightly Bound Granular Materials

<u>New</u>

Lightly bound granular materials are typically specified to have a UCS between 1.0 and 2.0 MPa at 28 days when used in lightly bound base or subbase layers, and 1.0 to 2.0 MPa at seven days when used in lightly bound improved layers.

While this approach may result in a material that is more prone to fatigue and/or shrinkage cracking than cement modified materials (with maximum 28 day UCS of 1.0 MPa, as defined in AGPT02), it has a number of benefits which include:

- reduced moisture sensitivity
- higher strength and stiffness
- reduced permeability
- reduced erodibility
- 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, Transport and Main Roads typically adopts additional controls such as:

- minimum support conditions, as detailed in Section 8.2.8, and
- minimum thickness of base, as detailed in Section 8.2.9.

Characterisation for pavement design

Lightly bound materials in base, subbase and improved layers are characterised and modelled as follows (Austroads, 2020):

- presumptive Poisson's ratio of 0.35
- a single vertical design modulus for the full depth of each pavement course (that is, no sublayering) – where there are multiple lightly bound pavement courses, a single modulus is assigned to the total lightly bound base thickness, and a single modulus is assigned to the combined thickness of all lightly bound subbase and lightly bound improved layers, and
- cross-anisotropic (with a degree of anisotropy of 2).

The presumptive vertical design modulus of lightly bound granular materials is the lowest value determined from both the following tables:

- Table 6.8(a), considering the thickness and modulus of overlying bound materials, and
- Table 6.8(b), considering underlying support conditions (the modulus is limited to four times the vertical design modulus of the underlying support layer, with a minimum of 240 MPa and maximum of 600 MPa).

Guidance on the determination of design modulus by direct measurement is provided in Austroads (2020).

Table 6.8(a) – Maximum vertical design modulus of lightly bound granular materials considering overlying bound and lightly bound materials

Total thickness of overlying bound and lightly bound material (mm)	**Modulus of the Overlying Bound or Lightly Bound Material (MPa)[1]**					
	600	**1000**	**2000**	**3000**	**4000**	**5000**
	Maximum Vertical Modulus of Lightly Bound Granular Material (MPa)[2]					
≤ 40	600	600	600	600	600	600
75	600	600	600	590	580	570
100	600	600	570	550	530	520
125	590	570	530	510	490	470
150	570	540	500	470	440	430
175	550	510	460	430	430	430
200	520	480	430	430	430	430
225	500	460	430	430	430	430
250	470	430	430	430	430	430
275	450	430	430	430	430	430
≥ 300	430	430	430	430	430	430

(Adapted from Austroads, 2020)

Note:

1. Equivalent modulus (E_e) is determined using Equation 5 in AGPT02.
2. These values apply to lightly bound base, subbase and improved layer material complying with MRTS10. For lightly bound material manufactured using Type 2.4, 2.5, 3.4 or 3.5 material, a maximum vertical modulus of 210 MPa applies regardless of the thickness and modulus of the overlaying bound materials.

Table 6.8(b) – Maximum vertical design modulus of lightly bound granular materials considering underlying support conditions

Vertical Design Modulus of Support Layer (MPa)[1]	Maximum Vertical Modulus of Lightly Bound Material (MPa)
20 to 60	240
70	280
80	320
90	360
100	400
110	440
120	480
130	520
140	560
≥ 150	600

(Adapted from Austroads, 2020)

Note:

1. Minimum support of 150 MPa applies to lightly bound base layers, as detailed in Section 8.2.8.

7 Design Traffic

7.4 Procedure for Determining Total Heavy Vehicle Axle Groups

7.4.2 Selection of Design Period

Addition

The design periods typically adopted by Transport and Main Roads are as detailed in Table 7.4.2.

Table 7.4.2 – 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

Addition

Designers are referred to the Traffic Surveys and Data Management (TSDM) web reporting tool as a source of traffic data such as Traffic Census, Traffic Analysis and Reporting System (TARS) and Weigh-In-Motion (WIM) reports. Transport and Main Roads officers can access TSDM at https://www.tap.qdot.qld.gov.au/tsdm/html/tsdm-index.html.

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 7.4.4(a).

Equation 7.4.4(a) – Traffic growth factor

$$GF = (1 + 0.01 \times R)^x$$

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 7.4.4(b).

Equation 7.4.4(b) – Average daily ESA in the design lane in the year of opening

$$ESA/day = N_i \times N_{HVAG} \times {}^{ESA}/_{HVAG}$$

where N_i, and N_{HVAG} are as detailed in sections 7.4.4, 7.4.7 and 7.6.2 of AGPT02.

7.4.5 Cumulative Number of Heavy Vehicles when Below Capacity

Addition

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

Presumptive heavy vehicle growth rates are provided in Table 7.4.5. These values are not intended to replace sound project-specific information.

Table 7.4.5 – Presumptive growth rates for below capacity traffic flow based on freight forecasts

Road	Presumptive Annual Growth (%)
Key freight routes (refer to Figure 7.4.5 for outline view, and http://maps.infrastructure.gov.au/KeyFreightRoute for detailed view.	3
Other state controlled roads	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, heavy vehicle growth rates exceeding about 10% per annum may be considered excessive.

Figure 7.4.5 – Queensland key freight routes

7.4.6 Cumulative Number of Heavy Vehicles Considering Capacity

<u>*Addition*</u>

Consideration should be given to any changes in the lane configuration (for example, widening with an additional lane) during the design period and its effect on capacity and heavy vehicle growth rates.

7.5 Estimation of Traffic Load Distribution (TLD)

<u>*Addition*</u>

Refer to Appendix E for guidance on the estimation of traffic load distributions. 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

<u>*Addition*</u>

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 detailed in Table 8.1.

