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# SEALED ROADS

## BEST PRACTICE GUIDE

# 3

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# The Hon Michael McCormack MP

# Deputy Prime Minister and Minister for Infrastructure, Transport and Regional Development

## Foreword

I am pleased to support the Australian Road Research Board's suite of Best Practice Guides for Local Governments, which seek to expand Local Governments' understanding and capacity to manage road infrastructure.

Australia's Local Governments manage a majority of the road network, meaning capacity building for our Local Government road managers is vitally important. These Best Practice Guides will support national and international best practice in procurement, design and management of materials for road construction and for essential structures such as bridges.

As our nation's National Transport Research Organisation, the Australian Road Research Board has an important role in road management research and advice.

Road safety is a key priority of mine as the Federal Member for Riverina in regional New South Wales and as Minister for Infrastructure, Transport and Regional Development, especially as rural and regional roads currently account for a disproportionate level of road casualties.

With a user-friendly focus, these Guides aim to provide technical information in a simple-to-understand format that will be readily available and accessible for all road managers.

The Australian Government provided the Australian Road Research Board with $2.6 million as part of the 2019-20 Federal Budget, in recognition of the importance of road management.

This funding enabled ARRB to deliver these Best Practice Guides and a Portable Assessment Device project to assess in-situ road infrastructure conditions across a variety of national Local Government and council infrastructure networks.

I applaud the collaboration between ARRB and Local Government in the development of these Best Practice Guides, which will be an important road management resource.

Australian Government
Department of Infrastructure, Transport, Cities and Regional Development

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# Summary

Local Governments fulfil a vital part in the provision and management of Australia's road assets and are responsible for over 80% of the Australian road network. The construction and management of these road assets is challenging considering the significant and diverse assets Local Governments are responsible for while often being under pressure to obtain better value from their budgets.

The purpose of the Best Practice Guide for Sealed Roads is to provide Local Government authorities, state and territory road agencies and other agencies responsible for the management of sealed roads with guidelines on ways to best manage them to achieve a high performing, sustainable and cost-effective outcome.

Having a holistic understanding of sealed road design, construction and ongoing in-service operations provides a roads practitioner with the tools and abilities to produce and maintain a cost-effective, durable asset while maximising sustainable practices and road user safety.

The Guide provides a strong focus on the understanding and management of sealed roads and addresses the main topics of sealed road design, construction, maintenance and rehabilitation operations, including the following aspects:

Asset Management: covers the economic evaluations of alternative designs, the pavement management processes and risk management, describes pavement evaluation techniques to identify conditions, selection and design of alternative treatments, and economic comparisons.

Planning and Design: covers pavement surfacings, drainage, pavement design processes, subgrade evaluation, traffic loading, drainage and design thickness procedures including a number of examples of granular and rigid pavements, overlay design, geometric design and safety in design. It also covers environmental considerations for all stages.

Construction: includes the main stages in construction, site preparation, drainage, earthworks, subgrade preparation, pavement construction, equipment types, worksite safety and quality management systems.

Operation and Maintenance: includes both routine and periodic maintenance activities, pavement assessments and treatments, provision for traffic, drainage, sign and roadside maintenance, and pavement rehabilitation processes and safety considerations during the maintenance phase.

This Guide is part of a suite of guides including Road Materials, Unsealed Roads, and Bridge Management and the reader should refer to these for details on these topics.

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# 1. Introduction

## 1.1 Background

Local Governments fulfil a vital part in the provision and management of Australia's road assets and are responsible for over 80% of the road network. The construction and management of these road assets is challenging considering the significant and diverse assets Local Governments are responsible for while often being under pressure to obtain better value from their budgets.

The *Best Practice Guide for Sealed Roads* is one of a suite of guides developed for Local Government with the aim of expanding the understanding and capacity to manage road infrastructure. The guides will assist Local Government and other organisations that manage lower-volume roads across Australia to manage their road assets effectively and fulfil their obligations to the community while also improving mobility and safety.

Each guide reflects current global best practice and information and has been tailored to Local Government requirements.

## 1.2 The Local Road Network

***Purpose of Sealed Roads***

- *provide a safe, economical and durable all-weather surface*
- *protect lower layers of a pavement from moisture*
- *provide surface characteristics to reflect community expectations*
- *provide a dust-free surface*
- *extend the life of the pavement*
- *reduce vehicle operating and maintenance costs.*

Australia's population is over 25 million and it has 907 520 km of road network length (BITRE 2013). The bulk of the road network length, 574 660 km (63%), is unsealed. The remaining length of 332 860 km (37%) is sealed with nearly 87% of these roads being a sprayed bitumen seal over an unbound crushed rock base. The remaining 13% of the sealed roads are surfaced with asphalt. Nearly half of the sealed roads (146 000 km) are in urban areas.

Although national highways and state and arterial roads carry the major portion of the road traffic by volume, sealed Local Government roads are estimated to make up ~ 210 000 km or over 60% of the total sealed road network by length in Australia.

Local roads play an important part in the nation's transport in terms of:

- providing access to urban and rural communities
- enabling the movement of primary produce to markets
- facilitating educational, recreational and tourist pursuits.

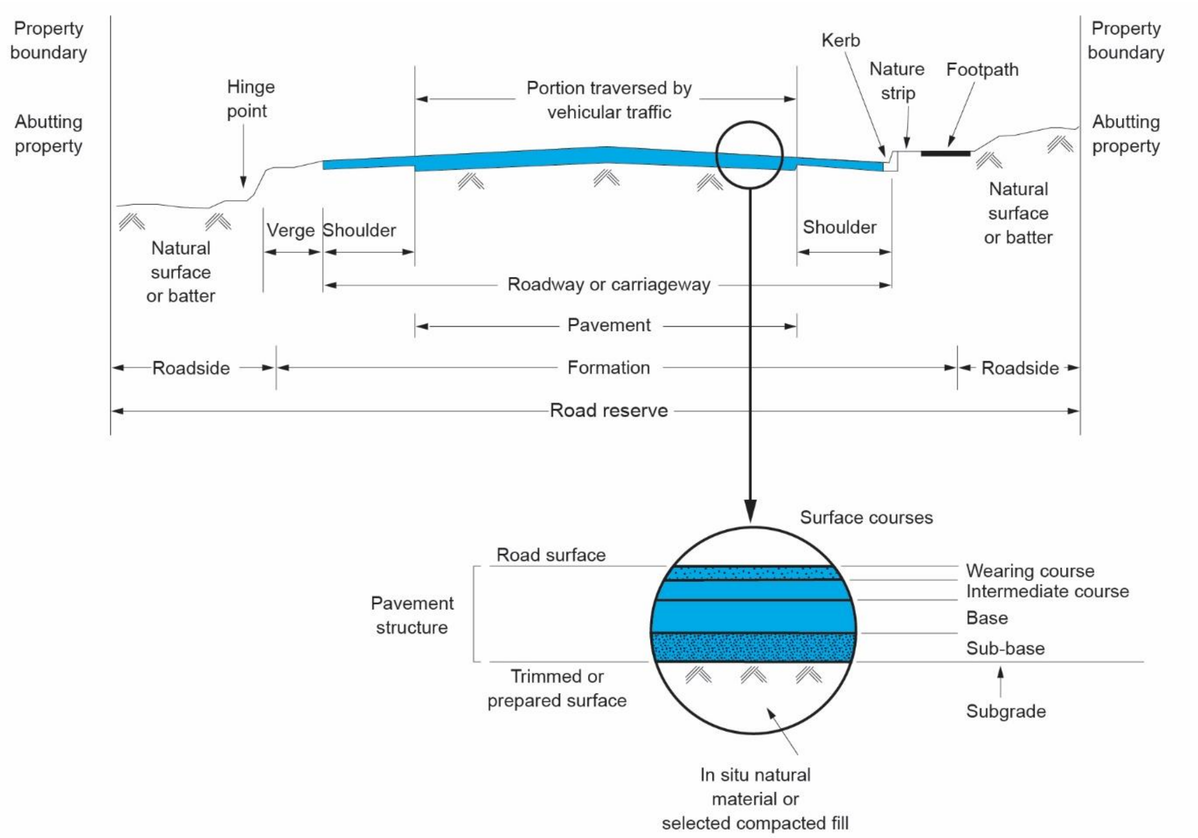
There can be considerable variation in the definition of a 'local road' and the type and amount of traffic carried. In general, a sealed local road carries less than 6 000 vehicles per day in urban areas and much less in rural areas. In some urban metropolitan areas, a local collector road can carry well in excess of 10 000 vehicles per day.

Local roads usually carry fewer heavy trucks except in industrial areas and areas such as grain terminals. In rural areas, local roads may be subject to heavy agricultural machinery and harvest trucks. These factors should be allowed for in pavement design, construction and maintenance.

Sealed local roads have a pavement structure which, in many instances, has evolved over time rather than having been designed and upgraded according to systematic procedures. In general, the main pavement structure is a flexible pavement consisting of unbound layers with a surface of spray seal or asphaltic mix.

The terminology used throughout the Guide in relation to road and pavement elements is as shown in Figure 1.1.

**Figure 1.1: Typical pavement structure and commonly used road terms**




*Source: Dickinson (1984).*

In 2017–18, $22 billion was spent on road and bridge transport infrastructure engineering construction work (BITRE 2018). In the 2019–20 federal budget it was highlighted that the Australian Government will invest $100 billion in significant transport infrastructure projects over the next 10 years. Sealed roads play a key role in the nations road network, so any efficiency gains in the construction, maintenance and rehabilitation of sealed local roads will result in significant benefits.

Improving the performance and management of the sealed local road networks – in terms of ride quality, greater efficiency and reduced road costs – by the application of good practices and technologies, has the potential to provide considerable benefits to the economy and mobility of the community.

The Guide has been prepared using the accumulated knowledge and practical experience of many Local Governments in Australia. It has borrowed extensively from many valuable publications such as those of Austroads and the state and territory road agencies and includes contributions from councils, the construction industry, suppliers and consultants. The Austroads *Guide to Pavement Technology Part 2: Pavement Structural Design* (Austroads 2018a) aims to take a better account of local roads; it remains 'the parent document on pavement design', and the state and territory supplements to it provide further information that may cater for local conditions.

The guide is based on the *Sealed Local Roads Manual* (ARRB 2005) and offers comprehensive and practical information for the various aspects associated with the latest developments and practices for sealed local roads.

The publication is not intended to replace any existing operational instructions in the road construction agencies or road-controlling authorities. Rather, its purpose is to guide users to information relevant to their situation. This will lead to a more informed and uniform approach to the construction, maintenance and rehabilitation of sealed local roads for the benefit of the road user.

## 1.3 Purpose and Scope of the Guide

Wherever the term 'the Guide' is used in this publication, it refers specifically to this Guide, not other manuals or guides listed in the references. It is intended to be an ever-evolving document, consistently building upon and updating knowledge as research, and industry practices, evolve. The Guide was developed through the input of Local Government, state government and industry practitioners and as such is intended to fit the requirements of its target audience.

Comments, suggestions or requests for information to be included in the Guide for future updates can be directed to guides@arrb.com.au.

### 1.3.1 Purpose of the Guide

The purpose of the Guide is to provide the local roads practitioner with a practical resource for the better basic understanding and management of sealed local road pavements. This is achieved by consolidating in one document background knowledge of the latest methods in pavement design procedures, developments in road surfacing technology and road building practices for sealed local roads in urban, rural and remote areas around Australia.

The intended reader will generally be a junior engineer, field staff, design and asset management engineer, works supervisor, or contractor responsible for the construction, maintenance and rehabilitation of sealed local roads. The Guide also serves as a useful source for a senior engineer on the latest developments and a reminder of best practices.

In addition to providing general information and guidance, the Guide also serves as an excellent source document because of its comprehensive lists of references from which readers can obtain more detailed information to meet their particular needs.

### 1.3.2 Scope of the Guide

The Guide covers only sealed pavements which form but a part of the overall road asset management requirements faced by a council. Throughout the guide, readers are directed to other publications, such as the Austroads/AAPA Work Tips, Austroads Guides and road agency documents as these provide detailed information as well as information suitable for individual jurisdictions. The Guide is part of a suite of publications including *Unsealed Roads*, *Road Materials* and *Bridge Management*. Readers should refer to these for details on unsealed roads, selection and testing of road materials, and management of structures respectively.

The Guide provides a strong focus on pavement management requirements relating to sealed local roads, and addresses the main topics of design, construction, maintenance and rehabilitation in the following five parts:

1. Introduction: outlines the scope of the Guide, describes the various road pavement components and the concept of pavement life cycle.

Asset Management: covers the economic evaluations of alternative designs, the pavement management processes and risk management, describes pavement evaluation techniques to identify conditions, selection and design of alternative treatments, and economic comparisons.

Planning and Design: covers pavement surfacings, drainage, pavement design processes, subgrade evaluation, traffic loading, drainage and design thickness procedures including a number of examples of granular and rigid pavements, overlay design, geometric design and safety in design. It also covers environmental considerations for all stages.

Construction: includes the main stages in construction, site preparation, drainage, earthworks, subgrade preparation, pavement construction, equipment types, worksite safety and quality management systems.

Operation and Maintenance: includes both routine and periodic maintenance activities, pavement assessments and treatments, provision for traffic, drainage, sign and roadside maintenance, and pavement rehabilitation processes and safety considerations during the maintenance phase.

The Guide does not cover areas relating to associated roadside structures such as footpaths, parking areas and bicycle lanes. Design, construction and maintenance of concrete pavement structures is only briefly covered. Detailed information for these areas can be found within relevant AUS-SPEC documentation at https://www.natspec.com.au/.

## 1.4 Limitations

While this Guide presents best practice information for sealed roads, it is important to understand that there are significant regional differences when it comes to the design, construction, maintenance and performance specification. Therefore, proven local practices should be maintained.

This publication is also not intended to replace any existing mandated design guidance, specifications, operational instructions or other guidelines. It is intended to supplement these resources while providing a foundation of knowledge regarding sealed roads to a range of readers, both technical and non-technical.

# 2. Asset Management

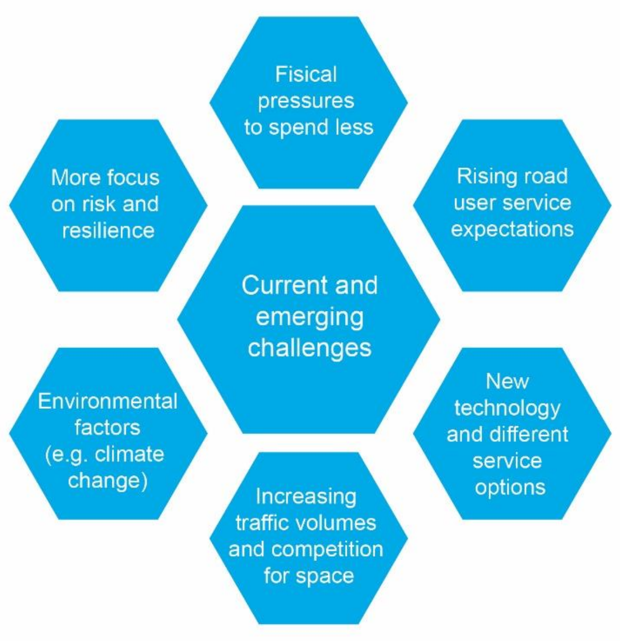
***'Asset Management' is Defined as:***

*A systematic process of effectively maintaining, upgrading and operating physical assets, combining engineering principles with sound business practice and economic rationale, and providing the tools to facilitate a more organised and flexible approach to making decisions necessary to deliver optimal community benefits (Austroads 2015a).*

Since 1990–91 the annual road freight task across Australia has more than doubled from 90 billion tonne-km to 210 billion tonne-km in 2013/14 (BITRE 2015). Over the same time the amount of metropolitan passenger travel increased by 36% from 14 billion passenger-km to 19 billion passenger-km. Current annual funding on construction, maintenance and operations on all public roads is over $30 billion, with around one-third of this spent on road maintenance. With increasing road user demand and increasing funding requirements on a large and highly dispersed road network, sound evidence-based processes and decisions need to be practised across the technical, economic, financial and environmental areas that road agencies deal with.

Figure 2.1 shows the broad spectrum of the many factors impacting and challenging road agencies, including the ones noted above. Many of these factors are interrelated such as climate change which requires the road infrastructure to be resilient to the changing climate while still providing an acceptable level of service to the road users at the lowest possible whole-of-life-cycle cost (WOLCC).

**Figure 2.1: Factors impacting and challenging road agencies**




*Source: Austroads (2018d).*

## 2.1 Definitions and Scope of Asset Management

Asset management is the means by which the optimal value out of the whole road network is obtained. The ISO *Standard for Asset Management* 55001:2014 (ISO 2014) specifies requirements for an asset management system within the context of an organisation and recognises that a broad approach needs to be taken with the practice of asset management.

***There are three broad levels of asset management:***

- *strategic – the establishment of policies, objectives, strategies and plans which respond to current and future levels of service expectations*
- *tactical – the development of prioritised work programs which address levels of service expectations and challenges*
- *operational – the implementation of the programs*

Asset management is a 'whole of organisation' business approach that uses decision support systems in creating and maintaining physical assets which deliver the services valued by the agency's customers in the most cost-effective and efficient manner.

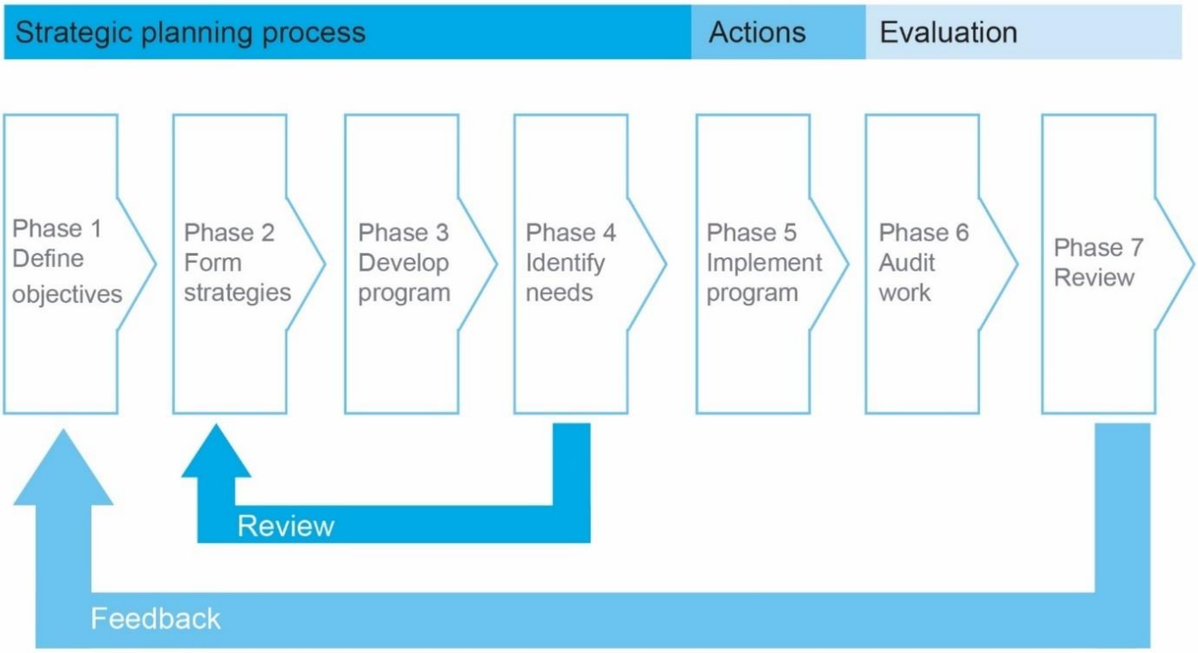
Asset management is a key business process in any organisation managing infrastructure networks and physical asset systems that deliver services to customers. The asset management business processes must be robustly integrated with other business functions, such as finance, human resources, customer management and information technology.

Road agencies in Australia have acknowledged the above international approach documented in ISO 2014 and in continuing to strengthen and develop their management systems and processes have adapted and incorporated these within contemporary whole-of-organisation asset management (AM) practice for road networks. The latest Austroads *Guide to Asset Management* (GAM) (Austroads 2018d), was produced to provide such guidance to road agencies, with its 15 parts flowing from high level to detailed technical level providing the following:

- a management overview,
- a description of asset management processes, and
- detailed technical information.

The GAM also acknowledges earlier progress in this area through the Austroads *Integrated Asset Management Framework* (Austroads 2002), and notable publications such as the *International Infrastructure Management Manual* (IIMM) (IPWEA 2015). The following text therefore draws on this work and reflects the cyclical nature of the asset management process, where setting objectives and developing strategies through needs and program development and implementation means that audit and review stages are essential. As shown in Figure 2.2, the process is both iterative and cyclical, with the latter in recognition of the need to adjust objectives and strategies, e.g. in response to constraints between desirable and affordable service levels and investment needs.

**Figure 2.2: Simplified integrated asset management framework**



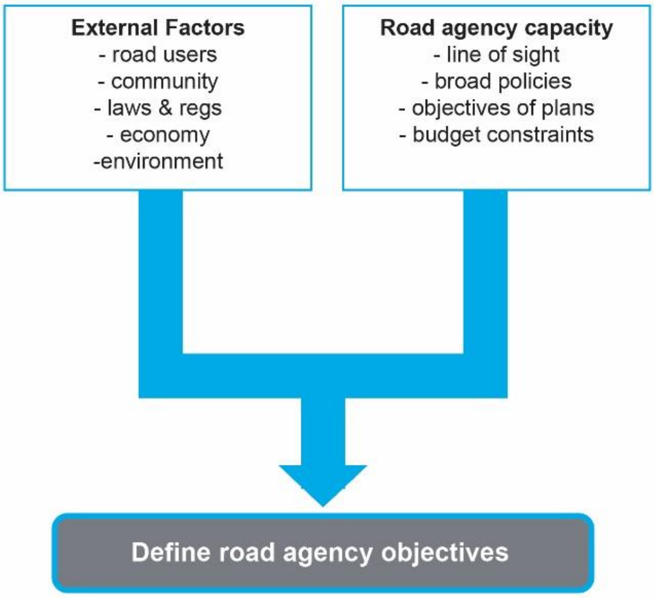

*Source: Adapted from Austroads (2002).*

## 2.2 Objectives of Asset Management

*The clear purpose of asset management is to provide the required levels of service at the lowest life-cycle cost to present and future road users and customers, using a whole-of-agency approach to the acquisition, management and disposal of physical assets.*

Figure 2.3 shows that the development of each road agency's operating objectives is a function of both external factors and the internal capacity of the agency. The external factors are self-evident in the need to comply with laws and regulations within the broader environment of the community, the economy and the road users. The internal capacity of the road agency needs to be aligned with its 'line of sight' (i.e. the overriding purpose of the agency, noted above). The strategic, tactical and operational levels of asset management practised within the agency, in reality, are constrained by budgets as these ultimately dictate what levels of service (LoS) can be delivered for road users and the community. As an input to the subsequent steps in the AM process, it is important to consider different LoS (ranging from minimum to desirable/optimum) in informing decision makers of the budget implications and performance consequences of any constraints. Quantitative LoS are preferred as they can be applied through strategic planning, reviewing outcomes and informing future objectives.

Figure 2.3: Development of road agency objectives




## 2.3 Develop Strategies to Manage a Sealed Road Network

### 2.3.1 Asset Strategies for Managing the Road Network

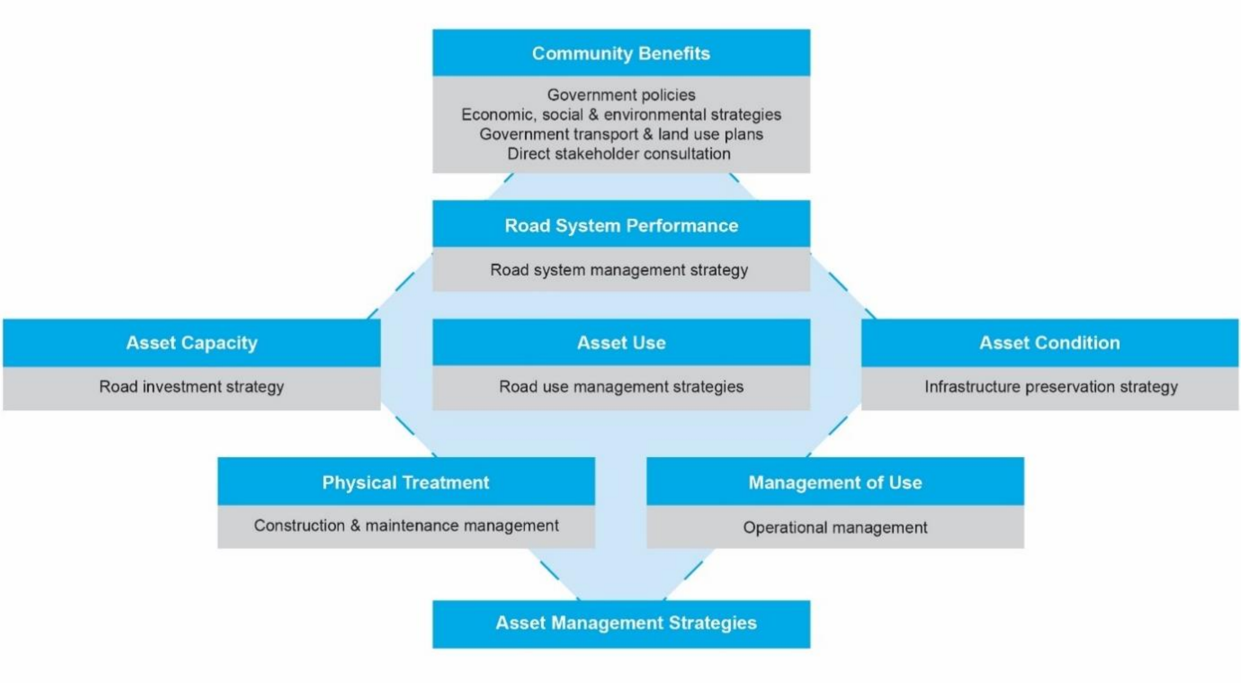
Asset strategies are important because they provide the road agency with a structured direction-focus to guide its actions, and to demonstrate and articulate its stewardship and practice in providing outcomes to the community.

***Asset strategies ensure that there is:***

- *an integrated approach to the management of the capacity, condition and use of assets*
- *a consistent approach across all elements of the network and by all geographic parts of the organisation*
- *transparency and auditable accountability to the community for the rationale of asset management by the road agency, with road system performance standards driven by community objectives and achieved through the efficient and effective management of community road assets.*

Figure 2.4 shows that the development of asset strategies for investment (capacity), preservation (maintenance) and road use are driven by the overall performance of the road network to give the community and road users the maximum possible benefits through the levels of service provided. These levels of service are meant to be fit-for-purpose, in terms of capacity, performance and condition.

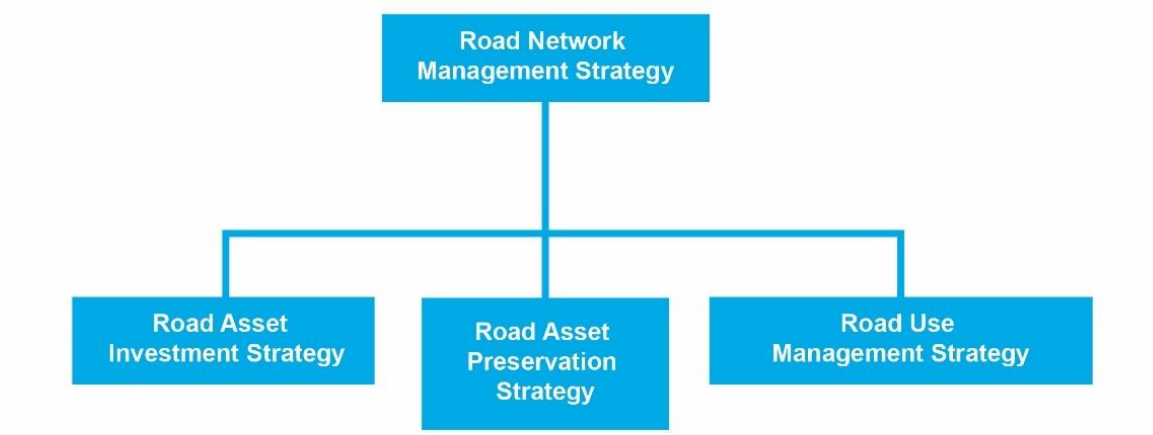
**Figure 2.4: Development of road agency strategies**




*Source: Austroads (2018d).*

From Figure 2.4, three main road asset management strategies emerge as shown in Figure 2.5 that are used to manage the overall road network. Each of these road asset management strategies has levels-of-service attributes assigned to them that are regarded as appropriate for each of the strategies.

**Figure 2.5: Development of road investment, preservation and road use strategies**



## Levels of service

### *Levels of Service*

***Levels of service (LoS) are at the very heart of asset management for road agencies because:***

- *they represent road standards and qualities that the asset owner agrees to provide to users*
- *they are key drivers critical to good asset management practice and the basis upon which recommendations, conclusions, decisions, and budgets are based.*

***If services are to be delivered to the required LoS, then the LoS are separated into two categories:***

- *Customer LoS (CLoS): focus on how customers experience services. They tend to be outcomes about service attributes that customers understand. These include safety, ride comfort, the availability of direction signage and the accessibility and reliability of travel.*
- *Technical LoS (TLoS): relate to the service the physical asset provides measured in objective technical terms. It is linked to the CLoS, but expressed using technical language, such as average travel speed, crashes per hundred thousand kilometres travelled, and roughness (rideability) levels.*

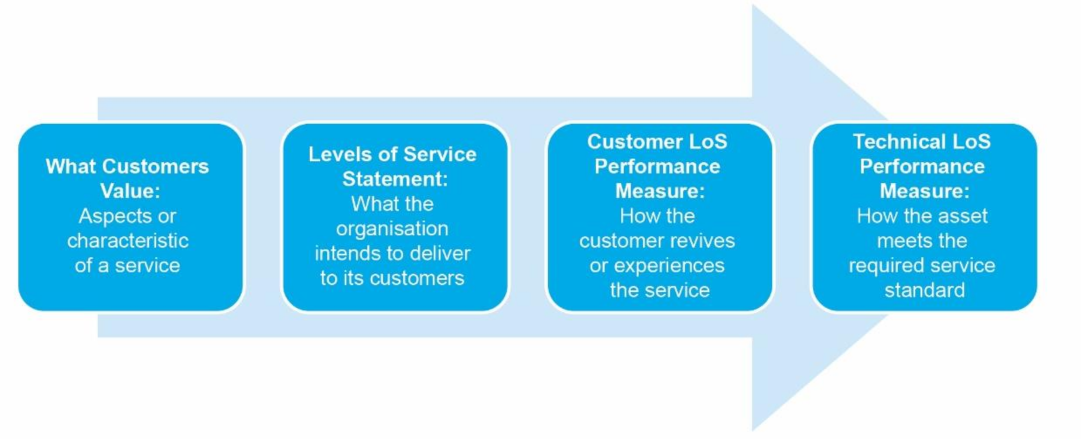
Table 2.1 summarises a typical range of LoS attributes alongside their TLoS technical measures. In order to provide fit-for-purpose LoS, the standards of LoS are assigned in accordance to where the roads sit in the road classification hierarchy: that is, the highest standards of LoS occur on the highest road classification and the lowest standards occur on the lowest road classification.

Table 2.1: Summary of CLoS attributes, descriptions and TLoS measures

| CLoS attributes | CLoS description | TLoS measures |
|---|---|---|
| Accessibility | The network is available at all times to enable journeys to destinations to be completed | Roads aim to have 100% to 90% annual availability to traffic |
| Function | Different roads are available to different road users (cyclists, heavy vehicles, etc.) based on their functional needs | Rideability (roughness, potholes, cracking)<br>Suitable lane width and numbers of lanes |
| Navigation | Signs, delineation and markings are clear, easy to read and provide information | Suitable reflectivity, conspicuity |
| Safety | The road network is becoming safer to use<br>Safety risks are proactively managed | Adequate skid resistance, surface texture<br>Limits to lane rut depth and edge drop-off<br>Number of crashes per 100 000 km travelled<br>Suitable shoulder width and surfacing |
| Reliability | Users can expect consistent travel times with some exceptions | Average travel speed (km/h) |
| Resilience | The likelihood of a journey being disrupted by an unplanned incident or hazard event is minimised | Adequate stability rating (factor of safety) of embankments and cuttings<br>Minimal closures due to flooding |

Measuring and meeting LoS performance begins with the characteristics of the service that are ‘valued’ by customers and ends with the delivery of actions, through the use of TLoS measures as illustrated in Figure 2.6.

**Figure 2.6: Aligning CLoS and TLoS with what customers value**




*Source: Austroads (2018d).*

Table 2.2 shows typical TLoS applied to a mainly arterial road network by the Queensland Department of Transport and Main Roads (TMR).

**Table 2.2: TLoS for road condition measures**

| Road category: general description | Definition | Example: Rutting (mm) *(80th percentile)* | | Roughness-IRI (m/km) | | Speed |
|---|---|---|---|---|---|---|
| | | Max. | Min. | Max. | Min. | |
| Priority Road Network 1 | These roads are assessed using specific criteria including population, socio-economic contribution, traffic, strategic, social equity and network connectivity | 20 | | 6 | 3.5 | 100 km/h max posted speed and specified 110 km/h speed limited zones |
| Priority Road Network 2 | These roads are assessed using specific criteria including population, socio-economic contribution, traffic, strategic, social equity and network connectivity | 20 | | 6 | 3.5 | |
| Priority Road Network 3 | These roads are assessed using specific criteria including population, socio-economic contribution, traffic, strategic, social equity and network connectivity | 20 | | 6 | 3.5 | |
| Other State Controlled Road Network | These roads main function serves the purpose of collecting and distributing traffic from local areas to the wider road network | 20 | | 6 | 3.5 | |

*Source: Austroads (2017a).*

Examples of common surface and structural condition and ride quality pavement performance indicators are illustrated in Austroads (2018d) which are typically used for reporting purposes, and for identifying candidate treatment locations, although more detailed measures are often applied either individually or in combination for the latter purpose. The AusLink ride quality indicator (RQI) is one such example and be used to illustrate desirable and undesirable road operating conditions. This indicator when applied takes account of measured roughness, traffic and traffic composition, and typical operating speeds. The sense of the relationship is illustrated in Table 2.3 where a logical structure of lower (desirable) roughness values coincides with greater traffic use.

Table 2.3: Illustration of the AusLink ride-quality indicator (RQI)

| Example | Traffic range (vehicles per day) | | | | | |
|---|---|---|---|---|---|---|
| Roughness range (IRI) | 0–500<br>Very low traffic | 501–1 500<br>Low traffic | 1 501–3 000<br>Below medium traffic | 3 001–5 000<br>Above medium traffic | 5 001–10 000<br>High traffic | > 10 000<br>Very high traffic |
| 0 – 2.8 | Good | Good | Good | Good | Good | Good |
| 2.8 – 3.2 | Good | Good | Good | Good | Good | Mediocre |
| 3.2 – 3.6 | Good | Good | Mediocre | Mediocre | Mediocre | Mediocre |
| 3.6 – 4.0 | Good | Mediocre | Mediocre | Mediocre | Mediocre | Poor |
| 4.0 – 4.6 | Mediocre | Mediocre | Poor | Poor | Poor | Poor |
| 4.6 – 5.2 | Mediocre | Poor | Poor | Poor | Poor | Very poor |
| 5.2 – 5.7 | Poor | Poor | Very poor | Very poor | Very poor | Very poor |
| 5.7 – 6.3 | Poor | Very poor | Very poor | Very poor | Very poor | Very poor |
| > 6.3 | Very poor | Very poor | Very poor | Very poor | Very poor | Very poor |
| **Average speed limit** | **105** | **102** | **101** | **97** | **94** | **96** |

*Source: Austroads (2018d).*

A further example is the AusLink preventative maintenance indicator (PMI) which is employed as a surfacing age condition measure, and is reported as the length of roadway occupying different categories of good (< target age), mediocre (1 to 1.3 times target age), poor (1.3 to 1.6 times target age) and very poor (> 1.6 times target age). For Australian conditions, the target age can also be determined using the ARRB oxidation model (Austroads 2010). Many road agencies have also developed local models or target values using field-performance data.

## 2.3.2 Road Asset Preservation Strategies

### Road Asset Preservation Strategy (RAPS)

The RAPS translates road network management strategy (RNMS) objectives, driven by CLoS outcomes, to priorities for managing the condition and performance of the road system assets. A RAPS identifies and prioritises what asset maintenance and renewal activities are required to achieve and sustain the asset condition and performance standards as identified in the overarching RNMS. It recognises both measured and forecast patterns of deterioration of asset condition, the effects of various treatment strategies on life-cycle costs of the asset and the effect of asset condition on road user costs, ride quality and safety.

The RAPS provides the strategic framework for managing the condition and performance of the road network. It enables the development of sustainable maintenance and restoration programs to achieve and maintain the asset condition and performance objectives and target TLoS standards developed in the road use management strategy. It is also the primary guidance for asset managers and maintenance management personnel. A pavement management system (PMS) is the decision tool that is used in developing these sustainable maintenance and renewal programs (see Section 2.5.1). Coordination between the RAPS, Road Asset Investment Strategy (RAIS) and Road Use Management Strategy (RUMS) can aid in improving the efficiency of the delivery of these various programs and the minimisation of disruption to the road network. The balance of investment in each program will also influence overall network outcomes, with alternative programs (and options) being a key input to assessing needs and the impact of different strategies.

***Road Asset Preservation Strategy (RAPS)***

***The key elements in formulating a RAPS are:***

- *Inventory and condition data collection and update for road lanes and shoulders.*
- *Review of the minimum CLoS acceptable road conditions for ride quality (roughness), safety (rut depth, pothole frequency, wearing-surface stability) and the accessibility and reliability of travel identified through community consultation.*
- *Analysis of road condition trends over time (patterns of deterioration and improvement). Strategy level analysis can be undertaken by predicting the common performance of broad groups of similar roads in similar operating conditions, e.g. rural and rural remote pavements by road classification.*
- *Five and ten-year expected performance and condition predictions, of each road group.*
- *Analysis of the effect of different surface treatments of (generic) routine and periodic maintenance treatments and different intervention levels for maintenance treatments on road asset conditions, road user costs and whole-of-life-cycle costs. Alternative scenarios for annual budget requirements also need review.*
- *Identification of the optimum condition intervention level to achieve and sustain acceptable target CLoS conditions at minimum life-cycle cost.*
- *Assessment of current and projected maintenance treatment needs and costs, recognising the current life-cycle stage of each road, predictions of deterioration and treatment effectiveness under assumed traffic demand growth scenarios.*
- *Prioritisation of projected maintenance needs as per the impact on road user safety, exposure and costs (strategic route importance, traffic volume), road serviceability and life-cycle costs.*
- *Review of forward funding scenarios (local, state, and federal government program sources) and potential private sector contributions.*
- *Documentation of proposed target road network conditions, treatment regimes, and budget requirements for each road.*

The RAPS adopted will suit the pavement types and their performance, climatic patterns, characteristics of road use (particularly traffic volumes, axle-loads and distributions), the cost of construction and maintenance treatments, and the impact of the conduct of maintenance works on traffic flow.

### 2.3.3 Road Asset Investment Strategies

The RAIS translates road network management strategy (RNMS) objectives, driven by CLoS outcomes, to priorities for investments in meeting the needs of road system capacity. A RAIS identifies and prioritises what capital investments are required that will progressively achieve the target network configuration and capacity identified in the RNMS, recognising forecast patterns of road use demand and funding availability.

The RAIS articulates the priorities and effectiveness of capital investments in the capacity of the road system. It provides the framework for the progressive development and evaluation of road system improvements to achieve the performance objectives and target standards developed in the overarching RNMS. It is used for the guidance of planners, project designers and the developers of road investment proposals.

***Road Asset Investment Strategy***

***The key elements in formulating the RAIS are:***

- *Review the RNMS to identify priority locations of current poor road system performance and social and environmental impacts with respect to current CLoS.*
- *Review the RNMS for future travel demand and road system performance predictions for at least five and 10-year scenarios based on traffic growth assessments.*
- *Examine the identified performance deficiencies and development of project concepts which would provide potential cost-effective short-term (< 5 years) and medium-term (5 to 10 years) treatments considering network connectivity and relevant RUMS.*
- *Develop a planning concept, including the scope, design standards, and estimate of costs for such proposed works.*
- *Evaluate the benefits and impacts of proposed works, including indicative marginal benefit/cost ratios (MBCR). Evaluation of the effectiveness of implementation of individual projects and implementation of groupings of suitable compatible projects is also required.*
- *Review scenarios for the phased implementation of the RAIS, recognising priorities for progressively achieving road network performance targets and the forward funding scenarios (local, state, and federal government program sources) and potential private sector contributions.*
- *Recognise that capital investments in new road and increased capacity road assets through implementation of the RAIS have long-term maintenance implications to be considered and integrated into the RAPS. The predictions of asset growth in the RAIS are an important input to the RAPS.*
- *Review and refine the strategy with stakeholder consultation.*

### 2.3.4 Road Use Management Strategies

The RUMS provides a strategic framework to manage the use of the road system (Austroads 2016a). Examples include vehicle registration criteria, mass and dimension limits, operational requirements, licensing of drivers and operators, traffic management, and road space allocation. Such operational management strategies are complementary to the RAIS and the RAPS.

The road system cannot respond to unconstrained use. Strategies to manage use are commonly included in a RUMS and as separate focused strategies for particular road user groups (e.g. freight strategy, port access strategy, timber cartage strategy, grain haulage).

***Road Use Management Strategies***

***A typical RUMS may include:***

- *designated routes for heavy or oversize vehicles*
- *speed management strategies*
- *restricted hours for the movement of oversize loads*
- *peak-hour operation of transit and high-occupancy vehicle lanes*
- *priority for public transport vehicle movements.*

Travel demand management (TDM) strategies – which focus on managing the level of travel demand and influencing modal choice – are a sub-set of RUMS.

## 2.4 Identify Needs for Investment and Preservation

### 2.4.1 Measurement of Road Condition and Performance

The measurement, collection and reporting of road condition data, such as roughness, rutting, strength (deflection), cracking, skid resistance and texture needs regular routine measurement to ensure technical levels of service (TLoS) are not being exceeded as part of the strategies for RAPS and RAIS. Suggested threshold surface distress levels for two given road types are shown in Table 2.4. A deflection survey for strength should be initiated when either any of the performance indicator limits and/or rates is exceeded. Strength data is also becoming more widely available at a network level for example through the use of the traffic speed deflectometer (TSD) (Austroads 2019a). This data is a valuable input to determining pavement maintenance and renewal needs because it can help inform treatment selection, including the extent and requirements of structural treatments as opposed to surface or semi-structural treatments.

