

Roads

Master Specification

RD-PV-D2 Pavement Rehabilitation Design

Document Information

K Net Number:	13585674
Document Version:	2
Document Date:	24/09/2019
Responsible Officer:	Prc Pavement Eng.

DEPARTMENT OF
PLANNING, TRANSPORT
AND INFRASTRUCTURE



Government of South Australia
Department of Planning,
Transport and Infrastructure

Document Amendment Record

Version	Change Description	Date	Endorsement record (KNet ref.)
1	Initial issue	28/06/19	
2	Formatting for publishing	24/09/19	

Document Management

This document is the Property of the Department of Planning Transport and Infrastructure (DPTI) and contains information that is confidential to DPTI. It must not be copied or reproduced in any way without the written consent of DPTI. This is a controlled document and it will be updated and reissued as approved changes are made.

Contents

Contents	3
RD-PV-D2 Pavement Rehabilitation Design	4
1 Introduction	4
2 Project Definition	4
3 Pavement Data and Inspection	4
4 Investigative Testing	7
5 Selection of Treatments	9
6 Thickness Design of Structural Overlays	18
7 Thickness Design of Stabilisation Treatments	25
8 Economic Comparison of Alternative Treatments	25
9 References	26
10 Appendix 1: Examples of Structural Overlay Calculations	28
11 Appendix 2: Plane and Reinstatement Thickness Design Worksheet	31

RD-PV-D2 Pavement Rehabilitation Design

1 Introduction

- 1.1 This document is intended to act as a supplement to the Austroads publication Guide to Pavement Technology Part 5 Pavement Evaluation and Treatment Design (2011a). The Supplement reflects current knowledge and experience of the performance of South Australian pavements. In addition, it draws on the experience of other state road authorities as documented in their Guide supplements.
- 1.2 This Supplement refers to pavements within three South Australian traffic loading categories, comprising lightly, moderately and heavily trafficked roads. The following guidance is given on the load intensities of these categories:
- Lightly trafficked roads have design traffic loadings less than 1×10^5 ESA;
 - Moderately trafficked roads have design traffic loadings greater than or equal to 1×10^5 ESA and less than 5×10^6 ESA; and
 - Heavily trafficked roads have design traffic loadings greater than or equal to 5×10^6 ESA.
- 1.3 Construction of pavement rehabilitation treatments shall comply with the DPTI Master Specification for Roadworks.

2 Project Definition

Acceptable Risk

- 2.1 The long-term performance characteristics of multi-cemented layers have yet to be fully established in South Australia. Specifically, configurations with thick asphalt over 2 cemented layers placed on the same day, have been constructed in and around Adelaide since about 1989, and are yet to reach 20 years' service life. While it is known that sound structural performance is critically dependent on the continued bonding of cemented layers, how this may deteriorate with load repetitions and environmental factors is not well understood. It is considered reasonable to assume that the risk of premature distress and the extent and severity of distress increases significantly with higher traffic loadings.
- 2.2 Apart from the chart-based approach to overlay design (Section 6.2, Austroads 2011a), the design of flexible pavement strengthening treatments utilises procedures similar to the mechanistic design of new flexible pavements. The method allows pavements to be designed to a desired reliability level of outlasting the design traffic. Minimum project reliability levels to be used for the design of rehabilitation strengthening treatments on DPTI roads are shown in Table RD-PV-D2 2-1.

Table RD-PV-D2 2-1 Minimum project reliability levels for rehabilitation treatments

Road Class	Project Reliability (%)
Freeways	95
Highways and Main Roads	90
Minor Roads	85

3 Pavement Data and Inspection

General

- 3.1 The TIMS intranet web site contains a number of interactive road maps and databases from which the following information for the DPTI road network may be obtained:
- Pavement condition (roughness, rutting, texture, and cracking)
 - Pavement age and type
 - Surfacing age and type
 - Lane configuration and lane width

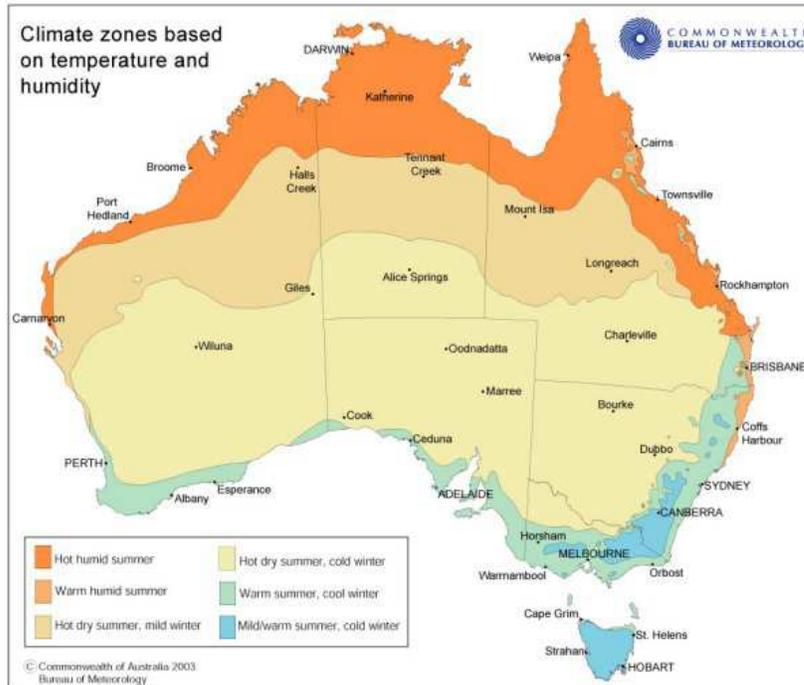
- e) Road Features File: running distance location of significant features (e.g. side streets, bridges, culverts, speed limit signs, maintenance marker pegs)
- f) Traffic information: AADT, percentage of commercial or heavy vehicles, weigh-in-motion reports
- g) Soil reactivity

Historical Data

Climatic Conditions

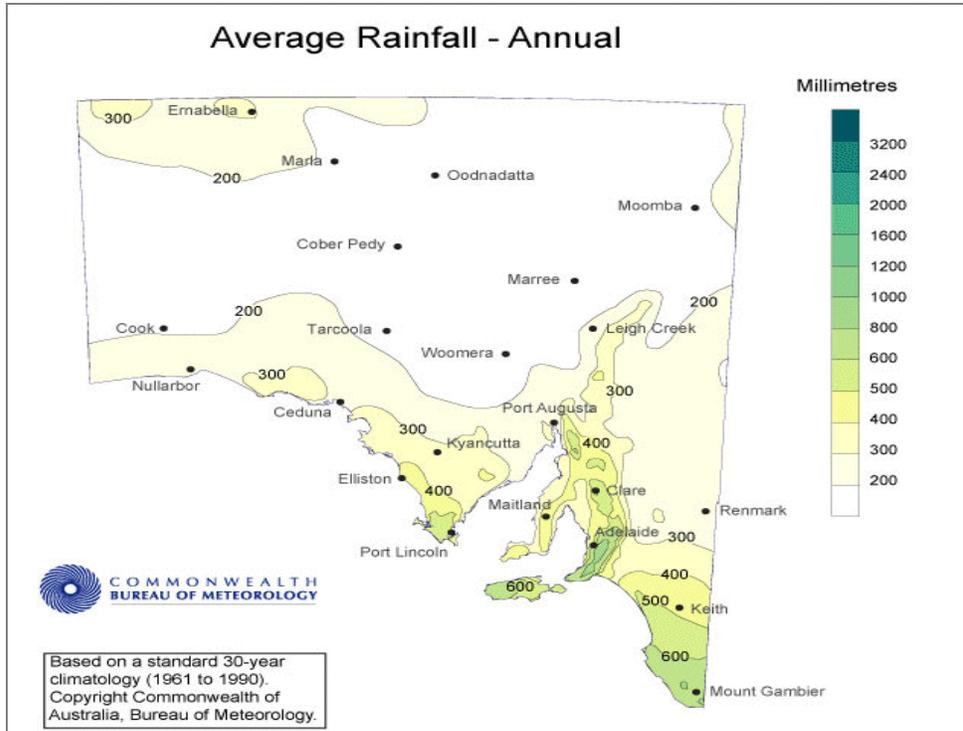
- 3.2 Australian climatic zones based on temperature and humidity are indicated in Figure RD-PV-D2 3-1 and the average rainfall and evaporation values are shown in Figure RD-PV-D2 3-2 and Figure RD-PV-D2 3-3 respectively.

Figure RD-PV-D2 3-1 Australian Climatic Zones



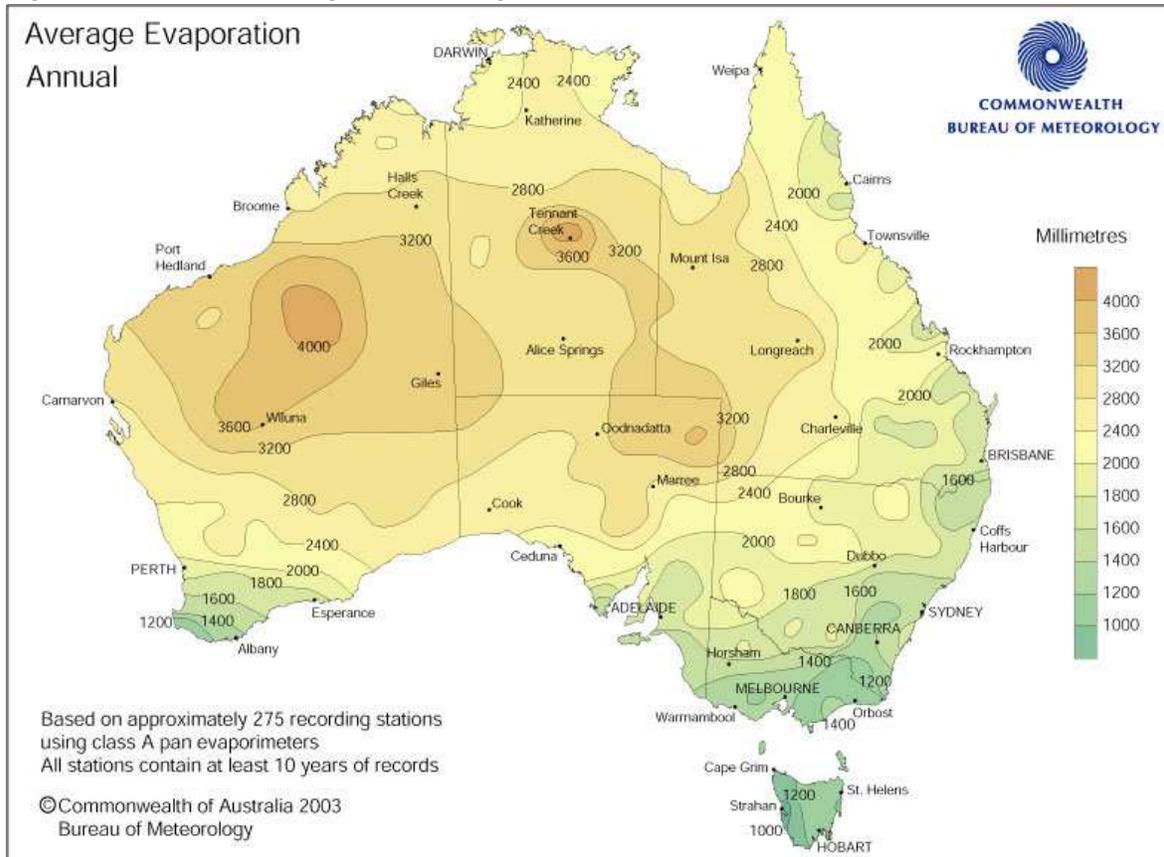
Source: Commonwealth Bureau of Meteorology 2003, copyright Commonwealth of Australia reproduced by permission.
(www.bom.gov.au/climate/averages)