Table 8.1 – Construction tolerances for flexible pavements

Pavement Type	Construction Tolerance (mm)	Tolerance is Applied to
Unbound granular	20	Total design thickness
Lightly bound base	20	Base course
Full depth asphalt, AG(A)	10	Base course
Deep strength asphalt, flexible composite, ASt(A)	10	Base or subbase (whichever course governs the overall allowable loading)
ASt(B)	20	Base course
Foamed bitumen stabilised granular pavements	15	Foamed bitumen stabilised granular material

8.2 Mechanistic-empirical Procedure

Addition

Mechanistic-empirical design is typically undertaken using the latest version of AustPADS or CIRCLY.

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

For the design of pavements comprising foamed bitumen stabilised materials, the calculation of critical strains and the interpretation of results is consistent with the procedure for asphalt detailed in tables 8.1 to 8.3 of AGPT02, and sections 8.2.4 and 8.2.5 of AGPT02. Material input parameters for foamed bitumen stabilised materials are as detailed Section 6.7 of this supplement.

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

Difference

Lime-stabilised subgrade materials

Where the mix design for lime-stabilised subgrade material is undertaken according to the Transport and Main Roads *Materials Testing Manual* (Part 2), the lime-stabilised material is characterised and modelled as follows:

- presumptive Poisson's ratio of 0.45
- presumptive vertical design modulus of 210 MPa, which applies to the full depth of the lime-stabilised material (that is, no sublayering)
- cross-anisotropic (with a degree of anisotropy of 2), and
- permanent deformation is assessed using the vertical compressive strain at the top of the underlying untreated subgrade material rather than at the top of the lime-stabilised subgrade.

The depth of subgrade to be stabilised is typically 300 mm.

The minimum thickness of granular pavement material to be used over lime-stabilised subgrade is as detailed in Table 8.2.2.

Table 8.2.2 – Minimum thickness of granular material over lime-stabilised subgrade

Design Traffic in Year of Opening (ESA/day)	Minimum Granular Thickness over Lime Stabilised Subgrade (mm)
< 100	150
100–1000	200
> 1000	250

Further details are provided in the Transport and Main Roads Guideline *Structural Design Procedure for Lime Stabilised Subgrade*.

Selected subgrade materials

For selected subgrade materials, sublayering is undertaken according to steps 1 to 6 in Section 8.2.2 of AGPT02, with the following amendments:

- The stiffness of the underlying existing subgrade may be neglected if the total thickness of selected subgrade material is 1.5 m or more (rather than 2 m as detailed in AGPT02).
- The following additional steps are included prior to Step 1 for each selected subgrade material:
    - For each selected subgrade material (commencing with the lowest selected subgrade material), calculate the minimum sublayering thickness (T) using Equation 8.2.2. The minimum sublayering thickness (T) is calculated such that the top sublayer of five equi-thick sublayers can achieve a vertical modulus equal to 10 times the design CBR of the material (up to a maximum 150 MPa).

Equation 8.2.2 – Selected subgrade minimum sublayering thickness (T)

$$T = \frac{150}{\log 2} \log\left(\frac{Ev\ material\ in\ top\ sublayer}{Ev\ underlying\ material}\right)$$

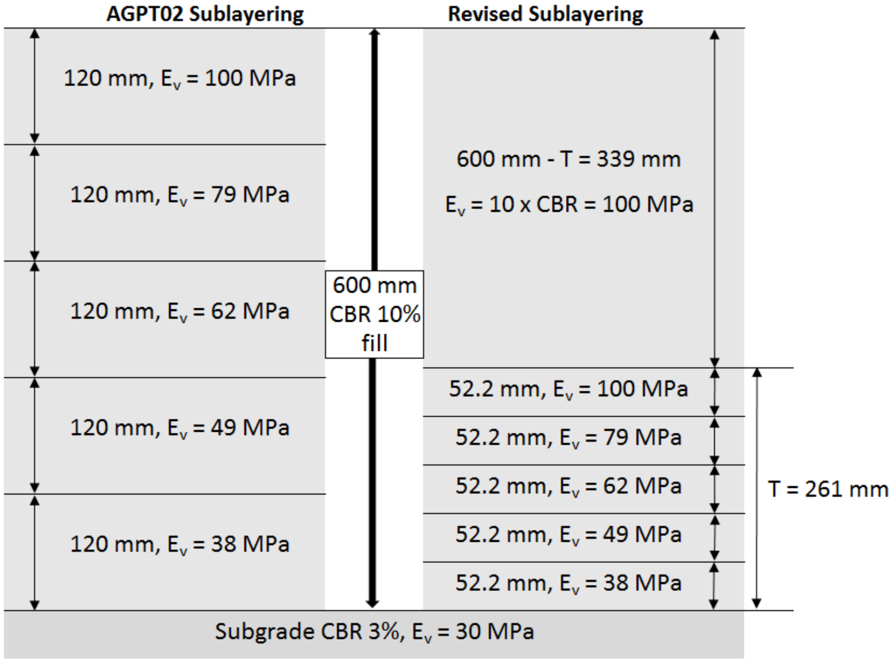
-
    - If the thickness of the selected subgrade material is less than T plus 100 mm, sublayering of the entire thickness of that material is undertaken according to steps 1 to 6 in Section 8.2.2 of AGPT02.
    - If the thickness of the selected subgrade material is at least T plus 100 mm, only the thickness T is sublayered into five equi-thick sublayers according to steps 1 to 6 in Section 8.2.2 of AGPT02. The remaining overlying thickness of that material is not sublayered and is instead assigned a vertical modulus 10 times the design CBR of the material (up to a maximum 150 MPa).

An example of this revised sublayering is shown in Figure 8.2.2. In the example, there is 600 mm of CBR 10% select fill overlying a subgrade with design CBR of 3%.

The left side of Figure 8.2.2 shows sublayering according to Section 8.2.2 of AGPT02. The right side of the Figure shows the revised sublayering.