**Table 2.4: Indicative threshold surface performance indicators to initiate targeted discrete network-level surveying**

| Road type | Typical operating conditions | Performance indicators | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | AADT (v/day) | Roughness | | Rutting (1.2 m straight edge) | | Cracking | | |
| | Speed (km/h) | | Limit (IRI mm/km) | Rate (IRI/yr) | Limit (mm) | Rate (mm/yr) | Limit (% area) | Rate (% area/yr) | |
| Medium trafficked arterial | 80–100 | 2 000–10 000 | 4.2 | 0.2 | 15 | 0.6 | 5 | 0.5 | |
| Low trafficked arterial or main road | Various | < 2 000 | 5.4 | 0.3 | 20 | 0.8 | 10 | 1 | |

*Source: Austroads (2018d).*

The road condition and performance measurements will inform whether preservation and investment works will need to be initiated when the TLoS limits are exceeded, or predicted to be exceeded, within the next two- to-five years.

There are other measurable forms of surface condition such as edge drop-off, surface texture and skid resistance, not included in Table 2.4, that impact on safety. These conditions have investigatory levels for the initiation of measurement surveys (Austroads 2011a). Austroads has also developed a common data output specification for roughness, rutting, strength, texture and skid resistance (Austroads 2015b) to give guidance on the collection of these distress measures.

Table 2.5 gives some guidance on the expected frequency of road condition surveys for roughness, rutting, strength, cracking, skid resistance and texture for medium to low trafficked local roads.

**Table 2.5: Road condition survey frequency**

| Road network | Frequency | | | | | |
|---|---|---|---|---|---|---|
| | Roughness | Rutting | Strength | Cracking | Skid resistance | Texture |
| Arterial roads with average deterioration | 2–3 years | 2–3 years | 5–15 years | 2–3 years | 1–5 years | 1–5 years |
| Low trafficked local roads with low deterioration | 5 years | 5 years | 5–15 years | 3–5 years | 5 years | 5 years |

*Source: Roberts and Martin (1996).*

### Pavement condition assessment of surface distresses

Apart from the major measurable forms of pavement distress such as those noted in Table 2.4, there are other observable forms of surface distress (Table 5.1) such as potholes, bleeding of the bitumen binder, loss of surfacing, severe local cracking, edge drop-off and edge break. These distresses need to be detected and their extent and severity documented by regular inspections. In some instances, these defects, such as loss of surfacing, cracking and bleeding, can be addressed by planned resurfacing programs that form part of the road asset preservation strategy (RAPS).

However, some distresses such as potholes and edge drop-off have significant safety impacts and need to be addressed promptly. Regular routine maintenance is the usual means of rectifying many of these defects with a dedicated maintenance crew to ensure that the safety TLoS is not exceeded.

Many of these surface distresses can be detected by monitoring equipment, such as a network survey vehicle (NSV) used to measure roughness, rutting and texture at highway speed. Most NSVs are equipped with digital cameras that detect these distresses, but in order to meet safety and hazard management requirements regular inspections are required.

### Roughness

Roughness is a road condition parameter that quantifies the ride quality of a pavement. Measurement of roughness focuses on characteristic dimensions that affect vehicle dynamics, ride quality and dynamic pavement loads. Road roughness characterises deviations from the intended longitudinal profile of a road surface with characteristic dimensions that affect vehicle dynamics (and hence road user costs), ride quality and dynamic pavement loading (Austroads 2018d).

Road roughness can be measured using an inertial profilometer in the form of lasers mounted on a beam (Figure 2.7) or it can be assessed visually and rated, although this approach can be highly subjective and more suitable for unsealed roads. Roughness measurement frequency for local roads can vary from once every two years to once every five years, depending on the amount of traffic.

Figure 2.7: Inertial laser profilometer

Current practice measures the longitudinal profile of the road in both wheel paths in a selected lane with an inertial profilometer and mathematically modelling the response of a hypothetical vehicle (quarter-car simulation) to the longitudinal wheel path profile. Roughness measured in this way is lane roughness (Lane $IRI_{qc}$) and is the average of the International Roughness Index (IRI) quarter-car values measured in each wheel path. Lane roughness is reported at 100 m intervals as the reporting standard (Austroads 2018d).

### Rutting

Rutting is defined as the permanent traffic-associated deformation within pavement layers which, if channelised into wheel paths, accumulates over time and becomes visible as a rut (Paterson 1987). Rutting is a pavement condition parameter that characterises the transverse profile of a road surface and aims to quantify the severity and extent of ruts over a pavement surface.

Automated objective measures of transverse profile can be used to estimate the depth (severity) and extent of rutting. Automated rutting measurement uses the same inertial profilometer used for measuring roughness. Rutting measurement frequency for local roads can vary from once every two years to once every five years, depending on the amount of traffic.

Rutting depth is measured relative to a 2 m straight edge and reported at 100 m intervals as the reporting standard (Austroads 2018d), common to both manual and automated measurement techniques. Figure 2.8 shows how rutting can be measured manually.

The monitoring and control of rutting has important performance implications because it influences vehicle operation (affecting vehicle tracking), safety (aquaplaning) and dynamic loading (Kannemeyer 1995). A major use of rut measurement is as a measure of the serviceability of the pavement surface through ponding of water and the associated potential loss of skid resistance.

Rutting depths measured over a given length can be reported by the percentages of rut depths occurring between rut depth limits.

**Figure 2.8: Manual measurement of rutting**

*Source: Knowledge bases Australia – Local Government and municipal (LGAM) (2020).*

### Strength

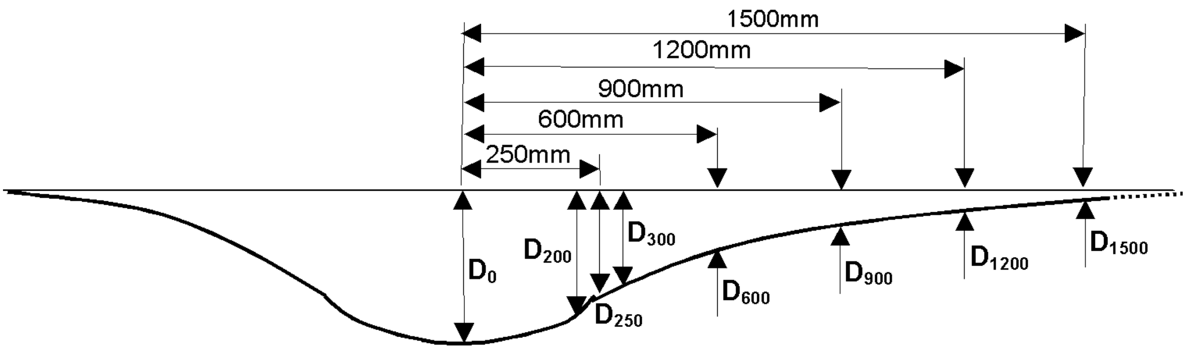
Pavement strength is an important characteristic defining the general condition of a road. As well as being the main input to an assessment of the need for pavement rehabilitation works, strength is a significant determinant of the surface performance of the pavement in terms of distresses such as roughness, rutting and cracking. Pavement strength has a major influence on the asset valuation of a road pavement.

The assessment of pavement strength is by deflection testing under a standard load, which is the approach used by industry. The indication of a pavement's strength can be known through measurement of the magnitude and shape of its deflection bowl when tested under a standard load.

### Pavement deflection

Figure 2.9 shows the vertical cross-section through the deflection bowl depression in the pavement surface under a standard load. The magnitude and shape of the bowl is described in terms of the deflection value 'D' (usually microns, but sometimes mm), and its offset (mm) from the centre of the bowl. Thus '$D_0$' is the deflection at the centre of the bowl (which is also the site of the maximum deflection), '$D_{250}$' is the deflection 250 mm offset from the centre, '$D_{600}$' is the deflection 600 mm offset from the centre, and similarly for other values, as shown in Figure 2.9.

**Figure 2.9: Pavement deflection bowl**




*Source: Austroads (2018d).*

The maximum deflection, and shape of the bowl, depends on a number of other factors, including the magnitude of the standard load (usually measured in kN, typically 40 or 50 kN), and the means of load delivery to the pavement surface; for example, the Benkelman beam (BB), the traffic speed deflectometer (TSD) and the deflectograph (DFG) measure deflection due to a rolling load application using twin truck tyres, while the falling weight deflectometer (FWD) uses an impulse load via a circular loading plate.

Default relationships between deflections from the above devices, excluding the TSD, vary with pavement type and structure and have been determined for granular pavements in Australia (Austroads 2018d, Part 15.1.3). A deflection relationship between the FWD $D_0$ and the TSD $D_0$ for granular pavements was found by Lee and Conaghan (2016) and further research based on this work has produced standardisation factors for standardising TSD deflections as equivalent Benkelman beam values by Austroads (2019a) for use in empirical design. Such relationships are also applicable for network-level asset planning purposes with the maximum measured deflection, $D_0$, related to the pavement/subgrade strength estimate of the modified structural number, SNC, (Paterson 1987).

### Cracking

Cracking is a pavement defect usually identified as one or more visible discontinuities (minimum width 1 mm) at the surface, often indicating unplanned vertical fracturing of the pavement. There are multiple types of cracks, which can be classified by their direction through the pavement, and whether they are isolated or in groups, and the spacing between them (Table 5.1 lists the various types of cracks).

The scope of a network-level cracking survey refers to the size of the cracking sample (length, (% of network), width, and the sampling frequency of the pavement surface surveyed. The scope of network-level surveys varies between manual and automated survey methods. A cracking survey is regarded as 'manual' when it uses manual crack recognition and recording (RTA 1990). A cracking survey is regarded as 'automated' if it uses detailed photography and visual crack recognition and interpretation (partially automated) or crack recognition and interpretation (fully automated) by an algorithm developed for this purpose.

Cracking measurements, in terms of % of lane area cracked, should be reported at 100 m intervals for both manual and automated cracking.

Surface cracking is recognised as an indicator of overall pavement condition. The different types of cracking result from of a variety of deterioration mechanisms occurring at the surface, within the pavement structure or in the subgrade. Therefore, the collected cracking data can be used, together with other condition data and drainage condition, as diagnostic tools to identify the causes of pavement distress. When the causes are determined, appropriate remedial measures can be implemented.

### Skid resistance

Skid resistance is a condition parameter that characterises the contribution that a road surface makes to the level of friction available at the contact patch between a road surface and vehicle tyre during acceleration, braking and cornering manoeuvres. The skid resistance of a road surface is at its lowest when it is affected by water and/or subject to contaminants, such as mud or loose detritus resulting from the day-to-day usage of the road network.

If the available level of friction at any of the contact patches between the tyre and road surface is insufficient for the manoeuvre being attempted, then the driver of the vehicle is likely to lose control of the vehicle, which may in turn result in a collision with another road user and/or highway-related infrastructure.

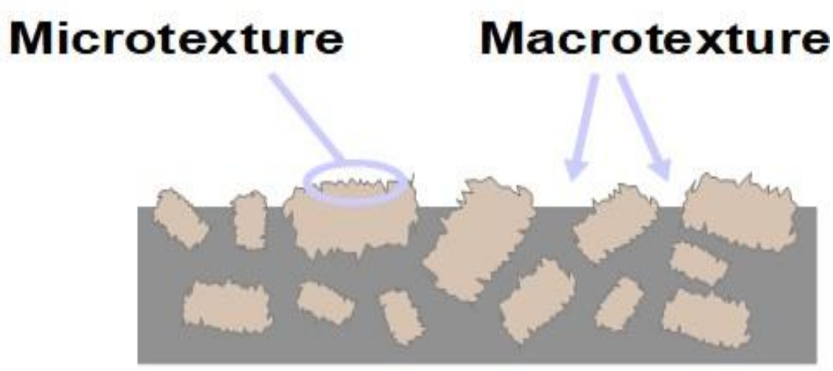
Austroads (2011a) has guidance for the development of policies to manage skid resistance that support road agencies to establish a local strategy to manage skid resistance at individual site and/or network levels.

### Texture

The texture of a road surface makes a vital contribution, along with the skid resistance, to the total available level of friction at the contact patch between the vehicle tyre and road surface, and particularly so at higher vehicle speeds and/or in wet conditions.

There are two forms of surface texture, microtexture and macrotexture, as shown in Figure 2.10. The network texture surveys only measure macrotexture. Macrotexture can be measured manually by the sand patch method (TNZ 1981) giving the mean profile depth (MPD) and by a mobile laser profile method (Austroads test method AGAM-T013-16 *Pavement Surface Texture Measurement with a Laser Profilometer*) giving either the MPD or a sensor-measured texture depth (SMTD).

**Figure 2.10: Representation of microtexture and macrotexture**




*Source: Viner et al. (2006).*

### Pavement condition index

The PCI is based on the individual condition indices (CIs) of the attributes. The PCI is an aggregate of these individual CIs, using the concept of a 'weighted maximum' (COST 2008). The composition of the attributes in a modified version of the PCI is outlined in Table 2.6.

**Table 2.6: Composition of PCI**

| Composition of PCI | |
|---|---|
| **Attribute** | **Description** |
| NAASRA roughness (NRM) | NAASRA counts/km with separate limits defined by traffic level and speed zone |
| Rutting | Mean rut depth (mm), with separate limits defined by traffic level, climate and speed zone |
| Cracking | Area (%) of all cracking |
| Remaining useful life (RUL) | RUL of the road pavement in years |
| Surface age | Age of the latest surfacing in years |
| Skid deficiency | % less than investigatory skid resistance |

*Source: Martin, Kadar and Sen (2017).*

In order to express the overall condition of an asset in terms of a PCI, the above condition indices are aggregated (COST 2008). The estimation of the remaining useful life (RUL) attribute is detailed below using a traffic capacity relationship. The RUL is based on the traffic speed deflectometer (TSD) measurements of pavement deflection to assess remaining structural life (Martin, Kadar & Sen 2017). The PCI is shaped by a decision-making approach that gives the greatest weight to the worst condition, while the other condition indices are considered as minor adjustments (COST 2008). The PCI is calculated by applying Equation 1, as follows:

$$PCI = MAX(w_i * Index_i) + p * (\frac{SUM(w_i * Index_i) - MAX(w_i * Index_i)}{\sum(w_i) - Avg(w_i)}) \quad 1$$

where

$w_i$ = weight for individual condition criteria, covering cracking, roughness, rutting, surface age (default value for each weight is 1)

$Index_i$ = index value for individual condition criteria, including cracking, roughness, rutting, surface age and RUL (1–5)

$p$ = condition factor (the current default value is 0.1).

## Estimation of RUL using TSD deflection, $D_0$, and traffic load capacity, CAP, relationship

The following traffic capacity relationships (Equation 2 to Equation 6) were derived from (Austroads 2008) for asphaltic (AC) and granular (GN) pavement bases. It should be noted that these capacity relationships were for the design of granular and asphaltic overlays on in-service pavements.

$$CAP_{AC} = [3.1077 / (D_0 – D_{200})]^{4.415} \quad \text{for } WMAPT \leq 2 \quad 2$$

$$CAP_{AC} = [2.6898 / (D_0 – D_{200})]^{5.105} \quad \text{for } WMAPT > 25 \quad 3$$

$$CAP_{GN} = 10^{(3.666 – D_{0\,95})/0.422} \quad \text{for } D_{0\,95} \geq 1.134 \quad 4$$

$$CAP_{GN} = [91.2 / (D_{0\,95} – 0.731)]^{1/0.3924} \quad \text{for } 0.8 \leq D_{0\,95} \leq 1.134 \quad 5$$

$$CAP_{GN} = 100\,000\,000 \quad \text{for } D_{0\,95} \leq 0.8 \quad 6$$

where

*WMAPT* = weighted mean annual pavement temperature (°C)

$D_0$ = TSD maximum deflection (mm)

$D_{0\,95}$ = 95th percentile of maximum estimated TSD deflection, $D_0$ (mm)

$D_{200}$ = estimated mean TSD deflection 200 mm from the maximum TSD deflection (mm).

For granular pavements the TSD $D_0$ was converted to a falling weight deflectometer (FWD) $D_0$ via the following relationship (Equation 7)(Lee & Conaghan 2016) as Equations 4, 5 and 6 are based on FWD deflections:

$$D_{0\text{-}FWD} = 0.9 \times D_{0\text{-}TSD} + 0.138 \quad 7$$

The $D_{0\ 95}$ was estimated via the coefficient of variation, COV, from the Australian long-term pavement performance (LTPP) study sites (Choummanivong & Martin 2016). The COV was found to be 40%. The $D_{0\ 95}$ of a cumulative distribution, in this case the $D_0$ distribution, is as follows (Equation 8) (Brown & Berthouex 2002):

$$D_{0\ 95} = 1.645 \times \sigma + \mu$$

$$D_{0\ 95} = 1.658 \times \mu \qquad 8$$

where

COV = $\sigma / \mu$

$\sigma$ = standard deviation of the deflection, $D_0$, distribution for each 100 m segment

= COV $\times\ \mu$

$\mu$ = mean of the deflection, $D_0$, distribution for each 100 m segment.

The RUL, in terms of years, using a known annual traffic loading, $MESA_{annual}$ was estimated by Equation 9 using the appropriate capacity estimate ($CAP_{AC}$, $CAP_{GN}$) from Equations 3 to 6.

$$RUL = CAP / MESA_{annual} \qquad 9$$

### 2.4.2 Inventory Update, Road and Surfacing Age

Inventory data describes the road asset, its constituents and other relevant data associated with its identification (location, lane and shoulder width). Recoding of road inventory data is critical to the asset data management process, in that all other functions associated with the collection and use of the condition data related to the selected road asset are dependent on the inventory. For instance, the adopted naming convention for road numbers needs to ensure that a consistent yet flexible approach is adopted. Because road networks are always evolving through local and regional development, road agencies may acquire or inherit additional road assets and they therefore need to be able to accommodate these changes in their asset registers.

Inventory data is also related to aspects of the road asset that may describe its current state such as pavement age (number of years since construction or the last rehabilitation, whichever is the lesser) and current surfacing age, road category and route designation (bus, freight, national significance). Some of the additional inventory data required to describe the road network may be acquired through the use of the same equipment undertaking pavement condition surveys. Geometry data such as rise and fall, curvature and grade can be obtained initially from an automated survey. Further inventory data relating to the roads' dimensions may also be obtained in this same manner through review of digital imaging that would have been captured as part of a network survey. While it is appreciated that such fundamental information may already be present in the agency's asset register, there are occasions where such information may benefit from validation and confirmation, especially if the origin and source of the base data is uncertain. In this manner, road agencies can extract additional benefit from their data collection procedures to take the opportunity to gather data related to the asset at the same time as obtaining condition-related data.

Use of manual and visual inspection approaches to confirming road inventory data are time consuming, lack repeatability, rely on the expert opinion of the inspector and have associated potential personnel safety implications.

### 2.4.3 Road Use

Pavement deterioration and long-term pavement performance is a function of the extent of heavy vehicle road usage. This is characterised by the road use data that includes the traffic volume and loading at selected locations. The collection methods and best practice of road use data collection are described in detail in Austroads (2017b), and key data parameters are as shown in Table 2.7.

Table 2.7: Key data parameters

| Parameter | Remarks |
|---|---|
| Traffic volume | Traffic volume is reported in terms of average annual daily traffic (AADT). The AADT is a processed and aggregated parameter based on detailed traffic counts assembled over a longer period. |
| Traffic composition | Traffic composition is reported in different ways, with the Austroads 12-bin classification being an example (Austroads 2017b). Other classifications also exist, including those employed by road agencies. The *Australian Transport Assessment and Planning* (ATAP) guideline PV2 (DIRD 2016) provides the most comprehensive description where a 20-vehicle fleet is provided as a basis for determining vehicle operating costs and road user costs. A number of classifications, including the Austroads 12-bin, have been mapped against each other in ATAP PV2. |
| Axle load | Axle load data is collected with appropriate measuring techniques. The data is processed and aggregated either into the actual number of vehicle types or into the percentage heavy vehicles (%HV) counted on the road and is used to estimate the cumulative or annual number of equivalent standard axles (ESAs) carried per lane. Typical gross vehicle masses and load damage factors are also reported in ATAP PV2 (DIRD 2016). |
| Traffic growth | Traffic growth is derived from past data and other economic/demographic forecasts. It is important input data for estimating future pavement performance. |

### 2.4.4 Asset Management Information Systems

An asset management information system (AMIS) is a tool that provides a comprehensive and structured approach to the long-term maintenance of physical road infrastructure using sound engineering, economic, business and environmental principles to facilitate the effective delivery of community benefits (Austroads 2018d). AMIS is a database used by road agencies to systematically collect and store information regarding road and road-related assets so that statutory and discretionary reporting on the performance of these assets is regularly undertaken.

*An AMIS provides the data needed to use decision-making tools such as pavement management systems (PMSs) that address the programming, budgeting and appropriate pavement treatment selection for road asset management. The PMSs aim to achieve an optimised approach to decision making aimed at the preservation (maintenance and rehabilitation) and investment (construction) of the road infrastructure.*

In the past it was common to build an AMIS in-house. Whilst these tailor-made systems might have functioned well, they usually failed to keep up with changing technology. Road agencies are ill equipped to maintain complex software, so these home-made systems are being replaced by commercial systems. Details on the functional requirements for procurement of an AMIS are outlined in Austroads (2018d, Part 9).

Austroads (2002) indicates what a typical AMIS should comprise, including the following core components:

- asset reference system, which allows the identification and location of individual components of the road network

- asset register, which lists the information relating to various aspects of the road asset such as inventory, condition, traffic and other road use data
- historical records of construction and historical records of routine maintenance, periodic maintenance and rehabilitation, etc.
- other information required within the system which may include:
  - key operational and performance data
  - maintenance data (available treatments and costs and benefits)
  - unit costs (maintenance and rehabilitation)
  - levels of service (CLoS and TLoS) framework linked to the road classification hierarchy.

### 2.4.5 Gap Analysis

A gap analysis determines the difference between the current actual road conditions, road use and performance of the road conditions and the expected performance and conditions required by the CLoS and TLoS from road use. This analysis also determines the needs for preservation and investment from which the works programs for these types of funding are derived. A major role of a PMS, after the information for the gap analysis is fed into the PMS, is to determine the programming, budgeting and appropriate pavement treatment selection location and the extent for preservation and investment work on the road.

In determining a total needs program for a defined network covering all road classes and surface types, a gap analysis can be undertaken to identify more specific needs where rules (measures and criteria) are applied for condition/performance or provision deficiencies/compliance in relation to:

- road preservation and renewal (sealed), considering measures such as ride quality, rutting and cracking/distress against stated TLoS
- road preservation and renewal(unsealed/formed), considering roughness, surface condition, shape and gravel adequacy against stated TLoS
- surface upgrading needs, by applying indicative breakeven traffic thresholds to warrant sealing or surface replacement (e.g. to asphalt)
- configuration including lane and carriageway width and numbers, shoulder types, kerb and channel requirements, etc. with these informed by policy guidelines/warrants
- intersection deficiencies informed by policy guidelines/warrants, e.g. for non-signalised and signalised intersections, and other types
- HV route improvements considering configuration and alignment, and the level of access by road class considering heavy vehicle types
- safety improvements based on crash statistics and risk analysis or policy guidelines/warrants.

The intent is to determine a comprehensive view of needs, i.e. not solely for unsealed or sealed roads, with programs and projects with options subject to further analysis and prioritisation. Gap analysis may also be informed by different traffic demand scenarios, as network growth can vary significantly on a geographical basis. Other similar impacts can include flood and climate risks, with these being important in considering future needs.

# 2.5 Develop Works Programs

## 2.5.1 Program Analysis Tools – Preservation Works Program

Within the framework of an AMIS, most road agencies use a PMS that provides appropriate rigour and additional focus to the management of the pavement assets. A PMS is often a module or component of the wider AMIS that is deployed corporately. The generic components of a PMS are outlined in Figure 2.11 which shows typical elements of an information system for managing pavement assets.

The AMIS database feeds this information to the PMS, the decision support system shown in Figure 2.11 where pavement life-cycle costing (PLCC) analyses over a defined period are conducted that include the road agency costs (RAC) of maintenance and rehabilitation, the road user costs (RUC) and other externality costs such as crashes and greenhouse gas (GHG) emissions. The PLCC analysis is a discounted cash flow analysis using a real discount rate and may include pavement salvage costs where maintenance treatment and rehabilitation options are not over the same time period. Omitting such considerations can seriously compromise an analysis, particularly where the benefits of a high-value option are not fully represented, e.g. where the analysis period is too short such that the full benefits are not captured. In such cases, salvage value can be applied as a negative cost (effectively a saving), otherwise a longer analysis period should be chosen.

### Specific components of a PMS for infrastructure preservation

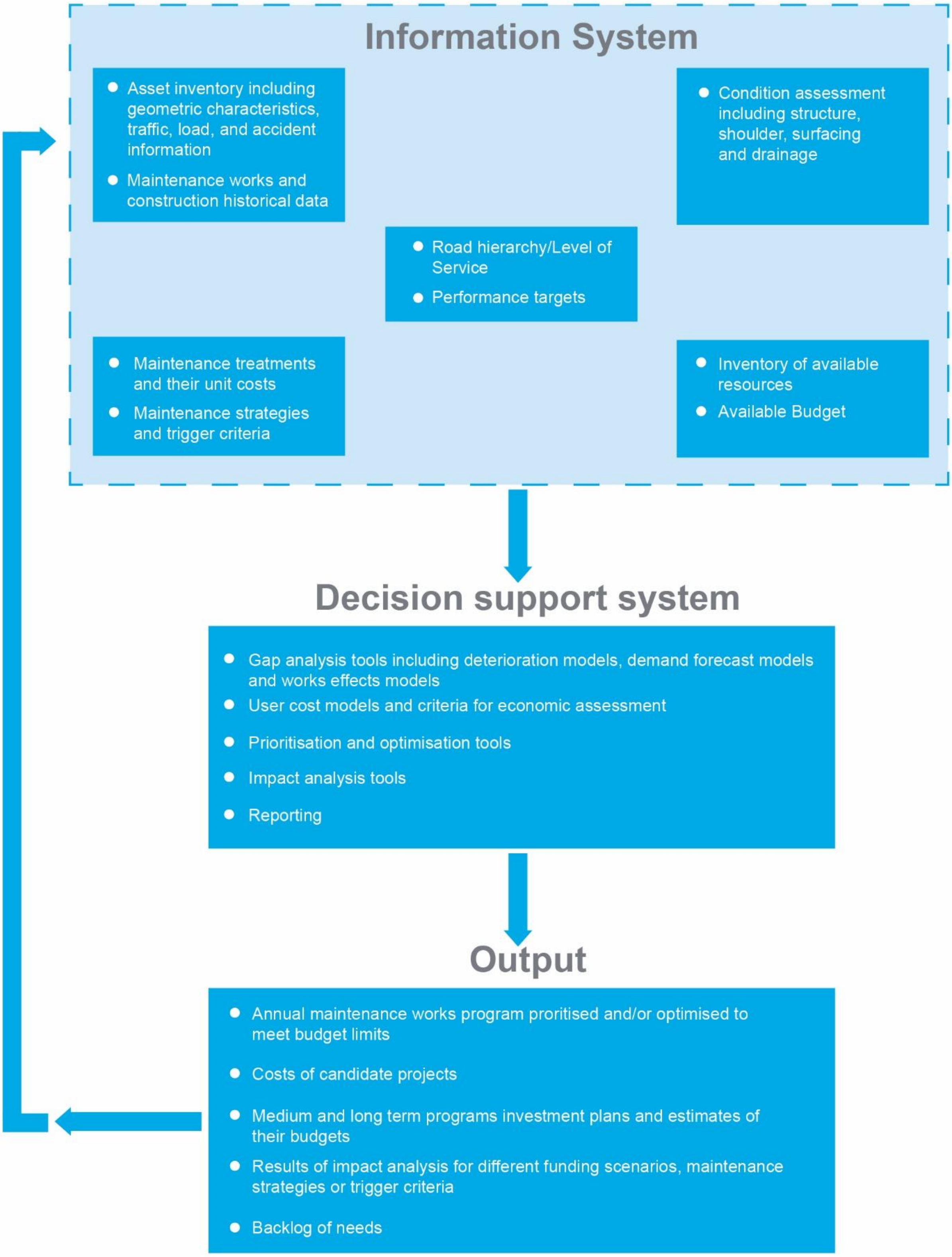
Specifically referring to the components of a PMS, the American Association of State Highway and Transportation Officials (AASHTO) (2011) outlines the common functional elements. These include the following:

- AMIS database – of road inventory, road use, performance and condition information, cost rates of maintenance and rehabilitation, that is fed into the PMS.
- Prediction models – for condition and pavement performance. This is the heart of the PMS, as this is where the functionality to take the current condition data and predict its future state is undertaken. The prediction models cover road deterioration (RD) models and works effects (WE) models for the various maintenance and rehabilitation treatment options examined (Figure 2.12). Martin and Choummanivong (2018) have documented RD and WE models based on Australian data for arterial and sealed local roads, and examples of their application specifically to low and medium trafficked roads are reported by Austroads (2020) with an emphasis on the sustainable use of local road material resources.
- Treatment selection – this component works with the RD model predictions to determine when a treatment option is applicable, based on a predefined suite of condition intervention thresholds and limits (TLoS). Typically, pavement resurfacing, rehabilitation and reconstruction treatments are defined in this component so that road segments with condition distresses within the range of each of these treatments will be considered as candidates for treatment. In the treatment selection framework, several critical components need to be defined:
  - the rules/criteria defining when a treatment may be applied
  - unit cost information related to the treatment, which can vary depending on the level/standard the treatment is required to deliver
  - the improvement predicted by the WE models for the various condition parameters that the treatment will yield.
- Annual budget allocation – an output annual program of potential preservation works from treatment selections is used to estimate of the amount of funding available to the agency to undertake these works. Depending on the budget, the analysis outcomes can determine the following:
  - if the agency has insufficient funding to address all selected treatments under a constrained budget and therefore a backlog of works will need to be addressed over the coming years

  - that sufficient funding is available to ensure that the desired TLoS is met with an optimal selection of proposed treatments under a constrained budget, although this may mean that the set TLoS cannot be fully delivered over the long-term
  - that sufficient funding is available with an optimal selection of proposed treatments under a constrained budget and as a consequence the agency is able to fulfil its LoS obligations now and into the future.
- Program of works – this is the final output of the PMS. This finalises the proposed works program with input from the works manager. The various functions that are undertaken by this module include:
  - finalising of the candidate list of treatments following site inspection, including review of the proposed treatments and their scheduling
  - rationalisation of the works program so that treatments are either brought forward or delayed to facilitate effective and logical works packaging to streamline procurement and reduce overall costs associated with undertaking the treatments
  - works procurement and management, including generation of contract documents, creation of works orders, tracking of completed works, closure and inspection of the completed works and maintaining a record of work histories and as-built details.

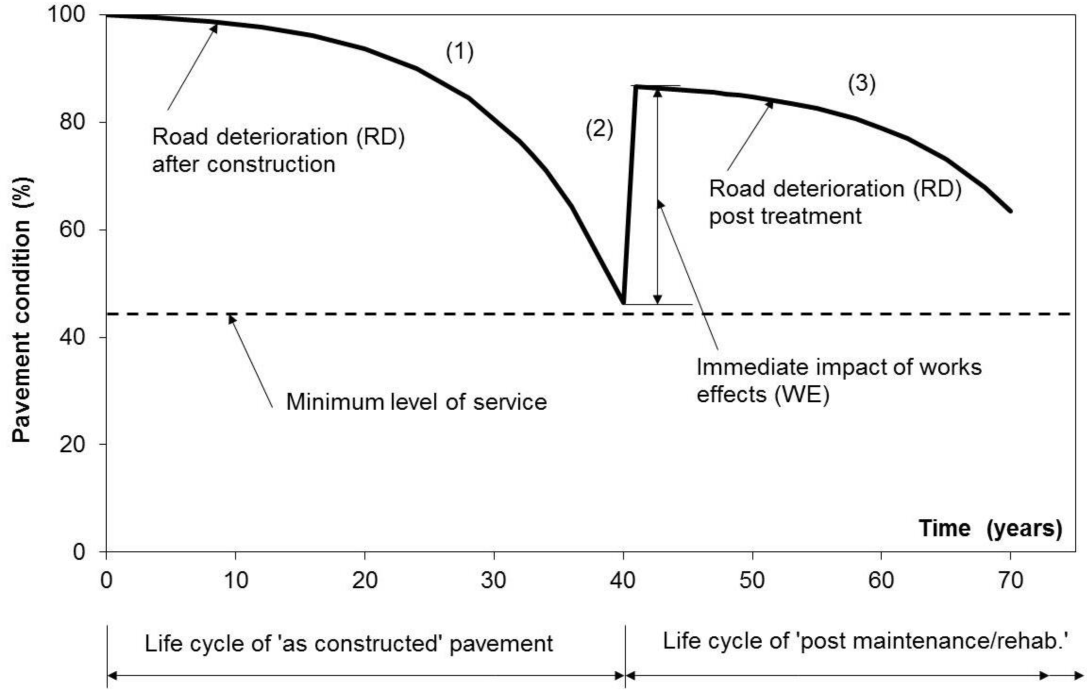
A number of PMS software platforms are commercially available. Michel (2015) conducted a review of some 14 PMS software platforms that have a range functionality that could meet typical local road agency requirements.

**Figure 2.11: Typical elements of AMIS and PMS**




*Source: Austroads (2018d).*

Figure 2.12: Three stages of pavement performance




*Source: Martin and Choummanivong (2018).*

## 2.5.2 Pavement Maintenance Treatments

The uppermost layer of a sealed road is called a surfacing or wearing course whose purpose is to:

- provide surface characteristics to meet CLoS for the particular road class such as ride quality (IRI), safety (texture and skid resistance), acceptable travel speeds and a durable surface
- reduce surface moisture reaching the pavement or subgrade and/or the loss of pavement moisture (waterproofing)
- reduce the rate of pavement wear and maintenance costs and extend pavement life
- reduce vehicle operating and maintenance costs.

Most sealed local roads have a bituminous surfacing which may be a sprayed seal treatment, an asphalt concrete (AC) or bituminous slurry. In some cases, concrete, segmental paver surfaces or clay brick pavers are provided. These surface treatments are applied to the existing road surface and selected to suit particular situations on the basis of achieving the required CLoS and lowest life-cycle cost.

Further details of these treatments and how they are applied are provided in Table 5.6.

## 2.5.3 Program Analysis Tools – Investment Works Program

### Context

Investment planning, evaluation and programming is about identifying where and when to invest resources in the most cost-effective manner on the road network for road users (Neumann & Markow 2004). This process needs to be undertaken in the context of the following:

- broad policy framework that may cover initiatives such as sustainability, a growing economy, and safety; this is embodied in the road asset investment strategy (RAIS) that allows the development of the investment works program

- performance measures that are identified from the RAIS and form a reference for future network condition and performance that need to be achieved by the investment works program
- technical tools and data that allow objective economic evaluation and optimisation to select the appropriate strategy from various investment alternatives to preservation works to improve road network performance
- monitoring and feedback that are needed to assess the impact of past and present investments on the road network.

### Investment program formulation

This is about identifying investment intervention options to close the asset performance gaps. These intervention options comprise the investment program. Owing to budget and resource constraints, only a portion of the investment program usually receives funding. To ensure an equitable allocation of resources and to achieve the organisation's RAIS, prioritisation of the investment program should occur from which an optimised outcome is the result.

Formulation of the investment program involves applying the following process for each asset performance gap (Austroads 2002):

- *Investment planning* involves investigating intervention options including engineering and management solutions such as road use policy initiatives, preventive or periodic maintenance, rehabilitation, reconstruction, construction, education, incentives, or penalties. During this process, maintenance works can be integrated with capital upgrades to ensure efficient and sufficient investment of funds.
- *Investment evaluation* involves defining and broadly costing phases of potential projects (both preservation and investment) and identifying the optimal intervention option to close the gap. Investment evaluation is applied to all programs. Coordination of these programs should be considered to ensure no duplication of works and a well-integrated program between preservation and investment works programs. Investment evaluation involves the following:
  - A list of investment options must be developed. For each option, a cost needs to be defined, the impact of the option on asset needs to be defined, and intervention criteria need to be defined for each option.
  - Once investment options and intervention criteria are defined, the AMIS database can supply information for the economic evaluation.
  - A list of maintenance and investment strategies that can be applied to the different road TLoS classes and their associated costs needs to be generated. Examples of pavement asset management prediction models include the road deterioration (RD) and works effects models of Martin and Choummanivong (2018) and road user cost models (vehicle operating costs, travel time costs and crash costs) from the *Australian Transport Assessment and Planning* (ATAP) guidelines (DIRD 2016).

The total needs program (preservation and investment) is the final list of projects created from this process.

Budget scenarios defined for asset management predict the amount of money that can be spent in any particular year of the analysis. This prediction uses the allocated money to optimise the network. Optimisation in this context is a single strategy selected for each of the analysis sections based on the overall benefit to the network as a whole and on the available funds. Optimisation is a mathematical technique for allocating scarce resources within the optimisation criteria that is aimed at gaining the most benefit or return possible in the given context.

The result of optimisation and funding scenarios will lead to the identification of the works program that will receive funding. The funding scenarios need some form of prioritisation based on their benefit-cost ratio (BCR) ranking and associated risk of not funding the projects within the overall budget constraints, see for example the evaluation of road maintenance projects in ATC (2006).

Note that for the ranking of maintenance and renewal investment of existing infrastructure the marginal benefit-cost ratio (MBCR) can be used as an indicator under circumstances where a budget constraint applies. It expresses the benefit to road users for each additional dollar of investment (including maintenance) relative to a given base case. Where new investment is undertaken, the denominator in the BCR is the total cost representing the new investment. Guidance is provided in the *National Guidelines for Transport System Management*, specifically Volume 3 (ATC 2006). These however will be replaced by the ATAP (www.atap.gov.au) guidelines in due course.

### 2.5.4 Economic Evaluation and Optimisation

#### Preservation and investment

The following is a brief description of the measures and approaches used for evaluating intervention/investment options. Decision-making at the strategic, program and project level can operate with different degrees of sophistication as follows:

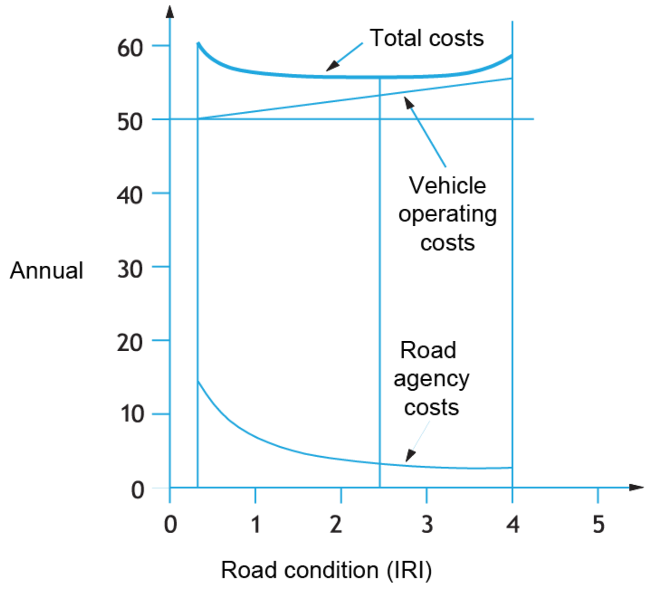
- *Current status* – the current condition is the driver in decision making and is often associated with a worst first approach to investment.
- *Whole-of-life-cycle-costing* (WOLCC) – future performance is the main driver in decision making and requires condition prediction modelling over the whole-of-life analysis period (DIRD 2016, 2018).
- *Multi-criteria analysis* (MCA) – this analysis covers aspects other than WOLCC, including environmental, social and political issues (Austroads 1998). Using MCA, the performance of options against qualitative criteria can be assessed together with the present values (PVs) to produce overall scores for the options that consider all relevant criteria. The overall scores can then be used to rank the options. To optimise budget expenditure, the cost to overall score ratio can be used as the measure to rank the options.
- *Risk analysis* – also involves consideration of multi-criteria, where investment options are evaluated using a risk assessment method.

#### Whole-of-life-cycle-costing

An example of a WOLCC analysis technique is shown in Figure 2.13 for optimising or minimising total community life-cycle costs.

In the context of asset management economic evaluation, optimisation should be focussed on evaluating what are regarded as the most important aspects of asset management. These aspects usually relate to minimising total life-cycle costs while meeting community and broader social expectations. Figure 2.13 shows minimisation of the total life-cycle costs of the road agency costs (maintenance, rehabilitation and construction) and the road user costs (vehicle operating costs and travel time costs), in annual road agency cost terms.

**Figure 2.13: Minimisation of total life-cycle costs**

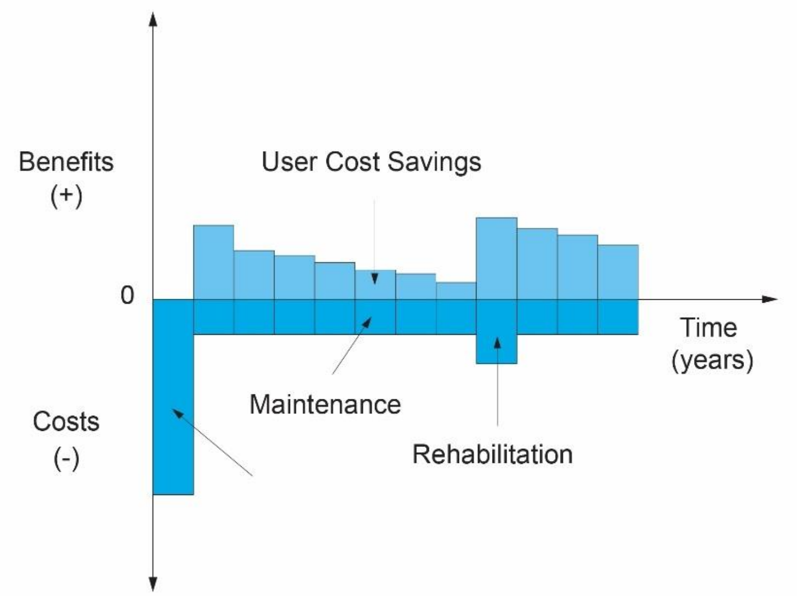



*Source: ARRB (2005).*

Other costs such as operating costs, crash costs, salvage and GHG emission costs could be included in minimising the total life-cycle cost. Figure 2.13 is the result of a discounted cash flow analysis over a given analysis period (30 to 50 years) for a number of different levels of road agency funding that result in different levels of road condition (IRI roughness) that give levels of vehicle operating costs and travel time costs.