Figure RD-PV-D2 3-2 Average Annual Rainfalls for South Australia]



Source: Commonwealth Bureau of Meteorology 2001, copyright Commonwealth of Australia reproduced by permission. (www.bom.gov.au/climate/averages)

Figure RD-PV-D2 3-3 Average Annual Evaporations



Source: Commonwealth Bureau of Meteorology 2003, copyright Commonwealth of Australia reproduced by permission.
(www.bom.gov.au/climate/averages)

- 3.3 Most of the coastal areas of South Australia experience warm summers and cool winters, while the more scarcely populated regions are generally within the Hot, Dry Summer, Cold Winter zone.
- 3.4 South Australia is relatively dry compared to other Australian states and typically has low rainfall and high evaporation rates. Except for the south east corner of South Australia, the remainder is wholly arid or semi-arid. The south east and Adelaide regions, have dry summers with median annual rainfall of 400 – 800 mm, mostly in the winter months.

4 Investigative Testing

Skid Resistance / Surface Texture

Skid Resistance and Texture Depth Data

- 4.1 DPTI uses the Griptester to evaluate skid resistance. Parts 5F and 5G of the Austroads Guide to Asset Management describe the Griptester and its method of operation.

Using Skid Resistance and Texture Depth Data

- 4.2 DPTI recommended investigatory levels of skid resistance as measured with the Griptester are given in Table RD-PV-D2 4-1.

Table RD-PV-D2 4-1 Recommended Investigatory Skid Resistance Levels

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

Note. The approximate conversion between British Pendulum No. and the Grip No. is Grip No.= 0.01x BP

- 4.3 Surface texture has an important effect on the friction available to high speed vehicles, particularly in wet conditions (Austroads 2005), and Table RD-PV-D2 4-2 provides recommended investigatory levels. As the speed of a vehicle increases, it becomes more difficult to displace water from beneath the tyre until in the limiting case, the tyre hydroplanes and braking and directional control are completely lost.
- 4.4 The reduction in skid resistance resulting from increased speed on wet surfaces is minimised when there are good drainage paths for the water. These are normally provided by both the tyre tread pattern and the surface texture of the road.

Table RD-PV-D2 4-2 Recommended Investigatory Surface Texture Levels

Road Type	Texture Depth in Wheelpath (mm) (Sand Patch Equivalent) Sand Requirements
Freeways and other high class facilities with free-flowing traffic conditions	0.4
Highways (>80 km/h)	0.6
Other main roads subject to stopping and turning (<80 km/h)	0.6
Other local roads (sealed)	0.4

Surface Deflection of Flexible Pavements

Methods of Testing

- 4.5 The Deflectograph is usually the preferred method of deflection testing pavements that have been scheduled for periodic maintenance, as the data is cost-effectively collected at closely spaced

intervals (about 4 m) along both wheel paths. However, the Falling Weight Deflectometer (FWD) may be more suitable in the following situations:

- a) Asphalt overlays for strengthening pavements with cemented materials or a design traffic loading exceeding 10^7 ESA are designed using the General Mechanistic Procedures (GMP). For these projects the Deflectograph can be used to provide comprehensive information about the distribution of pavement strength along the project. Further testing with the FWD could be undertaken at selected locations for use in back-analysis procedures to better understand the past performance and assist in the detailed design of strengthening treatments.
- b) Pavements with thick and stiff bound materials often produce very low Deflectograph deflections. FWD deflection testing at a higher contact stress of 1132 kPa (80 kN) in addition to the standard 566 kPa (40 kN) loading, may reduce deflection measurement errors and improve moduli estimates from back-analysis.
- c) Projects which are short in length or are difficult to access with the Deflectograph.
- d) Testing of unsealed pavements, including unsealed shoulders.

Selection of Test Sites

- 4.6 For projects where FWD deflections are not complemented by detailed Deflectograph data, the spacing of individual test sites is arranged so that the general variability or deflection trends can be identified. Typically for projects less than 2 km in length, FWD measurements are taken at 10 m spacings in the outer wheel path of each test lane. For projects greater than 2 lane km in length, the spacing of test points may be increased to 20 – 50 m. When testing undivided rural roads in both directions, consideration should be given to staggering the test locations.

Pavement Composition and Material Quality

Pavement Composition and Material Quality Data

- 4.7 For existing asphalt surfaced pavements where the proposed treatment is an asphalt overlay or plane and reinstatement, the existing asphalt is usually cored at 250 m maximum spacing in the outer wheel path to determine the thickness and quality of the asphalt layers. In addition, one or two large diameter bore holes (eg 300mm) should be drilled through the full pavement depth (where there are no underground services) to confirm the existing pavement composition, enable sampling of pavement and subgrade materials for laboratory testing of gradings and soil constants, and for insitu subgrade strength testing by Dynamic Cone Penetrometer (DCP).
- 4.8 It is often useful to compare areas of sound and distressed pavement to determine whether variations in the pavement composition (e.g. layer thickness, quality of pavement materials or subgrade conditions) have been the primary cause of the difference in performance.
- 4.9 For projects where insitu stabilisation is a treatment option requiring detailed design, more extensive pavement investigation and material sampling should be undertaken. Pits are commonly excavated at 200 – 500 m spacings to enable the determination of:
- a) Type, thickness, quality, and variability of each pavement material;
 - b) Layers in which rutting and/or cracking is significant;
 - c) Other deficiencies or factors affecting structural performance;
 - d) Subgrade properties (moisture, gradings, soil constants, DCP strength);
 - e) The laboratory mix design of the stabilisation treatment.

Using Pavement Composition and Material Quality Data

- 4.10 In assessing the quality of existing granular materials, laboratory test properties should be compared to the pavement material requirements of RD-PV-S1 “Supply of Pavement Materials”.

5 Selection of Treatments

Treatments to Improve Drainage

General

- 5.1 Due to the relatively low rainfall and high evaporation rates in South Australia, sub-surface drains are generally not provided for pavements except in areas where definite water seepage is identified. These situations include hillside cuttings and areas where the median or verge irrigation may lead to water ingressing the pavement.
- 5.2 Ground water site investigations should preferably be undertaken during the wetter months as these flows may be seasonal. Where the site investigation occurs outside the wettest period and seepage observations are inconclusive, sub-surface drains may need to be installed in some high risk areas as a precautionary measure.

Treatments for Flexible Pavements

Treatments for Surfacing Distress – Seals

- 5.3 The selection of an appropriate sprayed seal as a rehabilitation treatment depends primarily on the traffic volume and composition, and the condition of the existing pavement (including strength, cracking, texture, site location).
- 5.4 Where the pavement is showing only age related signs of distress such as plucking or stripping of aggregate, a C170 binder may be adequate. However, over cracked pavements or in areas of high stress a polymer modified binder (PMB) may be needed. Guidance on the selection of the most appropriate PMB is provided in Austroads (2008) and Austroads (2009b).
- 5.5 If the purpose of a PMB is to minimise the occurrence of reflection cracking a minimum binder application rate of 1.6 l/m² is recommended. An aggregate size should be selected to achieve this while still providing adequate levels of texture. This may involve an iterative process using the Austroads seal design procedures (Austroads 2009b) to determine binder rates for various aggregate sizes.
- 5.6 For severely cracked pavements, particularly under heavy traffic (>15% HV) the use of a PMB alone may not be sufficient to waterproof the pavement. In these situations, a double (14/7 or 16/7) geotextile seal should be used, subject to the following conditions:
 - a) They must not be placed in areas subject to high shear forces such as intersections, tight corners and steep climbing lanes.
 - b) Application shall be restricted to the months of November to March inclusive.
- 5.7 Where a granular overlay is being constructed under traffic, it is usually not possible to prime and seal the pavement, and a primer seal would be required. It is advisable to leave cutback primer seals exposed for 6 – 12 months, ensuring they are trafficked for 3 months between October and March, before placing a sprayed seal or asphalt surfacing less than 100 mm thick (refer Table 3.2 DPTI 2014). Where it is not feasible to comply with the above time constraints an emulsion primer binder may be used, in which case the final surfacing can be applied after the emulsion primer seal has been subjected to several weeks of trafficking in hot weather.
- 5.8 Further direction is provided in Sections 3.15 and 8.3.5 (DPTI 2014), the Guide to Pavement Technology Part 3 Pavement Surfacing (Austroads 2009a), Guide to Pavement Technology Part 4K Seals (Austroads 2009b), and the Sprayed Sealing Guide (Austroads 2004).

SAM seal and SAMI treatment

- 5.9 A strain alleviating membrane interlayer (SAMI), generally size 10 mm S25E, shall be applied on top of cemented material subbase layers under an asphalt base to inhibit reflection cracking. The thickness of a SAMI shall not be included in the design pavement thickness.

Treatments for Surfacing Distress – Asphalt Works

- 5.10 Table RD-PV-D2 5-1 provides guidance for the selection of asphalt surfacing types. Table RD-PV-D2 5-3 lists the allowable range of layer thicknesses according to mix size.
- 5.11 Asphalt overlays in urban areas are typically 35 - 40 mm in thickness and normally require edge planing of the existing asphalt so that the subsequent overlay can be matched to the level of the concrete channel.
- 5.12 An A35P modified binder (and in some situations A10E or A15E) is generally used in these thin asphalt overlay resurfacings because of their superior performance compared to conventional binders.