For the revised sublayering, T is first calculated using Equation 8.2.2, where $E_{v\ material\ in\ top\ sublayer}$ is 100 MPa (10 times the CBR of the selected subgrade material), and $E_{v\ underlying\ material}$ is 30 MPa (10 times the CBR of the subgrade). This results in T = 261 mm. As the thickness of this selected subgrade material is more than T plus 100 mm, only 261 mm of the material is sublayered according to steps 1 to 6 in Section 8.2.2 of AGPT02. The remaining 339 mm of this material is not sublayered and is instead assigned a vertical modulus of 10 times its design CBR, which, in this case, equals 100 MPa.

Figure 8.2.2 – Example of revised sublayering for selected subgrade materials



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

Addition

For high modulus asphalt (EME2), the fatigue relationship in Equation 8.2.5 is used rather than Equation 44 in AGPT02.

Equation 8.2.5 – EME2 fatigue relationship

$$N_{ij} = \frac{1}{n} \times \frac{SF}{RF} \times \left[\frac{57{,}500}{E^{0.36}\mu\varepsilon_{ij}}\right]^{5.5}$$

where:

N_{ij}, n, SF, RF, E and $\mu\varepsilon_{ij}$ are as defined for Equation 44 in AGPT02.

Where a mix-specific fatigue relationship is used in pavement design (determined as detailed in Section 6.5.11), Equation 44 in AGPT02 is replaced with the corresponding mix-specific equation as detailed in Transport and Main Roads Technical Note TN167 *A New Approach to Asphalt Pavement Design*.

8.2.8 Minimum Support Conditions under Lightly Bound, Asphalt, Heavily Bound (Cemented) and Foamed Bitumen Stabilised Pavements

New

Where the subgrade design CBR is less than 2%, the treatments detailed in Section 5.9 should first be applied, and a presumptive design CBR of 2% is adopted at the top of this treatment in the mechanistic-empirical design model.

Lightly bound base pavements

For lightly bound base pavements, the base is typically supported on a subbase with thickness of at least 150 mm and which achieves a vertical design modulus of at least 150 MPa at the top of the subbase (determined using the procedures detailed in sections 8.2.2 and 8.2.3 of AGPT02 for unbound and selected subgrade materials, and Section 6.8 of this supplement for lightly bound materials).

This may be achieved by increasing the thickness of the subbase, and/or including additional select fill or unbound granular material beneath the subbase.

Asphalt and heavily bound (cemented) pavements

For asphalt and heavily bound (cemented) pavements with design traffic of 1000 ESA/day or more at opening (excluding temporary pavements), the minimum lightly bound or unbound granular improved layer thickness is determined from Table 8.2.8.

Table 8.2.8 – Minimum thickness of improved layer in asphalt and heavily bound pavements with design traffic of 1000 ESA/day or more at opening

Vertical design modulus immediately below the improved layer (MPa)	Minimum lightly bound or unbound granular improved layer thickness (mm)
70	150
60	175
50	200
40	250
30	300
20	375

Foamed bitumen stabilised pavements

For pavements comprising foamed bitumen stabilised granular material, the improved layer (and any underlying layers) is typically designed to achieve a vertical design modulus at the top of the improved layer of at least 70 MPa (determined using the procedures detailed in sections 8.2.2 and 8.2.3 of AGPT02).

This may be achieved by increasing the thickness of the improved layer, and/or including additional select fill or unbound granular material beneath the improved layer.

8.2.9 Design of Pavements Incorporating Lightly Bound Granular Materials

New

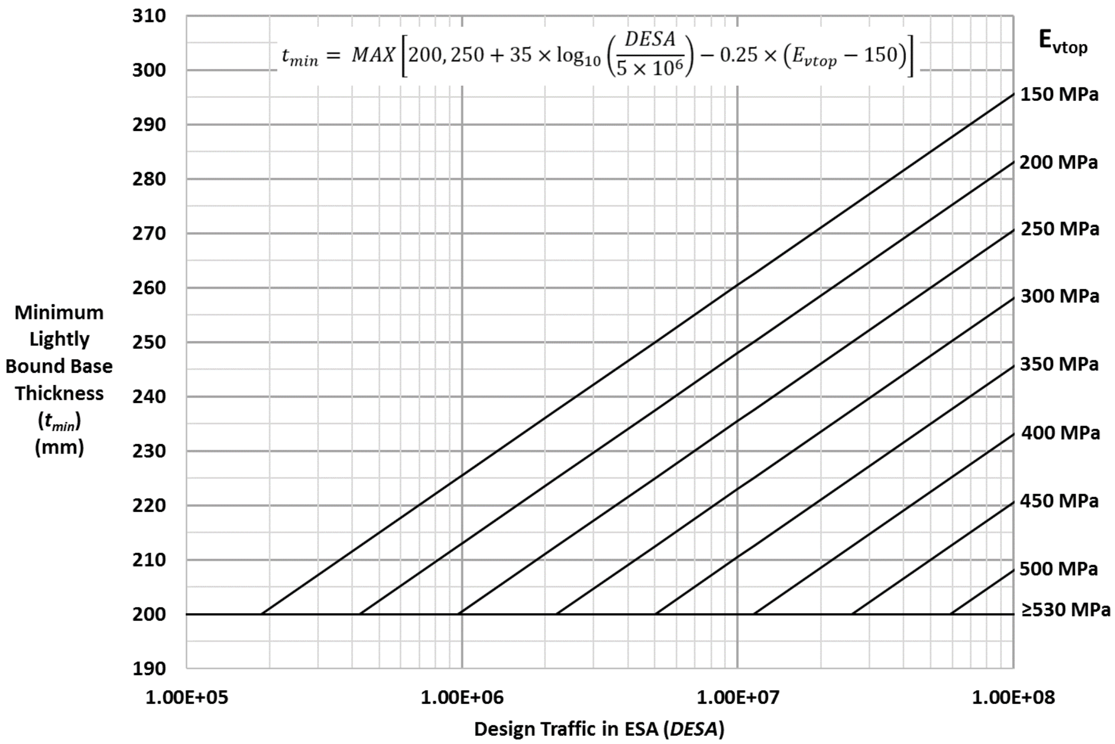
Lightly bound base pavements – minimum thickness of base

The minimum base thickness in lightly bound base pavements is determined from Figure 8.2.9, where E_{top} is the top sublayer modulus of the underlying material. The minimum base thickness from Figure 8.2.9 may be reduced by the thickness of any overlying dense graded or stone mastic asphalt; however, the lightly bound base thickness is not to be reduced to less than 200 mm.