Figure 2.14 shows details of the discounted cash flow analysis of the stream of costs associated with initial construction, maintenance works (routine maintenance and annualised periodic maintenance costs of resurfacing between construction and rehabilitation) and major rehabilitation. Against these costs are the benefits associated with reducing road users cost (vehicle operating and travel time costs) relative to a base case of the road user costs at minimum road agency costs.

**Figure 2.14: Distribution of costs and benefits during the life cycle of a road option**




*Source: ARRB (2005).*

### Definitions of work costs, benefits, net present value (NPV) and marginal benefit-cost ratio (MBCR)

*Maintenance works* for pavements are summarised in Table 2.8. The costs for these works should include the project costs associated with investigation, design, surveying, supervision, traffic management, environmental provisions and project procurement.

**Table 2.8: Types of maintenance works**

| Category | Description | Example |
|---|---|---|
| Routine maintenance | Minor repairs in response to specific pavement defects | Potholing, crack sealing, edge-break repair, minor patching, shoulder grading of unsealed shoulders |
| Resurfacing | To maintain surfacing integrity, especially cracking and ravelling – minor improvement in ride quality | Sprayed reseals, thin asphalt resurfacing, restoration of edge break and edge drop-off |
| Rehabilitation | Restores strength, and reduces roughness, rutting and cracking | Asphalt or gravel overlay, in situ stabilisation and major patching |
| Reconstruction | Full rebuilding of the pavement structure; results in 'as new' condition | Reconstruction |

*Capital, or construction works*, for investment pavement projects are summarised in Table 2.9. The costs for these works should include the project costs associated with investigation, design, surveying, supervision, traffic management, environmental provisions and project procurement.

**Table 2.9: Types of capital or construction works**

| Category | Description | Example |
|---|---|---|
| New pavement | Construction of a new pavement to meet TLoS, including earthworks, services relocation and installation of off-pavement assets | Pavement base and surfacing, subbase and surface and subsurface drainage works, line marking, guide posts, lighting |
| Pavement widening | As above, but usually limited to a lane width and shoulder | As above |
| Rehabilitation | Restores strength, and reduces roughness, rutting and cracking | Asphalt or gravel overlay, in situ stabilisation |
| Reconstruction | Full rebuilding of the pavement structure; results in 'as new' condition | Reconstruction |

*Benefits* are usually in the form of reductions in the following costs relative to a base case of level-of-service delivery of minimum road agency costs:

- road user costs (vehicle operating and travel time costs)
- crash costs (reduced incidence and severity of crashes)
- congestion costs where current traffic capacity is inadequate
- noise costs impact on the local community
- GHG emission costs associated with road users.

Other quantifiable benefits can be the salvage value of pavement at the end of the analysis period.

The costs and benefits cash flow streams are each reduced to a present value (PV) of $s in today's terms using Equations 10, 11 and 12

$$PV_{cost} = \sum_{I=1}^{N} cost_i / (1 + r)^n \qquad 10$$

$$PV_{benefit} = \sum_{I=1}^{N} benefit_i / (1 + r)^n \qquad 11$$

$$\text{Net present value (NPV)} = PV_{benefit} - PV_{cost} \qquad 12$$

where

$PV_{cost}$ = present value of the costs (sum of PV $cost_i$ in year 'i')

$PV_{benefit}$ = present value of the benefits (sum of PV $benefit_i$ in year 'i')

r = real discount rate (%), typically 7%, varies between 4–10% for sensitivity (DIRD 2018)

n = number of years in analysis

*Source: DIRD (2018).*

The investment/preservation option with the highest NPV is regarded as the most economic. The use of an NPV evaluation is particularly useful for the assessment of alternative investment/preservation options.

The costs shown in Equations 10 to 12 are the total PV of all costs (road agency and road user costs) expressed in terms of the annual costs for each road agency funding level.

The marginal benefit-cost ratio (MBCR), as defined below, is used for ranking projects where there is a budget constraint and as a convenient way to express the economic worth of an initiative:

$$\text{MBCR} \quad \frac{\text{PV net benefits}}{\text{PV additional net costs}} = \frac{\text{PV (benefits – operating costs)}}{\text{PV (additional investment costs)}} \qquad 13$$

*Source: DIRD (2018).*

Any MBCR greater than one also implies a positive NPV. A common issue encountered in the economic evaluation of maintenance and renewal projects is that net cost savings to the road agency can occur with a technically efficient solution. This means the denominator in the calculation is negative resulting in a negative MBCR, i.e. spending less provides more overall benefit. Strategies based on a 'stitch-in-time' concept can deliver such a result. The result is clearly beneficial, although it can confuse. In determining benefits and ranking indicators it is important to pay close attention to defining the base or 'business as usual' case and to seek specialist assistance in the analysis and interpretation of results.

# 2.6 Implement Works Program

## 2.6.1 Network and Project Management Levels

### Network management level

The network management level implies a top-down approach where the broad works for preservation/investment programs are more likely to define the preservation/investment strategies and other activities needed to achieve the TLoS and other network requirements rather than define detailed projects on specific lengths of each road in the network. The works program at a network level can provide the basis for scoping the work and provide options about how it could be packaged and delivered.

Alternatively, a bottom-up approach, means the broad works program is defined by the aggregation of well-defined project-level works. This approach may mean, as a consequence, that optimisation and prioritisation become more demanding in terms of data requirements and computing resources, although contemporary computer capacity is capable.

### Project management level

Project management level is concerned with managing specific details of maintenance treatments/investment works and other activities at clearly defined locations of the road network. Works programs at this level should be well defined so they can be accurately estimated for costs and completion programs that can potentially be implemented by means of a delivery package of project-level works.

Consequently, there is a feedback cycle between network and project level management. The information collected at a network level and subsequently used in analyses to estimate annual budgets, preservation/investment strategies, condition and performance limits on strategic road links can be the basis for setting condition and performance limits and budgets at a project level.

## 2.6.2 Requirements for Successful Program Implementation

The requirements for successful implementation of the works program from program initiation to completion and handover are as follows (Austroads 2014a):

- a well-defined brief for each package of the program which clearly states the objectives, scope, budget and major milestones
- a range of delivery strategies which impact on the scope of the program and how it is packaged and implemented
- a range of risk management strategies which also impacts on the delivery options
- adequate resources allocated for the program, which includes management resources
- compliance with occupational health, safety and welfare laws (Austroads 2009b) and other statutory requirements in relation to environmental and community concerns
- managing and monitoring the project.

### Project delivery strategies

The project delivery strategy adopted depends on the scale or scope of the project and the inherent risks associated with it. Table 2.10 shows the range of delivery strategies available that are associated with the varying scale and potential risk of the project.

Table 2.10: A summary of project delivery strategies

| Strategy | Suggested appropriate application |
|---|---|
| In-house | Minor works or maintenance |
| Design only, and subsequent construct only | Small to medium repetitive type e.g. standard bridge replacements |
| Hybrid, detail and construct (part design and construct) | Medium to large projects such as major maintenance/improvement works |
| Design, novate and construct (DN&C) | Transference of risks and benefits e.g. from client to a third party which replaces the original party as a party to the contract |
| Design and construct (D&C) | Contract delivery for large-scale works |
| Design, construct and maintain (DCM) | Multi-phase projects |
| Design, development and construct (DD&C) | A single or series of contracts delivered |
| Commercial development (i.e. BOOT, BOT) PPP(DB), PPP(DBO), PPP(DBFO), PPP (Concession) | Projects where funding is usually sourced commercially<br>Public private partnerships: e.g. tollways and tunnels |
| Alliance, PPP (Alliance), PPP(D&C), PPP(DD&C), PPP(DCM) | Complex projects requiring a high level of cooperation between parties |

*Source: Austroads (2018d).*

In addition, the competition and contestability for the project can influence project timing and its delivery arrangements. With small well-defined projects that are relatively low in risk, the use of in-house resources are appropriate. This approach may also be appropriate for high-risk projects that are poorly defined but relatively small in scale.

On the other hand, with large-scale projects that involve less prescriptive outcomes, that is, outcomes that can be better defined in term of performance, a range of delivery options is available that can involve complex contractual arrangements, alliances or partnerships.

## 2.6.3 Risk Management

*Delivery of projects is a risk sharing arrangement. Risks need to be identified before commencing the project and tracked during progress of the project. Initial identification of risks can define the project delivery options.*

When small-scale projects are undertaken in-house, all the risk is carried by the road agency. Conversely with large-scale projects that involve less prescriptive outcomes, the road agency can reduce its risk by packaging the project in such a way that the contractor carries all the risk by ultimately, in the extreme case, transferring ownership of the project to the contractor for a specified period of time.

There are usually commercial consequences in transferring risk to contractors as they will include a risk premium (cost) in their bid price to allow for risk. Where there is high contestability for the project, the premium for risk may be reduced by tenderers in order to secure the project. Consequently, contractual arrangements need to clearly define who is carrying/sharing the risk for the project so that completion of the project is secure and resorting to litigation minimised. A detailed description of project delivery packaging options is documented in Austroads (2009b).

### Risk management procedures

A council in undertaking treatment works on its roads needs to ensure that at all stages the procedures followed are in accordance with appropriate risk management practices.

Listed below is an outline of the procedures to be followed with regard to sealing and resealing operations. Further details are provided in the reference. The process outlined in Figure 2.15 can be used as a guide for a range of other treatment works.

The guidelines for sealing projects have been divided into four distinct stages. Each component stands by itself but is linked to the others.

**Stage 1 – Project identification**

Sealing projects should be developed in the context of an overall road policy. Once selected, the reasons for the treatment should be able to be stated in terms of the policy. Key elements of the project identification should be road network inspection and condition assessment, a rational method of candidate selection, a linking of that selection (costed) into a priority list with other candidates, a comparison of the list with available funding and a decision as to whether the project can be done in the current year or will need to be listed for consideration in a future works program. A good tool in this process is a five-year program.

**Stage 2 – Planning the project**

Once the list of candidates is confirmed, planning of individual sealing projects can commence. (Note that this does not mean that more than one project can be planned and undertaken together but that the process changes from a group of candidates to a single sealing project). The planning of the project will include technical elements, such as the design of the treatment, and operational elements such as the development of an environmental management plan (EMP), traffic control plan (TCP), traffic management plan (TMP) and checking contractors’ insurances etc.

Note that in relation to the development of TCPs with regard to signage, Australian Standards should prevail subject to other contract requirements.

**Stage 3 – Day of seal**

Once all the planning processes are complete, the works can be scheduled and carried out. The greatest risk of injury to staff or the public occurs on or soon after the day of work. The day should start with a risk assessment, a check on the pavement and on the weather, especially the temperature and risk of rain.

Statewide Mutual has developed an internet-based risk assessment software (JRS Risk Profiler Software System) which can be accessed via www.statewidemutual.com.au.

Once work has started, it should be done in accordance with an operational specification. TMPs, EMPs and TCPs should be adhered to and documented. Public utility services and other services need to be protected and reinstated after the work. After the sealing work is completed, a further risk assessment is required prior to the sealed surface being opened to traffic.

### Stage 4 – Post seal

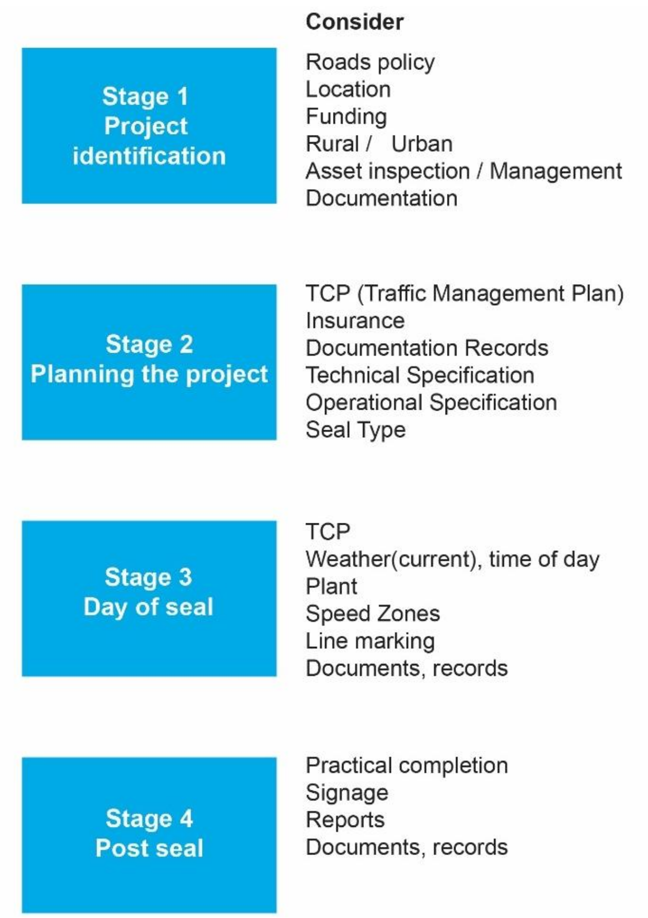
Immediately after the seal has been completed the site needs to be inspected on a regular basis to ensure it is safe. The inspection should concentrate on signs, aggregate build up and any indications that there is a problem with the seal, for example stripping or flushing.

Sweeping of the pavement needs to be undertaken to remove loose aggregate, especially if windrows develop. This should result from daily inspections of the new surface in line with the required procedures.

Line marking and pavement marking or remarking needs to be scheduled and undertaken. Once the line marking and pavement marking are complete, and loose aggregate has been reduced to defined acceptable amounts, the road can be reopened without any restrictions due to the works.

In line with the defect's liability period for the work, a final inspection between 6 and 12 months after the day of sealing should be carried out. If the surface is in good condition, the work can be signed off and all documents collected and stored.

**Figure 2.15: Flow diagram of the risk management process**




*Source: Statewide Mutual (2004).*

# 2.7 Audit and Review

## 2.7.1 Audit

The audit function involves monitoring the ongoing progress of the works program. This is also about ensuring that all the quantum of work listed in the works program is programmed and underway for completion within the specified program.

***The audit can also include examining the following as part of the works program delivery:***

- *the works program is on the way to achieving the specified outcomes*
- *any deficiencies in the outcomes are detected before program completion so they can be addressed and rectified before completion.*

## 2.7.2 Review

The review function involves monitoring the outcomes of the works program. This is not just about ensuring that all the quantum of work listed in the works program was completed, but that it was completed to the scope, standard and quality specified.

***The review can also include examining the following associated performance measures set by management as part of the works program delivery:***

- *financial performance of the works program*
- *were the expected improvements in condition and performance achieved and reflected by a customer survey after the works program?*
- *were the staff engagement, utilisation and productivity targets met?*

The results should be communicated to the wider organisation through meetings and forums to show the road agency's performance in delivering works programs. The results also feed back into the strategy development process for the next yearly asset management cycle.

# 3. Design

## 3.1 Road Planning and Development Overview

### 3.1.1 Overview

During the planning phase, an assessment of the proposed road aspects such as class, pavement type, purpose, location, impacts, costs and potential alternatives is undertaken. This process may take place over several, increasingly detailed stages, such as those outlined in Table 3.1.

Table 3.1: Example stages of road planning

| Planning stage | Aspects to consider |
|---|---|
| Assess feasibility | • Current transport needs (e.g. of the public)<br>• Existing land use<br>• Current road and traffic conditions<br>• Potential need for cross-jurisdiction collaboration<br>• Timeline and cost forecasting<br>• Potential impacts (e.g. on the network, environment, future development)<br>• Possible alternatives |
| Define the scope | • Approximate location<br>• Road hierarchy and classifications (Section 3.4)<br>• Estimated traffic capacity<br>• Design life<br>• Level of service<br>• Proposed pavement and surfacing types (e.g. flexible vs. rigid; sealed vs. unsealed; granular vs. asphalt vs. concrete) |
| Preliminary plan – to be approved | • Connection to existing network<br>• Allowance for future network connections<br>• Traffic, safety and road engineering solutions<br>• Environmental impact assessment and design considerations<br>• Climate and moisture considerations<br>• Roadside considerations<br>• Construction and future maintenance considerations<br>• Preliminary pavement design (including specific structural and drainage design, and pavement and surfacing types)<br>• Cost estimate<br>• Target timeline<br>• Construction outline (e.g. short-term stages or long-term staged construction) |
| Final plan – to be approved | • Precise location<br>• Geometric design of the road<br>• Detailed traffic, safety, environmental impact, and road engineering solutions<br>• Site evaluation (e.g. assessing the in situ conditions)<br>• Detailed plan for the roadside, including consideration of exclusion and clearance zones (Section 4.6.2)<br>• Finalised pavement design<br>• Refined cost estimate<br>• Construction plan including any and all required documents |

*Source: Adapted from Finnish Transport Agency (2010).*

### 3.1.2 Staged Development

The staged construction process may be used as part of the long-term implementation plan for a road. This strategy can be considered as a series of construction stages separated by long periods of time; it allows for a road to be open to the traffic at various stages throughout the construction timeline.

***Staged Construction Example***

*In a rural area, an initially unsealed road may be placed and opened, allowing some traffic compaction to occur (improving the structurally effective layer in the uppermost subgrade). This may later be followed by designed resheeting or granular overlay and eventually, sealing.*

Potential advantages of the staged construction process may be:

- ability to trial and observe the road under real conditions
- enables localised repairs to areas that do not perform to expectations
- required pavement depth may change from the design thickness (e.g. pavement depth may be less than required) if actual field performance indicates this is needed.

Considerations include (Austroads 2018a):

- economic and social consequences if the first stage fails due to delays in second stage construction
- cost of sidetracking and other provisions for traffic during each stage of construction
- effects of raising the pavement level for the second stage of construction (e.g. kerbs, culverts, guardrails and other road components)
- relative permeabilities of the subgrade and first stage paving materials, and the effect on pavement drainage, including the effect of leaving out the second stage materials
- difficulty in achieving a high standard of construction, with some paving materials, if construction under traffic is necessary.

The stages of a road construction are shown in Figure 3.1, comprising four steps:

- Clear and make a trafficable track (unformed).
- Construct the roadway formation and rehabilitate disturbed areas of vegetation (formed road).
- Provide pavement materials to the meet the pavement and geometric design (formed and gravelled).
- Seal the pavement.

**Figure 3.1: Stages of road construction**

a. Unformed road

b. Formed road

c. Formed and gravelled road

d. Paved road with a seal surface

## 3.2 Managing the Environment and Cultural Heritage

The planning and design stage offer the greatest opportunity to minimise potential environmental impacts throughout the life of the project and beyond. Section 3.8.2 summarises some of the main environmental considerations during this stage and also describes the effects of environmental stresses such as moisture and temperature on the pavement and how to manage them through design.

### 3.2.1 Managing Cultural Heritage

Cultural considerations are important where there is the potential for disturbance to Aboriginal cultural heritage sites or other heritage sites. A cultural heritage survey to determine if there are any areas within the site that need to be considered should be undertaken.

Where a high-impact activity is planned in an area of cultural heritage sensitivity it may be a state or territory regulation that a cultural heritage management plan or similar document be prepared.

Obtaining the plan prior to works starting usually provides an assessment of the impacts that may be possible within the proposed works area and provides measures to be taken before, during and after the works.

As each jurisdiction differs, appropriate cultural heritage planning information can best be found directly from the relevant road agency.

### 3.2.2 Planning, Design, Construction and Maintenance Considerations

#### Planning and design

The planning and design phase of a road project offers the greatest opportunity to minimise the environmental impacts of a road project. A summary of environmental considerations during planning and design are given in Table 3.2.

Table 3.2: Environmental considerations in design and planning stages

| Key aspect | Considerations |
|---|---|
| Water availability | • In remote areas, consider the availability of water for construction purposes as the cost of water can be very expensive. Possible sources can include river waterholes, bores and property dams. Permits may be required in certain locations. |
| Water salinity | • Some water sources may have higher salt levels that could impact the performance of a bituminous surfacing.<br>• Refer to Austroads/AAPA Work Tip AP-PWT47-08 *Sprayed Sealing of Drought and Salt Affected Pavements.* |
| Environmental management plan (EMP) | • Contractors should develop an EMP (or an equivalent document) for each contract. An EMP is a plan that:<br>– outlines how the contractor will comply with any contractual and legislative environmental requirements and conditions<br>– provides a framework to ensure that the environmental risks associated with the works are properly managed.<br>• The plan should include notes and drawings on the following aspects (Gosford 1998):<br>– locality<br>– contours (initial and final)<br>– existing vegetation assessment<br>– existing wildlife assessment<br>– existing site drainage<br>– limits of clearing, grading and filling<br>– land slope gradients<br>– critical natural areas (swamps, streams)<br>– location of topsoil stockpiles<br>– catchment area boundaries<br>– erosion and control practices<br>– sediment control practices<br>– locations of roads and all impervious surfaces<br>– details of site revegetation program. |
| General design | • Choose design standards which minimise the impact the road will have on the surrounding environment.<br>• Environmental induced stresses that may impact on the performance of the road and safety of the road users such as moisture and temperature should also be considered where appropriate as part of the long-term strategy.<br>• During the design stage, assess pavement strength at the highest moisture contents likely to occur in the materials. Note: continue with text from the next page. |

| Key aspect | Considerations |
|---|---|
| Drainage design | • The road's drainage system is potentially one of the main sources of degradation to the environment.<br>• Design drainage structures to minimise flow rates and erosion and minimise the impact on the surrounding environment.<br>• Ensure cut-off drains are adequately spaced to reduce volume and speed of stormwater discharge.<br>• Avoid directing table drains and cut-off drains directly into waterways.<br>• Ensure sufficient crossfall on the road surface.<br>• Crossfall should be unobstructed in shoulders/verges so water is not held near the pavement formation.<br>• Install sub-surface drains if ground water is likely to affect pavement strength/durability.<br>• Collect runoff in surface drains (e.g. lined table or median drains, kerb and channel) and collected water to an outfall. The outfall or receiving waters should not be degraded by the runoff. |

*Note: AUS-SPEC provides environmental management requirements for specific design activities within their provided design Worksections (available at www.natspec.com.au).*

### Construction

Road construction sites have the potential for detrimental impacts on the local environment. Take special care to minimise any soil disturbance and adverse impacts on native vegetation, soil erosion and effect on water quality. Table 3.3 provides a checklist of environmental considerations for various stages and aspects of construction.

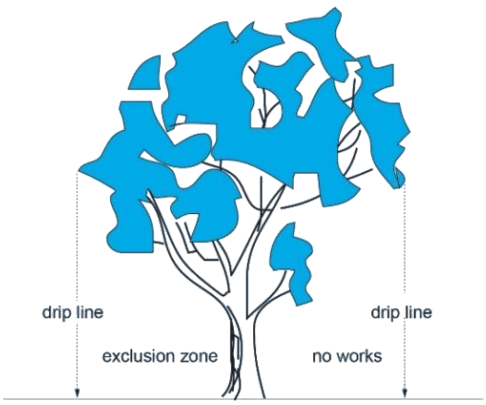
**Table 3.3: Environmental considerations during construction**

| Key aspect | Environmental considerations |
|---|---|
| Site location and set-up | • When setting up a construction site, consideration needs to be given to:<br>– protecting the local native vegetation and wildlife habitat<br>– the proximity of nearby creeks and rivers to minimise the potential for contamination,<br>– the aesthetic appeal for road users. |
| Risk assessments | • Examples of environmental hazards requiring control include:<br>– containment of spills<br>– prevention of contaminated runoff water (with sediment and/or other pollutants) entering stormwater drainage or natural waterways<br>– disturbance of wildlife habitats<br>– dust disturbance levels<br>– excessive noise.<br>• Contractors should develop and refer to their environmental management plan (EMP). This plan may need to be updated at the time of construction if unforeseen environmental conditions present themselves. Note: continue with text from the next page. |

| Key aspect | Environmental considerations |
| --- | --- |
| Clearing and site preparation | • Clearing is the removal of all vegetation, refuse and artificial features from the area to be occupied by the earthworks.<br>• Mark out areas to be cleared. Clearing should be within the boundary of earthworks. Check the environmental management plan for any 'no go' areas.<br>• Obtain permits/consent for removal of native vegetation where required.<br>• Consider special conditions relating to seed collection, the avoidance of the spread of noxious weeds and the possible pollution of waterways.<br>• Where acid sulphate soils are present, refer to local guidelines and authorities relating to their remediation and management.<br>• Methods for disposal of vegetation may include:<br>– converting it to mulch by tub grinding<br>– burning<br>– chipping<br>– on-site milling.<br>• Ensure any permits or consents are obtained from the fire service/authority or district and regional councils prior to commencement of disposal. |
| Construction zone boundaries | • The boundaries of construction zones should be designed to protect native vegetation.<br>• Vegetation close to the construction zone boundary should be marked to ensure machinery drivers/operators can recognise what vegetation is to remain.<br>• Vegetation areas can be taped off during construction to provide clear boundaries. |
| Stockpiling | • All stripped material including topsoil, should be stockpiled in designated areas ready for reuse for batter and embankment re-vegetation.<br>• Stockpiles should be neat and well-shaped capable of shedding water.<br>• Stockpiles should be close to the construction site, away from areas identified in the EMP and in areas with good drainage.<br>• If necessary, establish stormwater diversion drains and silt traps around stockpile sites.<br>• Consider the area required for vehicles and machinery to safely access the site without impacting on the surrounding vegetation. |
| Drainage | • Consider the impacts that the changed water movement in the landscape will have on the surrounding environment.<br>• Culverts should be designed and then constructed in a way that minimises disturbance to the stream environment.<br>• Refer to Section 0 for more detailed information on drainage considerations. |
| Earthworks | • Before carrying out earthworks consider factors such as:<br>– location of any vegetation to be avoided<br>– positioning of any stockpiles<br>– vehicle parking areas and cleaning locations<br>– pedestrian movements – ensure pedestrians are not detoured onto other existing vegetation. |
| Groundwater | • If groundwater is found during earthworks, an open drain can be dug to an outfall point and the water discharged in a suitable manner, however it is preferable to install a subsurface drain.<br>• In some catchments, groundwater is likely to be highly saline and should not be directly discharged to waterways or other environmentally sensitive areas. |

| Key aspect | Environmental considerations |
|---|---|
| Parking and operating vehicles and machinery | • Avoid vehicle and machinery movement in vegetated areas and on undisturbed soils as this often leads to disturbance of undergrowth, soil compaction and erosion.<br>• Park heavy vehicles away from the trees (drip line, Figure 3.2) to avoid compacting tree roots. |

**Figure 3.2: Park vehicles clear of dripline**




| | |
|---|---|
| Servicing vehicles and machinery | • Servicing vehicles on roadside reserves should be avoided wherever possible. Moving vehicles to another location, such as a works depot, is preferable to servicing on site.<br>• If servicing on site is unavoidable select an area of low conservation value and use pollution prevention techniques (such as bunding) against spillage of machinery fluids.<br>• Maintain vehicle exhaust systems to minimise air pollution and noise pollution and the possibility of starting bushfires. |
| Washing of vehicles and machinery | • All vehicles and machinery should be cleaned before being moved to a new work site.<br>• Employ where necessary a wash bay to remove excess soil from tyres and rumble strips to ensure that dirt is not carried off site.<br>• Water should be contained and taken to a suitable disposal site if possible.<br>• Excess soil left on the road by truck tyres should be removed by manual or mechanical sweepers. |
| Site clean up | • The site should be cleaned of all surplus material and rubbish and left in a clean and tidy state.<br>• All drains and culverts should be checked and cleaned of debris.<br>• Windrows around posts, trees and other fixtures should be removed.<br>• Tree butts, survey stakes, and other construction waste should be picked up, by hand if necessary, and disposed of at an approved location. |

*Note: AUS-SPEC provides environmental requirements for all construction activities within Worksection 0173 – Environmental Management (available at www.natspec.com.au).*

## Maintenance and operations

After a road has been constructed, certain measures will still need to be taken to protect the local environment. Table 3.4 provides a checklist of environmental considerations for various aspects of roadside maintenance and operations.

Table 3.4: Environmental considerations for road/roadside maintenance and operations

| Key aspect | Considerations |
|---|---|
| General | • Consult the local roadside management plan (if available) for guidelines to minimise the environmental impact of road maintenance activities.<br>• For new products or techniques undertake a small field trial first to assess their performance and the environmental risks before wide-scale application. |
| Drainage | • Clean table drains only when necessary; a rough and irregular surface with a shallow flat-based profile is preferable to a smooth readily erodible surface.<br>• Clean out other drainage structures regularly to maintain water flow similar to the natural drainage patterns. |
| Vegetation | • Always protect roadside vegetation and prune in a manner that minimises the impact on the biodiversity of the area.<br>• Conduct incremental clearing to maintain the width of any encroachment over time.<br>• Leave batters on cuts and embankments rough, to assist with revegetation.<br>• Before exposing any soil, have a planned rehabilitation program in place.<br>• Spraying of herbicide may be used in accordance with supplier instructions and other forms of control e.g. steam, for the control of noxious weeds. |
| Seeding/ planting | • Maintenance crews may be required to plant and maintain trees and shrubs including weeding, watering, pest control and fertilising.<br>• Wherever possible, indigenous species chosen from local provenance stock in the same location, or nearby, should be planted.<br>• When planting trees and shrubs, care should be taken to ensure that they will not obstruct the visibility of signs or approaching vehicles at intersections.<br>• Species should also be selected so that they are suited to the area and the roots will not extract an excessive amount of water from the subgrade.<br>• Plant tress far enough away from the road so that tree roots will not affect pavement performance. |
| Tree roots | • By extracting water from the subgrade in periods of dry weather, the roots can cause the subgrade soil to shrink, particularly where the subgrade is an expansive clay or a peat. This can lead to environmental cracking and poor pavement rideability.<br>• It may be necessary to stop roots reaching the subgrade by periodically cutting the roots by ripping along a line between the trees and the road. |
| Road user safety | • Grass and other vegetation should be mowed, slashed or cleared to ensure that road users have a clear view of signs, guide posts and other road furniture, provide adequate sight distance at intersections and to restore safety clearances. |

*Note: AUS-SPEC provides environmental requirements for all maintenance and operation activities within Worksections 1601 – General Requirements – Road Reserve (Maintenance), and 1603 – Road Reserve Maintenance Plan (RMP) (available at [www.natspec.com.au](http://www.natspec.com.au)).*

## 3.3 Safety in Planning and Design

It is important to understand what factors lead to the occurrence of crashes, and what measures may be undertaken to minimise them. This section provides guidance on practical and low-cost techniques for improving road safety and reducing potential litigation at the planning and design stages of a road project.

### 3.3.1 Safe System Approach

***Safe System Approach***

***Within the context of designing and maintaining roads, the following should be considered to align with Safe System principles:***

- *Designing, constructing and maintaining a road system (roads, vehicles and operating requirements) so that forces on the human body generated in crashes are generally less than those resulting in fatal or debilitating injury.*
- *Improving roads and roadsides to reduce the risk of crashes and minimise harm: measures for high-speed roads include dividing traffic, designing 'forgiving' roadsides, and providing clear driver guidance.*
- *In areas with large numbers of vulnerable road users or substantial collision risk, speed management supplemented by road and roadside treatments is a key strategy for limiting crash forces.*
- *Advising, educating and encouraging road users to obey road rules and to be unimpaired, alert and responsive to potentially high-risk situations.*

The Safe System approach is built on three basic principles (ATC 2011):

People make mistakes. Humans will continue to make mistakes, and the transport system must accommodate these. The transport system should not result in death or serious injury as a consequence of errors on the roads.

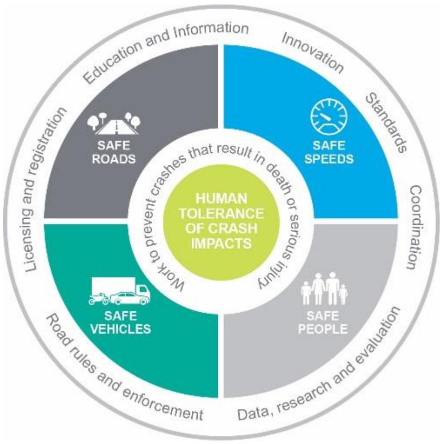
Human physical frailty. There are known physical limits to the amount of force bodies can take before being injured.

A 'forgiving' road transport system. A Safe System ensures that the forces in collisions do not exceed the limits of human tolerance. Speeds must be managed so that humans are not exposed to impact forces beyond their physical tolerance. System designers and operators need to take into account the limits of the human body in designing and maintaining roads, vehicles and speeds.

The Safe System focuses on creating safe roads, safe speeds, safe vehicles and safe road use (Figure 3.3). The ultimate goal would be to achieve (Ministry of Transport 2010):

- Safe roads – that are predictable and forgiving of mistakes. They are self-explaining in that their design encourages safe travel speeds.
- Safe speeds – travel speeds suit the function and level of safety of the road. People understand and comply with the speed limits and drive to the conditions.
- Safe vehicles – that prevent crashes and protect road users, including pedestrians and cyclists, in the event of a crash.
- Safe road use – road users that are skilled and competent, alert and unimpaired. They comply with road rules, take steps to improve safety, and demand and expect safety improvements).

**Figure 3.3: Overview of road transport Safe System**




*Source: Transport and Infrastructure Council (2018).*

### 3.3.2 Duty of Care

*A road authority has a duty of care to all users of the road network that might be adversely affected by its acts or omissions.*

The *National Road Safety Action Plan* (Transport and Infrastructure Council 2018) notes that up to 50% of serious casualty crashes occur on roads controlled by Local Governments and that Local Governments will need to support and apply cost-effective, innovative solutions in line with the Safe System approach.

In Australia, a series of court decisions established that road authorities have a duty of care towards road users. In practice, this means that they must do what is reasonable to be aware of deficiencies in the road system, to assess and prioritise them, and have a system for remedying them (Sarre 2003).

Note that the requirement of duty of care does not demand that there be no deficiencies in the road system – only that a road authority will do what is reasonable to monitor and remedy problems.

The court decisions recognise that the resources available to an authority, including the availability of material, skilled labour and funding, may limit how quickly defects can be addressed. If this results in a delay to remedying a situation which is hazardous for road users, the road authority should consider other alternatives such as using signs to alert road users of the hazard or, in extreme cases, closing the road. The minimum commitment to road safety is a process for identifying safety issues and prioritising them, a process for remedying these issues within a reasonable time frame and a process for managing unsafe situations until remedial works can be undertaken. Each of these processes must be defensible as ‘reasonable’.

### 3.3.3 Crashes on Sealed Roads

***What Can Cause a Crash?***

***Factors that may contribute to the incidence and severity of crashes on sealed roads include:***

- *poor road surface conditions (loose materials, slippery when wet, rough surface)*
- *poor geometric standards (tight curves, restricted sight distance, poor signage and delineation, poor vertical and horizontal coordination, roadside hazards)*
- *inconsistencies in the road conditions that can suddenly surprise an unsuspecting driver (e.g. sudden dip or an isolated sharp curve on an almost straight road)*
- *traffic composition which may include a high proportion of heavy vehicles*
- *driver behaviour (excessive speed, lower levels of restraint use, failing to keep left)*
- *native animals on the road*
- *driver impairment (alcohol, drugs, fatigue)*
- *driver inexperience*
- *low levels of enforcement.*

### 3.3.4 Typical Hazards on Sealed Roads

The illustrations in Table 3.5 cover a typical range of road and roadside hazards that can contribute to the incidence or severity of crashes. These hazards should be considered at the design and planning stages, as well as when maintaining a sealed road.

**Table 3.5: Typical hazards found on sealed roads**

| Hazard | Description/considerations | Example |
|---|---|---|
| Reduced skid resistance | • Can be due to loose material on the road surface or deterioration of the road surface such as polishing of aggregates or low texture levels from bitumen flushing in the wheel paths.<br>• May contribute to loss-of-control crashes. | <br>Bitumen flushing in the wheel paths |
| Superelevation | • It is important to provide correct superelevation at horizontal curves.<br>• Poor crossfall or superelevation may result in build-up of loose material on the outside of the curve, creating a potential safety hazard.<br>• Good superelevation will also assist driver comfort and safety in travelling around curves. | <br>Build-up of loose material on the outside of the curve |

| Hazard | Description/considerations | Example |
|---|---|---|
| Drainage | • It is important that roadside drains do not create a hazard.<br>• Table drains should be constructed so that they are 'driveable' should a vehicle run off the road.<br>• Culverts can be installed such that end walls are not located immediately on the edge of the road, or driveable end walls can be installed. | <br>Non-drivable table drain |
| Surface conditions | • The surface of the road should be maintained to limit development of surface hazards such as a rough surface, rutting, potholes. | <br>Potholes, and other hazards on the roadway |
| Roadside hazards | • Hazards such as poles, steep embankments and trees close to the edge of the road can result in serious injury or fatal crashes when vehicles run off the road.<br>• In some scenic locations, points of interest may cause visual distractions to drivers.<br>• Provision of an appropriate clear zone, which allows errant vehicles space to recover, is preferable at critical locations (such as near curves and intersections) where vehicles are more likely to run off the road.<br>• Should a clear zone not be able to be provided or the hazard removed, another mitigation measure such as a safety barrier should be provided.<br>• Maintenance of the roadside environment is discussed in Section 3.2.2. | <br>Hazards located close to the carriageway |

| Hazard | Description/considerations | Example |
|---|---|---|
| Sight distance | • It is important to provide adequate stopping sight distance so that drivers may safely navigate through the various road surface conditions and can see oncoming vehicles in time to take avoiding action.<br>• This is particularly important at critical locations such as at tight curves and intersections.<br>• Sight distance is influenced by road geometry and vegetation on the roadside. | <br>Drivers have restricted sight distance around this curve with no curve alignment markers or guide posts provided to delineate the tightness of the curve |
| Intersections | • It is important to provide adequate sight distance and/or signage to alert drivers that they are approaching an intersection.<br>• Intersections must be clearly visible by all approaching drivers and/or appropriate warning signs provided to alert drivers.<br>• Intersections should be designed according to appropriate geometric design standards. | <br>Drivers may not be aware that just over the rise there is an intersection |
| Bridges | • Delineation on the approaches to a bridge is a critical safety requirement to prevent drivers hitting the bridge or missing it altogether.<br>• Bridge approaches should have sufficient sight distance and good delineation to guide a driver over the bridge which is often narrower than the approaching road.<br>• Safety barriers should be provided to protect vehicles from the bridge structure or a hazard adjacent to the bridge or behind it (embankment, drop into creek bed etc.) and sometimes pedestrians, when warranted. | <br>On bridge approaches adequate signs and sight distances should be provided, and guardrails when warranted |
| Causeways/ floodways | • There should always be adequate signs and guide posts to indicate the alignment of the roadway over the causeway, as well as depth gauges and good sight distances on all approaches. | <br>Example of a poor causeway with a lack of safety provisions, including causeway signs on approaches, guide posts and depth gauge |

| Hazard | Description/considerations | Example |
|---|---|---|
| Railway crossings | • Many railway crossings are on low-volume roads. Some rail lines carry very few trains; some of these may operate only for part of the year.<br>• This combination of few cars and trains can make road users complacent when approaching a railway crossing and not take the necessary care to watch out for possible trains approaching.<br>• Special measures may need to be taken to alert a road user of the railway crossing and any approaching trains. | <br>Good sight distance to road signs at the rail crossing |
| Inappropriate, insufficient and poorly maintained signs | • It is important that road signs are used appropriately when required to warn motorists of potential hazards.<br>• Temporary road signs should be removed when not in use to avoid driver complacency.<br>• Road signs must be placed as to not interfere with sight distance.<br>• Road signs must comply with standards and be easily and quickly understood.<br>• Lack of signage is a major hazard in not being able to identify other hazards. | <br>Curve after crest with insufficient signage to identify the presence of a curve |

## 3.3.5 Safety Improvement Strategies

### Developing a road safety strategy

All state and territory jurisdictions in Australia have a formal road safety strategy which guides their efforts to reduce road deaths and injuries. While many Local Governments have comprehensive strategies, which are being actively pursued, others may not have started to develop them (Austroads 2013c).

A road safety strategy should consider the following:

- Vision - 'an innovative description of the future traffic system, or a desired direction of road safety development' (OECD 2002, p. 20).
- Strategy - a coordinated set of actions designed to achieve a specific result or set of results in a specified period.
- Plan - an expression of the strategy over a shorter period, so that the fulfilment of successive plans, modified in the light of changing circumstances and actual outcomes, achieves the desired result of the strategy.
- Target - an outcome expressed in quantitative terms, e.g. number of fatalities, percentage reduction in fatalities, or fatality rate per population or per distance travelled.

### Proactive road-network-level risk assessment and strategies

A key component of developing a road safety strategy is to identify the safety risk on the network. A road-network-level risk assessment is designed to provide a road authority with a picture of high-risk sections across the network. The process is summarised in Figure 3.4 and the respective strategies and methods to provide, manage and improve safety during the design of new roads or management of existing roads are discussed further in Table 3.6.