Open graded asphalt surfacing

- 5.13 As indicated in Table RD-PV-D2 5-1 open graded asphalt (OGA) used by DPTI is required to include A15E (or A35P) binder to extend the service life and to enhance structural integrity and stone retention.
- 5.14 Since an OGA layer is not waterproof, a S25E (1.8 – 2.0 l/m²) SAMI or C170 sprayed seal is required under OGA surfacings.
- 5.15 In most situations OGA surfacings are terminated at the edge of the concrete channel and not extended to the kerb face. If minimising the edge drop is of high priority for the safety of cyclists etc, then edge planing of the existing asphalt to a depth of 10 mm prior to overlay is an acceptable option. The effect of the remaining level difference can be further reduced by “rolling over” the edge of the OGA overlay.
- 5.16 RD-BP-C3 “Construction of Asphalt Pavement” requires that OGA not be placed between April and October inclusive, because of the reduced initial skid resistance on freshly placed mixes.

Table RD-PV-D2 5-1 Guide To The Selection Of Asphalt Types⁽³⁾

Course ⁽⁴⁾	General Mix Designations ⁽⁵⁾	Binder Class	Target Mix Design Air Voids (%)	Applications/Comments	
Wearing	Heavy Duty Wearing Course	AC10M	A5E	4.0	Motorway, significant grades, approaches to heavily trafficked signalised Intersections (50-150m, but consider level of saturation), Roundabouts, Bus Lanes, Bus Stops.
	Medium Duty Wearing Course	AC10M	A15E	4.0	Other signalised and non-signalised Intersections, mid-block zones.
		OG14	A15E	20	Non-signalised Intersections, mid-block zones, no high horizontal shear locations.
		SMA10	A5E ⁽¹⁾	3.5	Non-signalised Intersections, mid-block zones.
Structural	Modified Intermediate Course	AC10M, AC14M	A5E ⁽¹⁾	4.0	Motorway, significant grades, approaches to heavily trafficked signalised Intersections, Roundabouts, Bus Lanes, Bus Stops. AC10M required where wearing course delayed.
	Standard Intermediate Course	AC10M, AC14M	C320	4.0	Other Intersections, mid-block zones. AC10M required where wearing course delayed.
		AC14M	C320	4.0	Normal Works.
	Base Course	AC14HB	C320	2.5	High binder fatigue resistant bottom asphalt layer for full depth asphalt configurations.
Special Surfacing	Medium Duty Thin Flexible	SMA7	A15E	3.5	Texture, Noise Reduction, no high horizontal shear locations.
		OG10	A15E	20	Texture, Noise & Spray Reduction, no high horizontal shear locations
	Footpaths, Bikeways, Crossovers and Carparks and Sport Recreation Courts	FineAC7L	C170 ⁽²⁾	4.0	Light maintenance vehicle trafficking only, minimal use by heavy vehicles.
	Carparks and Local Roads	FineAC10L	C170 ⁽²⁾	4.0	Medium to heavy maintenance vehicles (mainly rigids), minimal large articulated heavy vehicles.

(1) A15E may also be approved.

(2) C320 may also be approved.

(3) This table reflects asphalt mixes and binders currently available in the SA market. There are other alternatives available in the Austroads Guide series which are also acceptable, following validation for SA use.

(4) Table RD-PV-D2 10-1 provides guidance on Course descriptions and position within the pavement structure.

(5) DPTI asphalt mix size designations are based on ensuring there is 10% of this nominal size material within the mix. (e.g. AC10 has a minimum 10% material retained on 9.5 mm sieve and AC14 has minimum 10% retained on 14mm sieve etc.) These may be coarser than other typical interstate mixes.

Stone mastic asphalt

- 5.17 Generally size 10 mm stone mastic asphalt (SMA) is used as a surfacing layer, of 35 or 40 mm thickness, and incorporating A35P binder.
- 5.18 To inhibit ingress of surface water to the pavement, a size 7 or 10 mm sprayed seal or SAMI is usually required under SMA surfacings.
- 5.19 RD-BP-C3 "Construction of Asphalt Pavement" requires that SMA not be placed between April and October inclusive, because of the reduced initial skid resistance on freshly placed mixes.

Ultra thin asphalt surfacings

- 5.20 Ultra thin surfaces are generally only used by DPTI on lightly to moderately trafficked roads (of less than 5×10^6 ESA) that are determined to be structurally adequate for the expected future traffic loadings.

Treatments for Strengthening Pavements

Heavy patching

- 5.21 The thickness design of heavy asphalt patching or plane and reinstatement (P&R) of flexible pavements is described in Section 6.7 of the Supplement.
- 5.22 The minimum width of heavy patching is generally 2.8m to allow the asphalt paver onto the planed surface. It is usual to extend patching to the full lane width so that construction joints can be placed on lane lines away from wheelpaths. Unmarked parking areas within wide kerbside lanes are often excluded because of the reduced loadings. Narrow patching such as half lane widths are acceptable when planing depths are less than 80mm (preferably about 50mm) and the paver can straddle the shallow excavation while placing the asphalt reinstatement.
- 5.23 The minimum practical length of asphalt reinstatement is 5m. A prime or heavy tack coat should be applied to all horizontal and vertical faces of the excavation to provide good bonding.

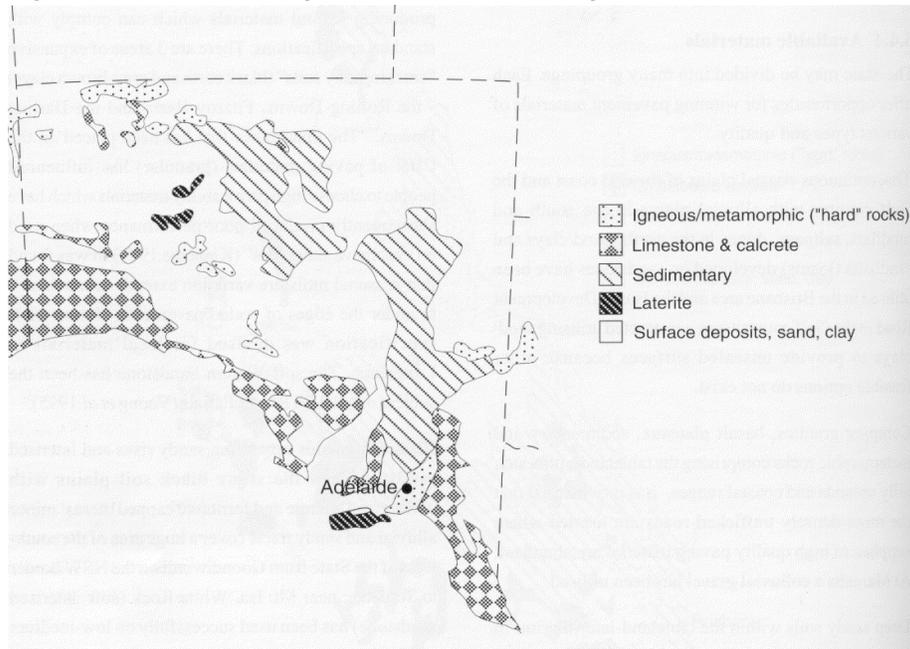
Granular overlay

- 5.24 A simplified surface rock map of South Australia is illustrated in Figure RD-PV-D2 5-1. It is apparent that hard rock sources are very limited in extent. Igneous rocks occur in some small outcrops in the central and far north-west of the state. Basalt is quarried near Mt Gambier. Metamorphic hard rocks are to be found on the Eyre Peninsula and in the Mt Lofty/Flinders Ranges. Otherwise sedimentary and superficial surface materials cover the state. Calcretes, with or without processing, are extensively used and perform satisfactorily on lightly to moderately trafficked roads. In outback areas a wide range of local materials are utilised including high gypsum content rubbles, shales, tableland stone, iron pan, river gravel and clays.
- 5.25 Further details on material availability can be found in Robinson, Oppy and Giummarra (1999), or on geological maps from Primary Industries & Resources SA.

Standard granular materials

- 5.26 The quality and strength characteristics required of granular materials depends upon the following factors and their interactions:
 - a) Traffic (volume, axle group types and loads)
 - b) Climate
 - c) Pavement configuration and drainage
 - d) Subgrade

Figure RD-PV-D2 5-1 Simplified surface rocks map of SA



- 5.27 Lightly traffic roads in dry environments can more successfully use lower quality granular materials than roads with higher traffic loadings in wet environments.
- 5.28 RD-PV-S1 "Supply of Pavement Materials" details requirements for standard granular materials comprising crushed quarry products, natural gravel, sand and recycled pavement materials. These specifications include the range of products that meet traditional grading based manufacturing tolerances, as well as those that use performance based mix design limits to deliver the required stiffness, shear strength and deformation resistance properties.
- 5.29 Specifications for higher standard Quarried Pavement Materials have recently been developed for the construction of very heavily trafficked unbound granular pavements with thin surfacings, and are designated PM1A or PM1B heavy duty materials. They provide improved stability and workability, are compacted to 100% Modified Maximum Dry Density, dried back to no greater than 60% Optimum Moisture Content, and are placed in layers not exceeding 125mm thickness. However, as their availability is limited, project specific assessment is required.
- 5.30 The general DPTI pavement material types suitable for granular overlays are summarised in Table RD-PV-D2 5-2. Size 40 mm materials are unsuitable as base layers as they tend to segregate during placement and do not provide adequate surface tightness and finish.

Table RD-PV-D2 5-2 Granular Overlay Material Types

Material Type/Class	Source	Size (mm)	Primary Usage
PM1A*, PM1B*, or PM1† (Class 1)	Quarried	20	Granular Overlay
		30	
PM1† (Class 1)	Recycled	20	Base Layer
		30	
PM2† (Class 2)	Quarried	20	Sealed or Unsealed Shoulders
		30	
		40	

* heavy duty pavement materials use only a grading based specification

† grading based or mix design specifications

Note: Recycled, heavy duty and mix design products require project-specific consideration and DPTI approval.

Non-standard granular materials

- 5.31 Marginal or non-standard granular materials should only be used after consideration of:

- a) The documented performance history of the proposed material
 - b) Costs relative to standard materials
 - c) The predicted traffic loading
 - d) The climate at the site
 - e) The moisture sensitivity of the subgrade
 - f) The quality and uniformity of the materials as shown by laboratory testing
 - g) Consequences of poor performance
 - h) Suitability and cost-effectiveness of mechanical or chemical stabilisation
- 5.32 These materials commonly have lower moduli than standard granular materials, so greater thickness is required to reduce the stresses/strains on the subgrade. However, it is not always possible to obtain equivalent performance by using thicker layers of non-standard materials.
- 5.33 Thicker pavement layers for lower moduli materials may result in the same subgrade strain as for thinner layers of standard materials; thus the extent of rutting of the subgrade is similar. However, the use of the non-standard materials may result in inferior performance due to deformation within the pavement layers under traffic loading leading to rutting and early pavement distress. The use of repeated load triaxial testing to provide the values for modulus and permanent deformation will assist in predicting the performance of non-standard materials compared to standard materials. Specialist advice should be sought in undertaking such evaluations.