Conformance with the minimum base thickness in Figure 8.2.9 is to be assessed after addition of 20 mm construction tolerance to the calculated design thickness.

For lightly bound base pavements with unbound subbase, an iterative approach is required to satisfy both the minimum lightly bound base thickness (Figure 8.2.9) and the maximum design modulus for the underlying support (Table 6.2.3(c)).

Figure 8.2.9 – Minimum thickness of lightly bound base



8.3 Empirical Design of Granular Pavements with Thin Bituminous Surfacing

8.3.1 Determination of Basic Thickness

Addition

The thickness design charts (figures 8.4 and 12.2 in AGPT02) 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 Transport and Main Roads; for example, a terminal roughness of approximately 5.7 m/km can be expected, assuming that the initial roughness is 1.9 m/km.

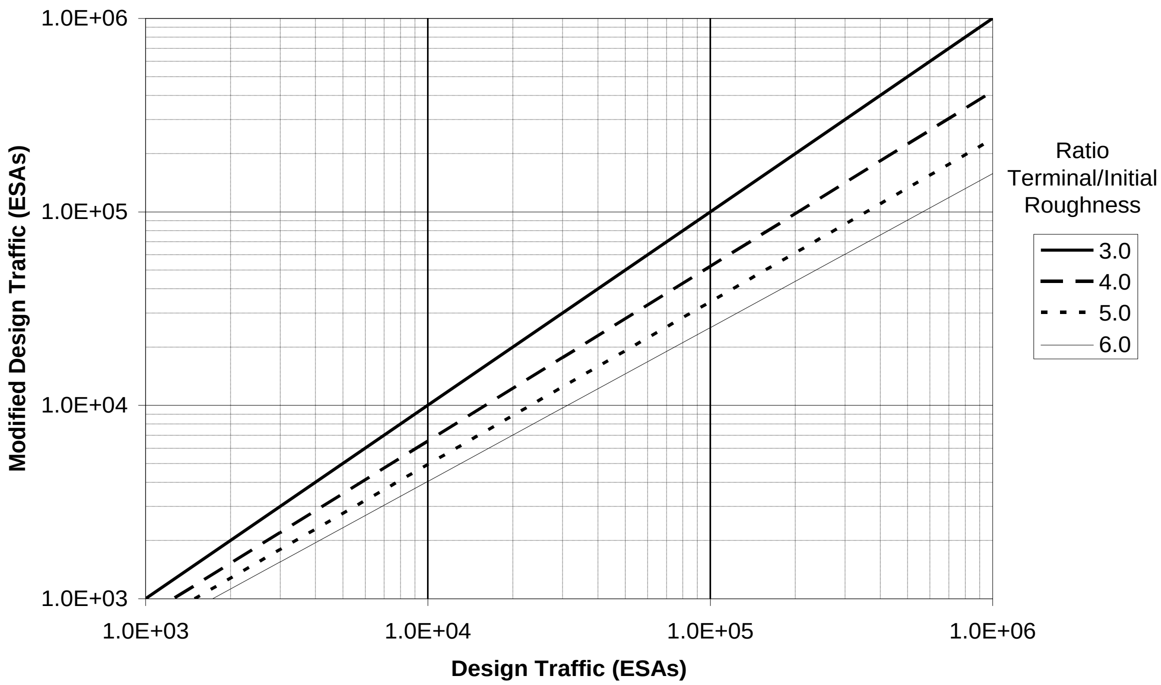
If a higher ratio of terminal to initial roughness is accepted, a thinner pavement can be designed by adjusting the design traffic using Figure 8.3.1 which is based on NAASRA (1987b) and detailed further in Austroads (2008). Such an adjustment should only be considered following a project-specific assessment of the effects 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, safety 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:

- staged construction
- special maintenance works which will be subsequently overlaid
- parking lanes
- low volume roads (for example, average daily ESA in the design lane in the year of opening < 100)
- pavements where environmental effects dictate performance, and
- temporary connections.

Figure 8.3.1 – Modified design traffic for an increased terminal roughness condition



8.3.2 Pavement Composition

Addition

Guidance on the design of pavements over lime stabilised subgrades is included in Transport and Main Roads Guideline *Structural Design Procedure for Lime Stabilised Subgrade*.

9 Design of Rigid Pavements

9.2 Pavement Types

9.2.2 Subbase Types

Difference

Due to its proven ability to provide uniform support and erosion resistance, Transport and Main Roads has typically adopted lean-mix concrete subbase, even at traffic levels less than 1 x 10^7 HVAG. Transport and Main Roads 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 specifications.

In tunnels, project-specific requirements are typically required.

9.2.3 Wearing Surface

Addition

Where the concrete base also functions as the pavement surfacing, diamond grinding may be required to meet surface property requirements.

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 affecting the concrete base.

9.3 Factors used in Thickness Determination

9.3.1 Strength of Subgrade

Addition

Where the subgrade design CBR is less than 2%, the treatments detailed in Section 5.9 should first be applied, and a presumptive design CBR of 2% is then adopted in the determination of the equivalent subgrade design strength.