Figure 3.4: Proactive road-network-level risk assessment process

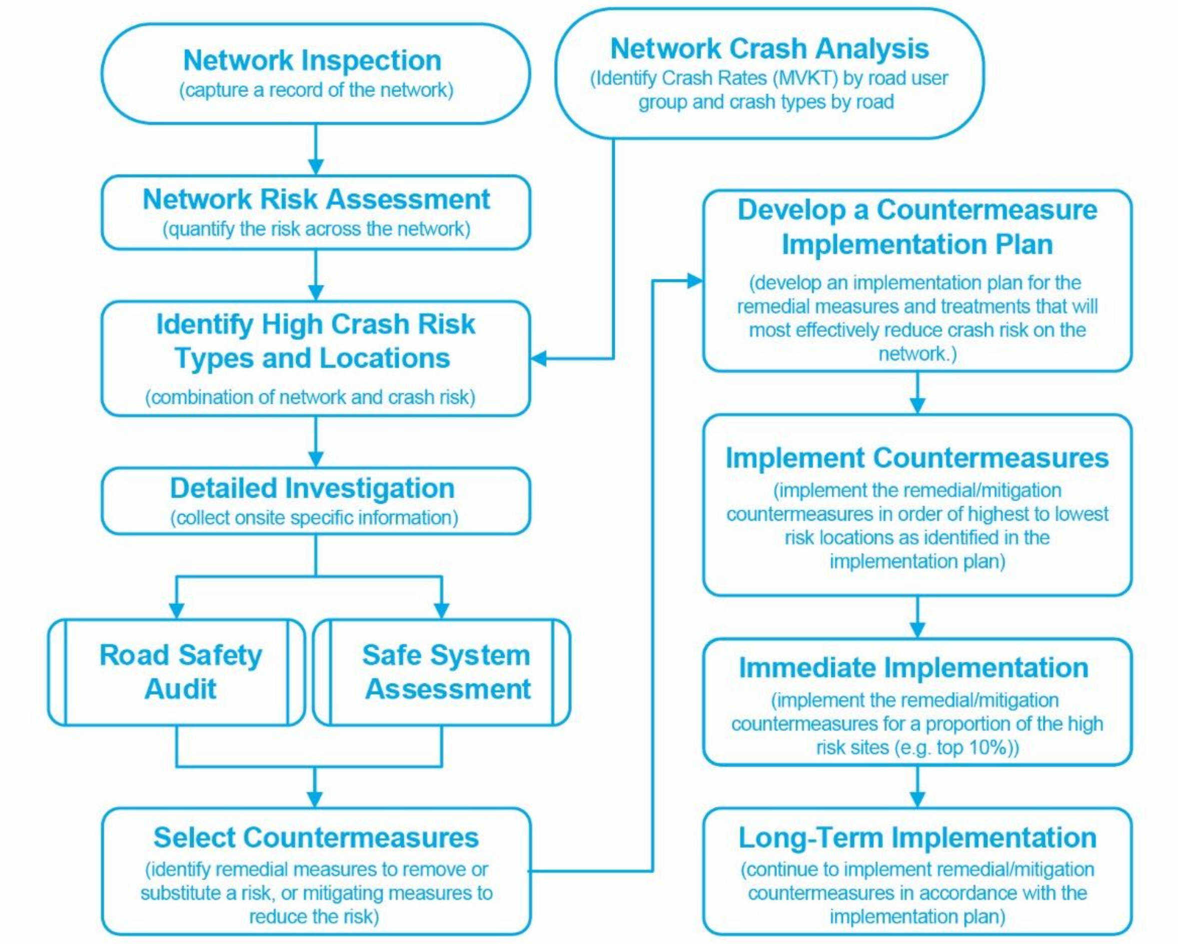



Table 3.6: Strategies and methods to provide, manage and improve safety

| Strategy/method | Description |
|---|---|
| Provide a self-explaining road | • A self-explaining road is where the design of the road is such that drivers are able to readily interpret how they should act on the road.<br>• For drivers to be able to drive to conditions, and thus adjust their driving behaviour to moderate risk, they need to be able to readily interpret what those conditions are.<br>• Signage, delineation, and low-cost countermeasure treatments can assist in providing a self-explaining road, however ultimately this should be provided though good road design practices. |
| Road-network-level inspections and surveys | Undertaken to identify locations by risk for various road users and crash types. Inspections and surveys may consider pavement condition (rutting, roughness, shape loss, skid resistance, texture loss), roadside hazards, signage or other local condition factors. The risk identification along a road or network can be used for several purposes. These include:<br>• selecting appropriate treatments<br>• prevention of fatal and serious injury crashes<br>• calculation of a benefit-cost ratio and net present value based on a reduction in crash costs<br>• development of a safety strategy.<br>• identification of locations for road safety audits and Safe System assessments. |

| Strategy/method | Description |
|---|---|
| Road safety audit | • Undertaken to identify and document detailed information about the road design, road condition, and roadside condition and features contributing to crash risk. This is achieved by an on-site inspection. A qualitative measure of risk is provided by the road safety auditor. |
| Safe System assessment framework | • Undertaken to consider key crash types that lead to fatal and serious crash outcomes, as well as the risks associated with these crashes (exposure, likelihood and severity).<br>• Each pillar of the Safe System is considered, and a treatment hierarchy is also provided to help identify the most effective treatments that might be used to minimise death and serious injury. |
| Identify and implement countermeasures | • Selection of countermeasures that are most effective in reducing crash risk for a given crash type and road user group.<br>• Low-cost measures that can be implemented in the short term to help the motorist to drive to conditions.<br>• Higher-cost treatments that can be implemented typically include improving the road geometrics and intersection layouts.<br>• Implementation of the countermeasure treatments through an implementation plan to incrementally reduce risk. |
| Monitoring and review | • The implementation and effectiveness of countermeasures should be monitored and reviewed.<br>• The road safety strategy should be reviewed based on crash reduction performance. If required, the road safety strategy should be modified, and a new implementation plan developed. |

### 3.3.6 Signs and Delineation

It is particularly important to alert drivers (through the use of signs and delineation) to hazards they might not ordinarily expect (for instance, due to sudden changes in conditions).

Typical signs and delineations used for sealed roads include:

- guide posts and reflectors
- line marking and raised reflective markers
- hazard markers and sight boards
- road signs.

Some guidance on the use of road signs and delineation markers to improve the safety of sealed roads is provided in the ARRB *Unsealed Roads Best Practice Guide*.

> *It is recommended that reference is made to the relevant Australian Standard AS 1742.1 Manual of Uniform Traffic Control Devices series and road agency codes of practice documents for further, more detailed guidance.*

## 3.4 Road Hierarchy and Classifications

Road classifications exist to ensure that appropriate management, engineering design, construction standards, and planning practices are applied to a road based on its function. It also enables more efficient use of limited resources by allocating funding to those roads that are in greater need, and on which expenditure is better justified.

Without an adequate road hierarchy for local roads there may be inefficient allocation of resources, road user expectations may vary, and the scheduling of road works and priorities made more difficult.

In developing a road hierarchy system, the following guiding principles should be used:

- The classification system should link and be consistent with other road authority and Local Government systems (Table 3.7 summarises Australian state/territory-based classifications).
- Classifications need to be functionally based. The road classification should not be affected by traffic volumes and vehicle type. Table 3.7 shows a typical mobility and access-based hierarchy.
- The width of a road, or whether it is sealed, are not necessarily criteria that influence a classification.
- Special purpose roads, i.e. quarry, logging or tourist roads, should be made to fit existing classifications rather than establish a separate classification.
- Unused road reserves, or 'paper' roads, are to be ignored and used only for mapping purposes.

Table 3.7: Road hierarchy terminology across Australia

| State/ territory | Arterial | Collector | Access |
|---|---|---|---|
| ACT | Arterial roads | Major collector roads<br>Minor collector roads | Access streets |
| NSW | Major arterial<br>Sub-arterial | Regional roads | Local roads |
| NT | National highway<br>Primary arterial (Urban and Rural)<br>Sub-arterial/rural secondary or distributor road | Collector road | Local road<br>Pastoral |
| Qld | Controlled access roads<br>Major roads | Collector/distributor roads | Local roads |
| SA | Rural arterial<br>Urban arterial | | Rural local roads<br>Urban local roads |
| Tas | Major highways | Urban connectors | Residential streets |
| Vic | Arterial roads | Connector street level 2<br>Connector street level 1 | Access street level 2<br>Access street level 1<br>Access place<br>Access lane |
| WA | Primary distributor<br>District distributor<br>Regional distributor | Local distributor | Access roads |

For a local road network it is considered that up to four functional road categories could be used, for both rural and urban roads as listed in Table 3.8 and Table 3.9 respectively.

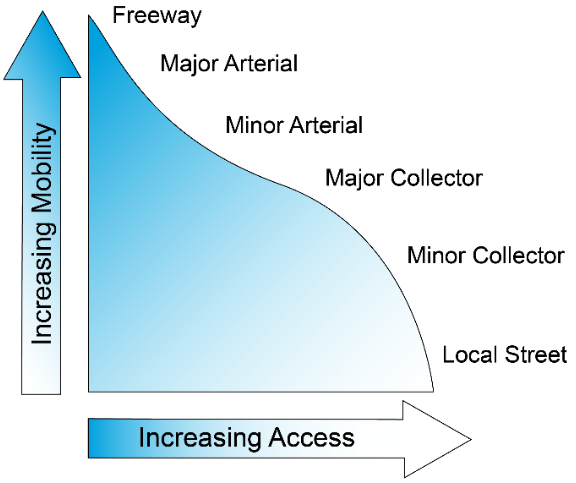
**Table 3.8: Rural area – proposed road classifications**

| Road class | Class type | Service function description | Brief description |
|---|---|---|---|
| A | Local arterial road | Primarily the main connection from town centres and local areas to the wider state main road network or state highway system | Two-way, two-lane, mainly sealed |
| B | Collector road | Collect and distribute traffic, and act as a feeder service to local arterial roads | Two-way, sealed or unsealed road |
| C | Access roads | Predominantly for direct access to properties, recreational areas and industries in urban and rural zones | Two-way, mainly two-lane, sealed or unsealed road |
| D | Limited access tracks | Primarily for limited access and using four-wheel-drive vehicles | Two-way, unformed single-lane track with possible access restrictions imposed |

**Table 3.9: Urban area – proposed road classifications**

| Road class | Class type | Service function description | Brief description |
|---|---|---|---|
| A | Local (major and minor) arterial road | Primarily for the main connection from urban centres and local areas to the wider state main arterial road network or state highway system | Generally, a two or four-lane, two-way sealed road with parking provisions |
| B | Collector road | For collecting and distributing traffic and acting as a feeder service to local arterial roads | Mainly a two-lane, two-way sealed road |
| C | Access road | Predominantly for direct access to properties, recreational areas and industries in urban zones | A two-lane, two-way sealed road |
| D | Limited access | Primarily for limited access to the rear of properties or within recreational parks | Generally, a one-lane, two-way road at the rear of properties or informal tracks within recreational parks |

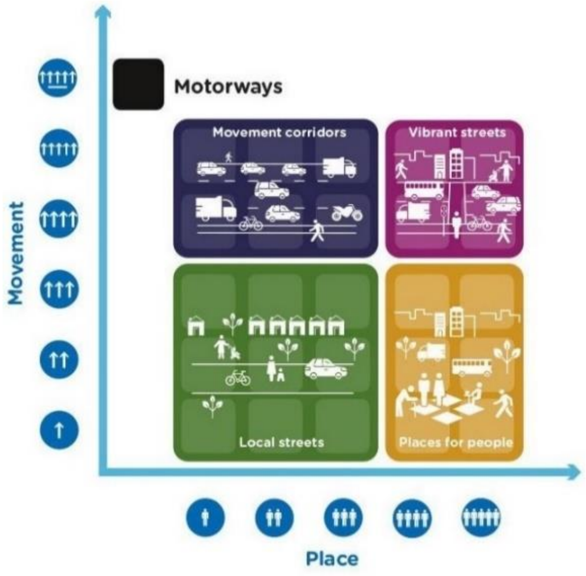
**Figure 3.5: Conceptual roadway functional hierarchy**




*Source: Adapted from FHWA https://ops.fhwa.dot.gov/access_mgmt/what_is_accsmgmt.htm.*

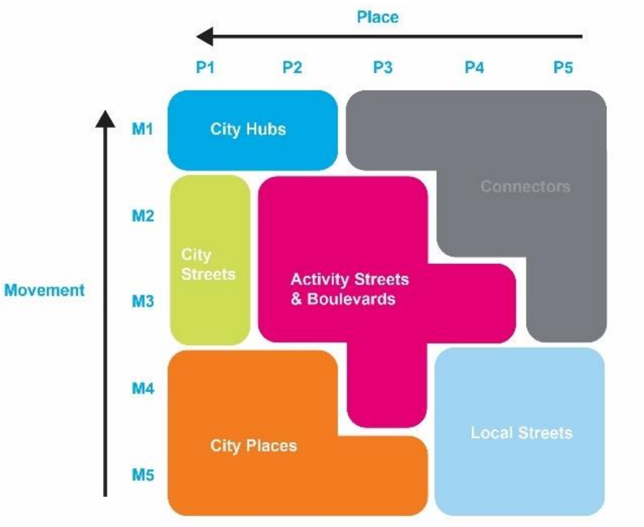
Many cities and regions across the world are also beginning to shift their road hierarchy systems away from a linear approach, instead considering the mobility and access nature of a road while also recognising that roads exist as places and destinations in their own right (DoT 2019). This system is often referred to as 'movement and place', incorporating planning, design and safety considerations that both prioritise efficient and reliable journeys, as well as enhancing the liveability of a place (TfNSW 2018). Figure 3.6 and Figure 3.7 provide example applications of the movement and place framework in Australia, to classify roads within the context of this dual application.

**Figure 3.6: Movement and place framework (NSW)**




*Source: Transport for NSW (2018).*

**Figure 3.7: Movement and place framework Victoria**




*Source: Department of Transport (2019).*

## 3.5 Construction and Maintenance Considerations

Construction and maintenance considerations play an important role in the selection of design alternatives as they can influence the type of surfacing, base and subbase material requirements, and the choice of pavement type. The following significant construction and maintenance factors are discussed in Austroads (2018a):

- extent and type of drainage
- use of boxed construction
- surfacing type
- availability of equipment – especially material mixing, placing and compaction plant
- use of staged construction
- use of stabilisation
- pavement layering considerations
- transverse variations in pavement design
- use of strain alleviating membrane interlayers (SAMIs)
- aesthetic and environmental requirements
- social considerations
- construction under traffic

- maintenance strategy
- acceptable risk.

## 3.6 Transport Infrastructure Product Evaluation Scheme

There are numerous materials and products available in the market that can be used in the construction and maintenance of road assets. It can be difficult to ascertain whether these materials and products are suitable for a project purely based on the information and data provided by the suppliers. A way to determine their suitability is to utilise independent assessment and certification schemes such as the Australian Paint Approval Scheme (APAS) or Transport Infrastructure Product Evaluation Scheme (TIPES).

TIPES is a process aimed at providing an independent fit-for-purpose assessment of innovative road construction products. TIPES is intended for the evaluation of products that fall outside the scope of established standards and specifications.

Understanding how well a proprietary product will perform for pavement applications reduces risk and can also provide cost-saving design options or construction techniques.

TIPES is a national scheme endorsed by all state and territory road agencies as well as the Institute of Public Works Engineering Australasia, Queensland (IPWEAQ), the Queensland Local Roads Alliance and the Western Australia Local Government Association (WALGA).

### 3.6.1 Process of Obtaining TIPES Certification

Products are assessed by an expert panel (inclusive of road agency representatives), who determine what is required to substantiate the proponent's claims for a product. This involves products being evaluated through a gating process where products need to pass each stage to move to the next phase of evaluation.

The stages of an evaluation are:

1. Stage 1: Evaluation
   a. An evaluation of available product information by the expert panel.
2. Stage 2: Test
   a. An independent series of laboratory tests recommended by the expert panel based on the product application and claims.
3. Stage 3: Trial
   a. Field trials to assess real-world performance. These are often incorporated into existing road authority and Local Government projects.
4. Stage 4: Certification
   a. Final assessment of results and certification of product.

Figure 3.8: TIPES certification


*In order to improve the geometric design features of many existing rural sealed roads, priority should be given to rectifying sections of road where there are significant design inconsistencies that can 'surprise' a driver and pose a particular risk.*

## 3.7 Geometric Design

This section briefly covers the main aspects relating to the geometric design of major road upgrades or new road construction and highlights those features which are of particular relevance to rural sealed roads. The section can also be used to help in identifying those parts of a rural sealed road which do not conform to appropriate geometric and safety requirements.

Details of the engineering principles, design values and design methods are provided in the Austroads *Guide to Road Design Part 3: Geometric Design* (Austroads 2016b). It is recommended for more detailed information where necessary alongside, AUS-SPEC Worksections *0041 – Geometric Road Design,* and *0051 – Geometric Rural Road Design – Sealed.*

A summary of key geometric aspects relating to the design of sealed roads are given in Table 3.10.

Table 3.10: Main aspects relating to the geometric design of sealed roads

| Design aspect | Technical considerations |
|---|---|
| Route location | • Most new roadworks are confined to existing road reserves or unsealed roads.<br>• May require evaluation of several alternative routes based on social, environmental and economic considerations.<br>• Where a new alignment is selected, consider drainage requirements, reduce the extent of cut and fill, and conform to existing property boundaries where possible. |
| Traffic volumes | • Low traffic volume roads present a unique challenge because there is generally a lower number of crashes making conventional design standards less cost-effective.<br>• Design standards can be less stringent than for higher-volume roads, however it is critical to consider safety implications.<br>• Guidelines suggest that a consistent driving experience should be provided to avoid any surprises.<br>• Design should be a balance between road purpose, traffic volumes, terrain, standards, costs and the standard of maintenance to be adopted. |
| Road classification | • The primary purpose of a road hierarchy is to ensure appropriate management and standards are applied (refer to Section 3.4).<br>• Allows more efficient use of limited resources by allocating funding to higher-priority roads |

| Design aspect | Technical considerations |
| --- | --- |
| | • A functional road classification should be established in each road agency which outlines design standards, performance criteria and maintenance intervention levels for each road class.<br>• Functional road classification systems allow for consistent treatment of all roads on the network in terms of driver expectations and the provision of a safe and economical road network. |
| Geometric requirements | • Should be a balanced consideration of construction, maintenance, safety, vehicle operating speed and costs, as well as level of service.<br>• Need to cater for safety of all road users, especially large vehicles, at minimal cost.<br>• Must consider the coefficient of friction for varying road surfaces and response times. |
| Cost-sensitive design | • The design domain approach places emphasis on developing appropriate and cost-effective designs rather than providing a design that simply meets standards. |
| Geometric safety features | • Key geometric features that influence safety include road alignment, stopping sight distance, road widths, intersection layouts, road crossfall/superelevation, drainage and roadside vegetation.<br>• Appropriate vertical and horizontal alignment standards should be used for prevailing speeds:<br>– Co-ordination of horizontal and vertical alignments ensures horizontal curvature is not hidden and is a basic geometric design principle and a key safety factor.<br>– Drivers react to horizontal curvature, and often will not react and reduce speed when sight distance is restricted by vertical curvature.<br>– When a horizontal curve is combined with a crest vertical curve, the horizontal curve must start before the vertical curve, to allow drivers to perceive the horizontal curve and make the appropriate speed adjustment.<br>• Drivers should receive a consistent message about safety travelling speeds from the road geometry, for example, a good quality pavement will tend to produce higher speeds. In order to provide a safe travelling environment, the pavement design standard should be matched with a geometric design of the same standard. |
| Design criteria | • Parameters that influence the geometric design of sealed roads include:<br>– manoeuvre sight distance (MSD)<br>– operating speed<br>– traffic volumes<br>– vehicle composition<br>– vehicle grades<br>– driver characteristics<br>– longitudinal deceleration<br>– skid resistance of surface (surface friction)<br>– driver reaction time. |

# 3.8 Pavement Design

## 3.8.1 Overview

The pavement design process aims to provide a pavement which will maintain its structural integrity, providing a good riding surface, over its design life. A correctly designed pavement should be able to serve out its design life, with only a small chance of structural failure occurring, without any form of rehabilitation.

AUS-SPEC Worksections *0042 – Pavement Design,* and *0053 – Rural Pavement Design – Sealed are* applicable here.

Detailed processes for undertaking pavement thickness design for both flexible and rigid pavements are contained in Austroads' *Guide to Pavement Technology Part 2: Pavement Structural Design* (Austroads 2018a). With section 12 of the document addressing the design of lightly trafficked roads.

Rather than replicate the detailed design procedures, this Guide instead provides sufficient background for the reader to be aware of the dominant factors affecting pavement design and also provides a design catalogue of typical pavement configurations and thicknesses.

A pavement's ability to perform is dependent on four main factors:

- the presence of water (which adversely affects most pavement materials)
- subgrade support
- traffic loading – both volume and loads
- pavement material performance.

## 3.8.2 Environmental Factors Influencing Pavement Design

### Moisture in road pavements

The moisture regime associated with a pavement in service has a major influence on the performance of the pavement. The stiffness/strength of unbound materials and subgrades is heavily dependent on the moisture content of the materials.

**What to assess:**

Factors that should be assessed in the selection of an appropriate pavement/surfacing solution for a given environment include (Austroads 2018a):

- rainfall/evaporation pattern
- permeability of wearing course/surface/shoulder material
- whether shoulders are sealed or not
- depth of watertable relative to the pavement structure
- relative permeability of pavement layers
- pavement type (boxed or full width)
- type of subgrade material and its susceptibility to moisture changes in terms of strength loss and volume change
- pavement or subgrade drainage or protection measures proposed.

The change of moisture in the pavements usually results from one or more of the following sources (Figure 3.9):

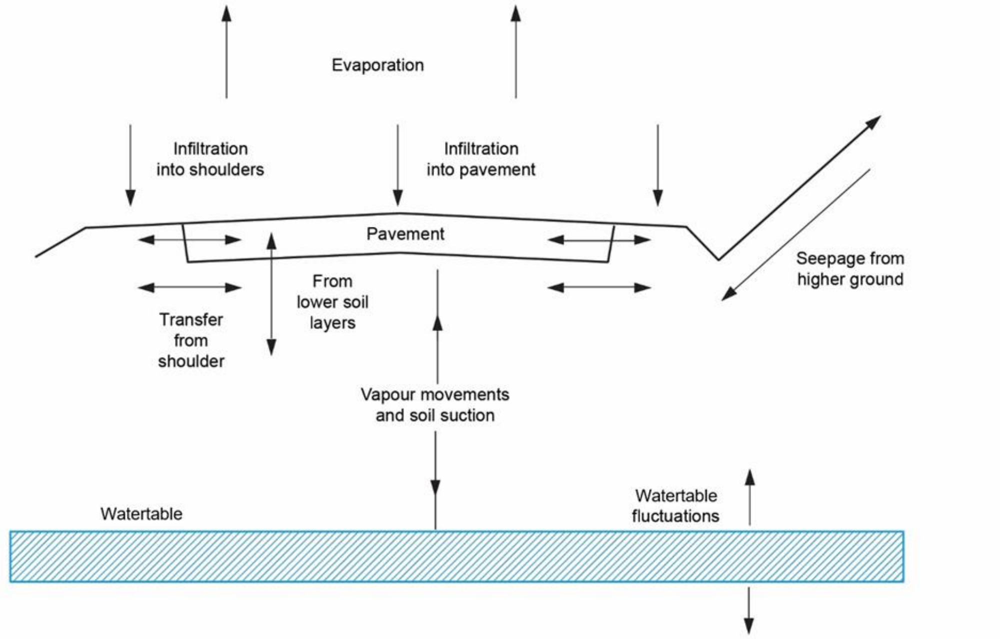
- seepage from higher ground into the pavement and/or subgrade
- fluctuations in the watertable
- infiltration of water through the surface of the road pavement, shoulders and embankment batters
- transfer of moisture as a result of moisture content or temperature differences in either the liquid or vapour state, including transfer due to the moisture content at construction differing from the equilibrium moisture content
- the relative permeabilities of the pavement layers and subgrade. A significant decrease in permeability with depth (permeability reversal) can lead to saturation of the materials in the vicinity of the permeability reversal
- leaking services in residential areas.

### *Permeability Reversal*

*Permeability reversals occur between two pavement layers when the lower-layer permeability is in the order of 100 times lower than the layer above. If moisture infiltrates the pavement, a perched watertable will form on top of the lower layer, requiring the lower pavement layer to have adequate wet strength to withstand any softening caused by the moisture.*

Figure 3.9 illustrates the common modes of moisture infiltration into and out of pavements.

**Figure 3.9: Moisture movements in road pavements**




**Effects of moisture infiltration into pavement**

Changes in subgrade moisture content can result in various changes in pavement condition depending on the amount of moisture and the nature of the material. This can include a change in the volume, cracking in reactive soils and/or a change in strength.

Austroads (2018a) provides the following comments as a guide:

- for sandy soils, small fluctuations in moisture content produce little change in volume or strength/stiffness
- for silty soils, small fluctuations in moisture content produce little change in volume but may produce large changes in strength/stiffness
- for clay, small fluctuations in moisture may produce large variations in volume and if the moisture content is near optimum moisture, large changes in strength/stiffness may also occur.

**How to minimise effects of moisture**

Volume changes caused by changes in the moisture environment in expansive subgrades can be minimised by (VicRoads 1993):

- using a low permeability lower subbase material

- including a capping layer with a minimum thickness of 150 mm
- ensuring that pavement drains, if required, are located within the impermeable subbase and not within expansive soils
- providing a minimum cover of material over the expansive soil for all pavement types
- restricting the planting of shrubs and trees close to the pavement
- including the provision of sealed shoulders and impermeable verge material
- ensuring a seal width of 1.0 to 1.5 m is provided outside the edge of the traffic lanes, to minimise subgrade moisture changes under the outer wheel path
- lime stabilisation of the subgrade to reduce the plasticity and increase the volume stability of the upper layer of expansive clay
- use of polymer stabilisers to reduce water movement through selected layers of pavement; they can repel water without having the chemical reactions experienced with lime
- during the design stage, assessment of pavement strength at the highest moisture contents likely to occur in the materials.

## Temperature effects on bituminous surfacing

### Effects of temperature on asphalt

At high temperatures:

- Asphalt is soft and viscoelastic which can cause rutting due to shoving caused by shear failure. When traffic is heavy and slow moving or is frequently accelerating or decelerating, asphalt rutting may become the predominant distress mode. Such situations may include approaches to intersections or traffic lights and bus stops.

At low temperatures:

- Asphalt becomes stiff and brittle making asphalt layers susceptible to fatigue (flexural) cracking.

### How to minimise the effects of temperature

- For a high temperature environment, consideration should be given to the use of alternative pavement surfacings or using concrete or asphalt modifiers which increase the high-temperature deformation resistance of the asphalt.
- The interaction of the traffic and operating temperature ranges must be taken into account at the design stage.

## Concrete materials

The temperature and wind environment during the construction and curing of cemented layers may affect the properties and performance of cemented layers.

High temperatures during construction may cause drying out of cementitious bound and cement modified materials, causing rapid early strength gain which may cause difficulties in achieving compaction and ride quality. High temperatures (> 35 °C) during construction may also reduce the ultimate strength and fatigue life of the cemented layer or concrete. Care is required to ensure adequate moisture for curing is maintained within the layer, particularly if high early temperatures occur during the curing period.

### 3.8.3 Subgrade Support

Subgrade support is largely beyond the control of either the designer or constructor and is therefore a primary factor influencing pavement thickness design. Subgrade support is typically expressed in terms of the California Bearing Ratio (CBR) of the subgrade material. The ARRB *Road Materials Best Practice Guide* describes CBR in more detail as well as discussing the means of its measurement. When designing new pavement structures, subgrade design CBRs are generally determined by laboratory testing of recompacted subgrade material, with testing having been carried out after a number of days of soaking of the material. Austroads (2018a) provides more detailed guidance on the methods for determining subgrade CBR.

The best way to start when evaluating existing subgrade material is with a site investigation to identify the extent and condition of various soil deposits likely to be encountered. This investigation should include obtaining samples followed by testing of the materials. Refer to the ARRB *Road Materials Best Practice Guide* for testing of subgrade materials and CBR determination (in addition to Austroads *Guide to Pavement Technology Part 2* (2018a)).

### 3.8.4 Design Traffic

One of the primary factors affecting the thickness design of pavements is the traffic loading that the pavement is expected to carry during its design life. Key inputs are:

- the volume of traffic expected
- the loads applied by that volume.

The Austroads vehicle classification system, shown in Table 3.11, details the range of vehicles commonly using Australian roads. It has been well established that light vehicles (Classes 1 and 2 in Table 3.11) contribute negligibly to structural deterioration, therefore only heavy vehicles are considered in pavement design.

For residential areas, particularly for new subdivisions, recognition should be given to traffic on future subdivision stages as well as the very large number of heavy vehicles used in the construction of the subdivision and new housing construction.

**Table 3.11: Austroads vehicle classification system**

| Level 1 | Level 2 | | Level 3 | Austroads classification |
|---|---|---|---|---|
| Length (indicative) | Axles and axle groups | | Vehicle type | |
| Type | Axles | Groups | Description | Class |
| Short<br>Up to 6.6 m | Light vehicles | | | |
| | 2 | 1 or 2 | Short<br>Sedan, wagon, 4WD, utility, light van, bicycle, motorcycle, etc. | 1 |
| Medium<br>6.6 – 14.5 m | 3, 4, or 5 | 3 | Short – towing<br>Trailer, caravan, boat, etc. | 2 |
| | Heavy vehicles | | | |
| | 2 | 2 | Two axle truck or bus | 3 |
| Long<br>11.5 – 19.0 m | 3 | 2 | Three axle truck or bus | 4 |
| | 4 | 2 or 3 | Four axle truck | 5 |
| | 3 | 3 | Three axle articulated<br>Three axle articulated vehicle, or rigid vehicle and trailer | 6 |
| | 4 | > 2 | Four axle articulated<br>Four axle articulated vehicle, or rigid vehicle and trailer | 7 |

| Level 1 | Level 2 | | Level 3 | Austroads classification |
|---|---|---|---|---|
| Length (indicative) | Axles and axle groups | | Vehicle type | |
| Type | Axles | Groups | Description | Class |
| | 5 | > 2 | Five axle articulated<br>Five axle articulated vehicle, or rigid vehicle and trailer | 8 |
| | 6<br>or > 6 | > 2<br>or 3[1] | Six axle articulated<br>Six (or more) axle articulated vehicle, or rigid vehicle and trailer | 9 |
| Medium combination<br>17.5 – 36.5 m | > 6 | 4 | B-double<br>B double, or heavy truck and trailer | 10 |
| | > 6 | 5 or 6 | Double road train<br>Double road train, or heavy truck and two trailers | 11 |
| Long combination<br>Over 36.5 m | > 6 | > 6 | Triple road train<br>Triple road train, or heavy truck and three trailers | 12 |

*1 Where axles are greater than six, axle groups are equal to three*

*Source: Austroads (2006).*

For local roads the typical vehicle classes encountered are:

- residential streets: all vehicle types up to class 7, buses and garbage trucks
- major urban areas on collector/distributor roads: all types up to class 10
- rural roads: all types up to class 10.

### Design period

The term *design period* is used to denote the time span over which is it considered appropriate for the road pavement to function without major rehabilitation or reconstruction. Typical design periods are shown in Table 3.12.

**Table 3.12: Typical pavement design periods**

| Pavement type | Typical design period |
|---|---|
| New granular pavement with spray seals or asphalt surfacing | 20–25 years |
| New rigid (concrete) pavement | 30–50 years |

### Design traffic

*Design traffic* is the cumulative traffic that is expected to load the pavement over the course of the design period. The damage caused to a pavement by the passage of a heavy vehicle depends not only on its gross weight but also on how this weight is distributed to the pavement. It depends on:

- the number of axles on the vehicle
- the manner in which the axles are grouped together (axle groups)
- the loading applied to the pavement through each of the axle groups (axle group load).

Austroads (2018a) uses this definition of design traffic for the design of new concrete pavements and also for the design of heavy-duty flexible pavements which contain bound materials (i.e. asphalt or cemented materials).

When considering the design of unbound granular pavements with sprayed seal surfacings, Austroads (2018a) uses the concept of equivalent standard axles (ESAs) to denote the design traffic. The ESA concept is also used in the section of Austroads (2018a) dedicated to lightly trafficked pavements (Section 12).

The standard axle is defined as a single axle with dual tyres applying a load of 80 kN to the pavement. In order to express the design traffic in terms of ESAs, the designer must determine how many repetitions of the standard axle would cause the same pavement damage as the design traffic. The process for doing this is contained in Section 7 of Austroads (2018a).

Austroads (2018a) provides detailed methods for determining the design traffic. In simple terms these methods follow the steps below.

*Design Traffic Estimations*

***The steps to estimate the design traffic for pavement design purposes are:***

1. *An estimation is made of the initial total annual average daily traffic (AADT) that the pavement is expected to be subjected to when opened to traffic.*
2. *The estimated percentage of this initial AADT that is comprised of heavy vehicles (i.e. Austroads classes 3 to 12) is determined.*
3. *The distribution of axle group types and load levels that are imposed by these heavy vehicles is estimated, either by direct measurement on comparable road pavements or by selecting presumptive distributions.*
4. *A reasonable annual traffic growth factor by which it is expected that initial traffic will grow cumulatively over the design period is selected.*

*These steps allow for the determination of the two components included in the design traffic:*

- *The total of heavy vehicle axle groups that will load the pavement over the design period.*
- *The manner in which these axle groups are distributed by axle groups type (single axles, tandem axles, etc.) and the load levels with which each is loaded.*

For ease of use, the example pavement designs given in Section 3.8.6 of this Guide are in ESAs.

### 3.8.5 Pavement Material Selection and Performance

Most pavement materials are carefully selected to meet minimum standards at the time of construction. At the design stage the issue of material performance is met by the selection of appropriate materials for the varying roles that they play in the pavement structure.

If minimum material quality standards are met during construction, the issue of material performance has a less dominant influence on the overall pavement design.

Refer to the ARRB *Road Materials Best Practice Guide* for information on pavement materials.

*Material Quality*

*It is important during the construction of a road pavement that the assumptions made about material quality during the design process are satisfied.*

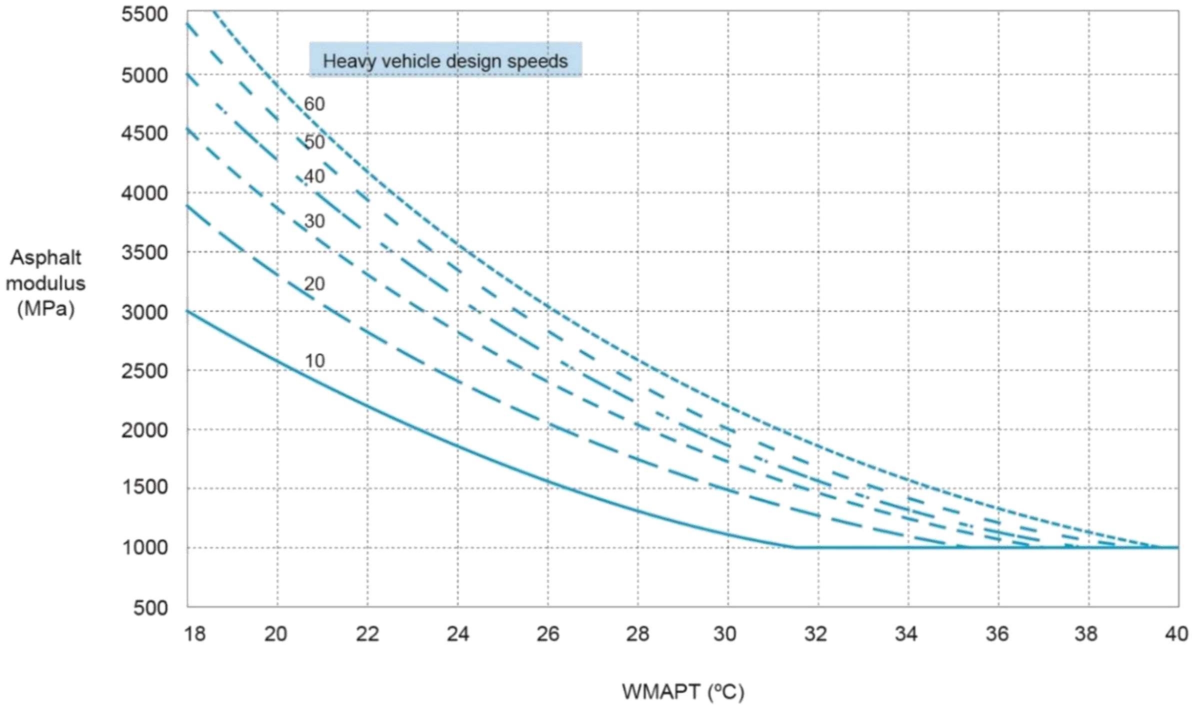
### 3.8.6 Example Designs for Typical Pavement Configurations

As previously noted, Austroads (2018a) contains detailed procedures for designing the structures of a range of pavement configurations. The procedures should be used when designing a specific pavement.

In order to inform the practitioner of the general material thickness requirements, and depth of pavement constructions required, the design processes have been used to develop pavement thicknesses for the typical pavement structures given in Table 3.13. A range of subgrade and design traffic inputs are considered and, where appropriate, a range of asphalt modulus values. Asphalt material behaves as a viscoelastic material: the elastic modulus (stiffness) of the material is dependent on both the rate at which it is loaded as well as the temperature of the material, as demonstrated in Figure 3.10.

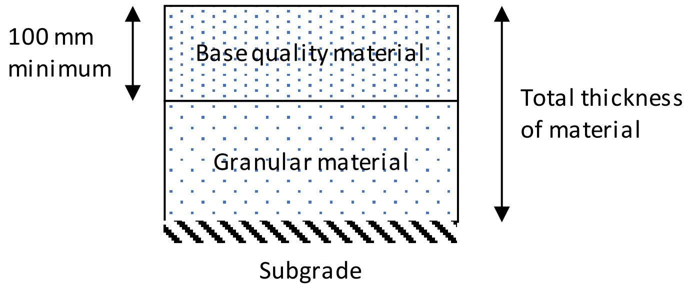
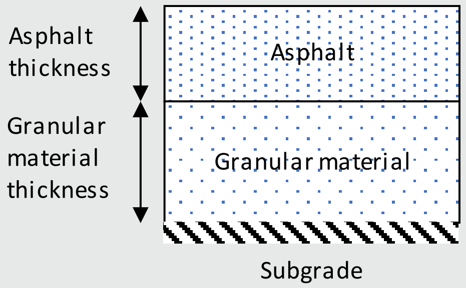
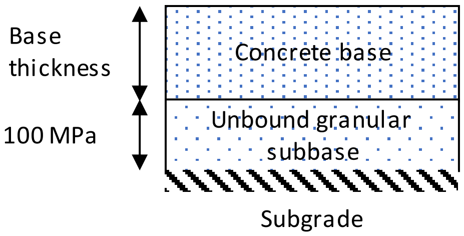
Table 3.13 shows the three pavement structures for which typical example designs have been determined and indicates which tables contain the corresponding design thicknesses.

**Figure 3.10: Presumptive moduli for dense graded mixes with Class 320 binder**




*Source: Austroads (2018a).*

**Table 3.13: Example pavement structures**

| Pavement type | Pavement structure | Example thicknesses |
|---|---|---|
| Unbound granular pavement with thin bituminous surfacing |   | See Table 3.14 |
| Asphalt surfaced pavement with granular base |   | See Table 3.15 |
| Rigid pavement |   | See Table 3.16 |

*Notes:*

*Unbound granular pavement with thin bituminous surfacing:*

*2 Top 100 mm must meet minimum standards for base quality material.*
*3 Table 3.15 shows the total thickness of material required above the subgrade.*
*4 Material thickness may include lime-stabilised subgrade.*

*Asphalt surfaced pavement with granular base:*

*1 Asphalt modulus varies with traffic speed and operating temperature (Figure 3.10).*
*2 Design traffic: ≤ $10^5$ ESA: permanent deformation is the only distress considered.*
*3 Design traffic > $10^5$ ESA: permanent deformation and asphalt fatigue distresses considered.*

*Rigid pavement:*

*1 Fatigue of the base is the only distress mode considered.*
*2 All rigid pavement types, i.e. plain concrete pavement, dowel and continuously reinforced, require the same base thickness when erosion distress is not considered.*
*3 For lightly trafficked roads, Austroads (2018a) suggests typical project reliability levels of 80% to 90%. This range corresponds to load safety factors of 1.05 to 1.20 used in the rigid pavement design procedure.*
*4 A flexural strength of 4 MPa was assumed for the concrete base.*

*All structures:*

*1 Table O.1 of Austroads (2018a) was adopted as the traffic load distribution for all pavement designs. This distribution is typical of collector roads with buses.*

**Table 3.14: Example design pavement thickness (mm): unbound granular pavement with thin bituminous surfacing**

| Design traffic (ESAs) | Subgrade CBR (%) | | | |
|---|---|---|---|---|
| | 3 | 5 | 7 | 15 |
| $1 \times 10^3$ | 260 | 200 | 160 | 100 |
| $5 \times 10^3$ | 300 | 230 | 190 | 120 |
| $1 \times 10^4$ | 320 | 240 | 200 | 120 |
| $5 \times 10^4$ | 340 | 260 | 210 | 130 |
| $1 \times 10^5$ | 380 | 290 | 240 | 150 |
| $5 \times 10^5$ | 480 | 360 | 300 | 180 (1) |
| $1 \times 10^6$ | 520 | 390 | 320 | 200 (2) |

1 *Minimum thickness of base quality material is 180 mm.*
2 *Minimum thickness of base quality material is 200 mm.*

Table 3.15: Example design asphalt thickness (mm): asphalt-surfaced pavement with granular base

| Design traffic (ESAs) | Asphalt modulus: 3500 MPa Subgrade CBR: 3% | | | Asphalt modulus: 3500 MPa Subgrade CBR: 7% | | | Asphalt modulus: 3500 MPa Subgrade CBR: 15% | | |
|---|---|---|---|---|---|---|---|---|---|
| | Granular material thickness (mm) | | | | | | | | |
| | 300 | 200 | 100 | 300 | 200 | 100 | 300 | 200 | 100 |
| 1 x $10^3$ | 40 | 40 | 55 | 40 | 40 | 40 | 40 | 40 | 40 |
| 5 x $10^3$ | 40 | 50 | 65 | 40 | 40 | 40 | 40 | 40 | 40 |
| 1 x $10^4$ | 40 | 60 | 70 | 40 | 40 | 40 | 40 | 40 | 40 |
| 5 x $10^4$ | 50 | 75 | 85 | 40 | 40 | 55 | 40 | 40 | 40 |
| 1 x $10^5$ | 60 | 85 | 90 | 40 | 40 | 60 | 40 | 40 | 40 |
| 5 x $10^5$ | 105 | 115 | 120 | 55 | 90 | 100 | 40 | 40 | 75 |
| 1 x $10^6$ | 115 | 130 | 135 | 80 | 100 | 115 | 65 | 75 | 90 |
| Design traffic (ESAs) | Asphalt modulus: 3000 MPa Subgrade CBR: 3% | | | Asphalt modulus: 3000 MPa Subgrade CBR: 7% | | | Asphalt modulus: 3000 MPa Subgrade CBR: 15% | | |
| | Granular material thickness (mm) | | | | | | | | |
| | 300 | 200 | 100 | 300 | 200 | 100 | 300 | 200 | 100 |
| 1 x $10^3$ | 40 | 40 | 55 | 40 | 40 | 40 | 40 | 40 | 40 |
| 5 x $10^3$ | 40 | 55 | 70 | 40 | 40 | 40 | 40 | 40 | 40 |
| 1 x $10^4$ | 40 | 60 | 75 | 40 | 40 | 45 | 40 | 40 | 40 |
| 5 x $10^4$ | 50 | 80 | 90 | 40 | 40 | 55 | 40 | 40 | 40 |
| 1 x $10^5$ | 60 | 90 | 95 | 40 | 40 | 60 | 40 | 40 | 40 |
| 5 x $10^5$ | 105 | 120 | 130 | 40 | 90 | 105 | 40 | 40 | 75 |
| 1 x $10^6$ | 120 | 135 | 140 | 80 | 105 | 120 | 65 | 75 | 90 |
| Design traffic (ESAs) | Asphalt modulus: 2000 MPa Subgrade CBR: 3% | | | Asphalt modulus: 2000 MPa Subgrade CBR: 7% | | | Asphalt modulus: 2000 MPa Subgrade CBR: 15% | | |
| | Granular material thickness (mm) | | | | | | | | |
| | 300 | 200 | 100 | 300 | 200 | 100 | 300 | 200 | 100 |
| 1 x $10^3$ | 40 | 40 | 65 | 40 | 40 | 40 | 40 | 40 | 40 |
| 5 x $10^3$ | 40 | 60 | 80 | 40 | 40 | 45 | 40 | 40 | 40 |
| 1 x $10^4$ | 40 | 70 | 85 | 40 | 40 | 50 | 40 | 40 | 40 |
| 5 x $10^4$ | 55 | 90 | 105 | 40 | 40 | 65 | 40 | 40 | 40 |
| 1 x $10^5$ | 70 | 100 | 110 | 40 | 40 | 70 | 40 | 40 | 40 |
| 5 x $10^5$ | 115 | 135 | 140 | 40 | 100 | 120 | 40 | 40 | 85 |
| 1 x $10^6$ | 135 | 150 | 155 | 80 | 115 | 130 | 40 | 70 | 100 |
| Design traffic (ESAs) | Asphalt modulus: 1000 MPa Subgrade CBR: 30% | | | Asphalt modulus: 1000 MPa Subgrade CBR: 70% | | | Asphalt modulus: 1000 MPa Subgrade CBR: 15% | | |
| | Granular material thickness (mm) | | | | | | | | |
| | 300 | 200 | 100 | 300 | 200 | 100 | 300 | 200 | 100 |
| 1 x $10^3$ | 40 | 45 | 80 | 40 | 40 | 40 | 40 | 40 | 40 |
| 5 x $10^3$ | 40 | 70 | 100 | 40 | 40 | 55 | 40 | 40 | 40 |
| 1 x $10^4$ | 40 | 85 | 110 | 40 | 40 | 60 | 40 | 40 | 40 |
| 5 x $10^4$ | 65 | 110 | 130 | 40 | 40 | 80 | 40 | 40 | 40 |
| 1 x $10^5$ | 80 | 125 | 145 | 40 | 40 | 90 | 40 | 40 | 40 |
| 5 x $10^5$ | 130 | 155 | 170 | 40 | 110 | 135 | 40 | 40 | 85 |
| 1 x $10^6$ | 150 | 175 | 185 | 40 | 125 | 150 | 40 | 40 | 110 |

Table 3.16: Example design concrete base thickness (mm): rigid pavement

| Design traffic (ESAs) | No concrete shoulders | | | | | |
|---|---|---|---|---|---|---|
| | Load safety factor = 1.05 | | | Load safety factor = 1.2 | | |
| | Subgrade CBR (%) | | | | | |
| | 3 | 7 | 15 | 3 | 7 | 15 |
| $1 \times 10^3$ | 160 | 150 | 145 | 175 | 160 | 155 |
| $5 \times 10^3$ | 170 | 155 | 150 | 185 | 171 | 165 |
| $1 \times 10^4$ | 170 | 160 | 155 | 190 | 175 | 170 |
| $5 \times 10^4$ | 185 | 170 | 165 | 200 | 185 | 180 |
| $1 \times 10^5$ | 190 | 175 | 170 | 205 | 190 | 185 |
| $5 \times 10^5$ | 200 | 185 | 180 | 220 | 205 | 195 |
| $1 \times 10^6$ | 210 | 195 | 185 | 230 | 210 | 200 |
| Design traffic (ESAs) | With concrete shoulders | | | | | |
| | Load safety factor = 1.05 | | | Load safety factor = 1.2 | | |
| | Subgrade CBR (%) | | | | | |
| | 3 | 7 | 15 | 3 | 7 | 15 |
| $1 \times 10^3$ | 135 | 125 | 125 | 160 | 150 | 145 |
| $5 \times 10^3$ | 145 | 135 | 130 | 170 | 155 | 150 |
| $1 \times 10^4$ | 145 | 140 | 130 | 170 | 160 | 155 |
| $5 \times 10^4$ | 155 | 142 | 140 | 185 | 170 | 165 |
| $1 \times 10^5$ | 160 | 150 | 145 | 190 | 175 | 170 |
| $5 \times 10^5$ | 170 | 160 | 155 | 200 | 185 | 180 |
| $1 \times 10^6$ | 180 | 165 | 160 | 210 | 195 | 185 |

# 3.9 Surfacing Selection and Design

## 3.9.1 Surfacing Selection

The uppermost layer of a pavement structure is often called a surface or wearing course.