In Situ Stabilisation of Granular Pavements

General

- 5.34 The key considerations in a pavement investigation where insitu stabilisation is being considered as a rehabilitation option include:
- a) The appropriateness of insitu stabilisation in terms of suitability of the construction process e.g. use of heavy vibratory rollers in residential streets may induce vibration damage to dwellings, or the use of quicklime in this situation could be extremely hazardous to residents.
 - b) The thickness, quality, type, uniformity and moisture content of the existing pavement materials to be stabilised e.g. large hard stones may cause significant wear on recycling equipment, poor mixing, compaction and finish.
 - c) The strength and variability of existing subgrade support and the ability to withstand compaction of the stabilised pavement layer should be assessed by deflection testing or direct measurement.
 - d) The presence and extent of asphalt or cement treated patches and other non-uniform material.
 - e) The presence and depth of any rock bars, public utilities and culverts.
 - f) The presence of deep patches which may slow the recycling machine and introduce wet material into the process.
 - g) Likely traffic loads and volumes.
- 5.35 If stabilisation is a preferred option for pavement rehabilitation, the following should be considered in selecting the stabilisation type:
- a) Suitability of the insitu material to the stabilisation process in terms of quantity of oversize material, whether subgrade material will be incorporated into the pavement, the requirement for additional granular material and where it will be sourced, and the change in material grading due to aggregate breakdown or layer mixing.
 - b) Future maintenance and rehabilitation implications of bound pavement in terms of re-stabilisation or overlay.
 - c) Logistics and costs of binder delivery to remote locations.
 - d) Sensitivity of stabilisation treatment performance to the support provided by the underlying pavement layers and subgrade.

- e) Sensitivity of stabilisation treatment performance to variations in depth of stabilisation.
- f) Seasonal effects on binders, such as slow setting cementitious binders that require a minimum air temperature of 20°C to effect hydration.
- g) Opportunities for staged construction e.g. using an interim granular overlay for the first 5-10 years of the design period followed by insitu stabilisation to provide satisfactory service over the remainder of the design period.

Cement and Cementitious Stabilisation

- 5.36 Laboratory testing of stabilised materials is undertaken to evaluate the compatibility and suitability of the binder in relation to the parent pavement material. Testing is generally used to characterise the material over a range of selected binders and or binder quantities. A detailed description of binder selection and mix design is presented in Austroads (2006).
- 5.37 To produce a cementitiously bound material suitable for insitu stabilisation of moderate to heavily trafficked roads, the binder content should be selected such that the minimum Unconfined Compressive Strength (UCS) is 5 MPa at 28 days. Where thin bituminous surfacings are used, a minimum 5% by mass cementitious binder is also required to ensure durability.
- 5.38 Finely graded gravels, clayey gravels, silty sands (>50% passing 0.425 mm sieve) and other materials which do not achieve significant particle interlock are not included in the definition of cemented materials as their fatigue performance would be variable and unpredictable.
- 5.39 The achievement of the specified compaction of cemented materials is essential for the development of the modulus and fatigue characteristics assumed in the design. The lower part of the cemented course is particularly critical as this is the zone in which maximum tensile strains occur. The requirement for adequate compaction limits the maximum layer thickness in these materials.
- 5.40 For single layer construction on heavily trafficked roads the maximum single layer thickness is 360 mm. The ability to obtain the required field density within the operating constraints of the construction equipment in urban areas (e.g. vibration) may reduce this maximum thickness for some projects.
- 5.41 Thickness design procedures as described in Section 7.4.

Lime Stabilisation

- 5.42 Lime stabilisation of subgrades is not a common DPTI rehabilitation treatment as there are usually a number of practical construction difficulties associated with the removal of existing pavement materials before stabilisation.
- 5.43 If lime stabilisation of subgrades is an option being considered for widenings or reconstruction, guidance on the thickness design of this treatment is provided in DPTI (2014).

Bitumen Stabilisation

Foamed bitumen

- 5.44 Laboratory testing of stabilised materials is undertaken to evaluate the compatibility and suitability of the binder in relation to the parent pavement material. Testing is generally used to characterise the material at various bitumen and supplementary binder (preferably lime) contents.
- 5.45 A detailed description of binder selection and mix design is presented in Austroads (2006). Samples are prepared using 80 cycles Gyropac at 70% OMC to determine the initial, cured, and soaked indirect tensile resilient modulus values, and the Relative Density requirements for construction assurance.
- 5.46 To produce a bituminous bound material suitable for the insitu stabilisation of moderate to heavily trafficked roads, the binder content should be selected such that:
 - a) The initial modulus, uncured and tested after compaction, exceeds 700 MPa;
 - b) The modulus M_{wet} after soaking in water for 24 hours or in a vacuum chamber for 10 minutes, is 1500 MPa or more;

- c) The ratio of the wet to dry modulus (M_{wet}/M_{dry}) ≥ 0.5 , where M_{dry} is the oven cured modulus (60oC for 3 days), and
 - d) There is a minimum 3% by mass of bitumen.
- 5.47 Finely graded gravels, clayey gravels, silty sands (>50% passing 0.425 mm sieve) and other materials that do not achieve significant particle interlock are not included in the definition of bituminous bound materials as their fatigue performance would be variable and unpredictable. Recommended particle size distribution limits are provided in Austroads (2006) Table 5.4.
- 5.48 Thickness design procedures are described in Section 7.5.

Design and Construction Considerations

New Pavement Abutting an Existing Pavement

- 5.49 In flexible pavements, construction joints introduce layer discontinuities and zones of structural weakness to the pavement. Hence longitudinal construction joints between the existing pavement and the widening should not be placed in the wheel paths, but on the lane lines or at the lane mid point. In some cases this may require the existing pavement to be trimmed back to coincide with these more lightly loaded locations, increasing the width of new work. Longitudinal reinforcement of asphalt surfacings with multilaminate tape, or paving fabric for sprayed seals, should be considered.

Shoulder Sealing

- 5.50 Shoulders provide structural support to the pavement edge. If not designed and constructed using the adjacent pavement composition, the functional purpose of the shoulder needs to be carefully considered so that appropriate materials and thicknesses are used. This is particularly important where the shoulder is sealed and may be used as a heavy vehicle climbing lane, for parking of vehicles or may be frequently trafficked on the inside edge of curves etc.
- 5.51 Shoulder sealing should be undertaken in accordance with the route strategy for the road. Where permeable shoulder materials are used it is good practice to seal the full shoulder width on the high side of superelevated curves and one-way crossfalls to minimise moisture ingress to the pavement.
- 5.52 For construction of sealed shoulders, the minimum total thickness of shoulder material shall be not less than that obtained from Figure 8.4 of the Guide to Pavement Technology Part 2 Pavement Structural Design (Austroads 2012) using a design traffic value for the shoulders of 2%-5% of the pavement design traffic value, as appropriate. Where the sealed shoulder is full lane width, an emergency stopping lane, or is likely to be frequently trafficked, up to 100% of the design traffic should be adopted. FWD deflection testing of unsealed shoulders may also be used to assess whether the shoulder needs strengthening prior to sealing.

Risk, Design Sensitivity, Construction Tolerances and Degree of Control

- 5.53 In selecting treatments, careful consideration needs to be given to the risks of premature distress of the various options. This is a critical concern for:
- a) Roads of strategic importance; and
 - b) Roads where there are no alternative routes to divert traffic during lane closures for maintenance (e.g. roundabouts, overpasses, tunnels etc).
- 5.54 Issues related to the risk of developing premature distress include:

Granular overlays

- a) Ability to construct the overlay under traffic.
- b) Potential for material to breakdown under repeated reworking and reshaping due to trafficking prior to sealing.
- c) Availability of suitable base materials for the anticipated traffic loading.
- d) The use of primer seals rather than prime and seal when sealing under traffic.

Modification of existing granular materials

- e) For low dosage cementitious binders, the difficulty in preventing the formation of bound materials with unsatisfactory fatigue performance.
- f) Where chemical binders (other than cementitious or bituminous products) are used to modify granular materials, the performance risks relating to uncertainty in the mix and thickness design procedures are usually higher. Field trials are often required to provide adequate information on treatment performance.

Cementitious stabilisation

- g) Uniformity of binder spread rates, mixing uniformity (with depth), and deep compaction for single layers in excess of 250 mm thickness.
- h) For multi-lift stabilisation, development of debonding between cemented layers leading to structural distress.
- i) Uncertainty about minimum surfacing requirements to inhibit erosion at construction joints and shrinkage cracks.
- j) For heavily trafficked roads, the rate of distress progression after structural failure and the high cost of remediation.

Foamed bitumen stabilisation

- k) Limited experience in the use of mix and thickness design procedures, requiring further refinement and performance review of the technology.
- l) Uniformity of binder application rates and compaction/density profile of single layers in excess of 250 mm thickness.
- m) Flushing of sprayed seals due to migration of the binder to the surface under trafficking.

Pavement Layering Considerations

5.55 The number and thickness of pavement layers shall comply with DPTI Master Specification for Roadworks, construction practicalities and minimum performance requirements.

5.56 The following pavement layer thickness constraints also apply:

- a) All layer thicknesses shall conform to Table RD-PV-D2 5-3.
- b) A minimum total thickness of 75 mm of asphalt placed in two layers is required over unbound granular material, except for rural intersections where single asphalt layers may be used over sprayed seals to withstand localised high horizontal shear stresses.
- c) A minimum total thickness equivalent to 100 – 175 mm asphalt is required over cemented subbase (refer Section 3, RD-PV-D1).
- d) A minimum 35 mm thickness of asphalt wearing course shall be provided.
- e) RD-BP-S2 "Supply of Asphalt" includes Type AC14HB, which has lower air voids and additional binder to provide improved fatigue resistance. To inhibit rutting of these mixes, a minimum thickness of cover of 125 mm of dense-graded asphalt is required.
- f) At least three asphalt layers should be used where the total asphalt thickness exceeds 120mm, and preferably four layers when greater than 220mm, to provide better riding surfaces.
- g) If possible, the lowest layer of asphalt of a full-depth asphalt pavement should be at least 75 mm thick to reduce the construction stresses on the subgrade and limit damage to the asphalt due to construction traffic, while still achieving the minimum specified standard of compaction.
- h) Consecutive asphalt layers should generally differ by not more than one mix size.

Table RD-PV-D2 5-3 Pavement Layer Design Thicknesses

Material	Nominal Size (mm)	Typical DPTI Standard Materials	Design Thickness Range (mm)
Asphalt	7	FineAC7	25 – 35
	10	FineAC10	35 – 50

Material	Nominal Size (mm)	Typical DPTI Standard Materials	Design Thickness Range (mm)
Unbound Granular	10	AC10	40 – 55
	14	AC14	50 – 80
	20	PM1A, PM1, PM2, PM3	80 - 175
	30	PM1, PM2	90 - 175
	40	PM1, PM2, PM3	100 - 200
	55	PM3	130 -220
Plant Mixed Cement Stabilised – Single Layer Construction	All Sizes	SPM2C4	125 – 200*
Plant Mixed Cement Stabilised – Multiple Layer Construction	All Sizes	SPM2C4	125 – 175*

(1) Also referred to as “nominal compacted thickness” on pavement work schedules.