For concrete pavements with design traffic of 1000 ESA/day or more at opening, the improved layer (and any underlying layers) is typically designed to achieve an equivalent subgrade design strength of at least 5% (determined using Equation 55 of AGPT02).

This may be achieved by increasing the thickness of the improved layer, and/or including additional select fill or unbound granular material beneath the improved layer.

9.4 Base Thickness Design

9.4.1 General

Addition

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 affect 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.

9.4.3 Minimum Base Thickness

Addition

Conformance with the minimum base thickness in Table 9.7 of AGPT02 is to be assessed after addition of 10 mm construction tolerance to the calculated design thickness. The additional grinding / milling tolerance should be added to the minimum base thickness.

10 Economic Comparison of Designs

10.1 General

Addition

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

Addition

An analysis period of 40 years is typically adopted by Transport and Main Roads.

11 Implementation of Design and Collection of Feedback

11.2 Collection of Feedback

11.2.1 Need

Addition

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

Addition

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

Addition

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 technical specifications be developed. These technical specifications 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.

Refer to the Transport and Main Roads *Western Queensland Best Practice Guidelines* for further information.

12.6.2 Cemented Materials

Addition

Where non-standard unbound materials (such as Type 4) are incorporated into heavily bound (cemented) 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.

Refer to the Transport and Main Roads *Western Queensland Best Practice Guidelines* for further information.

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Appendices

Appendix E Characteristics of Traffic at Selected WIM sites

E.1 Introduction

New

This appendix provides guidance on the selection and derivation of Traffic Load Distributions (TLDs) for use in pavement design. While TLDs are readily available from Weigh-In-Motion (WIM) data, there is a limited number of WIM sites in Queensland; hence, in many cases, assumptions will be required to select or derive a TLD so that pavement designs can be undertaken.

One of the key features of this appendix is the introduction of an analytical method that combines vehicle class-specific TLDs with classified vehicle counts (or estimates) for the project site. The Austroads 12-bin classification system is adopted in this appendix, as detailed in Table 7.1 of AGPT02.

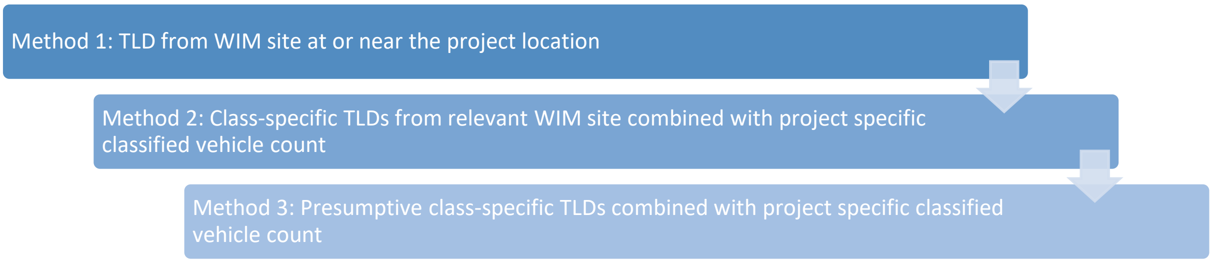
A spreadsheet that accompanies this appendix is available from https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Pavement-design-supplement.

E.2 Methods for Selecting or Deriving TLDs for Pavement Design

New

This appendix describes a hierarchy of methods for selecting or deriving TLDs, as shown in Figure E.2.

Figure E.2 – Hierarchy for selecting TLDs



The highest level of confidence is expected at the top of the hierarchy, with confidence reducing down the hierarchy. A method commensurate with the importance of the project, availability of relevant data, and resources available for data collection should be adopted.

The methods in this appendix are based on the use of data for existing heavy vehicles. Where future changes are expected, such as changes to axle loads and/or proportions of vehicles within each vehicle class, the procedures should be tailored to the specific circumstances.

It is typical practice to impose an upper limit on the loads determined from WIM measurements to remove small proportions of potentially spurious values that can have a disproportionate effect on pavement designs. The method for adjusting TLDs to remove these values is detailed in Section E.6.

The methods for selecting or deriving a TLD are detailed in the following sections.

E.3 Method 1: TLD from WIM Site at or near the Project Location

<u>New</u>

A TLD from the project site generally provides the highest level of confidence. This data should be used where there is an existing WIM site at or near the project location, or where a temporary WIM site is used to collect data for the project.

This method is also suitable where there is no WIM data from the project location, but the mix of traffic (vehicle types and loads) at the project location is similar to that at a selected WIM site.

TLDs from Transport and Main Roads WIM sites are available from TSDM (refer to Section 7.4.4). These TLDs should be adjusted using the method detailed in Section E.6.

When Method 1 is selected, a more advanced analysis of the WIM site data may be undertaken in some cases. Where a more advanced analysis is to be undertaken, designers are referred to the additional notes on Method 1 in Section E.7.

E.4 Method 2: Class-specific TLDs from Relevant WIM Site Combined with Project-specific Classified Vehicle Count

<u>New</u>

This method should be used where there is no WIM site located at or near the project. This method requires the following data:

- classified vehicle count (or estimates) at or near the project, and
- class-specific TLDs from a relevant WIM site.

In this method, 10 class-specific TLDs are required, comprising one TLD for each vehicle class from Class 3 to Class 12. These class-specific TLDs are combined at the proportions determined from the classified vehicle count to provide an overall TLD for use in pavement design calculations.

The WIM site considered most relevant to the project location should be selected.

The spreadsheet that accompanies this appendix includes a list of Transport and Main Roads WIM sites, and class-specific TLDs for each site. The spreadsheet can be used to derive an overall TLD by combining class-specific TLDs at the classified vehicle count proportions.

E.5 Method 3: Presumptive Class-specific TLDs Combined with Project-specific Classified Vehicle Count

<u>New</u>

This method is identical to Method 2 described in Section E.4, except it uses presumptive class-specific TLDs rather than values from a relevant WIM site.