The surface should resist traffic stresses, provide adequate skid resistance and a smooth ride for vehicles. Skid resistance is a function of the microtexture and macrotexture of the finished surface, where ride quality (roughness) is a function of macrotexture and longer wavelength vertical deviations in the surface. Microtexutre, macrotexture and roughness can be described as:

- Microtexture: defined as the surface irregularity having a wavelength less than 0.5 mm and as such describes the texture of individual stones or the fine texture of the cement mortar as would be seen under a magnifying glass or felt by rubbing a finger over the surface.
- Macrotexture: of greater importance for high speed or wet weather operation is the surface macrotexture. This is defined as the surface irregularity having a wavelength between 0.5 and 50 mm and as such is the texture felt by fingers pressing into the gaps between the stones or into the tyne marks (concrete roads).
- Roughness: defined as the deviation from a perfectly level plane, may be specified to ensure an adequate level of ride comfort and to reduce vehicular noise to abutting properties.

### *Purpose of Surfacings (Wearing Course)*

- *provide surface characteristics to reflect community expectations*
- *provide an adequate level of skid resistance*
- *provide a dust-free surface*
- *reduce surface moisture reaching the pavement or subgrade and/or the loss of pavement moisture*
- *extend the life of the pavement*
- *reduce the rate of pavement wear and maintenance costs*
- *provide acceptable ride qualities and travel times*
- *provide a safe, economical and durable all-weather surface*
- *reduce vehicle operating and maintenance costs.*

## Types of surfacings

The major categories of sealed road surfacing types are:

- sprayed seals
- asphalt
- slurry/microsurfacing
- concrete/segmented pavers.

## Choice of surfacing

The choice of surfacing is influenced by:

- road user expectations
- community expectations
- stresses imposed by traffic
- environmental conditions
- accepted local practice
- availability of materials
- price/budget limitation
- whole-of-life-cost of the treatment
- maintenance practices and requirements.

Concrete surfacings are only used on concrete pavements. Concrete segmental pavers are designed to have high material strength and this surfacing type contributes to the structural capacity of the pavement for moderate to low traffic loading. They should not be used as a surfacing over a bituminous pavement.

A broad overview of factors affecting the choice of a bituminous surfacing type is given in Table 3.17, with the suitability of various surfacings for several applications provided in Table 3.18. A flow chart to assist in the selection of an appropriate bituminous surfacing type is then shown in Figure 3.11.

**Table 3.17: Factors affecting the choice of bituminous surfacings**

| Approximate traffic volume vehicles/lane/day (v/l/d) | Surfacing |
|---|---|
| Heavily trafficked roads e.g. more than 6000 v/l/d | Generally, asphalt surfacing with a full depth asphalt pavement will be used. Granular pavements with double/double seals as initial treatments and single/single seals as retreatments have been used satisfactorily.<br>In industrial areas with a high % of HVs, asphalt surfacings may be used on lower-volume roads to avoid surface damage by the turning movements entering or exiting properties.<br>Good quality, polish-resistant aggregates to maintain skid resistance. |
| Medium to heavily trafficked roads e.g. between 2000 and 6000 v/l/d | Either asphalt or sprayed seals may be used depending on construction and maintenance strategies.<br>Good quality, polish-resistant aggregates to maintain skid resistance. |
| Light and moderately trafficked roads e.g. up to 2000 v/l/d | Generally, sprayed seals are used in rural areas and asphalt or slurry seals in major metropolitan areas. |
| Very lightly trafficked roads e.g. less than 75 v/l/d | Economics, maintenance strategies and community acceptance should be considered. Generally, aggregate quality requirements can be less stringent. Depending on operating conditions, fine-textured surfaces and low-cost treatments may be feasible, e.g. surface enrichment, slurry seals, small nominal size aggregate in sprayed seals or asphalt surfacing. |
| Areas of high horizontal shear forces (intersections, turning lanes, etc.) | If there are more than 1000 vehicles per lane per day and more than 15% heavy vehicles, then asphalt (or concrete) will be required; other situations can be surfaced with varying types of specialised sprayed seals. |

**Table 3.18: Suitability of bituminous treatments**

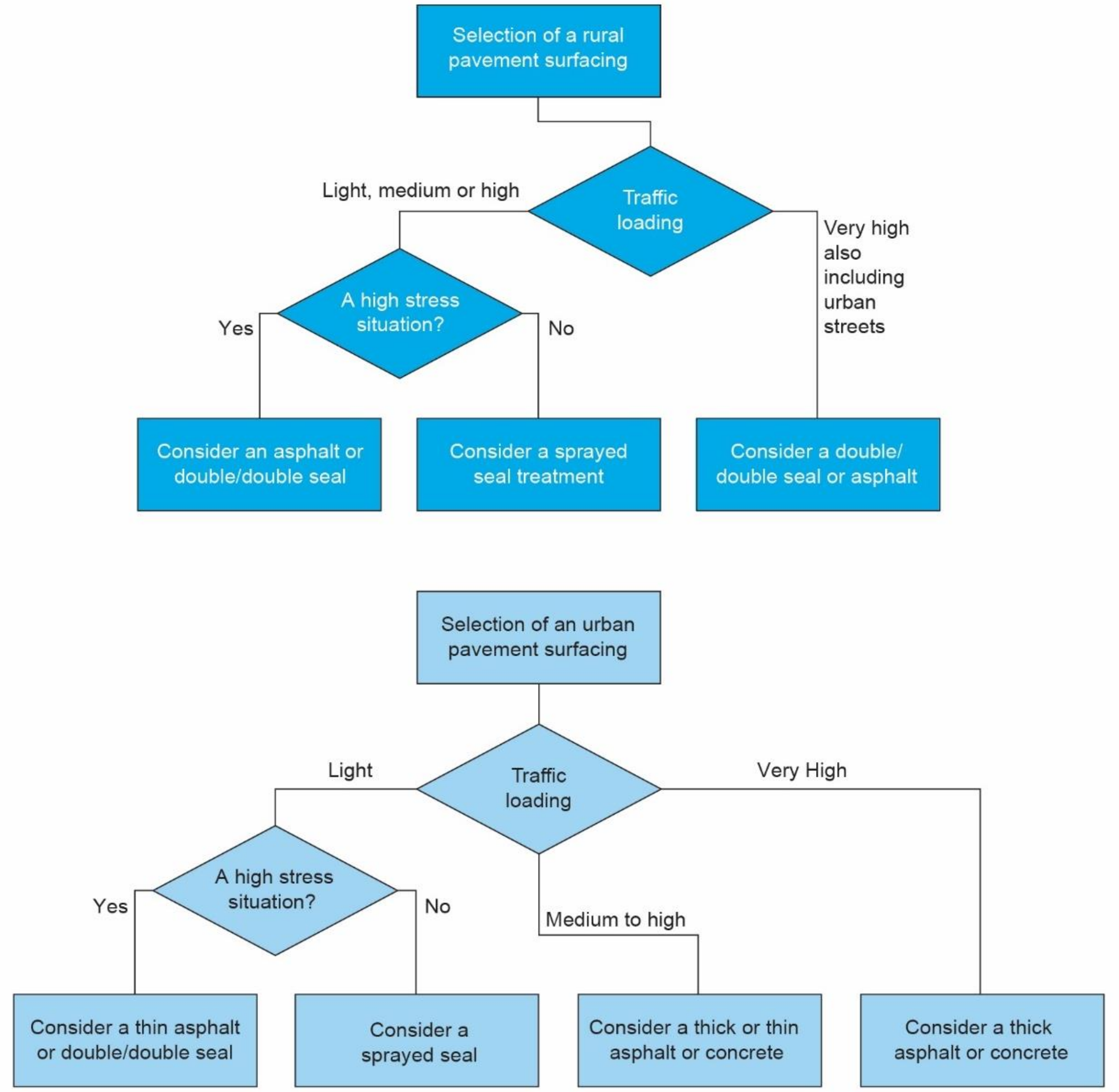
| Property requiring improvement | Asphalt | | | | | Sprayed seals | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dense graded | Fine gap graded | Stone mastic asphalt | Ultra-thin open graded | Open graded | Surface enrichment | Single/single | Double/double | Geotextile reinforced | Microsurfacing | Correction seal plus GRS | Correction seal plus GRS & asphalt overlay |
| Bitumen aging/oxidation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Roughness improvement | ✓ | ✓ | ✓ | ✓ | ✓ | × | × | × | × | 1 | ✓ | ✓ |
| Waterproofing properties | ✓ | ✓ | ✓ | × | × | 2 | ✓ | ✓ | ✓ | 1 | ✓ | ✓ |
| Skid resistance | 3 | 3 | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | 3 | ✓ | 4 |
| Structural strength | 6 | 1 | ✓ | × | 1 | × | × | × | × | × | 4 | 4 |
| Shear resistance/robustness | ✓ | 1 | ✓ | × | × | × | × | 2 | 1 | ✓ | 1 | 4 |
| Water-spray reduction | × | × | ✓ | ✓ | ✓ | × | 5 | 5 | 5 | × | ✓ | 4 |
| Impermeable surface | ✓ | ✓ | ✓ | × | × | 1 | ✓ | ✓ | ✓ | × | ✓ | ✓ |
| Flexibility (strain tolerance) | 2 | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | × | ✓ | ✓ |
| Resists reflection cracking | 1 | 1 | 2 | 2 | 1 | × | ✓ | ✓ | ✓ | × | ✓ | ✓ |
| Shape correction ability | ✓ | ✓ | ✓ | ✓ | ✓ | × | × | × | × | 2 | ✓ | ✓ |

✓ *Recommended*
× *Not recommended*
1 *Little to no improvement*
2 *Moderate improvement*
3 *Reasonable skid resistance at low speeds*
4 *Depends on asphalt type*
5 *Depends on nominal aggregate size*
6 *Depends upon substrate*



arrb

**Figure 3.11: Selection of surfacings for rural and urban situations**




## Sprayed seals

Sprayed seals are mainly used in rural areas which have low to medium trafficked roads in Australia. Sprayed treatments have also been used on heavy to very heavily trafficked roads in both Australia and New Zealand, with traffic exceeding 20 000 vehicles per day, particularly with the use of polymer modified binders. A summary of the strengths and limitations of sprayed seal treatments is provided in Table 3.19.

Detailed information on sprayed seal selection and design is published in the Austroads *Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals* (Austroads 2018b) and is considered an important reference for practitioners. Design and construction of sprayed seals is also included in AUS-SPEC Worksection *1143 – Sprayed Bituminous Surfacing*.

Guidance for the selection and usage of materials for sprayed seals is provided in the ARRB *Road Materials Best Practice Guide*.

Table 3.19: Strengths and limitations of sprayed seal treatments

| Strengths | Limitations |
|---|---|
| • They can be used as either an initial treatment or retreatment.<br>• They are relatively cheap in comparison to other treatments.<br>• They have high flexibility under reasonable traffic volumes.<br>• They can provide a high skid resistant surfacing with the larger aggregates, i.e. size 10 or larger.<br>• They can provide a good waterproof surfacing.<br>• The use of polymer modified binders provides a more durable treatment over cracked pavements.<br>• Geotextiles, or fibre reinforcement improve the ability of the seal to resist cracks even further. | • They will not strengthen or correct the shape of pavement.<br>• They have high tyre noise, particularly with single/single seals and nominal size applications.<br>• They are less satisfactory when used on non-uniform or rutted surfaces.<br>• They are not suitable for use at heavily trafficked signalised intersections, roundabouts or other areas of high shear stress.<br>• There is a risk of aggregate loss and delamination when applied in wet weather or on high-plasticity bases.<br>• They are far more successful when applied in warmer weather conditions.<br>• Sprayed seals also require more frequent periodic maintenance than asphalt or concrete pavements. |

Most spray seal binders are applied hot, at temperature between 170 to 200 °C. It should be noted that transport of bituminous materials at elevated temperatures needs to comply with the requirements of AS 2809-1 *Road tank vehicles for dangerous goods.* Equivalent binders supplied as an emulsion are generally available and these are applied below 90 °C, and as such are not considered as dangerous goods.

An overview of commonly used sprayed seal treatments is provided in Table 3.20.

Table 3.20: Sprayed seals

| Type | Purpose/applications | Life expectancy | Materials/types |
|---|---|---|---|
| Prime | • Seal the pores in pavement material<br>• Bind the pavement surface<br>• Contribute to waterproofing the pavement surface<br>• Prepare pavement for overlying surfacing | Several weeks – not trafficable | Cutback bitumen<br>Specialised emulsion |
| Initial seal | • Application to basecourse that has not been primed<br>• Provide a trafficable surface immediately after sealing pavement<br>• Minimise disruption to traffic compared to prime<br>• Permits delay of final surfacing (e.g. when waiting for more favourable weather) | 3–24 months | Single/single, or double/double for a more robust treatment<br>Conventional bitumen, PMB either as a cutback or an emulsion |
| Sprayed seals (secondary and retreatments) | • Application of a sprayed seal over an existing bituminous surface<br>• Provides a low cost, low maintenance wearing surface that can be applied in remote locations<br>• Provides good texture and skid resistance<br>• Extends life of a dry or weathered surfacing<br>• Good at supressing reflective cracking<br>• Wide range of treatments available | 5–15 years | Conventional bitumen<br>PMB – HSS1, HSS2, XSS, SAM, SAMI (Austroads 2018b)<br>Single/single or multiple-layer applications |

| Type | Purpose/applications | Life expectancy | Materials/types |
|---|---|---|---|
| Geotextile reinforced seals | • Treating badly cracked pavements that still have good shape<br>• To seal pavements constructed of low-quality base materials<br>• Enhanced waterproofing<br>• Provides highly waterproof wearing course | 5–15 years | Geotextile (generally non-woven, needle punched, polyester or polypropylene) with a double/double seal |
| Fibre reinforced | • A layer of glass strands sandwiched between two applications of polymer modified bituminous emulsion<br>• Resists reflective cracking more than a SAM seal<br>• Requires purpose-built sprayer with twin spray bars and fibre-dispensing system | 5–10 years | Fibreglass<br>Polymer modified bituminous emulsion<br>Typically, proprietary systems |
| Surface enrichment | • Light application of bituminous material to an existing highly textured bituminous treatment to increase the binder content at the surface<br>• Typically applied without a cover aggregate<br>• Extends life of oxidised seals with adequate surface texture | 4–6 years | Cutback bitumen, bituminous emulsion, foamed bitumen |

## Shoulders

Moisture ingress through unsealed shoulders may be associated with surface shape loss due to moisture changes in expansive soils and loss of subgrade strength. Sealed shoulders provide a means of retarding moisture ingress through the shoulder material, particularly where shoulder material is permeable or where pavement permeability decreases with depth.

Moisture stability may also be efficiently obtained by stabilising the shoulder with a cementitious binder, polymer or bitumen.

Sealed shoulders may be required where regular maintenance of shoulders presents a problem.

In addition, sealed shoulders may offer increased traffic safety by providing some recovery area when vehicles leave the travelling lanes.

## Design of sprayed seals

Sprayed seals in Australia should be designed by the Austroads method (Austroads 2018b).

The general design concept is for the binder level to be between halfway and two-thirds of the average least dimension (ALD) of the aggregate. This provides a good compromise between the levels required to hold the aggregate in place, waterproof, and provide adequate surface texture and durability.

Aggregates in a sprayed seal rearrange during construction rolling into a more stable position, with the least dimension tending towards vertical. The aggregate continues to reorient under traffic at a rate dependent on the traffic volume. Under low traffic the reorientation is less, and the aggregate remains in a more random arrangement. Under high traffic the reorientation is greater and nearly all particles will have their least dimension vertical. Thus, less binder is required for highly trafficked sprayed seals than for low trafficked seals. The aggregate spread rate is designed to allow the aggregate enough space to move/rotate.

The following information is required to conduct sprayed seal designs:

- Traffic – in vehicles per lane per day, calculated from the AADT, the lane function and the number of lanes.
- ALD and flakiness index of the aggregate.
- Traffic effects outside the assumptions made, e.g. channelisation (overtaking lanes etc.), short-term traffic variations in volume or speed.
- Increases in heavy vehicular traffic (seasonal harvests etc.) or untrafficked areas (i.e. shoulders).
- Aggregate shape as measured by the flakiness index. Very cubical aggregate (e.g. less than 15% flakiness index) needs more binder than typical aggregates having a 20 to 30% flakiness index.
- Aggregate wear – generally not needed for a design when using good-quality aggregates on the higher traffic volume roads.
- Texture of the existing surface. It is not uncommon for the texture of the wheel paths to be markedly different to the texture outside the wheel paths. In these instances, consideration should be given to varying the binder application rate across the lane to obtain a more even final surfacing.
- Embedment – occurs mainly on initial treatments on softer pavements but may also apply to reseals where the binder is soft or there is excess binder near or on top of the surface. Embedment is measured using the ball embedment hammer (Austroads test method AGPT-T251-10 *Ball Penetration Test).*
- Absorption – into the pavement or aggregate. May be needed for initial treatments on absorptive bases or vesicular aggregates otherwise not generally required.

### Asphalt

Hot mix asphalt is the main material used to construct and surface heavily trafficked pavements in urban areas, rural highways, residential streets and industrial roads. The main aim is to provide a smooth all-purpose surface with minimal future maintenance, regulation and pavement repairs.

Guidance for the selection and usage of materials for asphalt is provided in the ARRB *Road Materials Best Practice Guide,* Austroads *Guide to Pavement Technology Part 4B: Asphalt* (Austroads 2014b), and AUS-SPEC Worksection *1144 – Asphalt (Roadways)*.

The strengths and limitations of asphalt treatments are summarised in Table 3.21.

Table 3.21: Strengths and limitations of asphalt treatments

| Strengths | Limitations |
|---|---|
| • It can be used as either an initial treatment or retreatment.<br>• It can strengthen and stiffen a pavement.<br>• It can improve riding quality by shape correction.<br>• It provides lower tyre noise when compared to sprayed seals.<br>• It has low water spray generation and good to high skid resistance if an open graded or stone mastic asphalt is used.<br>• It is excellent for resisting high traffic forces at intersections and roundabouts providing an appropriate design mix is used.<br>• It is excellent as a non-structural ultra-thin surfacing to resurface heavily trafficked roads while also overcoming minor irregularities, compared to a sprayed seal.<br>• Polymer modified binder improves resistance to rutting and shoving. | • It is relatively expensive.<br>• It must be spread and compacted while hot (typically while the mat remains above 90 to 100 °C (varies depending on binder type). This may mean that asphalt layers may need to be placed thicker in colder areas.<br>• It should be used on sound pavements.<br>• It requires a SAMI if placed over cracked pavements.<br>• When used as an overlay, it can change pavement surface levels resulting in access issues for adjacent properties and alterations to gutter capacity. |

#### Dense graded asphalt

Dense graded asphalt (DGA) is the most common asphalt. It is a designed and controlled, continuously graded mixture of coarse and fine aggregates, mineral filler and binder, which is mixed, spread and compacted while hot.

By varying the combination of the aggregates to provide a range of different air voids, and using different grades of binder, the asphalt mix properties can be altered to suit applications ranging from low-trafficked private streets, to freeways and airports.

***Uses for Dense Grade Asphalt***

- *strengthening an existing pavement*
- *constructing a new pavement*
- *correcting irregularities in an existing pavement*
- *repairing an existing pavement.*

#### Open graded asphalt

Open graded asphalt (OGA) has an almost single-sized grading with only a small amount of fine aggregate compared to dense graded asphalt. It has a large percentage of air voids and relies mainly on the aggregate particle interlock for stability. As a result, it has a high resistance to rutting and its main characteristic is an open-textured surface.

Because of its open grading, the underlying pavement surface on which it is placed must be waterproof and the edges of the open graded layer must be free draining. It may be desirable/necessary to apply a SAMI or geotextile seal prior to placing the open graded asphalt if there is any doubt about the supporting asphalt layer being impervious or remaining that way for the expected life of the open graded asphalt surfacing.

Where required, strengthening and application of a regulation layer should be carried out with dense graded asphalt prior to placing an open graded asphalt.

It is generally used in urban areas on arterial roads free from braking and turning where it is desirable to:

- reduce noise
- minimise water spray for improved visibility and safety, particularly on high-speed busy roads such as freeways
- provide a surfacing with high skid resistance, such as areas prone to frost or very tight curves where surface drainage may be a problem. However, it may have poor skid resistance immediately after construction.

***Uses for Open Grade Asphalt***

- *reducing noise*
- *minimising water spray*
- *to provide a high skid resistance surface*
- *not recommended for intersections due to relatively low shear resistance*

**Stone mastic asphalt**

Stone mastic asphalt (SMA) is a coarse gap graded mix with a high coarse aggregate content, which interlocks to form a strong aggregate skeleton that provides good resistance to rutting and shoving. The mix has a high binder and filler content to provide a strong mastic. A small percentage of fibres (typically cellulose but can also be mineral or other materials) are generally added to avoid drainage of the binder during transport and placing of the mix.

The mastic with the high binder/filler content makes it a fatigue-resistant, long-life asphalt surfacing provided that an impermeable mat is produced.

***Uses for Stone Mastic Asphalt***

- *good rutting resistance*
- *reducing traffic noise levels*
- *waterproofing due to thick binder mastic*
- *reducing reflective cracking*
- *providing a high skid resistance surface*

### Fine gap graded asphalt

Fine gap graded asphalt (FGGA) is an asphalt mix with the intermediate aggregate sizes replaced by sand-sized aggregate with a high binder content. It is also known as 'residential street mix' in Australia.

This has been designed for use as an overlay of minimal thickness in areas of low traffic and few heavy vehicles, such as private streets, where the asphalt cracks and ravels due to environmental conditions, weathering and oxidation of the binder, rather than due to the traffic loading. It has adequate skid resistance and surface texture for light, low-speed traffic conditions and is easy to place and compact to the required density compared to normal dense graded asphalt.

Existing cracking should be treated first, as the thin layer of gap graded asphalt is not designed to inhibit crack reflection. This is a very durable mix when placed in situations where traffic loading is light and will last in excess of 15 years. However, due to the thin nature of a fine gap graded wearing course, problems from underlying issues deeper in the pavement will manifest themselves through the wearing course in time.

### Ultra-thin asphalt

Ultra-thin asphalt (UTA) is a term generally applied to wearing courses that are less than 20 mm thick. UTAs are generally not available anymore. Other available mixes that can perform a similar function include a 7 mm SMA.

It is not a structural treatment nor will it correct existing pavement defects and will provide only minor shape correction.

***Uses for Ultra-thin Asphalt Surfacing***

- *as a non-structural wearing course*
- *fill ruts up to about 20 mm*
- *improve transverse shape and provide a uniform surface texture*
- *improve skid resistance*
- *reduce tyre noise and water spray*
- *extend the life of a weathered pavement when a sprayed seal is inappropriate.*

### Polymer modified asphalt

Polymer modified binders (PMBs) may be used in all types of asphalt, e.g. open graded, dense graded, SMA and gap graded. Asphalt may incorporate PMBs to meet specific requirements and to improve service performance. Where normal DGA can suffer minor fatigue cracking in cold conditions and self-healing in summer months, polymer modified asphalt once cracked remains cracked.

It must be remembered that the binder constitutes only one component of the asphalt mix and therefore the performance and properties of any asphalt will also be affected by the aggregate skeletal structure, aggregate quality, adhesion properties, compaction etc.

Conventional mix design and testing techniques are applicable to polymer modified asphalts. However, to realise the increased benefits from polymer modification of the binder, an allowance for the structural improvement brought about by the change in modulus, rut resistance and enhanced fatigue performance of the PMBs is recommended.

**Uses for Polymer Modified Binder Asphalt**

- *improved rut resistance*
- *improved fatigue resistance*
- *higher resistance to high traffic stress (turning movements)*
- *increased life of OGA*
- *better crack control*

**Asphalt mix design**

It is recommended that generally the selection of the mix type and design should be in accordance with Australian Standard AS 2150 for hot mix asphalt (Standards Australia 2005) or the road agency specification.

The design of the mix is commonly performed by the major asphalt suppliers. To design a suitable mix that meets the specified performance criteria requires a great deal of practical and laboratory experience. Asphalt contractors generally have a number of mix designs available, based on their supply of standard aggregate components. These mixes have been designed so that a suitable mix type is available to suit most service and traffic conditions, from freeways to private streets. In addition, special mixes may be designed for specific conditions and/or purposes.

The proposed use should be discussed with the contractor, to ensure an appropriate mix is selected.

## Microsurfacing

Microsurfacing is presently the only type of bituminous slurry surfacing in Australia, being a proprietary technique in which a mixture of a polymer modified emulsion binder and mineral aggregate, mineral filler and additives is spread as thin layers by purpose-built equipment.

Microsurfacing is good at regulating minor shape loss issues such a low level rutting and roughness caused by corrugations. The main benefit is that the treatment can be matched with the existing surface levels without the need for profiling. Microsurfacing is particularly suited to low-traffic residential streets that are structurally in good condition but where the surface is in need of renewal, but a sprayed seal surface may not be acceptable due to loose stones or tracking of binder.

Microsurfacings do not provide structural strength, have poor flexibility and are subject to environmental and reflective cracking, and are not as waterproof as sprayed seals or asphalt. They may be used in combination with other treatments to provide their benefits.

Design is undertaken by the contractor and is based on suitable aggregates compatible with the particular bitumen emulsion systems. Guidelines for use and a model specification is provided in Austroads (2018c).

Further information can be found in AUS-SPEC Worksection *1146 – Microsurfacing.*

### *Uses for Microsurfacing*

- *non-structural wearing course*
- *minimum thickness wearing surfacing (useful to match levels at kerbs etc.)*
- *provide a dense graded asphalt type surfacing, at low cost*
- *correct cross-sectional shape and fill ruts*
- *improve surface shape and/or provide a uniform surface texture for a reseal*
- *provide minor improvements in riding quality*
- *for intersections and roundabouts where loose aggregate would be a problem*
- *improving skid resistance*

## High friction surfacing treatment

High friction surfacing treatments (HFSTs) can be used for roads that require a high level of surface friction. They generally comprise a polymer resin adhesive binder that bonds a high polished stone value (PSV)/low aggregate abrasion value (AAV) aggregate, typically a graded 1–3 mm calcined bauxite, to the road substrate.

Polymer resin binders are installed as a continuous film of adhesive, onto which a calcined bauxite aggregate is placed. HFSTs are not normally applied to sprayed seals due to the high surface stress generated. On asphalt pavements it may be necessary to replace the asphalt surface prior to placing the HFST to provide a clean and uniform surface for the binder to bond to. If this is the case the asphalt may need to be trafficked for a period to allow vehicles to wear off the binder film present on the asphalt aggregate. Guidance should be sought from HFST suppliers.

Guidelines for use and a model specification are provided in ARRB (2018).

### *Uses for High Friction Surfacing*

- *approaches to major intersections*
- *approaches to schools or pedestrian crossings*
- *sites with gradients steeper than 10%, especially if other hazards are present*
- *potentially hazardous curves*

## Coloured surfacings

The appearance of traditional bituminous surfacing is generally acceptable but there may be instances where a specific colour is required or desired. The main methods of achieving this are:

- using a specific colour aggregate with a sprayed treatment
- adding a colour pigment to a normal binder in asphalt
- using a suitably coloured aggregate and a synthetic, honey coloured, binder in asphalt

- using a coloured resin and coloured glass or synthetic aggregate.

Preparation of the surface with these systems should follow the supplier's instructions. In some cases, a new asphalt surface may be required prior to placing coloured surfacing.

The type of surfacing is selected as normal, or it may be influenced by the colour requirements.

Sprayed seals with coloured aggregates, generally light coloured such as granite or river gravels, are the cheapest treatment and are often used on shoulders, traffic islands and lightly trafficked roads and car parks.

Asphalt wearing surfaces can better resist slow moving turning traffic than a seal. In addition, coloured asphalt may also be used in driveway and tennis court construction. Coloured mixes are generally produced by adding coloured pigments to the binder during the mixing process. Appropriately coloured aggregates should also be used, where available, to ensure that when the binder wears off the aggregate, the overall appearance is maintained.

The most common additive used is iron oxide, which provides a red or brown appearance to the asphalt. Other colours are available but are more expensive. Translucent binders are also expensive. In the interest of economy, it is desirable to keep the mat thickness as thin as possible while maintaining the engineering properties required.

The life expectancy of coloured asphalt is similar to that of normal asphalt and repairs can be made using coloured cold mix or hot mix as required.

***Uses for Coloured Surfacing***

- *alert traffic to special situations such as pedestrian crossings, bus stops etc.*
- *differentiate pavement functions such as parking areas, cycle lanes, bus lanes*
- *improve the effect of lighting such as in tunnels and flyovers*
- *increase the visual aspects, e.g. on tennis courts*
- *enhance or reduce the contrast with the environment, e.g. blend in with the vegetation*

## Concrete

Concrete generally provides a surface of very high durability in which the surface characteristics such as texture usually outlast that of bituminous surfacings. Due to the stiffness of concrete, it cannot be placed in very thin layers as can asphalt or bituminous seals and is not used as a surfacing on pavements other than concrete. It needs to be placed to act as the structural layer to support all the traffic-associated loading in addition to environmental loadings (e.g. heat, moisture).

Current concrete pavement design and construction practices virtually eliminate the annoying, characteristic harsh ride and bump at the end of each slab, typical of older-style (30+ years old) concrete pavements.

Careful selection of the surface finish and current jointing techniques produce surfaces having long-lasting skid resistance and which are as smooth and quiet as most other surface types. The longevity of the material and the reduction in maintenance costs can have a significant effect on the life-cycle cost for concrete pavements/surfacings.

For further information on concrete, the following AUS-SPEC Worksections are applicable:

- *1130 – Rural Concrete Base,*
- *1131 – Roller Compacted Concrete Subbase,*
- *1132 – Lean Mix Concrete Subbase,*
- *1133 – Plain and Reinforced Concrete Base,*
- *1134 – Steel Fibre Reinforced Concrete Base, and*
- *1135 – Continuously Reinforced Concrete Base*.

Table 3.22 summarises the advantages and limitations of concrete treatments.

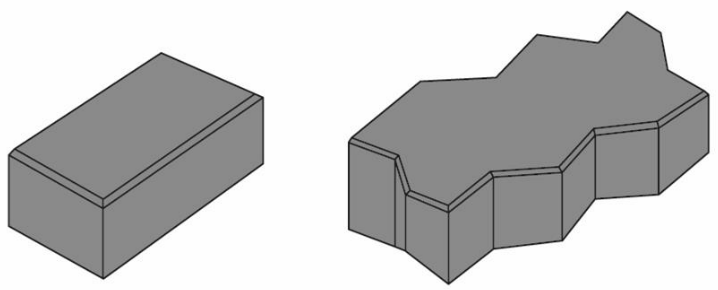
**Table 3.22: Advantages and limitations of concrete treatments**

| Advantages | Limitations |
|---|---|
| • Excellent whole-of-life cost based over a long design period as typically minimum maintenance is required to a properly constructed concrete pavement<br>• Excellent durability for abrasion and shearing forces<br>• Impermeability and durability to resist chemical attack<br>• Longevity of surfacing and the texture imparted thereon<br>• Light colour of surfacing provides greater night-time object conspicuity<br>• Wide variety of colours and decorative finishes are easily achieved | • Typically, high initial cost associated with providing the concrete base<br>• Any in-built imperfections are more difficult to remove than in a flexible pavement/surfacing<br>• More care is required, and it is more costly to reinstate service openings when placed through the concrete base<br>• Expensive maintenance in slab replacement<br>• Pavement marking is less conspicuous against a white surface |

## Concrete segmental pavers

Concrete segmental pavers designed for road paving are made of high-strength (50+ MPa) concrete, with each unit typically 0.02 to 0.025 $m^2$ in plan area, 60 to 80 mm thick, with plain or indented sides having the top and bottom faces parallel and having either chamfered or no chamfered edges (Figure 3.12).

**Figure 3.12: Typical shapes of concrete segmental paver units**



Due to the wide variety of available shapes and colours, pavers are often used when aesthetics are a priority. The mix design and surface microtexture have the prime influence on the skid resistance of the pavers.

As with concrete surfacing, the inherent durability of concrete segmental pavers makes them an ideal surfacing where excessive wear will be imparted to a pavement. The advantage of the concrete pavers over a concrete surfacing is that the initial construction costs may be lower due to the use of a wide range of materials for the supporting layers. A concrete segmental paver surface (incorporating a thin bedding layer of sand) can be placed on any quality substrate, either a fully bound material such as asphalt or concrete, a stabilised granular material or a non-bound granular material.

Although made of very high-strength concrete, individual paver units would only fracture under extraordinary loading because of their limited size. The discontinuous nature of this high-strength surfacing allows the surfacing/base to act in a much more flexible manner than that of concrete pavements. Design of these surfaces (pavements) is based on flexible pavement design with resultant savings on the initial cost compared to concrete pavements. Table 3.23 gives summarises the advantages and limitations of using concrete segmental pavers.

**Table 3.23: Advantages and limitations of concrete segmental pavers**

| Advantages | Limitations |
|---|---|
| • Excellent durability for abrasion and shearing forces, and chemical attack<br>• Unitary nature of the concrete pavers means that they can be designed using flexible design mechanisms, being able to be supported by a wide range of substrates, resulting in economic pavement compositions<br>• Visual differentiation via the paver pattern and introduction of colour provides for permanent delineation of pavement use or function<br>• Light colours provide excellent dry weather conspicuity of objects on the surface<br>• Ability to lift and reuse the paver units, especially for service-line restoration<br>• Longevity of surfacing macrotexture | • May not be able to source replacement pavers; in these cases, they usually have to be specially made to a smaller size for patches<br>• Can be noisy<br>• High labour content for the initial construction<br>• Require attention to ensure positive drainage of the bedding sand layer<br>• Expensive replacement patching<br>• Can be difficult to re-establish the integrity of interlocking when openings are made in a pavement |

For further information on segmental pavers, the AUS-SPEC Worksection *1146 – Segmental Paving* is applicable.

### 3.9.2 Choosing an Optimum Pavement and Surfacing Combination

The optimum pavement design solution is that which satisfies the design requirements for the specified input at minimum cost (including road user as well as agency costs, the whole-of-life costs of the pavement), and allows for constraints such as:

- design considerations which cannot be readily quantified and taken into account by the design procedures adopted in this Guide, such as the environment
- future maintenance
- environmental impact including energy consumption of different proposals
- availability of plant and materials
- risks of failure if required to construct the pavement during inclement weather
- local requirements for specific surfacings (for example, many municipalities or cities insist on asphalt surfacing of granular pavements in particular circumstances).

The following are examples of practical constraints on the choice of pavement type or surfacing (Queensland Department of Transport 1990):

- Asphalt surfaces are more costly than sprayed surface treatments; however, in many urban municipalities they are insisted upon due to surface finish requirements and the ability to accommodate truck turning movements.
- Certain combinations of pavement and shoulder materials and their configuration in the pavement may be required to promote pavement drainage.
- Where a pavement is likely to be exposed to soaked conditions for extended periods, cement or bituminous bound material may be required to protect the structural integrity of the pavement despite additional costs.
- When comparing the cost of structurally equivalent alternatives, consideration must be given to non-productive costs associated with establishment, overheads, provision for traffic and wet weather, which may be different for each alternative.

Table 3.24 details some typical applications for various pavement and surfacing types.

**Table 3.24: Typical applications for various pavement type**

| Pavement type | Typical application | Remarks |
|---|---|---|
| Granular with thin bituminous surfacing | • Rural roads<br>• Low to medium traffic<br>• Staged construction<br>• Special maintenance to be overlaid<br>• Service roads<br>• Expansive subgrade in rural areas | Thin surfacings have higher risk of failure when applied in cold conditions<br><br>Care in surface preparation of granular base is critical |
| Asphalt<br>(full depth and deep strength) | • Medium to heavily trafficked roads where rapid construction is necessary | |
| Bound material<br>(full depth)<br>(i.e. binders may include cementitious or foamed bitumen with thin AC or spray seal) | • Heavily trafficked roads, especially on low CBR subgrades<br>• Where services or other constraints dictate use of minimum thickness pavement<br>• Floodways in remote areas | On cementitious bases shrinkage cracking will require extensive maintenance possibly early in the life of the pavement |
| Granular on bound material with thin AC or spray seal | • Heavily trafficked roads, especially on low CBR subgrades<br>• Need to ensure permeability reversal does not lead to premature failure of basecourse | Reflective cracking possible if granular base < 200 mm |
| Granular lightly bound with thin AC or spray seal | • Light to medium trafficked roads<br>• Need to ensure permeability reversal does not lead to premature failure of basecourse | Difficult to apply small percentages of binder in practice, can lead to shrinkage cracking |
| Stabilised granular on granular | • Medium to high traffic | |
| Asphalt on granular | • Medium to high traffic roads or where noise is a consideration<br>• Roundabouts and signalised intersections | Need may be determined by surface finish requirements<br>Life may be controlled by asphalt fatigue with overlay when required<br>Early fatigue failure of asphalt under heavy traffic likely |

| Pavement type | Typical application | Remarks |
|---|---|---|
| Asphalt on cemented | • Heavily trafficked roads, especially on low CBR subgrades<br>• Where services or other constraints dictate use of minimum thickness pavement<br>• Where speed of construction is important<br>• Urban areas | Reflective cracking requiring maintenance likely if asphalt less than about 175 mm thick |
| Thick asphalt on granular bound | • Medium to heavily trafficked roads, especially on low CBR subgrades | Life may be controlled by asphalt fatigue with overlay when required |
| Concrete | • Lightly trafficked residential streets to heavily trafficked roads<br>• Where low maintenance is required<br>• Where decorative finishes are required<br>• Where lane definition is important<br>• Bus stops/roundabouts/intersections<br>• Floodways in remote areas | |
| Segmental block paving | • Residential areas<br>• Low-speed areas<br>• Where decorative finishes are required<br>• Pedestrian malls<br>• Bus stops, parking lanes<br>• Intersection approaches where asphalt rutting would be a problem<br>• Roundabouts<br>• Temporary paving areas and over services | Where appearance and/or lane definition is important |

*Source: Adapted from Queensland Department of Transport (1990).*

## 3.10 Design of Structural Overlays

An overlay is the application of a layer of granular material or asphalt onto an existing pavement that has structural deficiencies such as strength and/or surface deficiencies. The overlay must be designed at an appropriate thickness to overcome the structural deficiencies and should also consider the pavement's functional requirements.