* For layer thicknesses less than 100 mm, the top of existing base is mixed with the new granular material to provide a minimum 100 mm thickness to compact.

Pavement Jointing Considerations

5.57 The structural competency of the pavement at longitudinal construction joints is generally not as sound as in other areas. This may be due to:

- a) Reduced compaction arising from bridging of the joint by the roller;
- b) Lack of aggregate interlock;
- c) Segregation of coarse aggregate.

5.58 As a result, pavements tend to be weaker and more permeable at longitudinal construction joints. Load induced deformation of granular materials and shrinkage cracking of cemented materials can occur along these discontinuities.

5.59 To reduce the risk of premature distress, construction joints should not be located in wheel paths.

Pavement Widths

5.60 To reduce the effect on pavement performance of vehicles travelling on or near the shoulder, it is common DPTI practice to extend the pavement 0.5 m beyond the edge line.

Unsealed Shoulders

5.61 For unsealed shoulders, the minimum total thickness of granular materials is 150 mm for major Rural Arterials and 200 mm for National Highways.

5.62 The uppermost 100 mm or more should be a Class 2 pavement material or similar with reasonably high plasticity index (6 to 8) to provide low permeability and good surface integrity.

6 Thickness Design of Structural Overlays

Introduction

6.1 Chapter 6 of the Guide describes procedures for determining the design thickness of overlays placed to correct the structural deficiencies of an existing pavement.

6.2 For DPTI, Plane and Reinstatement treatments are commonly used to provide pavement strengthening. Section 6 (CL 6.18 to 6.24) of this Supplement describes procedures developed for DPTI (Jameson 2005) to determine the design thickness of an asphalt plane and reinstatement treatment.

Flexible Overlays using Design Charts

Adjustment of Deflections and Curvatures to Account for Seasonal Moisture Variations

- 6.3 Table 6.2 of the Guide provides moisture correction factors for deflections and curvatures where better information is not available. Although these factors are broadly consistent with limited monitoring of SA urban sites (Highways Department, 1986), the actual seasonal variations can vary significantly between projects. Hence, wherever possible and particularly for heavily trafficked roads, testing should be undertaken when the deflections are highest, or site specific factors should be used. If practicable, deflection testing during the dry period between January and April should be avoided. Local factors can be determined by means of selective retesting of key treatment areas. Alternatively, a common DPTI approach is to adopt correction factors of between 1.0 and 1.3 unless local conditions clearly indicate that no adjustment is needed.

Design Periods and Traffic Loading

- 6.4 The design period selected is the time span considered appropriate for the road pavement to function without major rehabilitation or reconstruction.
- 6.5 For the design of flexible overlays on flexible pavements, a 20 year design period is generally used to calculate the design traffic loadings that determine the thickness required to limit permanent deformation. However, 10 year design traffic loadings are commonly adopted by DPTI to assess the fatigue performance of asphalt overlays. This is mainly because heavily trafficked asphalt surfacings often need remedial treatments at intervals of less than 15 years due to shoving, environmental cracking and functional deterioration.
- 6.6 The design traffic loadings are calculated using the procedures in Chapter 7 of the Austroads Guide (2012). The Austroads overlay design method has been developed over many years using mechanistic modelling and in-service field performance data. The majority of this experience relates to pavements designed and constructed to outlast 20 years or more trafficking, with the loading spread relatively evenly over the design period. However, in some situations the pattern of loading differs markedly for that on which the procedures in the Guide were based. For instance:
- Temporary pavements may be required to carry high daily traffic loadings but because of their limited design life (e.g. 0-2 years) may have a relatively low design traffic loading.
 - In some areas of the State the haulage of grain or other produce results in large seasonal variations in traffic loadings.
 - Some dedicated busways in Adelaide have high loadings on weekends during the winter football season but very low loadings at other times.
- 6.7 In such situations the design traffic needs to be adjusted to allow for the greater impacts of these special loadings. For roads with intermittent or seasonal loadings, rather than the design traffic being calculated from the annual average daily heavy vehicle volume, the maximum daily heavy vehicle traffic per annum is used.
- 6.8 In accordance with the predicted doubling of road freight by 2020 (DOTARS 2002), all freeways, highways and major arterial roads on freight routes should be designed with a minimum heavy vehicle growth rate of 3.5%.
- 6.9 In finalising overlay and patching thickness designs, it is essential that the existing pavement site conditions and distress severity, the past structural performance and maintenance history, and the future loading and environmental influence, be adequately considered. Where the calculated thickness of a structural treatment is inconsistent with past performance the design traffic loading should be reviewed, including the assumed ESA per heavy vehicle value.
- 6.10 For wide traffic lanes where significant lateral traffic wander has been observed or is likely, the lower pavement damage resulting from this effect may be taken into account by reducing the lane distribution factor. The minimum lane distribution factor for use in these design traffic calculations is 0.65.

Fatigue of an Asphalt Overlay

- 6.11 Where the design charts for asphalt fatigue (e.g. Figure 6.6 of the Guide) provide multiple overlay thicknesses, the performance of thinner overlays (i.e. less than 50 mm thick) are generally much less reliable because of several factors not well accounted for in the design procedure.
- 6.12 Where the design traffic exceeds 10^6 ESA and a 40–50 mm thick asphalt overlay is an option from the design charts for asphalt fatigue, a 40–50 mm overlay may be adopted for fatigue provided:
- A 40 mm thick overlay also has adequate fatigue life when the measured characteristic curvature is increased by 20%;
 - All existing crocodile cracking is removed prior to placement of the overlay, regardless of the overlay thickness;
 - A SAMI is placed under the overlay; and
 - A modified binder is used in the asphalt overlay mix.
- 6.13 For projects with design traffic exceeding 10^6 ESA, the Table 6.4 adjustment factors (in the Guide) for modified binders shall not be used for the design of strengthening treatments, but may be used to indicate the best case performance.

Flexible Overlays using General Mechanistic Procedure

Estimation of Pavement Layer and Subgrade Design Moduli

- 6.14 Back-calculation of the surface deflection bowl data can be used to estimate the elastic modulus of the subgrade and granular materials from software packages such as EFROMD3. However, the errors and uncertainty associated with these back-analysis procedures generally limit their use to the development of indicative pavement models that explain past performance and hence can assist in the design of rehabilitation treatments.
- 6.15 In most cases it would be inappropriate to use back-calculation as the only means to determine a Design CBR for pavement strengthening treatments. In part, this is because back-calculation does not provide unique modulus solutions and they are more representative of idealistic average values for each assumed layer thickness, rather than the real insitu moduli. Hence supplementary subgrade testing should be used to validate the back-calculated support conditions and reduce the uncertainty.
- 6.16 It is also common for the back-calculation process to return only a limited number of useable solutions, which then introduces a bias or further uncertainty about the true characteristic value. Other inaccuracies can result when the actual variability of insitu subgrades are poorly represented by defined sublayer thicknesses.
- 6.17 In the design of pavement strengthening treatments, the following limitations on design moduli apply:
- Subgrade vertical design moduli should not exceed 10 times the laboratory 4-day soaked CBR value to a maximum 100MPa; and
 - For unbound granular materials and macadam layers, the design should be calculated in accordance with Sections 6.2.3 and 8.2.3 of the Austroads Guide (Austroads 2012).

Plane and Reinstatement of Flexible Pavements

P&R Design Using Design Charts

- 6.18 Plane and reinstatement (P&R) asphalt thickness designs for flexible pavements without cemented materials may be calculated using an approach similar to the design charts developed for overlay design (Section 6.2.6 and Table 6.6 of the Guide).
- 6.19 Table RD-PV-D2 6-1 lists the procedure for calculating the required P&R depth for projects with a WMAPT in the range 25-30°C.
- 6.20 This chart-based method is a further development of the mechanistically-derived overlay design method in Section 6.2 of the Guide, and the technical basis is reported by Jameson (2005). In general terms, the P&R design depths from these charts are expected to provide a similar or reduced

- performance risk than is associated with other methods previously used by DPTI to design these treatments.
- 6.21 The procedure is only applicable to design traffic loadings in the range 10^5 to 2×10^7 ESA. For traffic loadings exceeding 2×10^7 ESA, the General Mechanistic Procedures (Section 6.7.2) should be used.
- 6.22 The design charts have a maximum asphalt thickness on the excavated surface of 250 mm. However if the calculated asphalt thickness exceeds 200 mm, it is recommended that the design thicknesses be confirmed using the General Mechanistic Procedures (Section 6.7.2) in view of the assumptions associated with the design charts.
- 6.23 For projects with a design traffic exceeding 10^6 ESA, the adjustment factors for modified binders in Table 6.4 of the Guide shall not be used for design of strengthening treatments, but may be used to indicate the probable best case performance.
- 6.24 A worked example is included in Appendix 1: Examples of Structural Overlay Calculations and a P&R thickness design worksheet provided in Appendix 2: Plane and Reinstatement Thickness Design Worksheet.

Table RD-PV-D2 6-1 Procedure for Plane and Reinstatement (P&R) Thickness Design

Step	Activity
1	Calculate the design traffic loading in ESA (refer to Chapter 7 of the Austroads Guide (Austroads, 2012).
2	Using Table 6.6 of the Guide, calculate the Characteristic Deflection (CD) and the Characteristic Curvature (CC) for each sub-section and required overlay thickness without P&R for permanent deformation (OLAYdef) and for fatigue (OLAYfat).
3	If the required overlay thickness for a sub-section is either excessive compared to adjacent sub-sections or cannot be constructed due to level constraints, identify it as a sub-section for design of a P&R treatment.
4	Select a trial planing depth (PD) for the sub-section. In selecting a trial depth consider whether an overlay (OLAYp) will be placed over the pavement after reinstatement as the structural contribution of the overlay needs to be considered. The trial overlay thickness on the planed surface is then the sum of PD and OLAYp.
5	Calculate the trial thicknesses of existing asphalt and granular materials to be excavated based on the planing depth and the pavement composition.
6	Estimate CD after excavation of the asphalt using Figure 6.13 of the Guide. Then adjust the CD for the excavated granular thickness using Figure 6.15 of the Guide.
7	Use Figure RD-PV-D2 6-5 to estimate the asphalt thickness required to be placed on the excavated surface pavement at a WMAPT of 25°C. Adjust this thickness for the project WMAPT and overlay binder type using Figure 6.10 of the Guide.
8	If the asphalt overlay thickness required to inhibit permanent deformation (step 7) is greater than the total of the trial planing depth (PD) and overlay on the reinstated surface (OLAYp), then increase the trial PD and repeat steps 5-7 until the required asphalt thickness equals the sum of PD + OLAYp.
	Record the sum of PD and OLAYp required to inhibit permanent deformation.
	As a check on the calculated planing thickness the sum of PD and OLAYp should exceed the overlay thickness without P&R (OLAYdef, step 2).
9	Estimate CC after excavation of the asphalt using Figure 6.14 of the Guide. Then adjust the CC for the excavated granular thickness using Figure 6.16 of the Guide.
10	Using Figure RD-PV-D2 6-6 and CC after planing (step 9), estimate the allowable traffic loading in terms of asphalt fatigue of the asphalt overlay thickness on the excavated surface.