This method provides the lowest level of confidence and generally should only be used for low-risk sites and/or where no reasonable alternative option is available. The designer should consider the suitability of this method, noting that specific site characteristics may deem this method unsuitable; for example, the presumptive class-specific TLDs may not be suitable for sites with a high proportion of loaded cattle, quarry or mine haulage vehicles.

This method requires the following data:

- classified vehicle count (or estimates) at or near the project, and
- presumptive class-specific TLDs.

The spreadsheet that accompanies this appendix includes presumptive class-specific TLDs which have been derived from an analysis of Queensland WIM data.

To improve the confidence in the use of Method 3, Transport and Main Roads Districts and their design consultants should use local information to develop presumptive class-specific TLDs for use on specific routes in their local areas.

E.6 Upper Limit on WIM Loads

<u>*New*</u>

Small proportions of spurious loads are typically removed from TLDs as these loads can have a disproportionate effect on pavement designs. The procedure for removal of spurious loads is only intended for limited data removal (up to a few percent of HVAGs), otherwise further, more detailed analysis of the WIM data is needed to validate the data before it is used in pavement design.

HVAG proportions for loads that are greater than the loads listed in Table E.6 are typically removed. The remaining HVAG proportions in the TLD should then be increased so that, for each HVAG type, the sum of the remaining proportions does not change from its original value.

Table E.6 – Upper limit on WIM loads

HVAG Type	Upper Limit on WIM Load (kN)
SAST	90
SADT	180
TAST	170
TADT	330
TRDT	400
QADT	480

E.7 Additional Notes on Method 1

<u>*New*</u>

When adopting Method 1, pavement designers should recognise that the definition of heavy vehicles used at Transport and Main Roads permanent WIM sites differs from the definition used in AGPT02 for calculating pavement design traffic.

AGPT02 defines heavy vehicles based on vehicle classification, where all Class 3 and above vehicles are considered to be heavy vehicles. This definition is typically used to quantify the percentage of heavy vehicles (%HV) used to estimate the pavement design traffic (N_{DT}).

Conversely, at Transport and Main Roads, permanent WIM sites heavy vehicles are defined as those with a gross mass of 4.5 tonnes or above, and data for vehicles with gross mass less than 4.5 tonnes is not captured; hence, use of a TLD from a WIM site (which ignores vehicles less than 4.5 tonnes) together with the %HV from a classified vehicle count (which does include vehicles less than 4.5 tonnes) will usually lead to overestimation of the pavement design traffic. This overestimation may be accepted or may be corrected for. Where it is decided to correct for the overestimation, the procedure detailed in Method 2 should be followed.

Appendix L Examples of Use of the Mechanistic-Empirical Procedure for Flexible Pavements

Addition

This appendix gives examples of the design of the following flexible pavement types:

- asphalt over lightly bound base pavement (ALBB), and
- full depth asphalt pavement with lightly bound improved layer and EME2 base.

L.4 Asphalt over lightly bound base pavement (ALBB)

New

The following design parameters are used:

- subgrade design CBR = 5%
- design traffic for 20 year design period = 2.0 x 10^7 HVAG or 1.4 x 10^7 ESA
- design traffic at opening = 1433 ESA/day
- traffic load distribution (TLD) = example distribution given in Appendix G of AGPT02
- Weighted Mean Annual Pavement Temperature of 32°C, and
- design heavy vehicle operating speed of 80 km/h.

Step 1 – Selection of candidate pavement structure

Using tables 2.2.1, 2.2.10(b) and 6.5.10 for guidance, the selected pavement composition is as shown in Table L.4(a).

Table L.4(a) – Candidate pavement: asphalt over lightly bound base pavement (ALBB)

Course	Description	Thickness
Surfacing	Asphalt SMA14	50 mm
Prime and seal	Prime plus seal	–
Base	Lightly bound base	To be determined
Subbase	Lightly bound subbase	150 mm
Subgrade	Design CBR 5%	Semi-infinite

Step 2 – Asphalt characterisation

SMA14

$E_V = E_H = 1300\ MPa$ from (Table 6.5.7(a))

Step 3 – Subgrade characterisation

Design CBR = 5%

$E_V = 50\ MPa\ (10\ \times\ CBR)$

$E_H = 25\ MPa\ (0.5\ \times\ E_V)$

$v_V = v_H = 0.45$

Step 4 – Subbase characterisation

From Table 6.8(a), the maximum vertical modulus of the lightly bound subbase due to overlying bound and lightly bound materials is between 430 MPa and 600 MPa (as the overlying base thickness is unknown at this stage, the actual maximum value cannot be determined until Step 8).

From Table 6.8(b), the maximum vertical modulus of the lightly bound subbase due to underlying support conditions is 240 MPa (using a design modulus of 50 MPa for the underlying support as determined in Step 3).

Therefore:

$E_{V\ subbase} = 240\ MPa$ (the minimum value from tables 6.8(a) and 6.8(b))

$E_{H\ subbase} = 120\ MPa\ (0.5\ \times\ E_{V\ subbase})$

$v_V = v_H = 0.35$

No sublayering as it is a lightly bound material.

The vertical modulus of the lightly bound subbase satisfies the requirement in Section 8.2.8 that the minimum support below lightly bound base is 150 MPa.

Step 5 – Base characterisation

From Table 6.8(a), the maximum vertical modulus of the lightly bound base due to the overlying SMA (50 mm thick and 1300 MPa from Step 2) is 600 MPa.

From Table 6.8(b), the maximum vertical modulus of the lightly bound base due to underlying support conditions is 600 MPa (using a design modulus of 240 MPa for the underlying support as determined in Step 4).

Therefore:

$E_{V\ base} = 600\ MPa$ (the minimum value from tables 6.8(a) and 6.8(b))

$E_{H\ base} = 300\ MPa\ (0.5\ \times\ E_{V\ base})$

$v_V = v_H = 0.35$

No sublayering as it is a lightly bound material.