This section covers the basic empirical design principles of asphalt and granular overlay thickness on pavements without cemented layers. For current detailed empirical and mechanistic procedures for overlay design refer to Austroads (2019a) or to a pavement design specialist.

The need for an overlay will be based on both functional and structural reasons. Generally, the overlay/resheet procedure is as follows:

Evaluate the existing pavement condition including undertaking deflection testing where appropriate. If not utilising deflection testing, the existing pavement thickness and subgrade support must be established/estimated.

1. Calculate future traffic loadings.
2. Consider the pavement environment e.g. seasonal variations and WMAPT.
3. Consider the existing pavement material performance.

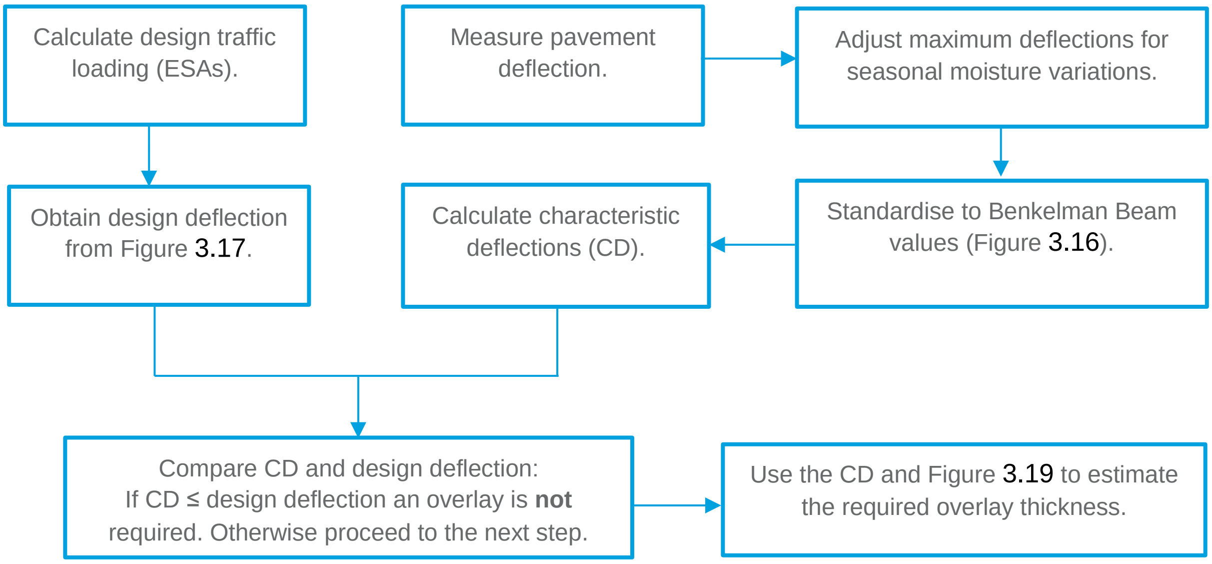
4. Determine the cause of pavement distress and whether the pavement needs overlay/resheet for structural reasons.
5. Determine whether the pavement needs overlay/resheet based on functional requirements.
6. Determine the materials available for overlay/resheet and consider future distress modes.
7. Determine the thickness of the overlay/resheet to satisfy both structural and functional requirements to carry future traffic loadings.

Note that the actual overlay placed will also have its thickness affected by such factors as the existing level control, overlay material used, existing pavement treatment and drainage improvements.

Assessment of the thickness of overlay required for functional reasons will generally involve undertaking a roughness and rutting survey. Various means of measuring these distress types have been discussed previously. The need to place a functional overlay may be based on a visual assessment or survey results.

A summary example of the process for designing the thickness of a granular overlay for various design scenarios is presented in Figure 3.13, and a worked example is provided in Section 3.10.1.

**Figure 3.13: Granular overlay design process**




*Source: Adapted from Austroads (2019a).*

Once provided the measured deflection and curvature information for an existing pavement, various correction factors may need to be applied depending on the climate, measurement device, proposed binder type and pavement condition (i.e. if milling is required).

Table 3.25 provides typical moisture correction factors for deflections and curvatures. These adjustment factors are applied to represent the pavement in its weakest condition. They should be used with taking into account the type of subgrade, drainage conditions and regional specific weather conditions.

**Table 3.25: Seasonal moisture correction factors**

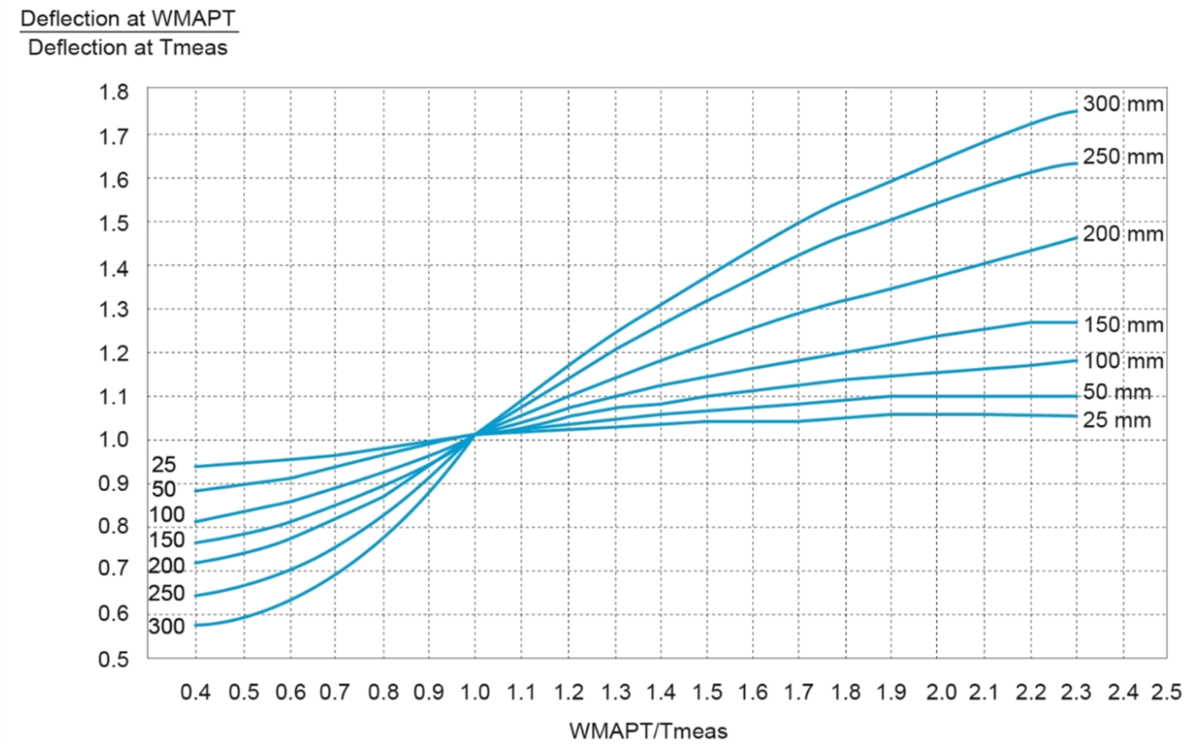
| Winter and spring rain (Temperate climates) | | Summer rain (Tropical and sub-tropical climates) | |
|---|---|---|---|
| Month when deflections are measured | | | |
| January to April[(1)] | May to December | June to December[(1)] | January to May |
| 1.3 | 1.0 | 1.3 | 1.0 |

*1. If the watertable is less than 3 m below the surface, the correction factor is 1.0.*

*Source: Austroads (2019a).*

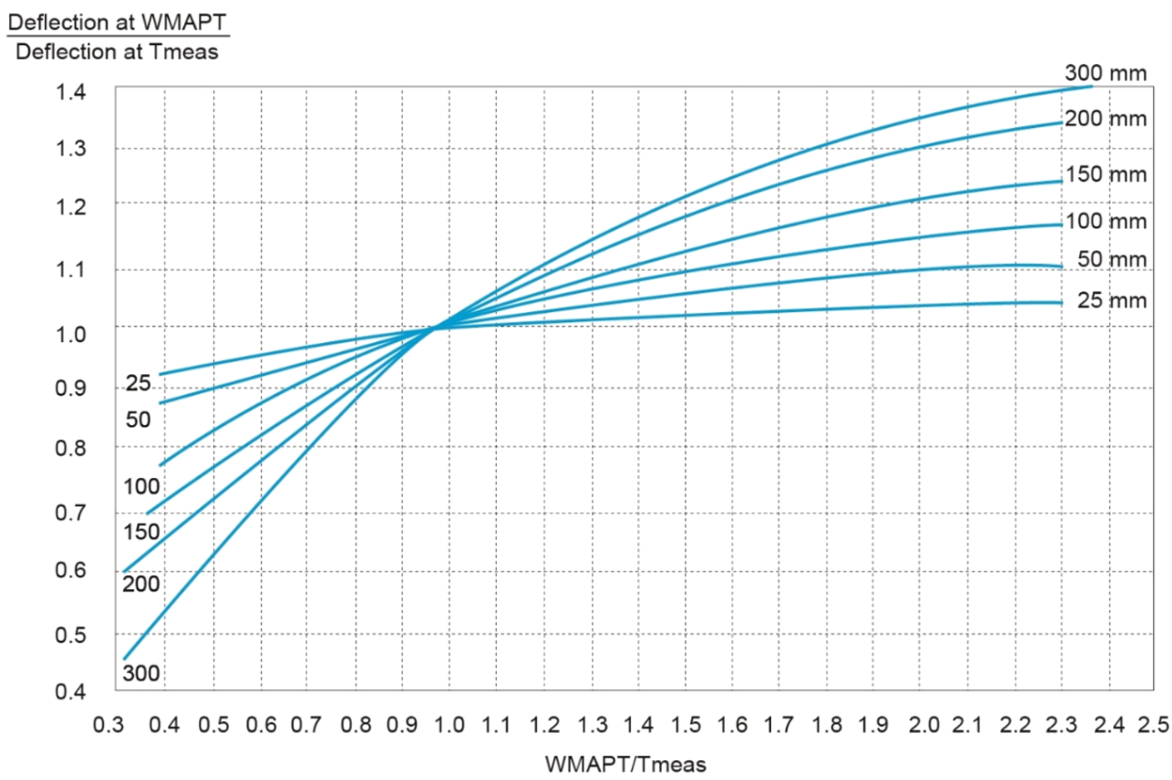
For asphalt overlays on asphalt surfaced granular pavements, a temperature corrections factor will need to be applied to the deflection as the pavement temperature can influence the pavement stiffness and response to load. The deflection must first be corrected for the seasonal moisture effects (Table 3.25), corrected to the WMAPT (temperature factor for WMAPT = WMAPT for the site/measure pavement temperature at time of testing). The temperature correction factor for the deflection and curvature can then be determined and applied using Figure 3.14 and Figure 3.15.

**Figure 3.14: Temperature correction of deflectograph and Benkelman Beam deflections for various asphalt thicknesses**




*Source: Austroads (2019a).*

**Figure 3.15: Temperature correction of FWD deflections for various asphalt thicknesses**




*Source: Austroads (2019a).*

An overlay adjustment factor as per Table 3.26 may also be applied depending on the assessment option.

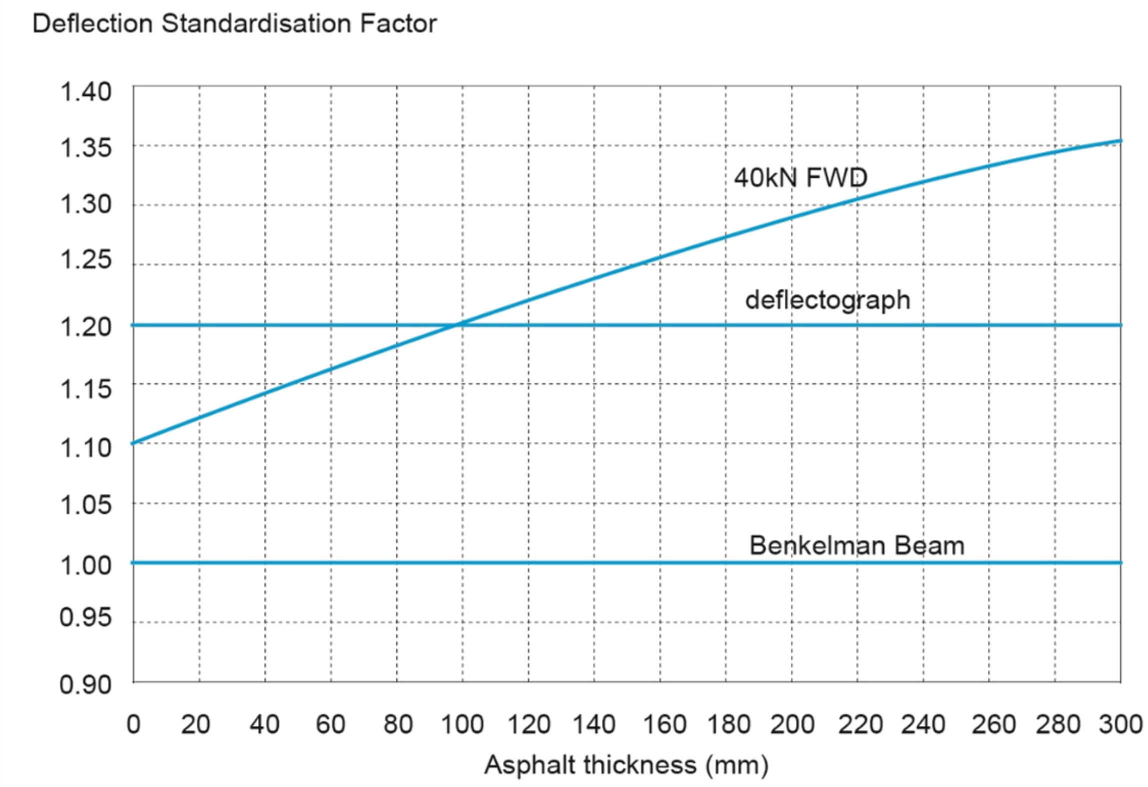
**Table 3.26: Presumptive allowable traffic loading adjustment factors for wearing course asphalts with non-conventional binders.**

| Binder grade | Allowable traffic loading adjustment factor |
|---|---|
| Multigrade 1000/320 | 1 |
| A30P | 1 |
| A35P | 1.5 |
| A20E | 2 |
| A25E | 2 |
| A15E | 2.5 |
| A10E | 3 |

*Source: Austroads (2019a).*

As there are many different ways to measure deflection of a pavement, the measurements must be standardised as per Figure 3.16.

**Figure 3.16: Deflection standardisation factors**

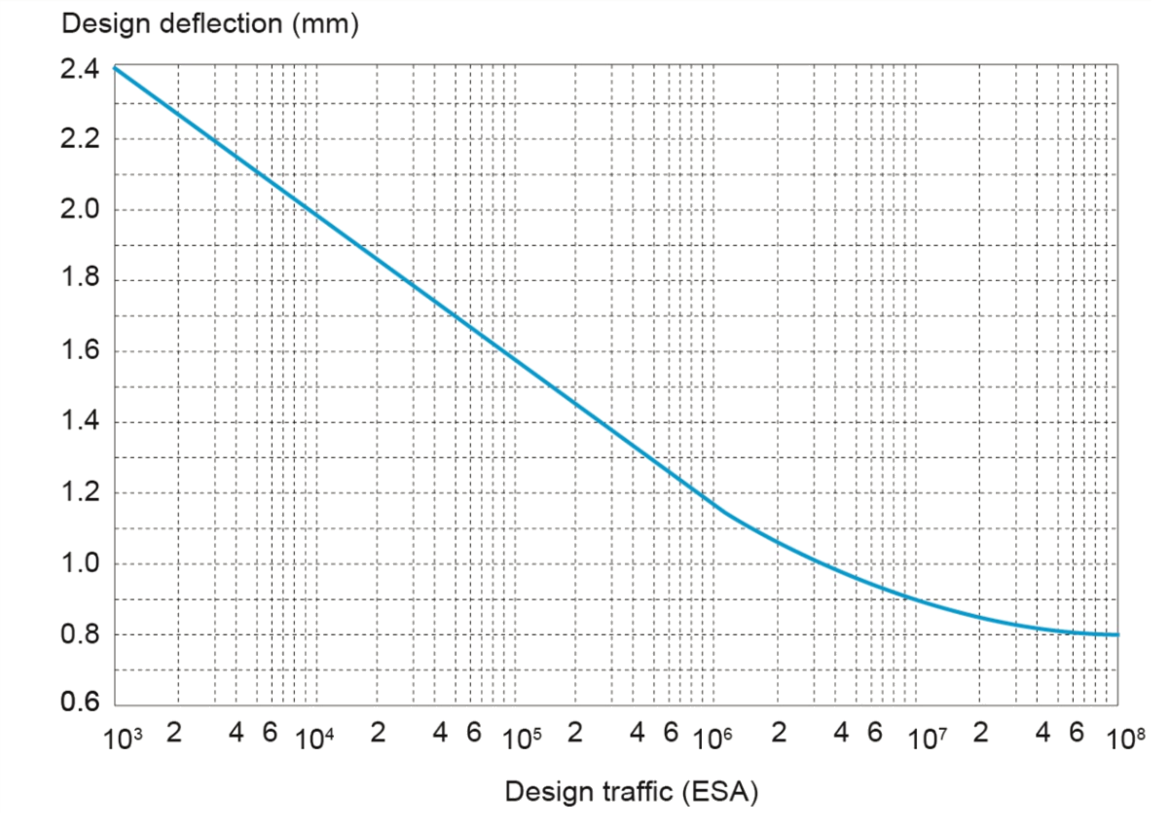



*Source: Austroads (2008).*

Design charts to be used during the granular overlay design process are given in Figure 3.17 to Figure 3.19.

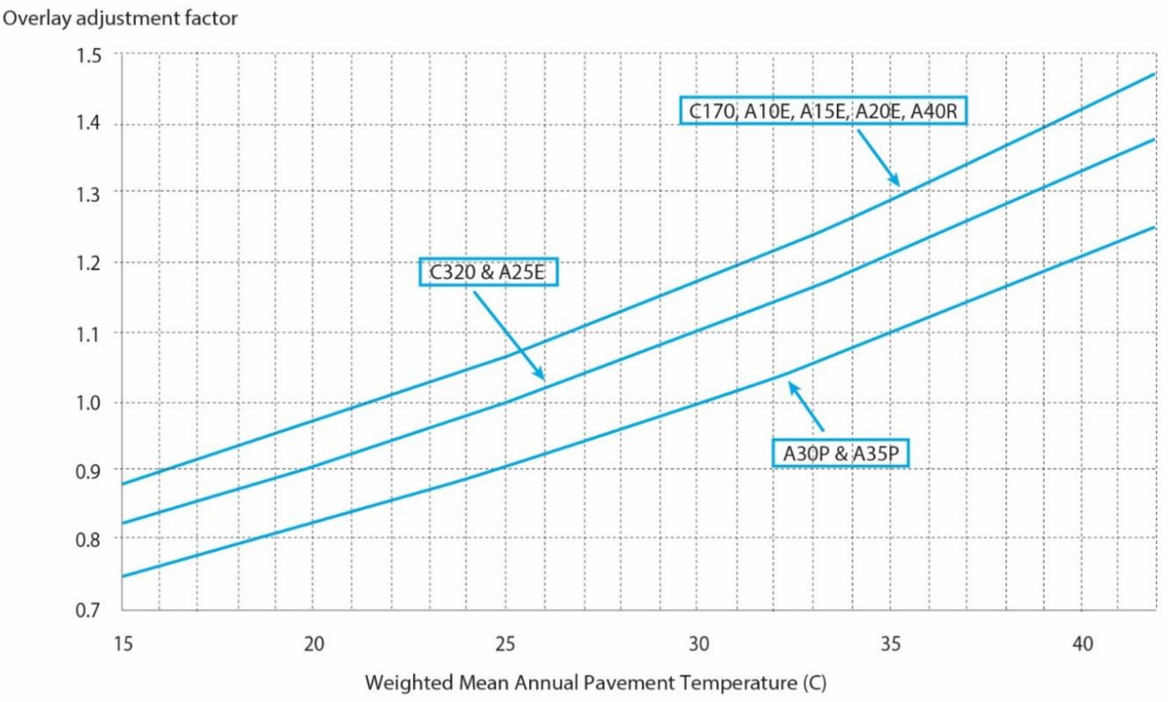
Asphalt overlays should be designed in accordance with the mechanistic-empirical design process outlined in Austroads (2019a).

**Figure 3.17: Design deflections to limit permanent deformation (for use with unbound granular pavements with thin bituminous surfacing)**



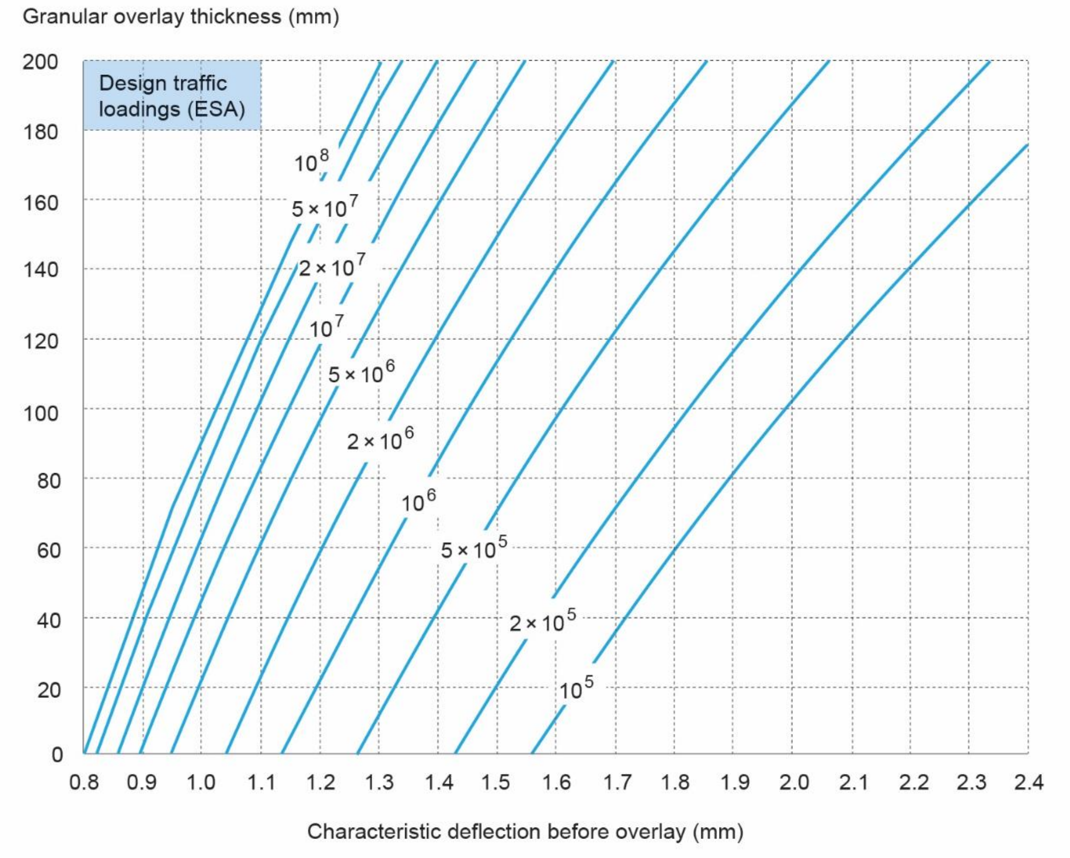

*Source: Austroads (2019a).*

**Figure 3.18: Overlay adjustment factors for asphalt mixes with various binders**




*Source: Austroads (2011b).*

**Figure 3.19: Granular overlay design chart**




*Source: Austroads (2011b).*

## 3.10.1 Granular Overlay Design Example

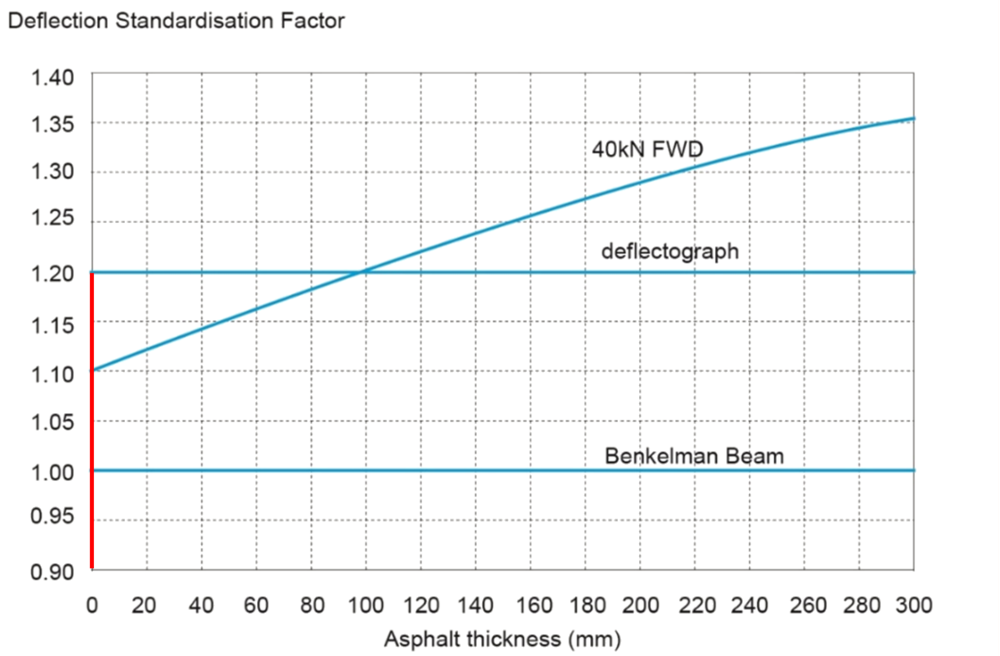
### Design information

The following design information was provided for an existing homogeneous section of sprayed seal granular pavement requiring a granular overlay:

- Design traffic loading = 4.0 × $10^5$ ESAs
- Deflection measurement device: Deflectograph
- Measured characteristic deflection = 0.90 mm
- As the deflections were measured in April and the project was located in a temperate climate, it was considered appropriate to use a seasonal moisture correction factor of 1.3 (Table 3.25).

**Step 1: Determine deflection standardisation factor**

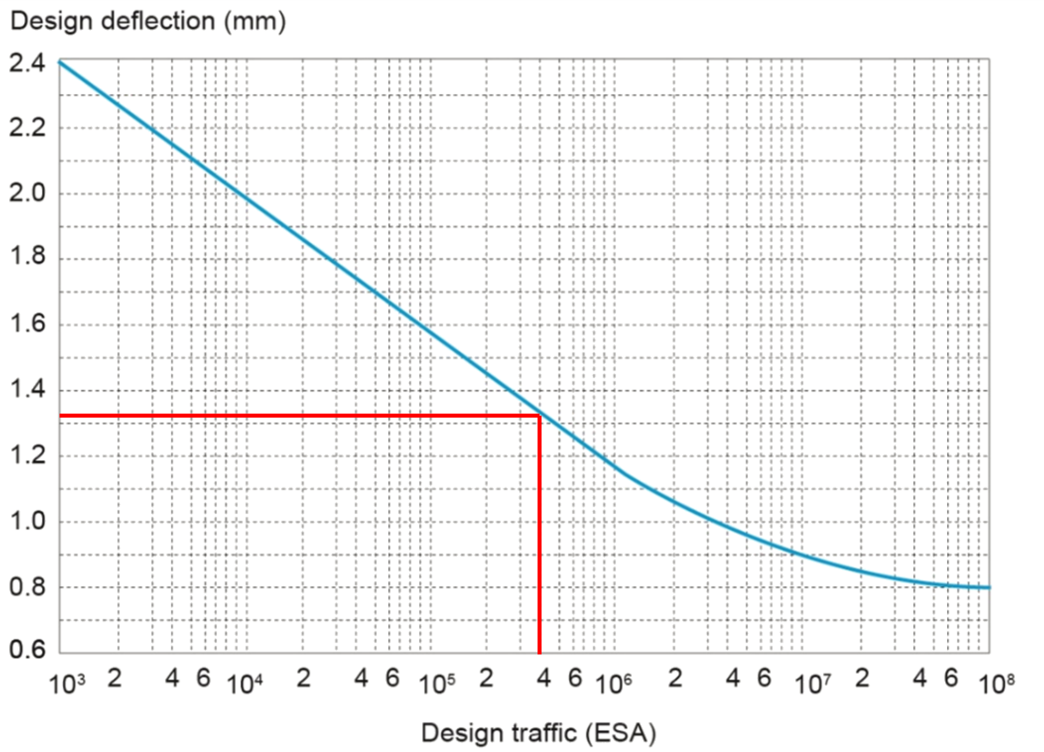
a. From Figure 3.16, the deflection standardisation factor on a pavement with zero asphalt thickness is 1.2.



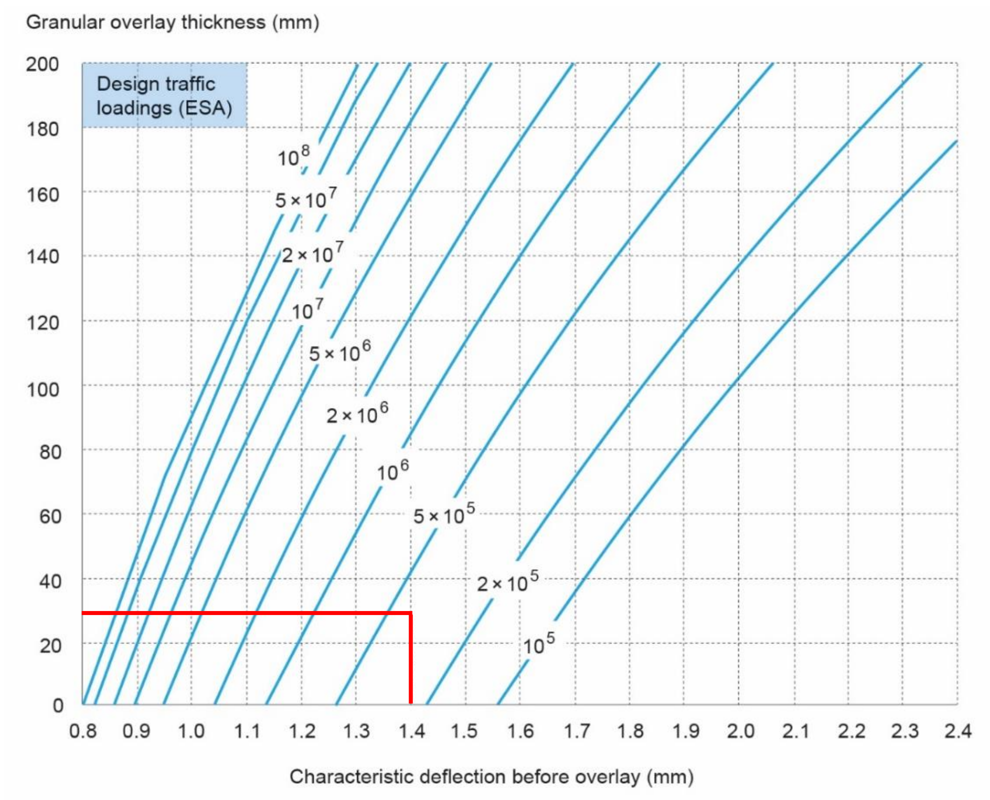

**Step 2: Granular overlay thickness required to inhibit permanent deformation**

b. Adjust measured characteristic deflection with the seasonal moisture correction factor and the deflection standardisation factor: 0.90 × 1.3 × 1.2 = 1.40 mm.

c. Calculate the design deflection: using Figure 3.17 and a design traffic of 4.0 × $10^5$ ESAs, the design deflection is 1.31 mm.



d. Calculate granular overlay thickness: From Figure 3.19, a granular overlay 30 mm thick is required to reduce the seasonally corrected characteristic deflection (1.40 mm) to the design deflection (1.31 mm).




## 3.11 Drainage Design

This section briefly covers design aspects of surface and subsurface drainage applicable to roads. In many cases the road drainage system is part of the local drainage system and it must be compatible with the requirements of the local drainage authority.

The objectives of a road drainage system are to (ARRB 2003a):

- contribute to a safe driving surface in all weather conditions within some economic constraints
- dispose of runoff in a safe, responsible manner without causing downstream problems
- maintain the pavement formation such that the strength and durability are not adversely affected by moisture ingress.

Key road user and design considerations when choosing road drainage are listed in Table 3.27.

Table 3.27: Road user and design considerations when choosing road drainage

| Design aspect | Drainage considerations |
|---|---|
| Road user considerations | • Reduction in visibility due to spray<br>• Aquaplaning<br>• Reduced availability of roadway during flood events<br>• Loss of stability for vehicles in floodways<br>• Spray and splashes from vehicles affecting cyclists and pedestrians<br>• Pit covers are used so as to not present a hazard for cyclists<br>• Velocities in gutters and channels are not excessive<br>• The safety of workers and the road users around them during maintenance activities<br>• Safe inlets to underground or outlet facilities |
| Design considerations | • Roadway grading with respect to flood levels and tidal influence<br>• Flow across the superelevation<br>• Calculation of storm discharge and rainfall intensity<br>• Development of a catchment area – homogenous or mixed in nature<br>• Acceptable flow widths<br>• Channel capacity<br>• Minimum pipe and box sizes<br>• Pit sizes and head losses<br>• Outlet condition<br>• Subsurface drainage |

Drainage systems are an important part of the moisture control for a pavement and the surrounding materials. Austroads *Guide to Roads Design Part 5A and 5B* (Austroads 2013a, 2013b), and, Austroads *Guide to Pavement Technology Part 5* (2019a) provide a comprehensive guide to the design of surface and subsurface drainage systems in addition to culverts and pipes.

## 3.11.1 Types of Drainage

Most pavements contain measures to control the ingress of water into the pavement structure. The provision of a surface seal, side drains, and in necessary circumstances subsurface drainage (or moisture barriers) will reduce the effect of water on pavement performance and hence on the design process.

Drainage systems for pavement applications can fall under the following categories:

- surface drainage
- subsurface drainage
- pipes and culverts.

Ingress control measures such as sealed shoulders can also be utilised in conjunction with pavement drainage to lessen the effect of moisture on a pavement system.

### Surface drainage

Surface drainage relates to the management of water which has fallen on the pavement surface or water which may flow onto the pavement from the surrounding environment. The key elements of surface drainage design are shown in Figure 3.20 and their typical components in Figure 3.21. Table 3.28 lists different surface drainage types as well as key usage and design considerations for each type.

The basis for provision of surfaces drainage is:

- to cater for the safety and convenience of road users
- to protect adjacent properties from damage due to uncontrolled surface runoff
- to protect the road pavement by keeping it waterproof
- during construction, provide protection for erosion-sensitive areas.

**Figure 3.20: Elements of surface drainage design**

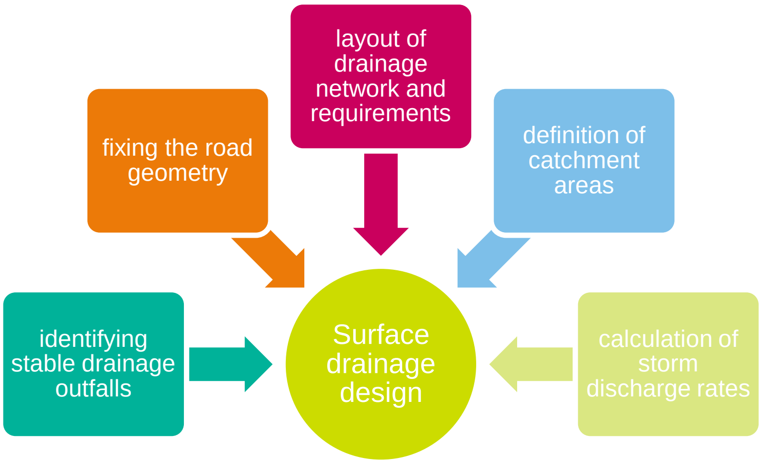
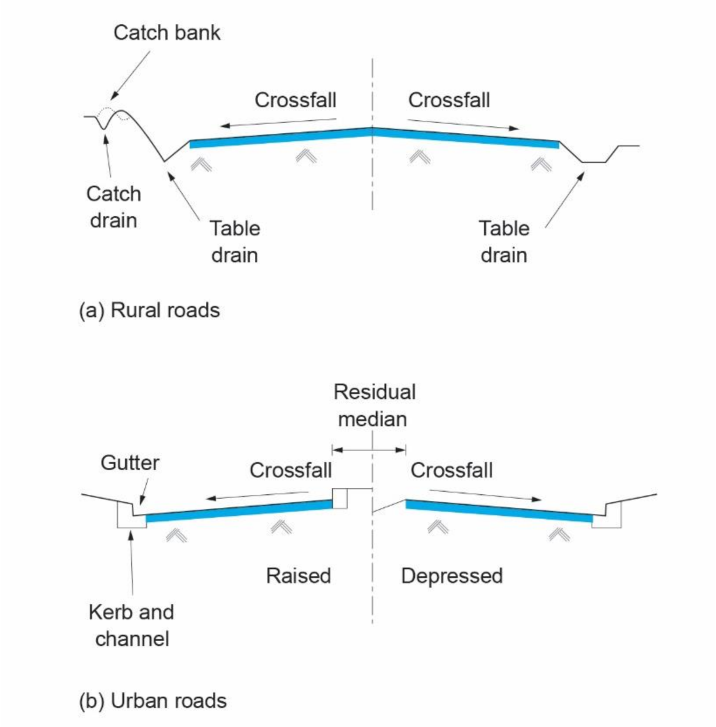



**Figure 3.21: Typical (a) rural and (b) urban road surface drainage components**




*Source: NAASRA (1986).*

**Table 3.28: Surface drainage types**

| Surface drainage | Suitability and use | Design considerations |
|---|---|---|
| Crossfall | • Part of the geometry of a pavement surface<br>• Direct surface flow toward surface inlets, table drains or kerb and channel structures | • Road user safety<br>• Shoulder materials<br>• Road speed limits |
| Surface inlets – kerb openings | • Do not block easily with debris<br>• Suitable for sag locations<br>• High capture rate at low flow velocity<br>• Depth of channel determines water capture<br>• Design for 100% capture is uneconomical | • Hydraulic efficiency<br>• Structural soundness<br>• Bicycle and pedestrian safety<br>• Self-cleaning capability<br>• Local practices and component availability |
| Surface inlets – grate inlets | • Tendency to clog with debris<br>• Intercepts flow directly<br>• High flow rates can clear blockages<br>• Not always suitable in sag locations | • Hydraulic efficiency<br>• Structural soundness<br>• Bicycle and pedestrian safety<br>• Self-cleaning capability<br>• Local practices and component availability |
| Table drains – longitudinal drains | • Essential for roads within cuttings or flat terrain<br>• Run parallel to the pavement alignment<br>• Gradient lower than 1 in 20 to avoid erosion, higher than 1 in 250 to avoid ponding | • Hydraulic efficiency<br>• Structural soundness<br>• Erosion resistance<br>• Cross-section |

| Surface drainage | Suitability and use | Design considerations |
|---|---|---|
| | • Depth at least 150 mm below subgrade level<br>• Catch and convey water from:<br>– road formation runoff<br>– overland flows toward the roadway<br>– flows from culverts or outlets | |
| Kerb and channel/gutter | • Urban version of a table drain<br>• run parallel to the pavement alignment<br>• catch and convey water from:<br>– road formation runoff<br>– overland flows toward the roadway | • Hydraulic efficiency<br>• Bicycle and pedestrian safety<br>• Self-cleaning capability<br>• Aesthetics |
| Catch drain | • Intercept and drain water flowing towards the road from the higher surrounding area<br>• Often used at the top of deep cuts<br>• Prevent severe erosion of cut batters<br>• Reduce pressure on table drains<br>• The longitudinal slope of the catch drain should be greater than 1% to prevent | • Hydraulic efficiency<br>• Structural soundness<br>• Erosion resistance<br>• Cross-section |

| Surface drainage | Suitability and use | Design considerations |
|---|---|---|
| | pooling of water but less than 5% to prevent scouring | |

### Subsurface drainage

Subsurface drainage is related to the removal and management of water which is located under a pavement structure. This water may be the result of a high watertable or though infiltration of moisture through the pavement shoulder or surrounding environment.

The basic objectives of subsurface drainage are to:

- minimise opportunities for groundwater to enter the pavement
- collect and convey infiltrated surface water to an outlet
- protect the subgrade
- minimise the cost of moisture control.

The use of subsurface drainage is crucial in areas where subsurface soils are not free draining as the infiltration of water into a pavement system is highly likely to cause premature failure.

Guidance around subsurface drainage is available in to AUS-SPEC Worksection *1171 – Subsurface Drainage*. This is further complemented by NATSPEC TECHnote *DES 036 – Need for Subsurface Drainage on Local Roads*.

***Subsurface Drainage: Types***

***The common types of subsurface drains are:***

- *pavement drains (both longitudinal and transverse)*
  - *placed just below the top of the subgrade to collect water infiltrating the pavement*
- *formation drains*
  - *placed in deep trenches to intercept underground flows and lower the watertable*
- *combined stormwater/pavement drains*
  - *useful where both are required but space is limited, and outlet levels are critical*

### Location of subsurface drainage

Choosing the correct location of subsurface drainage structures will ensure efficient and appropriate removal of water from the pavement system. Table 3.29 describes suitable locations different subsurface drainage types. The location of subsurface drains will depend on:

- permeability of pavement materials and all surrounding soils
- pavement superelevation and geometry

- pavement profile depth
- watertable depth
- surrounding environment
- pavement importance and level of service requirements.