Step	Activity
11	<p>Compare the allowable traffic loading with the design traffic loading (step 1).</p> <p>If the allowable traffic loading is less than the design traffic loading, increase the trial PD for the sub-section and estimate the CC after planing as detailed in step 9 and repeat steps 10.</p> <p>If the allowable traffic loading equals or exceeds the design traffic loading the trial planing depth and overlay on the reinstated surface is sufficient for asphalt fatigue.</p> <p>As a check on the calculated thickness the sum of PD and OLAYp should exceed the overlay thickness without P&R (OLAYfat, step 2).</p>
12	<p>The P&R treatment applied is the thicker of the treatments to inhibit permanent deformation (step 8) and that required to inhibit asphalt fatigue (step 12).</p>

Figure RD-PV-D2 6-1 Increase in deflection due to removal of asphalt

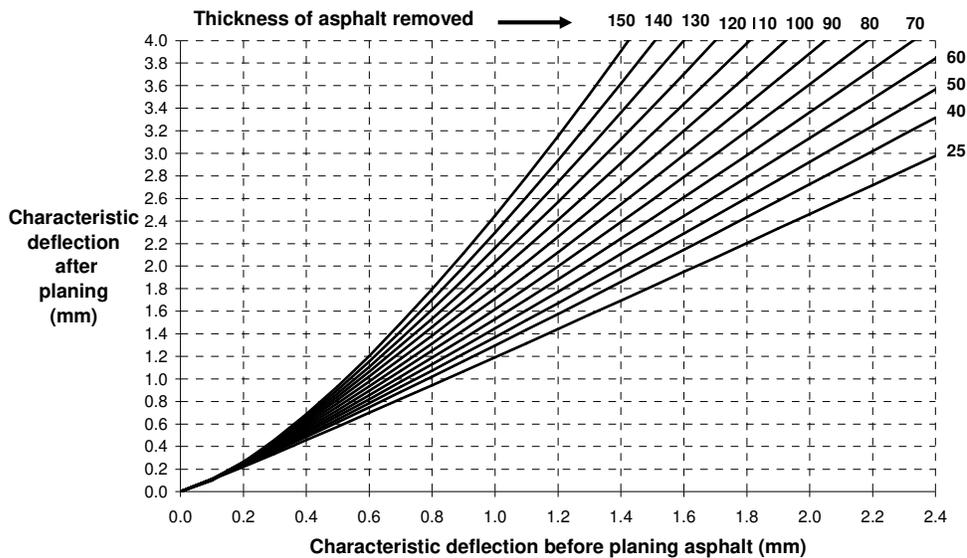


Figure RD-PV-D2 6-2 Increase in curvature due to removal of asphalt

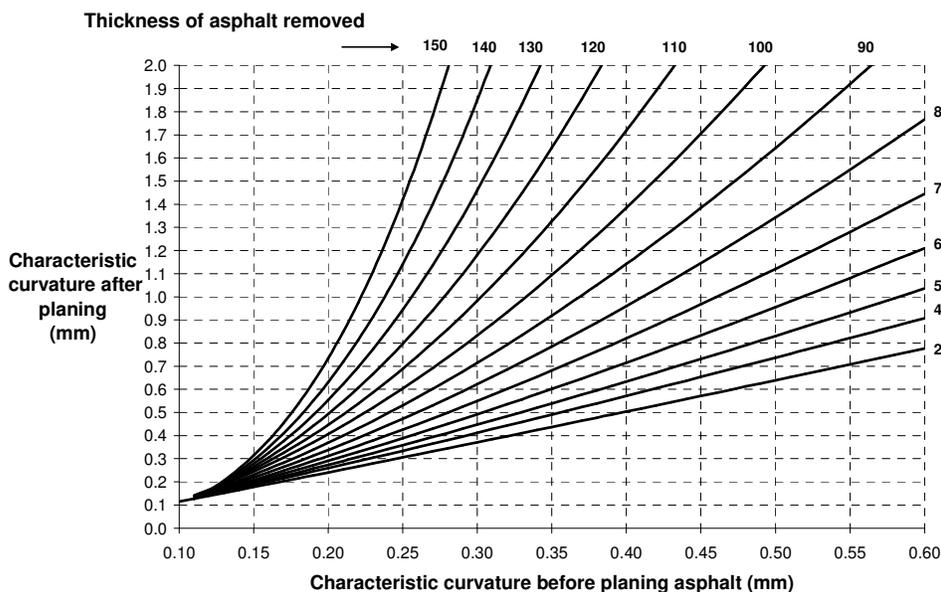


Figure RD-PV-D2 6-3 Increase in deflection due to removal of granular material

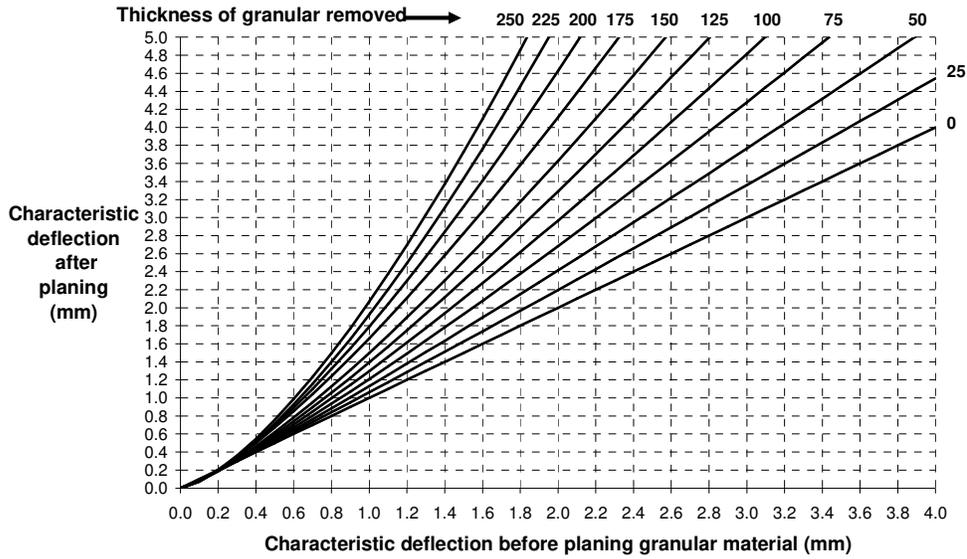


Figure RD-PV-D2 6-4 Increase in curvature due to removal of granular material

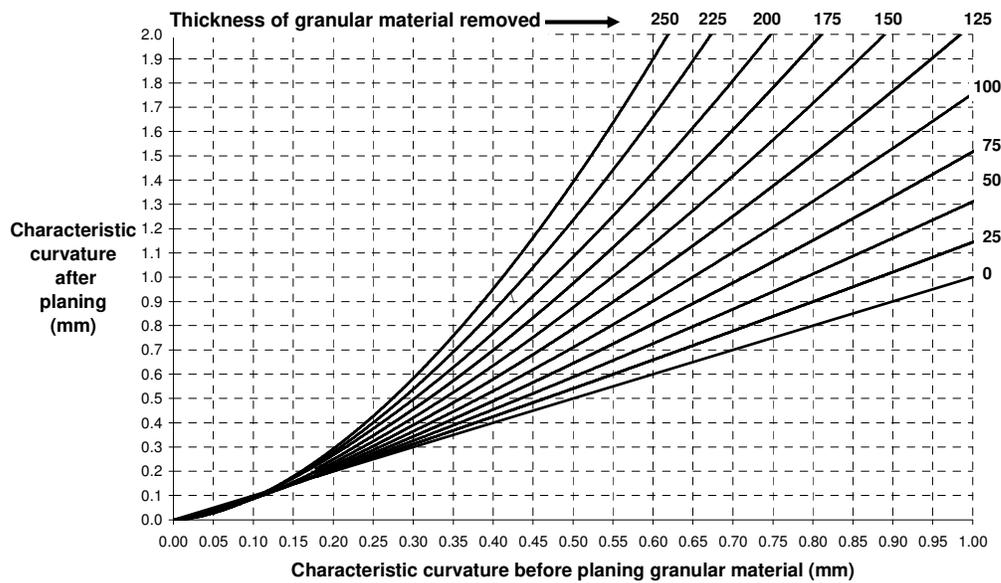


Figure RD-PV-D2 6-5 Asphalt overlay design chart for permanent deformation

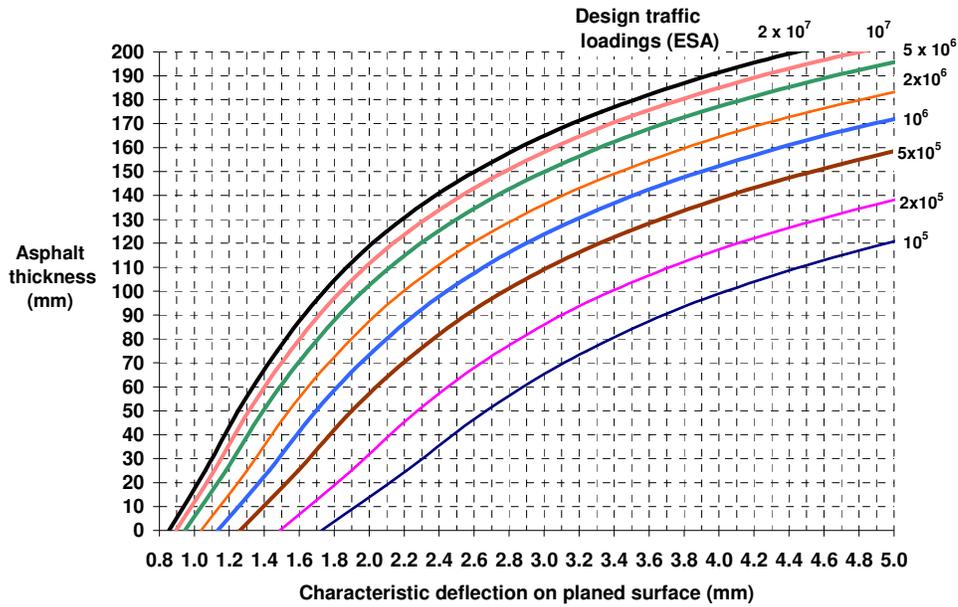
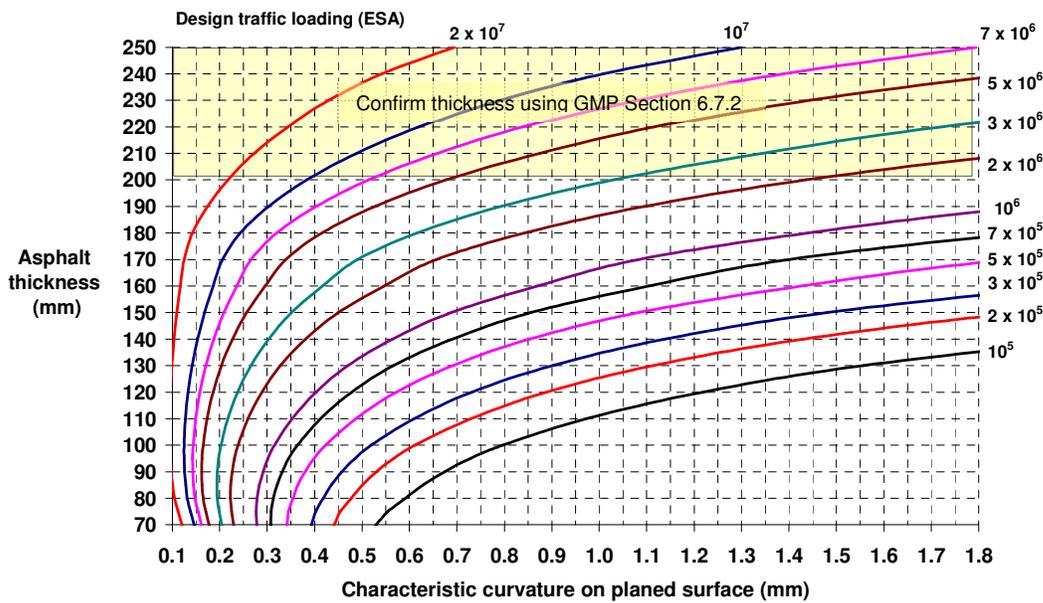


Figure RD-PV-D2 6-6 Asphalt overlay design chart for asphalt fatigue for projects



P&R Design Using General Mechanistic Procedures

6.25 For all flexible pavements, the General Mechanistic Procedures (GMP) for the design of overlays (Section 6.3 of the Guide) may be adapted to assess the required plane and reinstatement depth. Having estimated the moduli of the existing pavement materials and subgrade, a trial asphalt reinstatement (mix types, moduli, layer thicknesses) is selected and the layer thicknesses and design moduli of the remaining pavement and subgrade are determined. These layer moduli and thicknesses are used in the linear elastic model CIRCLY. The maximum vertical compressive strain on the top of subgrade and the maximum horizontal strain at the bottom of the asphalt layer are calculated. The allowable traffic loadings are then determined for each distress mode. If the allowable loadings exceed the design traffic, the trial P&R depth is acceptable. Otherwise, a new depth is selected and the above analysis steps repeated.

7 Thickness Design of Stabilisation Treatments

Cemented Materials

- 7.1 The stabilisation depth shall be calculated using the mechanistic procedures in Section 7.4 of the Guide (Austroads 2012). A maximum design modulus of 5000 MPa shall be used for materials with a minimum UCS of 5 MPa.
- 7.2 Multi-layer insitu stabilisation with a cementitious binder may involve performance risks associated with layer debonding, as discussed in 3.6.2 DPTI (2014). Same day placement of multiple layers is essential, not only to achieve effective chemical bonding between the layers, but also to ensure shrinkage cracking is continuous through the multiple layers.
- 7.3 For single layer thicknesses in excess of 200 mm, the thickness design needs to allow for the lower compaction likely in the lower portion of the layer. An interim thickness design procedure used by DPTI for such situations requires the stabilisation depth to be calculated using a maximum design modulus of 5000 MPa for the top 2/3 of the cemented layer and 2000 MPa for the bottom 1/3 of the layer.
- 7.4 To achieve adequate compaction and mixing with depth the maximum thickness of a deep-lift layer shall be 360 mm. If the subgrade CBR at the time of construction is less than 5%, a minimum 100 mm unbound granular material should be retained over the subgrade to improve compaction, and additional material may be needed to meet this requirement. Strengthening can be achieved by placing one or more asphalt layers over the stabilised materials.
- 7.5 DPTI requires the following minimum surfacing treatments on cementitious material:
 - a) For roads with design traffic loading of 10^7 ESA or more, a minimum 150 mm dense graded asphalt shall be provided.
 - b) For roads with design traffic loading less than 10^7 ESA, a geotextile reinforced seal or 50 mm minimum thickness of dense graded asphalt is required.

Foamed Bitumen Stabilisation

- 7.6 The minimum single layer thickness of foamed bitumen stabilisation should not be less than 200mm and to achieve adequate mixing and compaction with depth, the maximum single layer thickness should not exceed 300 mm. Prior to compaction, the bituminous binder should be thoroughly mixed in directly after the lime has been introduced, as occurs in the laboratory.

8 Economic Comparison of Alternative Treatments

Introduction

- 8.1 The validity of the economic comparisons invariably depends on the accuracy of the numerous assumptions and performance predictions that need to be made within each pavement whole-of-life costing model. For real pavements, the field performance can vary significantly between projects and differ from the typical or base expectations. Hence, it will often be necessary to consider the economic comparisons for the scenarios where rehabilitation and maintenance requirements are consistently either more or less than the average case. Comprehensive analysis would include economic comparisons of pessimistic, base and optimistic performance predictions and their associated maintenance costs over the analysis period.