Step 6 – Mechanistic-empirical modelling

Fatigue of the asphalt surfacing need not be considered as the pavement structure has been selected according to Table 6.5.10; therefore, the pavement thickness is determined by only considering rutting and shape loss in the subgrade.

Using CIRCLY, the required thickness of the lightly bound base is calculated to be 165 mm (rounded up to nearest 5 mm) to ensure the subgrade CDF ≤ 1.00.

A construction tolerance (refer Section 8.1) of 20 mm is added to this to give a required base thickness of 185 mm.

Step 7 – Minimum lightly bound base thickness

The minimum lightly bound base thickness to inhibit macro-cracking is determined from Figure 8.2.9.

Chart inputs:

Design traffic (DESA) = 1.4 x 10^7 ESA

$E_{V\ top} = E_{V\ subbase} = 240\ MPa$ (the support below the base)

From the equation in Figure 8.2.9, the minimum base thickness t_{min} = 245 mm.

As detailed in Section 8.2.9, the minimum base thickness from Figure 8.2.9 may be reduced by the thickness of any overlying asphalt; however, the lightly bound base thickness is not to be reduced to less than 200 mm. Additionally, no further construction tolerance needs to be added to the thickness determined from Figure 8.2.9.

In this case, there is 50 mm of overlying asphalt so the minimum base thickness can be reduced from 245 mm to 200 mm.

As this minimum base thickness (200 mm) exceeds the thickness determined in Step 6 (185 mm), the minimum base thickness of 200 mm is adopted.

Step 8 – Check subbase and base characterisation still applicable

In Step 4, the maximum vertical modulus of the lightly bound subbase considering overlying bound and lightly bound materials could not be determined as the base thickness was unknown. The base thickness from Step 7 can now be used to check that the adopted subbase modulus does not exceed the maximum value determined from Table 6.8(a).

Using a base thickness of 200 mm and vertical modulus of 600 MPa, and an asphalt thickness of 50 mm with vertical modulus of 1300 MPa:

- the total thickness of overlying bound and lightly bound material is 200 + 50 = 250 mm, and
- the equivalent modulus of this bound material from Equation 5 in AGPT02 is 710 MPa.

As a result, from Table 6.8(a), the maximum vertical design modulus is 460 MPa (determined by interpolating between 470 MPa and 430 MPa in the row for 250 mm thickness). As a design modulus for the lightly bound subbase of 240 MPa was adopted (Step 4), there is no need to amend the design in this case; however, if the maximum vertical design modulus determined here was less than that adopted in Step 4, it would be necessary to repeat steps 4 to 8.

Step 9 – Adopted pavement structure

The final pavement structure is as shown in Table L.4(b).

Table L.4(b) – Final pavement: asphalt over lightly bound base pavement (ALBB)

Course	Description	Thickness
Surfacing	Asphalt SMA14	50 mm
Prime and seal	Prime plus seal	–
Base	Lightly bound base	200 mm
Subbase	Lightly bound subbase	150 mm
Subgrade	Design CBR 5%	Semi-infinite

L.5 Full depth asphalt pavement with lightly bound improved layer and EME2 base

<u>*New*</u>

The following design parameters are used:

- subgrade design CBR = 3%
- design traffic for 30 year design period = 1.0 x 108 HVAG or 7.0 x 107 ESA
- design traffic at opening = 4046 ESA/day
- traffic load distribution (TLD) = example distribution given in Appendix G of AGPT02
- Weighted Mean Annual Pavement Temperature of 31°C
- design heavy vehicle operating speed of 80 km/h, and
- 95% reliability.

Step 1 – Selection of candidate pavement structure

Using tables 2.2.1 and 2.2.6(c) for guidance, the selected pavement composition is as shown in Table L.5(a).

Table L.5(a) – Candidate pavement: full depth asphalt pavement with EME2 base

Course	Description	Thickness
Surfacing	Asphalt OG10	30 mm
Seal	Waterproofing seal (WP-A)	–
Intermediate	Asphalt AC14H(A15E)	50 mm
Base	Asphalt EME2	To be determined
Prime and seal	Prime and seal	–
Improved layer	Lightly bound improved layer	150 mm
Fill	Earth fill CBR 7%	To be determined
Subgrade	Design CBR 3%	Semi-infinite

Step 2 – Asphalt characterisation

OG10:

$E_V = E_H = 800\ MPa$ (from Table 6.5.7(a))

AC14H(A15E):

$E_{32} = 1500\ MPa$ (at WMAPT of 32°C from Table 6.5.7(a))

Use Equation 6.5.7(a) to determine the design modulus at WMAPT of 31°C):

$E_V = E_H = \max\left(1000{,}1500 \times e^{(-0.08\times[31-32])}\right) = 1600\ MPa$ (rounded to nearest 100 MPa)

EME2:

Determine the design modulus by following steps a) to d) in Section 6.5.7.

a) Determine the temperature shift (a_T) at the design temperature (WMAPT):

   $\log_{10} a_T = a(T - T_{ref})^2 + b(T - T_{ref})$ (Equation 21 in AGPT02)

   where:

   $T_{ref} = 25°\text{C}$, $a = 7.049 \times 10^{-4}$ and $b = -0.143$ (from Table 6.5.7(b))

   $T = 31°\text{C}$ (the design WMAPT)

   therefore

   $a_T = 0.1470$

b) Determine the flexural modulus test frequency (f_{T274}) equivalent to the load frequency under a heavy vehicle travelling at the design heavy vehicle speed (V):

   $f_{T274} = \frac{V}{2\pi}$ (Equation 18 in AGPT02)

   where

   $V = 80$ km/h (design heavy vehicle operating speed)

   therefore

   $f_{T274} = 12.7$ Hz (Equation 18 in AGPT02)

c) Determine the reduced frequency (f_r) at the design temperature and heavy vehicle speed:

   $f_r = a_T \times f$ (Equation 20 in AGPT02)

   where

   $a_T = 0.1470$ (from step a)

   $f = f_{T274} = 12.7$ Hz (from step b)

   therefore

   $f_r = 1.87$ Hz

d) Determine the design flexural modulus (E*) at the design temperature and heavy vehicle speed:

   $\log_{10}|E^*| = \delta + \frac{\alpha}{1+e^{\beta+\gamma \log_{10} f_r}}$ (Equation 19 in AGPT02)

   where

   $\alpha = 2.759$, $\beta = -1.295$, $\gamma = -0.409$ and $\delta = 1.563$ (from Table 6.5.7(b))

   $f_r = 1.87$ Hz (from step c)

   therefore

   $E^* = E_V = E_H = 6000\ MPa$ (rounded to nearest 100 MPa

Step 3 – Subgrade characterisation

Existing subgrade material, design CBR = 3%

$E_V = 30\ MPa\ (10\ \times\ CBR)$

$E_H = 15\ MPa\ (0.5\ \times\ E_V)$

$v_V = v_H = 0.45$

Earth fill material, design CBR = 7%.

It is necessary to determine the thickness of CBR 7% earth fill so that the requirements of Table 8.2.8 are met. As the design includes 150 mm improved layer, to meet the requirements of Table 8.2.8 it is necessary to provide sufficient thickness of CBR 7% earth fill so that the vertical design modulus immediately below the improved layer is 70 MPa. The thickness of CBR 7% earth fill to obtain a vertical design modulus of 70 MPa in the top sublayer of the earth fill is determined using Equation 8.2.2:

$$T = \frac{150}{\log 2}\log\left(\frac{Ev\ material\ in\ top\ sublayer}{Ev\ underlying\ material}\right)$$

where

$E_{V\ material\ in\ top\ sublayer} = 70\ MPa\ (10\ \times\ CBR)$

$E_{V\ underlying\ material} = 30\ MPa$ (for the existing subgrade material

therefore

$T = 185\ mm$

$E_V = 70\ MPa$

$E_H = 35\ MPa\ (0.5\ \times\ E_V)$

$v_V = v_H = 0.45$

Step 4 – Improved layer characterisation

From Table 6.8(a), the maximum vertical modulus of the lightly bound improved layer due to overlying bound material is between 430 MPa and 600 MPa (as the overlying EME2 base thickness is unknown at this stage, the actual maximum value cannot be determined until Step 6).

From Table 6.8(b), the maximum vertical modulus of the lightly bound improved layer due to underlying support conditions is 280 MPa (using a design modulus of 70 MPa for the underlying support as determined in Step 3).

therefore:

$E_{V\ improved\ layer} = 280\ MPa$ (the minimum value from tables 6.8(a) and 6.8(b))

$E_{H\ improved\ layer} = 140\ MPa\ (0.5\ \times\ E_{V\ improved\ layer})$

$v_V = v_H = 0.35$

No sublayering as it is a lightly bound material.

Step 5 – Mechanistic-empirical modelling

The pavement model is summarised in Table L.5(b).

Table L.5(b) – Mechanistic model: full depth asphalt pavement with EME2 base

Course	Description	Thickness (mm)	E_V (MPa)	Sublayered
Surfacing	Asphalt OG10	30	800	No
Intermediate	Asphalt AC14H(A15E)	50	1600	No
Base	Asphalt EME2	To be determined	6000	No
Improved layer	Lightly bound improved layer	150	280	No
Fill	Earth fill CBR 7%	185	70 (E_{vtop})	Yes
Subgrade	Design CBR 3%	Semi-infinite	30	No

Fatigue of the asphalt base is assessed to determine the required EME2 base thickness. Fatigue of other asphalt courses and rutting and shape loss in the subgrade should also be checked but are not reported here as they do not affect the design in this case.

For the EME2 mix, fatigue is assessed using Equation 6.5.10. Using the design modulus of 6000 MPa, the fatigue constant *k* is calculated to be 2509 (input into CIRCLY as 0.002509).

Using CIRCLY, the required thickness of EME2 base is calculated to be 175 mm (rounded up to nearest 5 mm) to ensure the CDF ≤ 1.00.

A construction tolerance of 10 mm is added to this to give a required base thickness of 185 mm.

Step 6 – Check improved layer characterisation still applicable

In Step 4, the maximum vertical modulus of the lightly bound improved layer considering overlying bound materials could not be determined as the base thickness was unknown. The base thickness from Step 5 can now be used to check that the adopted lightly bound improved layer modulus does not exceed the maximum value determined from Table 6.8(a):

- the total thickness of overlying bound material (asphalt in this case) is 30 + 50 + 185 = 265 mm, and
- the equivalent modulus of this bound material from Equation 5 in AGPT02 is 4019 MPa.

Using Table 6.8(a), the maximum vertical design modulus is 430 MPa. As a design modulus for the lightly bound improved layer of 280 MPa was adopted (Step 4), there is no need to amend the design in this case; however, if the maximum vertical design modulus determined here was less than that adopted in Step 4, it would be necessary to repeat steps 4 to 6.

Step 7 – Adopted pavement structure

The final pavement structure is as shown in Table L.5(c).

Table L.5(c) – Final pavement: full depth asphalt pavement with EME2 base

Course	Description	Thickness
Surfacing	Asphalt OG10	30 mm
Seal	Waterproofing seal (WP-A)	–
Intermediate	Asphalt AC14H(A15E)	50 mm
Base	Asphalt EME2	185 mm
Prime and seal	Prime and seal	–
Improved layer	Lightly bound improved layer	150 mm
Fill	Earth fill CBR 7%	185 mm
Subgrade	Design CBR 3%	Semi-infinite