**Table 3.29: Suitable locations of subsurface drainage**

| Subsurface drainage type | Suitable location |
|---|---|
| Pavement drain – longitudinal | • The low sides of the pavement<br>• Both sides of the pavement near any cut-to-fill line<br>• Both sides of a kerbed pavement<br>• Both sides of the pavement where the crossfall is less than 0.02 m/m<br>• High side of the pavement where seepage is evident, or where water may enter from batters, full width pavement, service trenches or abutting properties<br>• Along the joins between an existing pavement and a pavement widening where pavement depths or permeabilities could create a moisture trap |
| Pavement drain – transverse | • Approximately 5 m upstream of cut-to-fill lines<br>• Along changes of pavement depth or permeability<br>• Both ends of bridge approach slabs<br>• At superelevation changes, to limit the length of the longest drainage path within the pavement to about 50 m |
| Formation drain | • Along both sides of cuts where the road is known to be below the watertable, or where seepage is encountered during construction, or expected in wet weather<br>• Transversely at any seepage areas, and further downgrade if required |
| Combination of stormwater and pavement | • Where the road is below the watertable for most of the year, and flows are expected to exceed the capacity of the standard size subsurface drain<br>• It can prove economical to lay slotted pipes in deep trenches to cater for both groundwater and stormwater flows. |

*Source: Austroads (2013a).*

### *Subsurface Drainage: Design Considerations*

***Subsurface drainage placement***

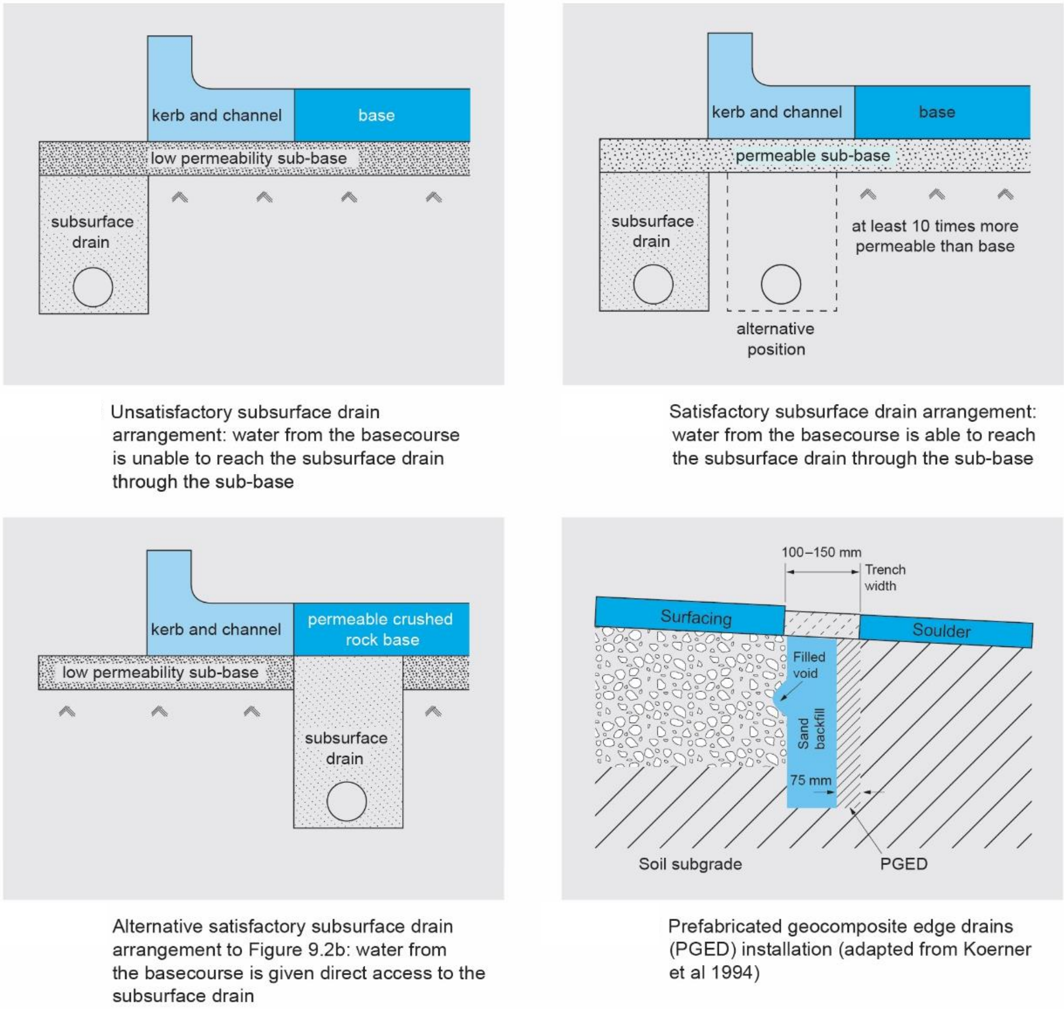
- *No pavement layer should be entirely surrounded by materials of lower permeability*
- *The flow path to the subsurface drain should proceed through materials of increasing permeability*
- *The capacity of the subsurface drainage system should be adequate to dispose of the estimated quantities of water from surface infiltration or other sources.*

***Subsurface drainage in expansive materials***

- *locating the subsurface drains at least 600 mm from the back of kerb, and not greater than 250 mm below subgrade level*
- *introducing an impermeable membrane on the pavement side of the drainage trench when it is decided to place the subsurface drain within 300 mm of the back of the kerb*
- *limiting the effectiveness of the subsurface drain by having it placed at a depth not exceeding 150 mm, somewhere within 200 to 400 mm of the back of the kerb.*

Examples of suitable and unsuitable subsurface drainage arrangement are shown in Figure 3.22

**Figure 3.22: Suitable and unsuitable subsurface drainage arrangements**




*Source: Adapted from Koerner et al. (1994).*

## Pipes and culverts

Pipes and culverts (Figure 3.23) direct surface flow under a pavement, allowing flow from one side of a pavement to the other. Selection and design of a culvert structure or pipe is critical as failure can cause damage to the overlying pavement system if overtopped by floodwater or damaged through high-velocity flows.

The following design considerations are critical to the correct function of a culvert or pipe system:

- location, orientation and grade (erosion or siltation avoidance)
- hydraulic efficiency
- structural soundness
- self-cleaning capability
- local practices and component availability.

The most common type of culvert used in road construction is precast reinforced concrete pipes and box culverts. For smaller sizes the trend is towards using precast concrete endwalls and pits which are made to match and are easily fitted on site. In all cases a stable and uniform foundation is required for the satisfactory performance of any culvert.

Figure 3.23: Typical culvert

### Control of water ingress

Surface shape loss due to moisture changes in expansive soils and loss of subgrade strength may be associated with moisture ingress through unsealed shoulders. Sealed shoulders provide a means of retarding moisture ingress through the shoulder material, particularly where the material is permeable or where pavement permeability decreases with depth.

Considerations when designing a sealed shoulder are:

- Moisture stability may also be efficiently obtained by stabilising the shoulder with a cementitious binder, polymer or bitumen.
- Sealed shoulders may be required where regular maintenance of unsealed shoulders presents a problem.

Sealed shoulders may offer increased traffic safety by providing some recovery area when vehicles leave the travelling lanes.

## 3.11.2 Calculation of Design Parameters

### Rational method for storm discharge calculation

A commonly used method for calculation of storm discharge from a road catchment is the rational method which considers rainfall intensity and catchment characteristics such as runoff and area. It is used to design stormwater drainage systems, spillways and culverts as shown in Equation 14.

$$Q = \frac{(C_Y \times I \times A)}{360} \qquad 14$$

where

| | | |
|---|---|---|
| Q | = | estimated maximum discharge for the selected design storm (in $m^3/s$) |
| CY | = | coefficient of runoff, dependent on the density of buildings, area of pavement, soil type, slope of catchment, vegetation cover, and storage or other delay-producing characteristics |
| I | = | rainfall intensity (in mm/h), for the chosen average recurrence interval and storm duration |
| A | = | catchment area (in ha) |

## Time of concentration

The time of concentration is defined as the time taken for water to flow from the most time-remote part of the catchment to the outlet being designed.

For road surface drainage the time of concentration is generally made up of:

- time of flow from road surface areas and adjacent roadside areas
- time of flow in gutters and surface channels
- time of flow in pipes.

### Urban catchments

Various methods are available for determining overland flow time. This is typically dependent on the length of flow and the average surface slope. An iterative approach is required because the rainfall intensity alters as the time of concentration alters.

The equation should be limited to overland surface flows on pervious areas of less than 200 m. Generally, sheet flows will enter some form of channel within 200 m and the flows are then calculated using Manning's equation for open channel flow.

$$t_c = 6.94 \times \frac{(Ln)^{0.6}}{I^{0.6} S^{0.3}} \quad (15)$$

where

$t_c$ = time of concentration (minutes)

L = overland flow path length (m)

n = Manning's roughness coefficient

I = rainfall intensity (mm/h)

S = slope of overland flow path (m/m)

### Rural catchments

For rural areas where large catchment areas may be involved, the time of concentration is calculated differently within each jurisdiction. However, Equation 16 will provide a reasonable estimation of the time of concentration for long overland flows.

$$t_c = 91 \times \frac{L}{A^{0.1} \times S^{0.2}} \quad (16)$$

where

$t_c$ = time of concentration (minutes)

L = overland flow path length (m)

A = catchment area (in ha)

S = slope of overland flow path (m/m)

## Rainfall intensity

The rainfall intensity for a particular design storm is a function of both the time of concentration and the average recurrence interval (ARI), for the design storm intensity. The critical storm duration is usually taken as the time of concentration. Rainfall intensity/duration diagrams covering a range of ARIs for a specific location are available from the Bureau of Meteorology for locations specified by latitude and longitude.

In addition to designing a minor stormwater management network to cater for the basic ARI values given in Table 3.30, the engineer needs to ensure that sufficient trafficable road surface remains open to allow traffic movement (Table 3.31).

**Table 3.30: Recommended minimum ARI for minor road drainage system elements**

| Item | Average recurrence interval (years) |
|---|---|
| Cross-drainage for national highways and arterials (typically roads with > 2000 vehicles per day) | 100 |
| Cross-drainage on roads other than national highways or arterials (typically roads ≤ 2000 vehicles per day) | 50 |
| Longitudinal surface drainage (including intersections and bridge decks)[1,2] | 10 |
| Flows over the trafficable surfaces | |
| Permanent sedimentation basins<br>Temporary sedimentation basins | 2<br>0.5 |
| Wide flat pavements | 1 |
| Water quality basins | 1 |
| Urban road surface drainage | See Section 6.4.1 of Austroads (2013a) |
| Temporary work sites[3] | 1 |

1 *If the road is sited in a town centre, the ARI should be increased to 20 years.*
2 *Local Government policies and the local drainage authority should be consulted for the design of minor rural road drainage schemes, since these can vary across Australia.*
3 *A contractor needs to provide adequate drainage to the side-track including off-road drainage in order to prevent ponding of water. Culverts need to l be installed at creeks and streams.*

*Note: For minor/convenience systems the above values are only applicable where an integrated major drainage system is planned and designed for a 100-year ARI.*

**Table 3.31: Surface flow guidelines – minor drainage system elements**

| Maximum flow widths (m) in traffic lanes for arterial roads | | | |
|---|---|---|---|
| Number of trafficable lanes on carriageway | Speed environment | | |
| | ≤ 70 km/h | 70 to 90 km/h | ≥ 90 km/h |
| 1 | 1.0 | 0.75 | 0.5 |
| 2 | 1.5 | 1.25 | 1.0 |
| 3 | 2.0 | 1.75 | 1.5 |
| > 3 | 3.0 | 2.5 | 2.0 |

*Other considerations:*

- *Car parks - Flow width should be restricted to two metres in a two-year ARI storm.*
- *Residential intersections - Cross flows of less than 0.005 $m^3/s$ are permitted at T-intersections of residential streets or at the ends of small isolated traffic islands.*
- *Arterial roads - Given values for multi-lane arterials. Maximum flow depth times velocity is 0.4 $m^2/s$.*
- *Freeways - Surface flows should be confined to the shoulders.*
- *Braking zones - Water depth and width should be restricted near braking areas such as approaches to traffic signals or freeway ramps.*
- *Secondary roads and residential streets - A least one lane each way on secondary roads, and at least one lane width on residential streets should be trafficable during a two-year ARI storm.*
- *Footpaths and pedestrian crossings - Maximum allowable flow width at bus stops and pedestrian crossings is 0.5 m.*
- *General - It should not be necessary for vehicles to change lanes in order to avoid flowing water or ponds during the design storm.*

### 3.11.3 Environmentally Sensitive Drainage Design

The design and operation of a road's drainage system can be a major source of degradation to the environment. The planning and design phase of a new road project offers the greatest opportunity to minimise the environmental impacts of road runoff and drainage. The route selection process must consider potential impacts on roadside vegetation and aquatic biodiversity in adjacent waterways.

Road crossings can affect catchment hydrology, potentially exacerbating localised salinity problems. Particularly in lowland agricultural areas, floodwaters tend to pond behind roadways with either silted or undersized culverts, damaging the land upstream of the crossing.

***Environmental Considerations in Drainage***

*Austroads (2001), Road Run-off and Drainage: Environmental Impacts and Management Options, contains many of the environmental considerations relevant to road drainage design.*

***The four principal objectives of the document are:***

1. *identify and quantify the potential impacts of runoff and road drainage on ecosystems*
2. *identify the source of the impacts*
3. *identify remedial measures and best practice approaches to reduce impacts*
4. *identify priority areas requiring further research and understanding.*

### 3.11.4 Sealed and Unsealed Shoulders

Surface shape loss due to moisture changes in expansive soils and loss of subgrade strength may be associated with moisture ingress through unsealed shoulders. Sealed shoulders provide a means of retarding moisture ingress through the shoulder material, particularly where the material is permeable or where pavement permeability decreases with depth.

Considerations when designing a sealed shoulder are:

- Moisture stability may also be efficiently obtained by stabilising the shoulder with a cementitious binder, polymer or bitumen.
- Sealed shoulders may be required where regular maintenance of unsealed shoulders presents a problem.
- Sealed shoulders may offer increased traffic safety by providing some recovery area when vehicles leave the travelling lanes.

# 4. Construction

Effective and efficient road construction (Figure 4.1) relies on a combination of good forward planning, technical knowledge and practical experience in the field.

As for all forms of roadworks, construction operations must be carried out in strict conformity with the relevant state/territory laws, local laws and bylaws, regulations and codes for safety and environmental protection. Refer to individual state/territory or Local Government codes of practice and specifications regarding construction operations in the particular jurisdiction.

Figure 4.1: Road construction

It is noted that in Australia, much of the responsibility for construction of local road pavements is controlled by councils. The tender process is controlled by the competitive pricing procedures (CPP) manual. The work must therefore be undertaken in accordance with contract specifications, which take precedence over the information in the Guide. In this respect, the Guide is intended to provide guidance to those who are supervising engineers and contractor staff.

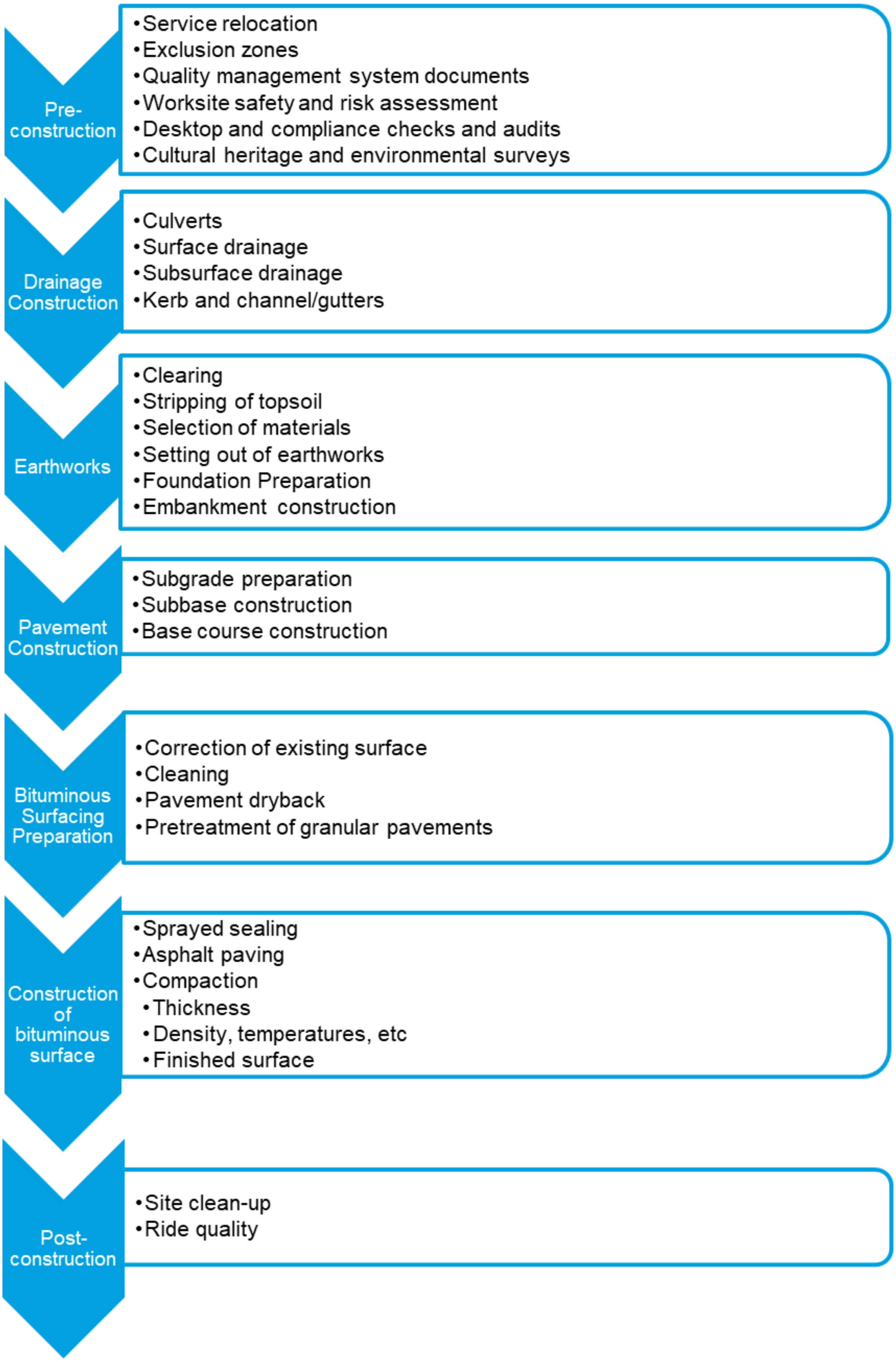
It is acknowledged that the Austroads/AAPA Work Tips and Austroads *Guide to Pavement Technology Part 8, Pavement Construction* (Austroads 2019b) were useful sources of information in the preparation of this section.

*Develop an integrated management system that takes into account quality, safety and environmental matters under a common project management plan.*

## 4.1 Construction Sequence

The usual sequence of operations in the construction of a new sealed road is summarised in Figure 4.2.

**Figure 4.2: Construction sequence**



# 4.2 Quality Management in Construction

## 4.2.1 Quality Management System

Most Local Governments have embraced the principles of quality management system (QMS) requirements as set out in Standard AS/NZS ISO 9001: 2016. QMS is now extensively specified in contracts as a requirement of road and street construction.

QMS provides management requirements which supplement sampling and testing requirements for product quality. It provides confidence to internal management and to customers that requirements for quality are being fulfilled or will be achieved in the delivered product.

## 4.2.2 Quality Control and Quality Assurance

***Quality control (QC)*** *refers to inspection and test procedures which are applicable to the control of the quality of product characteristics during the construction process.*

***Quality assurance (QA)*** *refers to inspection and test procedures which are required for the verification of the quality of end-product characteristics relative to specified requirements, whether the end-product is a purchased product for use in the process (incoming product, e.g. aggregates) or a product of the process (outgoing product, e.g. sprayed sealed road).*

For example, in the compaction process, QC would refer to inspection and test (I&T) procedures for control of moisture content, grading, levels, thickness of pavement and the application of the homogeneity of application of the compactive effort. QA, on the other hand, would refer to I&T procedures for the verification of compliance with the specified requirements for crushed rock characteristics (if aggregate is a purchased product) and of compaction.

QA also relies on collation of all documentation leading to the acceptance of work or remedial action required to satisfy non-conformance.

## 4.2.3 Quality System Documents

A quality system consists of a number of documents, details of which are summarised in Table 4.1.

**Table 4.1: Quality system documents**

| Document type | Purpose |
|---|---|
| Quality manual | The primary document which describes the full scope of an organisation's quality system. It contains all the relevant organisational policies relating to quality. |
| Project quality plan | Details the contractor's specific quality system for a particular project. Each new project has a new quality plan; however, once the base plan is set up, minor changes only are required to meet the particulars of a similar project. |
| System or quality procedures | Details how specific administrative processes are to be carried out, e.g. tender review. |
| System instructions | Detailed instructions on how to carry out a particular task within an administrative process, e.g. document numbering. |
| Technical procedures/method statements | Details how particular construction processes are to be planned and controlled, e.g. flexible pavement construction. |
| Technical instructions/work instructions | Detailed instructions on how to carry out a particular task within a construction process, e.g. supply and placement of pavement material. |

| Document type | Purpose |
|---|---|
| Inspections and test plans (ITPs) | Details the inspections and tests to be carried out for a particular construction process. As a minimum they should include all those inspections and tests set out in the project specification; however, the contractor may elect to carry out additional tests if so wished. |
| Non-conformance report | Records the detail of a non-conformance and subsequent actions taken to address the deficiency, known as the 'disposition'. |
| Checklists | Shows all the steps required to perform the process in accordance with the technical procedures. |
| Audit reports | Identifies problems and procedures required to achieve compliance. |
| Corrective action reports | Records the details of a deficiency and the subsequent corrective action taken to prevent its recurrence. |
| Documents register | Provides a record for particular types or groups of documents. |
| As-constructed drawings | Drawings of the as-constructed road structure, particularly if there were any deviations from design/standard drawings. |

AUS-SPEC has a series of quality-focussed worksections for use to enable contractors to meet quality requirements at all stages of the project. These worksections are as follows:

- *0010 – Quality Requirements for Design,*
- *0161 – Quality Management (Construction),*
- *0162 – Quality (Supply),*
- *0163 – Quality (Delivery),*
- *0167 – Integrated Management, and*
- *1603 – Road Reserve Maintenance Plan (RMP).*

### 4.2.4 Project Quality Plan

Prior to commencing construction on a project, the project quality plan (PQP) should be prepared based on, and using the general format of, the organisation's quality manual. At times, particularly for large projects all details may not be available at the commencement of the project. In such cases it is critical that the PQP is augmented or updated prior to executing the relevant part of the project.

A typical quality plan for a road construction project would contain the following details:

- contents of plan
- organisation quality policy
- project-specific quality policy
- project-specific quality objectives
- estimated contract duration and proposed dates
- audits and surveillance proposed
- project organisation chart
- project organisational responsibilities
- training and qualifications of all personnel, including the site-specific induction
- principal operations
- procedures schedule
- list of hold points and witness points

- technical procedures
- inspection and test plans
- subcontractors' quality plans
- site safety plan.

### 4.2.5 Technical Procedures

Technical procedures are an important part of the PQP as they describe in detail the purpose and scope of a construction process, what is to be done by whom and when, where and how. They should be prepared for each phase of the construction process, e.g. clearing, drainage, earthworks. Each technical procedure should detail:

- responsibilities
- sequence of operations
- work methods
- characteristics and tolerances to be met
- types of equipment to be used and their testing calibration requirements
- materials including their source
- safety requirements
- reference documents
- records produced.

### 4.2.6 Surveillance

The project owner will nominate a person responsible for surveillance on behalf of the council on the project, generally the project supervisor or a specific surveillance officer. Surveillance is the continual observation of the work and analysis of the records generated by the contractor or site manager, to gain assurance that the specified quality is being delivered.

Surveillance may also include ensuring that traffic, safety on site, and environmental issues are being managed appropriately during construction. For example, a surveillance officer could periodically check sites during non-working hours to ensure the signage and cones etc. are still upright and providing clear guidance and the site is safe.

***Hold Points***

*Hold points are introduced at critical stages throughout the specification to give the principal an opportunity to review an activity before proceeding further.*

*Witness points are used to indicate when testing or recording of current status is required prior to proceeding.*

### 4.2.7 Quality Audits

A quality audit is an activity aimed at verifying that the system, procedure or process complies with the relevant requirements. Audits may be either a system audit, i.e. an audit to verify the effectiveness of the overall quality system, or a compliance audit, which verifies whether the procedures which are in place have been complied with.

Audits may be either internal – undertaken by the contractor to check the quality system, or external – undertaken by the principal at least once during the period of the project. In both cases the audit should be undertaken by a person who is not directly associated with the project and has appropriate qualifications and experience.

Audits may uncover non-conformances. The contractor will need to propose a method or process to correct the non-conformance that is acceptable to the principal and possibly modify the quality system to prevent a reoccurrence. Systematic failure to comply with the quality system shows that a more in-depth audit process and review may be required.

# 4.3 Safety in Construction

## 4.3.1 Workplace Health and Safety

While the requirements for workplace health and safety vary between jurisdictions, it is generally accepted that all employers should be obliged to do all that is reasonable and practicable to protect the health and safety of employees working on construction sites. These obligations are usually fulfilled by employers establishing and applying effective safety management systems on the job site. This principle applies equally to large and small job sites.

On-site safety plans are generally a requirement of a quality system. The elements are discussed below.

### Risk assessments

For worksite management, examples of major risk factors are:

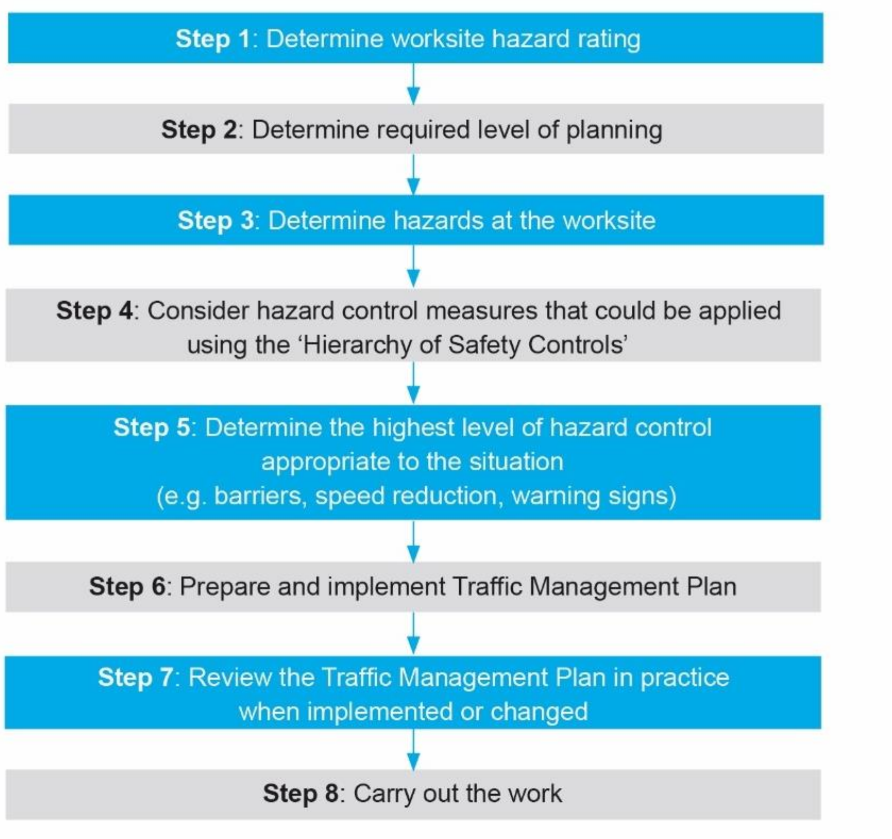
- speed of traffic adjacent to the worksite
- clearances between moving traffic, workers and plant and equipment
- traffic volume and composition.
- time-of-day work is being carried out
- sight distance
- weather
- pedestrian and worker movement.

Risk assessments or safe work method statements should be carried out on the site and construction activities. These assessments should be recorded along with the control measures required to reduce the associated risks to an acceptable level. The assessments should be regularly reviewed during the life of the project to ensure their adequacy. Risk assessment should be reviewed when a change of personnel, conditions and process etc. take place.

All inspections and audits that are proposed should be detailed, including the checklists to be used, plant fault and hazard reporting. Any highly dangerous work practices, e.g. deep trenches, or storage of explosives should be detailed.

A systematic approach is necessary to identify areas of hazard, to prioritise the critical risks from lesser risks, and to identify effective ways of reducing or eliminating hazards that may have an undesired or unexpected outcome. A methodology for risk-based assessment of worksite condition is given in Figure 4.3. This may be used as a guide to set up a risk assessment system, using a more interactive process, with likelihood and severity considerations.

**Figure 4.3: Safety and traffic risk assessment methodology**




*Source: Adapted from Road Management Act 2004: Code of Practice, Worksite Safety – Traffic Management.*

### Safety plans

It is generally a requirement of a council to cover the management of occupational health and safety by incorporation into the project quality plan. As a minimum, those sections of the jurisdiction's legislation relating to the duties of employers should be complied with. The safety plan should address, as a minimum, the following areas:

- plant maintenance including records, inspections, fault reporting and operator training programs
- systems of work including safe operating procedures, safety instructions etc.
- dangerous goods and chemicals and emergency procedures
- workplace hazard identification and risk control measures
- full details of safety training and induction procedures, training records etc.
- management of subcontractors
- names and addresses of all persons to provide expert occupational health and safety advice
- reporting procedures for incidents, ill health or near misses
- emergency procedures.

In addition to the above, the safety plan should include post-accident procedures for reporting and investigation, a list of all safety procedures, the format and frequency of site safety meetings, and a register of all dangerous goods and chemicals stored and used on the site along with material-safety data sheets. The detail for each on-site safety plan will depend on the size and complexity of the works. However, the basic elements outlined here should be used as a guide for any job.

### 4.3.2 Traffic Management

An integral part of safety on the worksite is the management of traffic, pedestrian and vehicular, through the worksite both while works are in progress and after hours. Each jurisdiction has developed its their own code of practice, generally based on AS 1742.3-2009, *Manual of Uniform Traffic Control Devices: Part 3 Traffic Control Devices for Works on Roads*. Key aspects of traffic management are summarised in Table 4.2.

Table 4.2: Key aspects of traffic management during construction

| Traffic management aspect | Key considerations |
|---|---|
| Traffic management plans | • Required for all works, may be as simple as a page selected from a field guide, or a plan specifically drawn for more complex sites.<br>• May consist of a complete assessment of the site conditions, emergency contacts, sign schedules, risk assessments, sequence of set-out and recovery signs as well as the traffic control diagram.<br>• Consideration of a separate after-hours traffic management plan.<br>• Need to be drawn by a person qualified in advanced worksite traffic management, and in some cases may need to be reviewed by a person of higher qualification.<br>• Any traffic controllers, and persons setting out the traffic control devices that may be required (these should be detailed in the traffic management plan) must be trained and accredited. |
| Traffic management audits | • For large jobs, jobs with a long duration or highly trafficked roads, to ensure that the appropriate standards are being met, a worksite traffic management audit should be undertaken at least once.<br>• Carried out by a suitably trained officer enables an objective assessment of compliance with the on-site safety plan and highlights areas that require attention.<br>• It is important that once an audit has been completed, any matters requiring attention are addressed immediately. |
| Traffic guidance/ signage | • Each state/territory has their own roadworks signing code of practice which should be used as the standard for signing.<br>• Signs and devices should be used in accordance with AS 1742.3-2009 in Australia.<br>• Signs and devices should be erected and displayed before work commences at a work site.<br>• Signs and devices should be regularly checked and maintained in a satisfactory condition.<br>• Certain signs should be removed or covered as soon as the need for them ceases to exist. For example, road work ahead, workman signs etc. must be removed, or covered at night or during outside hours.<br>• If a sign is left in place when there are no workers or plant in sight or no obstruction on the road, many drivers will tend to take less notice of the sign the next time it is seen; thus, its effectiveness is diminished.<br>• Signs should remain in place until all work (including any bituminous surfacing, removal of loose stones and line marking) has been completed.<br>• A mobile variable message sign (VMS) should be deployed when possible to provide motorists with necessary information about upcoming construction operations, maintenance, and roadway conditions. |
| Speed limits | • Refer to specific local requirements for construction-site speed limits. |

| Traffic management aspect | Key considerations |
|---|---|
| Detours | • Detours and side-tracks must be designed to carry the traffic safely at a speed appropriate for the prevailing conditions. Detours and side-tracks should:<br>– have a surface capable of taking the type and volume of traffic involved<br>– be of sufficient width<br>– have an alignment both vertical and horizontal for the safe passage of the traffic being detoured<br>• Where an existing road is to be used as part of the detour route, the consent of the controlling authority should be obtained first.<br>• A detour is generally foreign to most motorists; therefore, the detour should be signed in a logical sequence to ensure that motorists can easily find their way along the detour, irrespective of detour length. |

## 4.4 Environmental Management

Road construction sites have the potential for detrimental impacts on the local environment. Take special care to minimise any soil disturbance and adverse impacts on native vegetation, soil erosion and effect on water quality. Section 3.2.2 provides a checklist of environmental considerations for various stages and aspects of construction. Many of these considerations can be applied to future maintenance and rehabilitation works.

For further guidance on the environmental management of civil works and environmental controls refer to AUS-SPEC Worksection *0173 – Environmental Management*.

## 4.5 Plant Selection and Usage

The types of plant used when constructing a new sealed road, upgrading an unsealed road to a sealed road or conducting maintenance works are described in the following section.

**Plant Selection**

*Select the type and number of construction equipment units based on what is needed to carry out the task efficiently and effectively.*

### 4.5.1 Earthworks and Pavement Equipment

The main equipment types for earthworks and constructing a pavement for a sealed or unsealed road are described in Table 4.3. Refer to the ARRB *Unsealed Roads Best Practice Guide* for more detailed information.

Table 4.3: Summary of main pavement construction plant and equipment

**Truck dozer –** a dozer blade is fitted to the front of a tractor to push material forward or cast it to one side.

**Grader –** designed primarily for the work of trimming, mixing, shaping and finishing in road construction.

Excavator

**Front end loader and dump truck –** versatile pneumatic-tyred or tracked loaders for moving or loading materials.

Water tanker

**Screening/crushing plant –** small mobile screens, screening plants or screening and crushing plants may be employed to remove or crush oversized material in paving gravel.

**Scraper –** used to rip hard ground and reduce loading time.

**Rock breaker –** designed to break oversized rocks into smaller rocks.

**Steel drum roller –** applies static or vibratory pressure to the material for compacting the pavement. When using vibratory rollers in urban areas, care must be taken to limit the size of high-amplitude rollers when working near structures or buildings.

**Multi-wheeled roller –** applies pressure to knead and compact the material, useful for materials with low cohesion.

**Grid roller –** used to break up soft rock and force large rocks below the surface through impact force.

**Padfoot roller –** produces high contact pressure with low mass, tamping the soil and is most useful for compacting clay.

## 4.5.2 Stabilisation Equipment

The main equipment types for asphalting a road are described in Table 4.4.

**Table 4.4: Summary of main stabilisation plant and equipment**

**Rotary pulveriser/stabiliser –** for mixing the lime or other stabiliser into crushed rock material.

**Water cart** – a water cart fitted with a spray bar should be used to add additional moisture to the pavement, assisting in achieving desired compaction.

*Source: AustStab.*

**Grader –** for trimming and levelling.

*Source: AustStab.*

**Bitumen tanker –** used in foamed bitumen stabilisation for bitumen application, simulatiously moves with pulversier and water tanker in a train-like configuration.

**Truck-mounted cement/lime spreader –** for spreading of stabiliser.


*Source: AustStab.*

**Roller/s –** multi-wheeled, vibratory or padfoot (pictured) used for compaction of material.

## 4.5.3 Asphalting Equipment

The main equipment types for asphalting a road are described in Table 4.5.

**Table 4.5: Summary of main asphalt paving plant and equipment**

**Rotary broom –** either drawn or tractor mounted to sweep the surface of all loose or detritus material. **Suction sweepers** can also be used for this purpose.

*Source: Victoria DoT.*

**Profiler –** designed primarily for the work of trimming, mixing, shaping and finishing in road cosntruction. A profiler is used to remove the thick asphalt patches and for efficient removal of the existing asphalt wearing course.

**Asphalt delivery trucks** – either tip trucks or trucks with a moving floor which delivers asphalt into pavers. Trucks with metal bodies and heavy-duty covers should be used to minimise heat loss.

**Paver –** a self-propelled machine capable of spreading the asphalt to level automatically, pre-compact and screed. A paver can also include a joint matcher or a levelling beam where a reduction in roughness is desired.

**Static self-propelled steel roller –** applies static pressure to freshly paved asphalt layers. Used for initial and final rolling. Generally, has a mass of 6 t to 12 t and applies a load of 25 kN to 50 kN per metre width of roll.

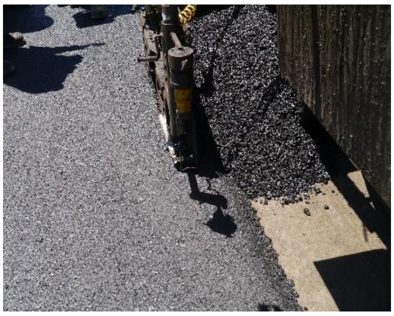
**Vibratory self-propelled steel roller –** applies vibratory pressure to asphalt. Used for initial rolling. Generally tandem rollers with a mass of 6 t to 12 t capable of vibration frequencies between 30 Hz to 70 Hz and amplitudes between 0.3 mm and 1.0 mm.

*Source: Victoria DoT.*

**Multi-wheel pneumatic- tyred roller –** applies pressure to knead and compact the material. Used for secondary and final rolling. Generally has a ballasted mass of 10 t to 20 t and has the ability to spray water or release agent on the tyres to prevent pick-up of asphalt.

*Source: Victoria DoT.*

**Plate compactor or tamper –** hand-manouved compactors used for compacting patches or small areas inaccessbale to rollers.



*Source: Victoria DoT.*

**Joint matcher –** attached to paver for construction of longitudinal joints.

*Source: Transport for NSW.*

**Skid steer –** A skid steer or bobcat is used for removing material, scraping, brooming and profiling. It can be easily modified on site for different applications.

## 4.5.4 Sprayed Sealing Equipment

Table 4.6 gives a summary of the equipment that can be used by a sealing crew to operate efficiently during sprayed sealing operations.

**Table 4.6: Summary of main sprayed seal equipment and plant types**

**Rotary broom** – either drawn or tractor-mounted to sweep the surface of all loose or detritus material.


*Source: Victoria DoT and Boral.*

**Road tanker –** used to transport bituminous binder to site. Tanker should be capable of heating and circulating binders.

*Source: Victoria DoT.*

**Aggregate loader –** truck-mounted, for loading aggregate and precoating of stone. Aggregate may also be precoated at the quarry and delivered to site.

**Bitumen sprayer –** sprays binder over prepared pavement at set spray rate. Calibrated annually against Austroads test methods. A minimum voulume of material is generally required in the sprayer to safely heat and spray the binder.

**Reverse aggregate spreader –** spreads aggregate by reversing. Rigid tip trucks fitted with a tail- mounted aggregate spreader box.


*Source: Boral.*

**Forward-moving aggregate spreader –** spreads aggregate in the direction that the driver is facing. Increasing in use and reduces the hazard of reversing vehicles on site**.**

**Multiroller and drag broom –** used immediately after aggregate has been spread to embed aggregate into bitumen layer. A broom attachment sweeps the surface of loose stones. Aggregate can also be embeded by traffic.

*Source: Victoria DoT.*

**Crumb rubber mixer –** a special mixer to combine crumb rubber and bitumen on site before spraying.

*Source: Victoria DoT.*

**Geotextile applicator –** rolls out geotextile fabric smoothly over the pavement. Can be mounted to a tractor or multi-tyred roller**.**

# 4.6 Pre-construction Considerations

## 4.6.1 Service Relocations

*Confirm the location of all underground services with service authorities and field test before digging is commenced. Work to the required clearances for both overhead and underground services.*

Before any works are undertaken it is essential that any utility services that may be located in the vicinity of the works area have been identified and if affected by the proposed works are removed or relocated.

Service authority assets include:

- communication carriers
- power authorities
- gas lines
- water and sewerage lines
- underground drains and associated facilities.

The identification and relocation of services is normally the first phase of any construction and the works program should allow adequate time for this to be carried out. This early identification of services will enable the most appropriate road alignment and design being chosen to allow for construction clear of services in order to avoid:

- damage to services
- injury to workers
- costly repairs
- delay of works
- disruption of services to the general public.

Underground services are located either by probing, electronic location and marking or exposing for easy recognition. Generally, due to the specialist nature of the facilities, they are relocated by the owning or responsible authority, or by its contractors. Refer to individual state and territory codes of practice for utility management requirements.