Method for Economic Comparison

- 8.2 The Present Worth of Costs (PWOC) method shall be used to calculate the Whole-of-Life costs.

Economic Parameters

- 8.3 A discount rate of 7% shall be used with sensitivity testing at 4% and 10%.

Road User Costs

- 8.4 Consideration must be given to the safety and service of road users and others who may be affected by the presence of the asset. Some issues to consider are:
- a) Disruption caused by frequency of maintenance activity.
 - b) Roughness impacts on the cost of operating vehicles.
 - c) For strategic routes, implications of damage/disruption due to low probability catastrophic events (e.g. floods, earthquakes), subsidence, expansive subgrade etc.
 - d) Traffic noise from particular surfaces.
 - e) Environmental issues during construction and maintenance e.g. potential for dust, material disintegration or ravelling, fumes or contamination to the environment from certain road materials
 - f) Aesthetic or visual intrusion effects.
 - g) Traffic and pedestrian safety which may be affected by:
 - i) surfacings (texture, colour/visibility, etc.);
 - ii) susceptibility of the pavement type to damage (e.g. rutting, cracking, ravelling); and
 - iii) practicality of adopting a different pavement type on a road length which is dominantly of another pavement type.
- 8.5 Although cost is a prime consideration in the selection of options, if any of the above non-measurable factors are considered important for the project under consideration, judgement will have to be used and the most economical solution may not be the most appropriate.

9 References

- a) Austroads (2011a). Guide to Pavement Technology Part 5 Pavement Evaluation and Treatment Design. Austroads, Sydney.
- b) Austroads (2012). Guide to Pavement Technology Part 2 Pavement Structural Design. Austroads, Sydney.
- c) Austroads (2009a). Guide to Pavement Technology Part 3 Pavement Surfacing. Austroads, Sydney.
- d) Austroads (2009b). Guide to Pavement Technology Part 4K Seals. Austroads, Sydney.
- e) Austroads (2008). Guide to Pavement Technology Part 4F Bituminous Binders. Austroads, Sydney.
- f) Austroads (2006). Guide to Pavement Technology Part 4D: Stabilised Materials. Austroads, Sydney
- g) Austroads (2005). Guidelines for the Management of Road Surface Skid Resistance. Pub. No. AP-G17/04 Austroads, Sydney.
- h) Austroads (2004). Sprayed Sealing Guide. Austroads/AAPA Pub. No. AP-G76/04 Austroads, Sydney.
- i) Clegg (1980). An Impact Soil Tester as an Alternative to California Bearing Ratio. Proc. 3rd ANZ Geomechanics Conference, 1, pp 225-230.
- j) DPTI (2011). Guide to Bikeway Pavement Design Construction & Maintenance for South Australia. Safety and Service Division.
- k) DPTI (2014) Pavement Design: Supplement to the Austroads Guide to Pavement Technology Part 2 Pavement Structural Design. Safety and Service Division.
- l) Highways Department (1986). Seasonal Variations in Pavement Deflection. Report MS 31-1.
- m) Jameson G W (2005). Plane and Reinstatement Thickness Design. ARRB Group Report VE71073-2 for Transport Services Division, DTEI.

- n) Little, D.N (1995). Handbook for Stabilisation of Pavement Subgrades and Base Courses with Lime. (Kendall/Hunt).
- o) Queensland Transport (1988). Applications for the Clegg Impact Soil Tester. Technical Note 5 (QDMR: Brisbane).
- p) Robinson, P., Oppy, T., Giummarra, G. (1999). Pavement Materials in Road Building: Guidelines for Making Better use of Local Materials. ARRB TR.

10 Appendix 1: Examples of Structural Overlay Calculations

Example of Plane and Reinstatement Thickness Design

This design example illustrates the method for calculating the required planing depth of pavements prior to reinstatement with asphalt. The required plane and reinstatement (P&R) depth is the greater of that required to limit permanent deformation and to inhibit fatigue of the asphalt patching material.

A homogeneous section of cracked asphalt surfaced granular pavement is situated in a locality where the WMAPT from Appendix B, is 29°C. The existing asphalt is 50 mm thick.

The following characteristic values were calculated from Deflectograph deflection testing undertaken at a pavement temperature of 25°C:

- Measured Characteristic Deflection at 25°C = 1.1 mm
- Measured Characteristic Curvature at 25°C = 0.30 mm

Based on experience, the designer considered that there was no need to apply a Seasonal Moisture Correction Factor to these measured deflections and curvatures.

The design traffic loading for the section was 5×10^6 ESA.

The proposed rehabilitation strategy is to P&R this trafficked lane and then place a 40 mm overlay for the full carriageway width.

P&R Thickness Required for Permanent Deformation

Design Deflection (from Figure 6.5 of the Guide) = 0.94 mm.

Temperature factor = $WMAPT / T_{\text{measured}} = 29/25 = 1.16$

From Figure 6.1 of the Guide for 50 mm existing asphalt thickness the deflection adjustment factor = 1.02, and the temperature adjusted characteristic deflection = $1.1 \times 1.02 = 1.12$ mm.

From Figure 6.3 of the Guide, a deflection standardisation factor for Deflectograph maximum deflections measured on a pavement with 50 mm asphalt thickness is 1.2. Therefore the adjusted Characteristic Deflection is $1.12 \times 1.2 = 1.35$.

To provide guidance on the required planing depth, the overlay required without P&R is first calculated. From Figure 6.9 of the Guide, for a design traffic of 5×10^6 ESA and CD of 1.35 mm, the required overlay without P&R is 50 mm. Using Figure 6.10 of the Guide, for a dense graded asphalt mix with Class 320 binder at a WMAPT of 29°C, the overlay adjustment factor is 1.08. Therefore the overlay required without patching is $50 \times 1.08 = 55$ mm, rounded up to the nearest 5 mm. Hence the P&R depth is expected to exceed 55 mm as the planing will remove some or all of the existing asphalt.

The next step is to select a trial P&R depth. The following treatment was selected after a number of trials: excavate the existing pavement to a depth of 80 mm, thus removing 50 mm of asphalt and 30 mm of granular material.

Using Figure RD-PV-D2 6-1, after removing the 50 mm asphalt surfacing the CD increases from 1.35 mm to 1.9 mm.

Using Figure RD-PV-D2 6-3 after removing 30 mm of granular material the CD increases from 1.9 mm to 2.15 mm.

From Figure RD-PV-D2 6-5 for a CD of 2.15 mm on the excavated surface and a design traffic of 5×10^6 ESA, a 112 mm overlay is required on the excavated surface to inhibit permanent deformation at a WMAPT of 29°C. From Figure 6.10 of the Guide for a WMAPT of 29 °C, the required thickness of dense graded asphalt (Class 320 binder) is $112 \times 1.08 = 120$ mm.

Hence a 120 mm asphalt thickness is required on the excavated surface for permanent deformation, comprising patching to 80 mm followed by a 40 mm overlay.

P&R Thickness Required for Asphalt Fatigue

Temperature factor = $WMAPT / T_{\text{measured}} = 29/25 = 1.16$

From Figure 6.1 of the Guide the curvature adjustment factor for 50 mm existing asphalt thickness is = 1.03.

Temperature adjusted characteristic curvature = $0.30 \times 1.03 = 0.31$ mm.

From Figure 6.4 of the Guide, curvature standardisation factor for Deflectograph curvatures measured on a pavement with 50 mm asphalt thickness is 0.88. Therefore the adjusted Characteristic Curvature (CC) is $0.31 \text{ mm} \times 0.88 = 0.27$ mm.

From Figure 6.6 of the Guide, for a design traffic of 5×10^6 ESA and CC of 0.27 mm, the required overlay without P&R is 130 mm.

Hence the required asphalt thickness after planing needs to exceed 130 mm. It was decided to trial a P&R depth of 150 mm.

Using Figure RD-PV-D2 6-2 after removing the 50 mm asphalt surfacing, the CC increases from 0.27 to 0.40 mm. Using Figure RD-PV-D2 6-4 after removing 100 mm of granular material the CC increases from 0.40 mm to 0.53 mm.

From Figure RD-PV-D2 6-6, for a CC of 0.53 mm on the excavated surface and a design traffic of 5×10^6 ESA, a 190 mm asphalt thickness is required on the excavated surface to inhibit asphalt fatigue.

This trial P&R depth is acceptable as the required 190 mm asphalt overlay on the excavated surface matches the total of the planing depth 150 mm and 40 mm overlay proposed on reinstated pavement surface.

The required P&R depth is the maximum of that required for permanent deformation (80 mm) and that required for fatigue of the patching material (150 mm).

Hence it was concluded that the following strengthening treatment would be suitable for the project:

- Plane 50 mm asphalt and 100 mm granular material from pavement;
- Patch the excavation by placing 150 mm thickness of asphalt in two layers; and
- Apply a 40 mm overlay over all traffic lanes.

The design calculations are provided in Table RD-PV-D2 10-1.

Table RD-PV-D2 10-1 Example of Plane and Reinstatement Thickness Design Calculations

Plane and Reinstatement Thickness Design	
Project: Appendix 6.6 design example	Design Date: 30 June 2011
Design Traffic Loading	5×10^6 ESA
Deflection Measurement Device	Deflectograph
Weighted Mean Annual Pavement Temperature (WMAPT, Append B)	29°C
Existing Asphalt Thickness (if any)	50 mm
Temperature of existing AC during deflection testing (T_{meas})	25 °C
WMAPT/ T_{meas} (for existing AC)	$29/25 = 1.16$
P & R Thickness Required For Permanent Deformation	
Measured Characteristic Deflection	1.1 mm
Seasonal Moisture Correction Factor (Table 6.2 of the Guide)	1.0
Deflection Adjustment Factor for Temperature (Figure 6.1 or 6.2 of the Guide)	1.02

Plane and Reinstatement Thickness Design	
Deflection Standardisation Factor for Measurement Device (Figure 6.3 of the Guide)	1.2
Adjusted Characteristic Deflection	$\dots 1.1 \dots \times \dots 1.0 \dots \times \dots 1.02 \dots \times 1.2 \dots = 1.35$ mm
Asphalt overlay required for permanent deformation, OLAYdef, (i.e. without P&R), Figures 6.9 and 6.10 of the Guide	$50 \times 1.08 = 55$ mm
Trial planing depth (PD)	80 mm
Trial thickness of asphalt excavated	50 mm
Trial thickness of granular excavated	30 mm
Overlay thickness on reinstated surface (OLAYp), if any	40 mm
Characteristic Deflection after excavation of asphalt (Figure RD-PV-D2 6-1)	1.9 mm
Characteristic Deflection after excavation of granular (Figure RD-PV-D2 6-3)	2.15 mm
Required asphalt thickness on excavated surface at 25°C (Figure RD-PV-D2 6-5)	112 mm
Overlay Adjustment Factor (Figure 6.10 of the Guide)	1.08
Required asphalt thickness on excavated surface at WMAPT	$\dots 112 \dots \times \dots 1.08 \dots = 120$ mm
Check that required asphalt thickness equals the sum of PD + OLAYp =	$80 + 40 = 120$ mm
P&R Thickness Required For Asphalt Fatigue	
Measured Characteristic Curvature:	0.3 mm
Seasonal Moisture Correction Factor (Table 6.2 of the Guide) :	1.0
Curvature Adjustment Factor for Temperature (Figure 6.1 or 6.2 of the Guide)	1.03
Curvature Standardisation Factor for Measurement Device (Figure 6.3 of the Guide)	0.88
Adjusted Characteristic Curvature	$\dots 0.3 \dots \times \dots 1.0 \dots \times \dots 1.03 \dots \times 0.88 \dots = 0.27$ mm
Asphalt overlay required for fatigue, OLAYfat, (i.e. without P&R), Figure 6.6 of the Guide	130 mm
Trial planing depth (MD)	150 mm
Trial thickness of asphalt excavated	50 mm
Trial thickness of granular excavated	100 mm
Overlay thickness on reinstated surface (OLAYp), if any	40 mm
Characteristic Curvature after excavation of asphalt (Figure RD-PV-D2 6-2)	0.40 mm
Characteristic Curvature after excavation of granular (Figure RD-PV-D2 6-4)	0.53 mm
Required asphalt thickness on excavated surface for WMAPTs of 25-30°C (Figure RD-PV-D2 6-6)	190 mm
Check that required asphalt thickness equals the sum of MD + OLAYp =	$150 + 40 = 190$ mm
Summary	
P&R depth required for permanent deformation =	80 mm
P&R depth required for asphalt fatigue =	150 mm
Overlay (if any) proposed on reinstated surface =	40 mm

11 Appendix 2: Plane and Reinstatement Thickness Design Worksheet

Table RD-PV-D2 11-1 Plane and Reinstatement Thickness Design

Plane and Reinstatement Thickness Design	
Project:	Design Date:
Design Traffic Loading	ESA
Deflection Measurement Device	
Weighted Mean Annual Pavement Temperature (WMAPT, Appendix B)	°C
Existing Asphalt Thickness (if any)	mm
Temperature of existing AC during deflection testing (Tmeas)	°C
WMAPT/Tmeas (for existing AC)	
P&R Thickness Required for Permanent Deformation	
Measured Characteristic Deflection	mm
Seasonal Moisture Correction Factor (Table 6.2 of the Guide)	
Deflection Adjustment Factor for Temperature (Figure 6.1 or 6.2 of the Guide)	
Deflection Standardisation Factor for Measurement Device (Figure 6.3 of the Guide)	
Adjusted Characteristic Deflection	...x...x...x... = ...mm
Asphalt overlay required for permanent deformation, OLAYdef, (i.e. without P&R), Figures 6.9 and 6.10 of the Guide	...x...=...mm
Trial planing depth (PD)	mm
Trial thickness of asphalt excavated	mm
Trial thickness of granular excavated	mm
Overlay thickness on reinstated surface (OLAYp), if any	mm
Characteristic Deflection after excavation of asphalt (Figure RD-PV-D2 6-1)	mm
Characteristic Deflection after excavation of granular (Figure RD-PV-D2 6-3)	mm
Required asphalt thickness on excavated surface at 25°C (Figure RD-PV-D2 6-5)	mm
Overlay Adjustment Factor (Figure 6.10 of the Guide)	
Required asphalt thickness on excavated surface at WMAPT	...x...=...mm
Check required asphalt thickness equals the sum of PD + OLAYp	...+...=...mm
P&R Thickness Required for Asphalt Fatigue	
Measured Characteristic Curvature:	mm
Seasonal Moisture Correction Factor (Table 6.2 of the Guide)	
Curvature Adjustment Factor for Temperature (Figure 6.1 or 6.2 of the Guide)	
Curvature Standardisation Factor for Measurement Device (Figure 6.3 of the Guide)	
Adjusted Characteristic Curvature	...x...x...x... = ...mm
Asphalt overlay required for fatigue, OLAYfat, (i.e. without M&R), Figure 6.6 of the Guide	mm
Trial planing depth (PD)	mm
Trial thickness of asphalt excavated	mm
Trial thickness of granular excavated	mm
Overlay thickness on reinstated surface (OLAYp), if any	mm
Characteristic Curvature after excavation of asphalt (Figure RD-PV-D2 6-2)	mm
Characteristic Curvature after excavation of granular (Figure RD-PV-D2 6-4)	mm
Required asphalt thickness on excavated surface for WMAPTs of 25-30°C (Figure RD-PV-D2 6-6)	mm
Check required asphalt thickness equals the sum of PD + OLAYp + = mm
Summary	

Plane and Reinstatement Thickness Design

P&R depth required for permanent deformation	=...mm
P&R depth required for asphalt fatigue	=...mm
Overlay (if any) proposed on reinstated surface	=...mm