### *Location of Services – Dial Before You Dig*

*'Dial before you dig' is a free national service that provides information on buried utility infrastructure directly from the asset owners of the utility services. Lodging an enquiry is a free and simple process:*

- *online via the website: 1100.com.au*
- *mobile website or app*
- *by phone on 1100 (within business hours).*

*Prior to dialling 1100 check the location details at the worksite (i.e. GPS coordinates) to accurately locate the information sought. It should be noted that not all utilities or councils may subscribe to dial before you dig. In such cases construction staff should contact their local council to determine the location of any services.*

*Further information can be found via the dial before you dig website www.1100.com.au*

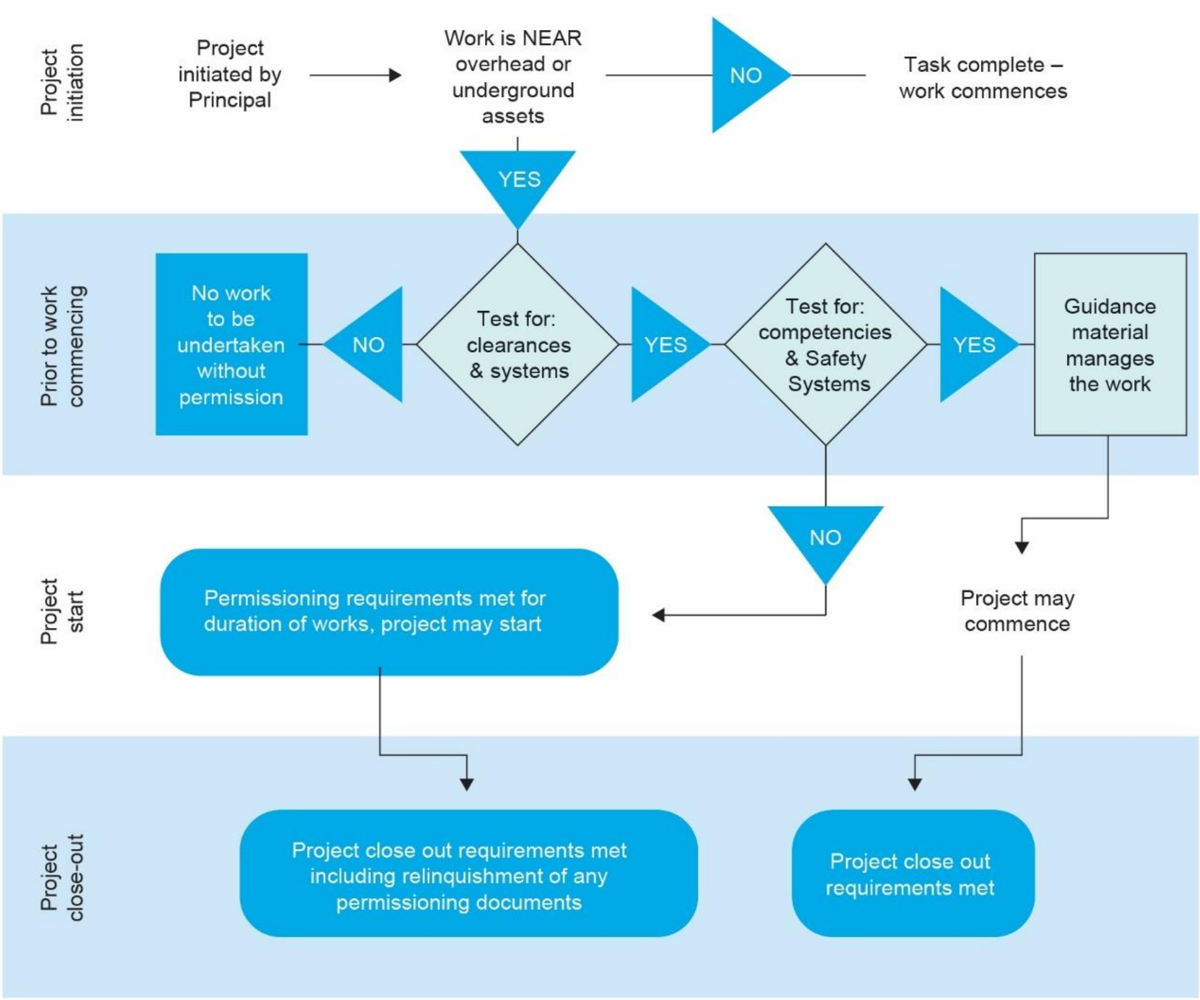
## 4.6.2 Clearance and Exclusion Zones

### Exclusion zones around services

Many service authorities have exclusion zones around their services. The exclusion zone requirements will vary between jurisdictions, possibly between regions and may vary according to a particular service. Further information on exclusion zones can be found via the work health and safety authority in the jurisdiction or via Safe Work Australia.

To assist in minimising any disruption to road works as a result of either overhead or underground services, the flow chart in Figure **4.4** should be used as a guide to assess exclusion zones.

**Figure 4.4: Framework for assessing exclusion zone requirements**



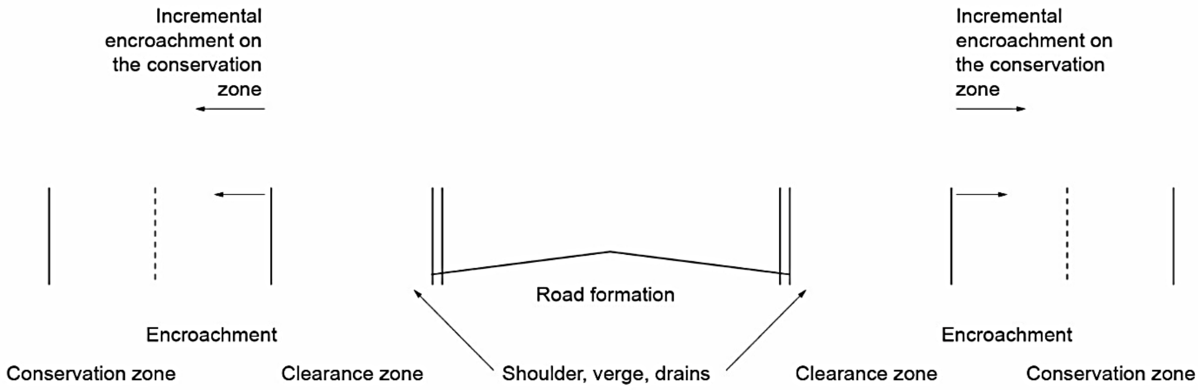

*Source: Worksafe Victoria Framework for Undertaking Work Near Overhead and Underground Assets: A Guide to the No Go Zones (2004).*

## Clearance zones

It is essential that before works commence consideration is given to clearance zones and approvals are sought if working within these zones. Figure 4.5 and Figure 4.6 are a schematic and visual representation of the road and roadside. The figures show the road surface as well as the shoulder, verge and drainage zone. In general, there are three broad zones:

- the 'pavement and shoulder maintenance zone' – extends from the midline of the road to the edge of the invert of the table drain
- a 'clearance zone' – is maintained for road safety reasons
- a 'conservation zone' – extends to the boundary of the road corridor that may contain environmental and heritage values that should not be disturbed by any maintenance works.

**Figure 4.5: Illustration of three broad road and roadside zones**




**Clearance zone:** Begins at edge of seal or white line. Roadside maintenance priorities include road user safety and maintenance of clearzone and line of sight distances.

**Conservation zone:** Roadside maintenance priorities include protection of environmental and heritage values. Roadside maintenance works may result in encroachment through the cumulative effects of mowing, incremental clearing, vegetation damage by vehicle movement and other activities.

*Source: Adapted from ARRB (2003b).*

**Figure 4.6: A typical road profile with the clear zone extending just beyond the upside of the table drain**

**Legend**

- Pavement and shoulder maintenance zone (pink)
- Clearance zone (from edge of traffic lane to likely hazard) (blue)
  Refer to Austroads (2003b) for minimum clear zones
- Conservation zone (clear zone from road reservation boundary) (green)
- Potential for encroachment into conservation zone (blue dashed arrow)

*Source: ARRB (2005) (Photo from Main Roads Western Australia).*

### 4.6.3 Stakeholder Notifications and Communication

Consideration will need to be given in the planning phase to ensure that the required public notifications are given, and permits issued. Police and motoring associations and any affected property owners should be advised.

Examples of notifications include:

- letter drops to surrounding residents and businesses
- signage such as variable messaging systems displaying dates and timing of construction works
- media advertisements/news releases in accordance with the authority's standing arrangements for such releases.

## 4.7 Drainage Construction

This section provides a brief summary of the key steps and considerations in the construction of subsurface drainage, kerbs and channels, table drains, and culverts.

### 4.7.1 Subsurface Drainage

The subsurface drains, most frequently used to intercept and remove groundwater, are narrow trenches cut with a backhoe, excavator or a trenching machine, and filled either wholly or partially with a porous material. A perforated pipe, normally with a sock or filter medium, is provided in the lower part of the trench to remove the water collected.

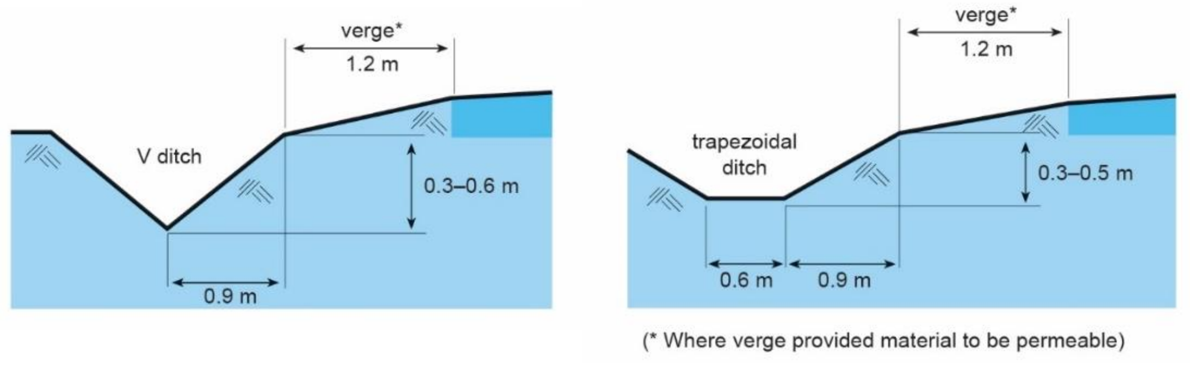
The perforated pipes used may be of corrugated or rigid smooth-walled plastic, corrugated galvanised steel or fibre-reinforced pipes. Entry of water into plastic pipes is through rows of slots approximately 2 mm wide cut into the inside corrugations or sides of the pipes. Diameters vary from 40 mm to 150 mm; however, the most common size is 100 mm. Care must be taken not to kink or crush the pipes during construction as this can render the subsurface drainage ineffective and result in rapid pavement failures.

The porous backfill material must act as a filter to retain the surrounding soil particles but allow the water to drain into the pipes. The backfill material must also be coarse enough not to enter the pipes and block them.

### 4.7.2 Table Drains

Table drains are usually constructed into the natural material on site adjacent to the road. They can be in the shape of a v, trapezoid, or parabola, although a flatter base will reduce the risk of erosion. During construction the levels must be controlled, and table drains should be graded to the nearest outfall. Figure 4.7 shows the shape of typical table drains.

**Figure 4.7: Typical table drains**




*Source: ARRB (2009).*

## 4.7.3 Kerbs and Channels/Gutters

Kerbs and channels/gutters are used to control drainage mainly in urban areas, channelise traffic and separate vehicles from pedestrians. They can be constructed either by hand or with a specialised kerb and channel machine (Figure 4.8). They are generally constructed with concrete but may also be made from cut stone or asphalt.

Key considerations when constructing kerbs and channels/gutters include:

- Ensure the kerbs sit on the primer seal or in some cases overlaps the asphalt surfacing to prevent moisture ingress to the base pavement layers.
- Ensure the subgrade or natural ground is stable. Damage to kerbs and channels can often be caused by settlement due to loss or lack of support of the underlying subgrade/ground or entry of excess moisture.
- Be mindful of surrounding vegetation. Tree roots close to kerbs can also lead to kerbs cracking and lifting.

**Figure 4.8: Construction of kerb and channel**

*Source: LGAM (2020).*

### 4.7.4 Culverts

Proper placement of culverts is critical during construction as it has the potential for early road failures. The typical steps of culvert installation and construction include:

1. Check the position and invert levels of every culvert.
2. Check the load class of each culvert for each location as per the design.
3. Excavate the trench for installation.
4. Install and compact the bedding material along the bottom of the trench.
5. Install the culvert structure.
6. Confirm the levels and grade through the use of laser levels.
7. Install and compact the backfill materials.

## 4.8 Earthworks

Earthworks form the foundation of bituminous sealed roads. Table 4.7 summarises the key steps and considerations when completing earthworks.

Table 4.7: Key steps and considerations for earthworks

| Key steps | Considerations |
|---|---|
| Pre-construction | • Locate the following:<br>– vegetation to be avoided<br>– positioning of stockpiles<br>– vehicle parking areas<br>– cleaning locations.<br>• Pedestrian movements around the site.<br>• Proximity to schools and other community areas.<br>• Access restrictions to adjoining properties. |
| Clearing | • Clearing is the removal of all vegetation, refuse and artificial features from the area to be occupied by the earthworks.<br>• This is generally the whole width between the outside edge of batters plus up to 3 m, but not beyond the road reserve boundary. |
| Stripping of topsoil | • Work site should be stripped of all topsoil.<br>• Stripped material should be stockpiled ready for use as batter or embankment re-vegetation material. Refer to Section 0 for stockpile considerations.<br>• Stripping should take place on all cut and fill areas between the limits of the batters as defined by the pegged batter and toe line.<br>• The depth of stripping will depend on the depth of topsoil, but generally is about 150 mm. |
| Selection and processing of earthwork materials (if not already detailed in design) | • Careful selection of embankment materials is important if the embankment is to retain shape, height and stability.<br>• Earthwork materials such as cuttings, soil gravel pits, river beds and rock quarries must be inspected, tested and evaluated prior to use to determine if the material can be used in its natural state or will need processing to meet requirements i.e. such as grading or compaction requirements.<br>• Ensure sufficient quantities of materials are available to meet project requirements.<br>• Detailed information on the selection, processing and delivery of earthwork materials can be found in the ARRB *Road Materials Best Practice Guide*, the Austroads *Guide* |

| Key steps | Considerations |
|---|---|
| | *to Pavement Technology Part 4I: Earthworks Materials* (Austroads 2009a) and the Austroads *Guide to Pavement Technology Part 8: Pavement Construction* (2019b). |
| Setting out earthworks | • Setting out of earthworks can be completed using various methods:<br>– manually using pegs and/or stringlines that are set with laser measurements; this method is suitable for small to medium-sized construction projects<br>– automatically using modern electronic equipment, such as global positioning systems (GPS), stringline and sensor or laser levels that are installed on earth-moving equipment.<br>• Peg references should be centreline at each cross-section at least 500 mm clear of the works.<br>• The reference stake should show the chainage, offset to centreline and level, either above or below the finished centreline level.<br>• Peg reference the batters at each cross-section. Figure 4.9 and Figure 4.10 show methods for setting out roadworks in cuttings or fills. |
| Preparation of foundation | • Backfill any holes or depressions that were a result of clearing. These holes should be compacted in layers no greater than 150 mm.<br>• Tyne and compact foundations for an embankment depth of 150 mm or to set design standards.<br>• Soil may need to be dried or moisture added to be at optimum moisture content for the material to be compacted.<br>• If soil has a high plasticity it may need to be removed and replaced with a non-plastic material or stabilised.<br>• Horizontal benches may need to be prepared to prevent slipping of material in longitudinal cut/fill zones where slopes are steeper than a 1 in 4 grade (Figure 4.11). Refer to the local region's standard drawings. |
| Embankment construction | • The surface of each layer should generally be kept parallel to the level of the design subgrade cross-section to ensure uniform thickness.<br>• To prevent water from washing over the edges of the fill and causing scouring in areas of high rainfall, the outer edges of fills should generally be kept higher than the remainder of the fills.<br>• Provision for drainage should be made by cutting drains at the ends of the fills to ensure any discharge is over undisturbed ground.<br>• Conversely, the centreline should be kept higher than the edges to allow construction equipment to work right up to the batter toe and for drainage to be facilitated along the edges.<br>• Where scouring is not likely to be a problem, the profile of the cut should be kept as near as possible parallel to the design subgrade level.<br>• Density of compacted layers should be tested to ensure the specification is met. Refer to ARRB *Road Materials Best Practice Guide* for information on density measurements and testing. |
| Compaction | • All embankment fill material should be placed and spread in uniform layers and compacted to the specified degree.<br>• The subgrade layer of embankments is compacted usually to a higher standard than for the deeper part of the embankment as it provides the foundation upon which the pavement will be placed.<br>• Care should be taken at the end of each day's work to ensure that all embankment material has been compacted to a tight finish, to prevent the entry of moisture in case of overnight rain. |
| Test rolling | • Test rolling, using an approved roller, should be undertaken as defined in the specification being followed or as directed by the supervising engineer on all layers of fill within 150 mm of the finished subgrade level in cuts. |
| Levelling and trimming | • Levelling and trimming of earthworks are usually undertaken with a grader.<br>• Profile and levels should be checked regularly using a straight level, camber board, laser level or GPS.<br>• Turning of the grader should be kept at a minimum as to not disturb the earthwork surface.<br>• The trimmed material should be removed, and surface given a final compaction. |

| Key steps | Considerations |
|---|---|
| Scarifying and ripping the surface | • The surface may need to be made rough or 'ripped' to allow for wet soils to dry and for dry soils to open up so water can be absorbed easily.<br>• This is usually done with a scarifier or ripper attached to a grader.<br>• All oversized rocks and boulders should be removed to a depth of 150 mm below subgrade level. Any depressions created should be filled with in situ material, reworked and compacted to the specified compaction. |

**Figure 4.9: Pegging of batters**

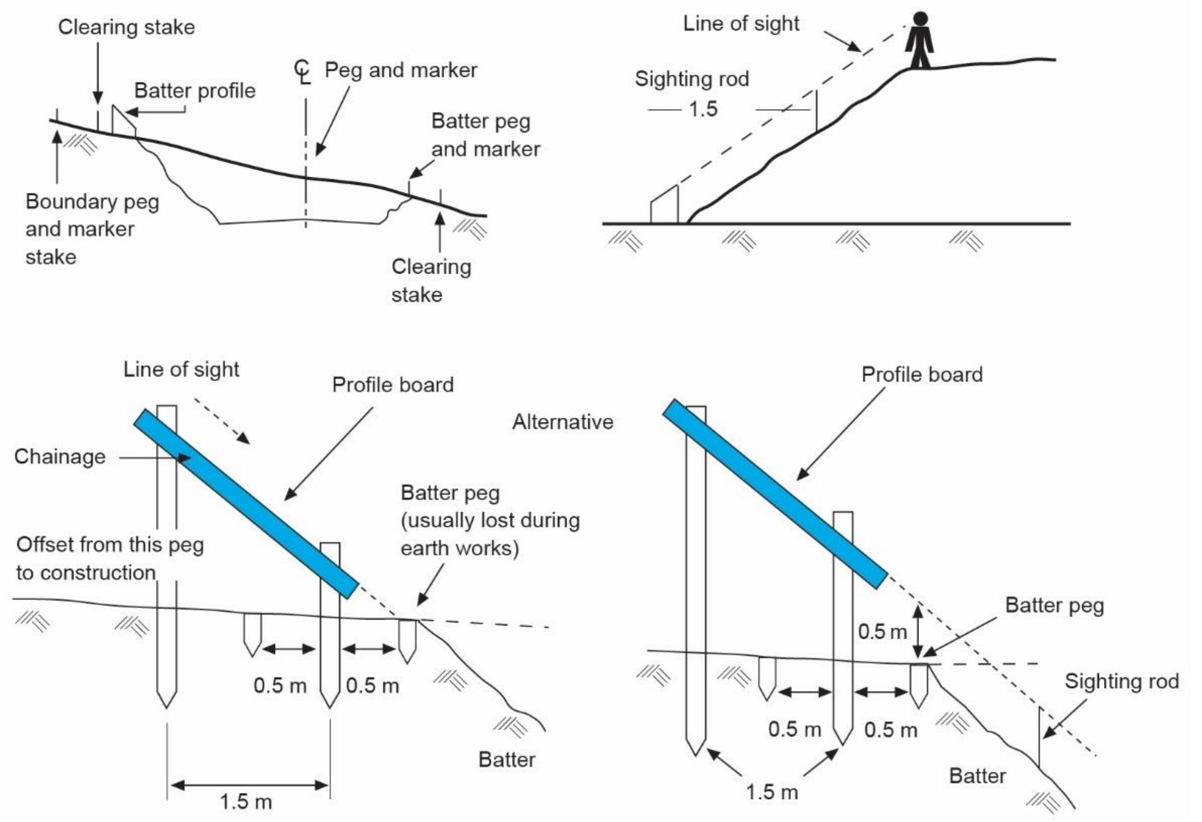
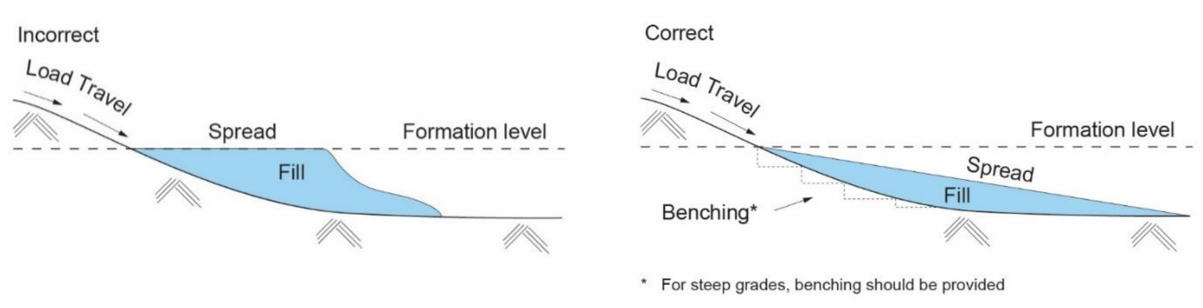



**Figure 4.10: Setting out roadworks in cuttings and on fill**

*Source: ARRB (2005).*

**Figure 4.11: Spreading of fill material**




*Source: ARRB (2009).*

## 4.9 Pavement Preparation

Table 4.8 summarises the main steps and considerations when preparing a site for construction of a bituminous sealed road. These steps can also be employed in maintenance and rehabilitation operations.

For more detailed information on pavement preparation, refer to the Austroads *Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals*.

**Table 4.8: Key steps and considerations for preparing pavement for construction**

| Key steps | Considerations |
|---|---|
| Pavement line, level and appearance | • Check that shape, level and rideability requirements meet specifications.<br>• Pavement material should look homogeneous and consistent across the site.<br>• Pavement should be uniform in texture, free of tearing, scabbing and lamination. |
| Cleaning of the surface | • As per AS 2150 (2005) the surface should be swept to remove loose stones, dirt and other foreign material.<br>• The pavement surface should be hard, dense and tight to enable sweeping.<br>• Unsealed roads may need to be dampened before sweeping to avoid surface damage.<br>• The sweeping should extend beyond the edge of the proposed seal or asphalt surface by at least 300 mm.<br>• Any areas that may be contaminated by oil should be cleaned or removed and replaced. |
| Correction of defects | • Prior to surfacing, any defects in the existing pavement should be repaired such as:<br>– cracking<br>– potholes<br>– flushing of bituminous surfaces<br>– build-up of fines on unsealed surfaces<br>– roughness<br>– soft spots<br>– oil spills. |
| Pavement dryback | • At the time of sealing, the pavement surface should be dry, except for granular surfaces which may be slightly damp.<br>• Before applying a bituminous surface to a road, the following should be completed satisfactorily (VicRoads 2014):<br>– dryback testing completed the day prior to sealing<br>– dryback re-tested where adverse weather events have occurred since original testing and could have increased pavement moisture content. Note, areas subject to slower dryback rates such as areas in shade from trees, bridges, cuttings etc. should be tested separately<br>– ball embedment testing (AGPT-T251-10 *Ball Penetration Test*).<br>• Refer to ARRB *Road Materials Best Practice Guide* for further information on pavement dryback management. |

| Key steps | Considerations |
|---|---|
| Pre-treatment of granular pavements | • Granular pavements/unsealed roads must be pre-treated prior to bituminous surfacing.<br>• Treatments may include primes or initial seal.<br>• Refer to ARRB *Road Materials Best Practice Guide* for detailed information on treatment techniques. |

## 4.10 Pavement Construction

The key steps in pavement construction are as follows:

- Subgrade preparation – prior to the placement of granular pavements, the earthworks (i.e. subgrade) layers should be checked for conformance to specifications in terms of compaction, shape and level. Any soft spots or areas damaged by construction traffic, regular traffic or weather must be rectified.
- Subbase and basecourse construction – the subbase material is brought in, desirably as a wet mix spread, compacted and trimmed. Refer to Table 4.9 for a summary of key steps and considerations. For detailed information on construction stages of unbound granular pavements, refer to the Austroads *Guide to Pavement Technology Part 8: Pavement Construction* (Austroads 2019b).

Table 4.9: Key steps and considerations in unbound granular base and subbase construction

| Key steps | Considerations |
|---|---|
| Delivery of materials | • Preferable that material arrives on site at or near target optimum moisture content (OMC).<br>• Materials should be delivered and tipped into a uniform windrow parallel to the centreline of the road.<br>• The windrowing also facilitates remixing any material segregated during transport and handling and the addition of water for compaction.<br>• The total amount delivered should not exceed what can be spread in one day. |
| Spreading | • Materials can be spread using a grader or mechanical spreader.<br>• Grader spreading is usually used on cohesive materials such as soil aggregates and natural gravels.<br>• Mechanical spreaders are used to spread unbound high-strength materials and lower-strength materials that have been plant mixed or processed through power screens.<br>• Graders should operate at a speed between 5 to 10 km/h to ensure a controlled spread. This will avoid segregation and corrugations.<br>• The flow of material along the blade is controlled by the pitch of the blade (top or mould board set slightly forward of vertical), the angle of the blade to the centreline of the road and the width of cut into the windrow.<br>• Control the depth, grade and crossfall using pegs or electronic levelling.<br>• Try not to turn the grader over freshly-spread material. |
| Mixing and watering | • The moisture content, segregation and crossfall of the granular material should be checked during spreading.<br>• Re-mixing of materials and/or the addition of water may be necessary, to ensure an even moisture content throughout the subbase material.<br>• At all times during pavement compaction and trimming, the material should be kept at optimum moisture content to achieve maximum compaction in the shortest possible time. |
| Compaction | • Refer to ARRB *Road Materials Best Practice Guide* for detailed information on compaction of pavement materials.<br>• The prime objective in compacting pavements and subgrades is to limit and if possible, prevent loss of shape from further compaction by traffic after construction.<br>• Compaction requirements may be specified as the number of passes with a certain class of roller or by the use of a required density obtained for that material in a laboratory. |

| Key steps | Considerations |
|---|---|
| | • There is an optimum dry density achieved for a given moisture content and compacted effort, known as the optimum moisture content (OMC). Refer to the ARRB *Road Materials Best Practice Guide* for information on the relationship between OMC and compaction effort and methods for determination of OMC.<br>• Density of compacted layer can be determined using a nuclear gauge. |
| Shaping | • After 2–3 passes with the roller, the depths and levels should be checked, and adjustments made with a grader if necessary. Refer to Table 4.10 for further rolling procedure tips.<br>• After the initial spreading, the material is trimmed to its final shape, preferably on the same day, but no longer than 24 hours later.<br>• For fine-grained soil aggregates, the surface can be dampened and trimmed and cut to shape. This is then followed by a static steel-drum roller to tighten the surface.<br>• For coarse-graded material, use of a grader for trimming should be avoided. Similarly, in soft subgrades, or sand subgrades and where a geotextile is used for subgrade separation, the subbase material must be 'pushed out' over the subgrade with a loader or similar equipment so that the wheel loads do not impact directly on the subgrade. |
| Final check | • The final surface should be:<br>– a hard, dense surface capable of being swept with a rotary broom or a drag broom for some granitic materials<br>– a tight surface free of loose materials, and have no tearing or scabbing<br>– of uniform texture and have no laminations within 75 mm of the finished surface.<br>• The density value of the compacted basecourse should be not less than 98% standard or modified density, as specified.<br>• Once the surface has been passed it must be maintained in the approved condition until bituminous surfacing is completed. |

Table 4.10 provides some useful tips for rolling procedures so as to achieve satisfactory compaction uniformly across the pavement, while maintaining the shape and evenness of the surface.

Table 4.10: Rolling procedure tips

| Rolling procedure | Tip |
|---|---|
| Compaction level | • The number of passes required to achieve a particular level of compaction depends on the roller, the layer thickness and the material.<br>• Pavement material should generally be compacted in lifts not exceeding 200 mm loose.<br>• The minimum loose layer thickness of material to be compacted is 2½ times the nominal stone size (i.e. for a 40 mm nominal size stone the minimum loose layer thickness should be 100 mm).<br>• When using vibrating rollers, a sequence consisting of a non-vibrating initial pass, followed by several high-amplitude passes, and finishing with low-amplitude passes, has been found to achieve good compaction and surface evenness. |
| Pattern | • Rolling should generally commence at the outer (lower) edge of the pavement and progress towards the centreline (or lower edge, if superelevated).<br>• Rolling with passes progressing towards the lower edge will cause material to move downhill and result in loss of shape.<br>• A forward and reverse pass is made over the same section of pavement before moving to the adjacent section. It is important to check that this is done at the edges of the pavement. When changing direction, the roller should be on the previously compacted section.<br>• Each pass of the roller should overlap the previous pass by up to 500 mm so as to ensure complete coverage. |
| Unsupported pavement | • Where the outside edge of the pavement is unsupported and squeezes out excessively, rolling should commence 200 to 300 mm from the edge and the 200 to 300 mm strip rolled later. |
| Equipment movements | • Best roller speed is usually at normal walking pace, that is 4–6 km/h. |

| Rolling procedure | Tip |
| --- | --- |
| | • Vibrating rollers should have the vibrator turned off when the machine is stopping or manoeuvring.<br>• All rollers should be slowly reversed without jolting. Sharp turns of the roller or sudden changes in direction should be avoided. Such practices can cause surface roughness.<br>• Static drum rollers should have the drive wheels leading on the initial pass so as to avoid pushing material ahead of the drum. |

### 4.10.1 Stabilisation Techniques

Stabilisation in road construction refers to the processes by which binders are used to enhance the properties of subgrade and pavement materials. Refer to ARRB *Road Materials Best Practice Guide* for the common forms of stabilisation currently in use. Further details on stabilisation are available in Austroads *Guide to Pavement Technology Part 4D: Stabilised Materials* as well as via AustStab (https://www.auststab.com.au/). AustStab is a member-driven industry association in the field of pavement recycling and stabilisation. The website provides useful information on all aspects of stabilisation, including construction of stabilised pavements.

The two principal methods of stabilisation are:

- in situ (Figure 4.12)
- plant mix.

For in situ work the construction of a stabilised pavement course consists of the pulverisation and preparation of the material to be stabilised, the spreading and mixing of the binder and water with the material, and the compaction, shaping and curing of the stabilised layer.

**Figure 4.12: In situ stabilisation**

*Source: AustStab.*

Specialised stabilisation equipment is available for the spreading of the binder and the pulverisation and intimate mixing of binders with the host material.

For plant-mix work, a stationary mixing plant (sometimes called plug mill), usually employing continuous mixing, is used to proportion and mix the binder, water and gravel or crushed rock, and the mixed material is transported to the site in trucks and laid by means of a self-propelled paver.

Further guidance around stabilisation is provided in AUS-SPEC Worksection *1113 – Stabilisation*, and NATSPEC TECHnotes *DES 034 – Pavement stabilisation for Unsealed Roads* and *DES 035 – Improvement and Stabilisation of Unsealed Roads*.

#### Lime and cementitious stabilisation

The construction techniques for lime and cementitious stabilisation of both the subgrade and the pavement are essentially the same. For stabilisation of existing pavements, the in situ method is used. However, for new pavements stabilisation may be done as a batch plant mix or in situ.

The typical in situ construction process for lime and cementitious stabilisation includes:

1. Scarify the surface and pulverise by rotary mixer with the addition of water.
2. Lightly compact and grade the surface.
3. Add water to the surface using a water cart.
4. Spread cement or lime using a truck-mounted spreader.
5. Mix materials using a rotary pulveriser.
6. Grade and compact to line and level.

The last procedure must be completed within two hours to gain maximum strength. Once the strength starts to take up it is very difficult to change the shape, level or surface texture. This can result in a permanent defect such as a rough-riding or dimpled surface. The surface should be primed, or primer sealed as soon as possible, preferably the next day for both highly and lightly trafficked roads.

#### Bituminous stabilisation

The two main methods of bitumen addition to base materials in Australia are:

- emulsion mixed in situ or in plant mix
- foamed bitumen.

The typical in situ construction process for bituminous stabilisation using foamed bitumen includes:

1. Pulverise and mix the material.
2. Spread lime onto the pavement during initial mixing.
3. Add water to bring the material up to OMC.
4. Lightly compact and shape.
5. Mix material with foamed bitumen using specialled equipment. Bitumen and lime can also be added in the same mixing run.
6. Shape, trim and compact.

## 4.11 Bituminous Surface Construction

The Austroads/AAPA Work Tips are recommended for useful advice and the processes involved in asphalt and sprayed sealing construction.

### 4.11.1 When to Seal an Unsealed Road

When a road authority considers sealing a road, it is usually with a view to reducing road maintenance costs, providing a smooth riding surface or minimising public concerns about dust and safety problems. The availability of suitable gravel is becoming more difficult and may be an important factor in deciding when to seal a road.

In spite of the benefits of sealed roads, well maintained unsealed roads are a cost-effective alternative and sometimes have lower maintenance costs and require less equipment and lower operator skill levels. For further information on this issue, refer to the ARRB *Unsealed Roads Best Practice Guide* and AUS-SPEC Worksection 0*053 – Rural Pavement Design – Sealed.*

### 4.11.2 Sprayed Sealing

Sprayed sealing is the application to the road surface of a thin surface layer of bituminous binder into which aggregate is incorporated. Refer to the Austroads/AAPA Work Tips for detailed sealing construction procedures. Table 4.11 details the key aspects and considerations for sprayed sealing.

**Table 4.11: Key steps/aspects and considerations for sprayed sealing**

| Key steps/aspects | Considerations |
|---|---|
| Preparation of pavement surface | • Always broom the pavement at least 300 mm wider than the binder coat to ensure that all foreign and loose materials are well beyond the sprayer width.<br>• Traffic should be kept off swept areas if possible; if not, traffic speed should be kept to below 20 km/h to prevent the surface ravelling or dusting up.<br>• The surface must be dry for priming and moist for initial seals.<br>• The pavement should be inspected to determine if the surface is hard (ball embedment test), smooth and free of defects such as small, soft spots etc.<br>• The pavement surface should have a mix of large and fine aggregate particles present. A build-up of fines can produce a soft surface and lead to aggregate embedment and flushing in the seal.<br>• Appendix A of the Austroads *Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals* has a good visual guide to pavement preparation alongside descriptions of the effect of embedment. |
| Aggregates | • Aggregate is normally delivered to a stockpile site near the work which is easily accessible by the aggregate loader and trucks.<br>• Aggregate should have one size grading, be free from dust (dust can cause stripping from bitumen binder) and consist of sound angular stone.<br>• Aggregates for sealing should be pre-coated with a light oil or cutback bitumen with or without an adhesion agent. Pre-coating can be completed at a central plant or in the field by the aggregate loader. |
| Initial seal | • An initial seal is an application of sprayed seal directly to a prepared pavement which has not been primed.<br>• It can be immediately trafficked after construction and can provide a wearing course if the application of a final surfacing must be delayed.<br>• 7 mm or 10 mm aggregate is commonly used with double/double initial seals being used under heavy traffic or where there is a desire to reduce risk of early aggregate loss due to traffic stresses or weather. |
| Prime | • Priming is the application of cutback bitumen or emulsion to the surface several days prior to a final seal being applied.<br>• Its main functions are to penetrate the surface, coat fine particles and seal surface pores, provide a uniform surface for the application of the binder coat for sealing, and to assist in achieving and maintaining the bond between the pavement and the subsequent bituminous surfacing.<br>• Priming is preferable but is generally confined to conditions where traffic can be kept off the job or where the traffic is only light and can be catered for by lightly sanding critical areas such as property entrances. |

| Key steps/aspects | Considerations |
|---|---|
| | • The surface should be dry for the application of the prime. Where conditions suit, overall priming and sealing are more cost efficient compared to initial seal and final seal. |
| Addition of crumb rubber | • Crumb rubber may be added to bitumen at site using a rubber 'duck' or mixing box.<br>• Heat binder in accordance with supplier instructions. |
| Spraying of bitumen | • The ambient temperature should be at least 10 °C and 15 °C for initial sealing or sealing. Undertaking sealing in cool weather should be avoided as the risks of poor seal performance increase.<br>• The surface should be dry for the application of the binder.<br>• To obtain uniform lateral and longitudinal distribution of sprayed material the appropriate pump speed or pressure in the spray bar needs to be maintained and the sprayer is driven at a constant speed for the desired application rate.<br>• A calibrated sprayer should be used. For more information on calibration on sprayers refer to Austroads test method AGPT-T530-19 *Calibration of Bitumen Sprayers: General Introduction and List of Methods*. |
| Spreading of aggregate and compaction | • Aggregate is generally applied at the design rate by reversing the trucks over the binder and using rear-mounted spreaders for controlling the aggregate application.<br>• Forward-moving aggregate spreaders are being introduced as a means of minimising the hazard of reversing vehicles on site.<br>• Aggregate should be applied as soon as possible after the binder is sprayed to achieve maximum adhesion of the stone and self-propelled rubber-tyred rollers should commence immediately. For emulsion binders, spreading of aggregate may be delayed until the binder starts to break (turn from brown to black).<br>• Ensure the aggregate spread rate is maintained and not over-applied to avoid stone damage to vehicles.<br>• Traffic can be allowed onto areas with aggregate as soon as the stone is placed; however, care must be taken to ensure that traffic speeds are kept to below 40 km/h to avoid stripping of aggregate. |
| Post-construction | • Sweep the surface.<br>• Check surface texture, aggregate retention (i.e. loose stones) and uniformity of spread.<br>• Erect appropriate aftercare signage such as reduced speed limits or advising of the presence of loose stones. |

## 4.11.3 Asphalt Works

Asphalt is used mainly for urban street construction where its higher initial cost can be justified, although it is finding more application in the rural areas where there are high volumes of turning trucks, especially at tight intersections. Table 4.12 details the key aspects and considerations for asphalt construction.

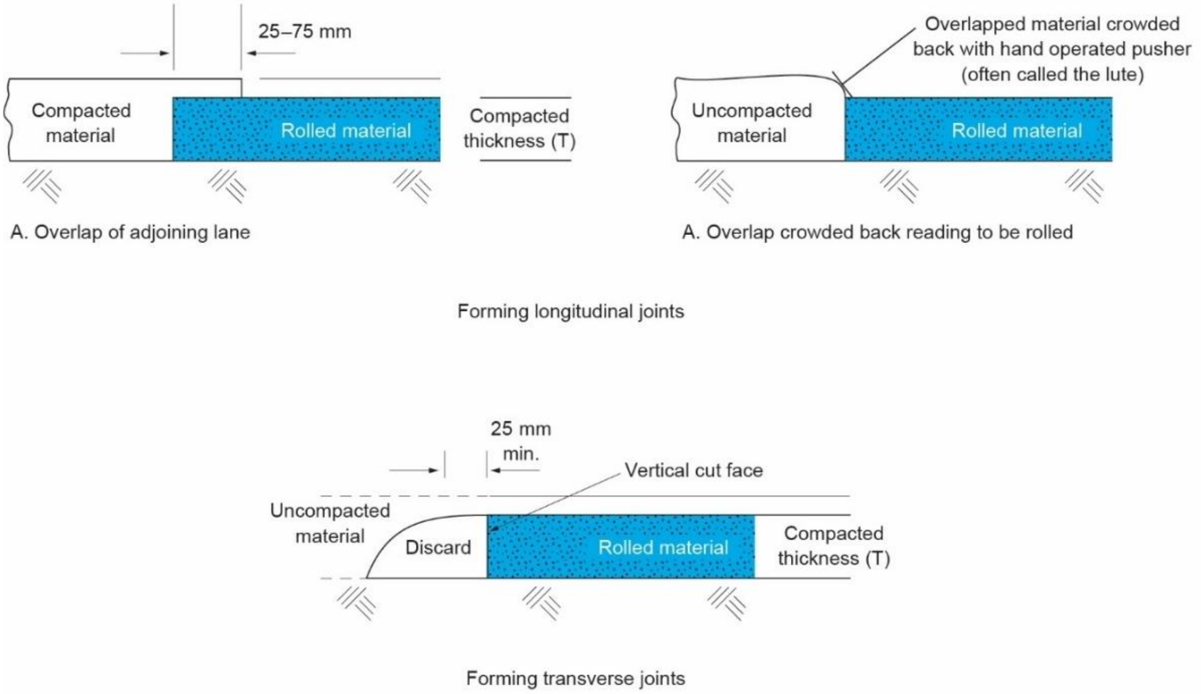
**Table 4.12: Key steps and considerations for asphalt construction**

| Key steps | Considerations |
|---|---|
| Preparation of pavement surface | • Always broom the pavement at least 300 mm wider than the binder coat to ensure that all foreign and loose materials are well beyond the sprayer width.<br>• Traffic should be kept off swept areas if possible; if not, traffic speed should be kept to below 20 km/h to prevent the surface ravelling or dusting up.<br>• The pavement should be inspected to determine if the surface is hard, (ball embedment test) smooth and free of defects such as soft spots.<br>• For a surface that already has a bituminous layer, ensure the surface is free from defects such as potholes, depressions, excess binder, edge breaks and cracking etc.<br>• Ensure the surface has the correct shape and all joints are clean.<br>• If it is a concrete pavement, ensure that any moving or settled concrete is restored. |

| Key steps | Considerations |
|---|---|
| Pre-treatment of granular pavement | • Prime or initial seal the surface some time in advance of the asphalt layer to enable curing.<br>• Use a prime where little to no traffic will travel on the surface prior to asphalting.<br>• Use an initial seal where traffic is expected on the surface prior to asphalting.<br>• A tack coat of bituminous binder is only applied to an existing asphalt surface prior to placing the asphalt layer. Tack coat does not need to be applied to primed surfaces or fresh asphalt surfaces unless they have been trafficked. |
| Delivery of asphalt into paver | • Asphalt is transported to site via a truck (tip truck or one with a moving floor trailer) and delivered into the front hopper of the self-propelled paver.<br>• The material flows back through the paver and is spread evenly to the design depth plus a margin for compaction by the screed plate. |
| Paving (spreading) | • Asphalt laid at temperatures lower than 145 °C will make it very difficult to achieve the required density, unless a warm-mix additive is used.<br>• The paving temperature may vary depending on the road surface temperature and layer thickness. Refer to AS 2150 – 2005 *Hot mix asphalt – A guide to good practice* for more detail.<br>• All spreading should be completed using a self-propelled paving machine.<br>• Handwork should be avoided where possible. If handwork is necessary, ensure appropriate equipment such as rakes is used to spread the mix and work is completed quickly.<br>• Check the spread rate constantly as well as the texture and shape of the surface. Any defects should be rectified while the asphalt is hot and uncompacted.<br>• Depending on the type and thickness of the overall asphalt layer, the asphalt may need to be placed in a number of lifts. |
| Joints | • The number of joints should be kept to a minimum.<br>• Avoid longitudinal joints being in the trafficked wheel paths.<br>• Longitudinal joints can be constructed as hot joints (two pavers working in echelon, i.e. side by side) or cold.<br>• Longitudinal joints should be continuous and parallel to the centreline and offset by 150 mm if there is more than one layer.<br>• Transverse joints should be at right angles, or angled to reduce traffic noise, to the direction of paving and staggered by at least 1 m between successive layers and adjacent runs.<br>– Figure 4.13 shows how transverse joints are formed. |
| Compaction | • Ensure a rolling pattern is developed. Refer to AS 2150 – 2005 *Hot mix asphalt – A guide to good practice* for detailed information on rolling techniques.<br>• Initial rolling is carried out as soon as possible after spreading the mix using a tandem steel (static or vibrating) wheel roller.<br>• Secondary rolling may be carried out using self-propelled pneumatic tyred or vibrating rollers. Normally 6 to 8 passes are adequate.<br>• Final rolling is done while the mix is still warm enough to permit removal of all roller marks, and to produce a uniform finish without causing cracking or shoving. Steel wheeled or pneumatic tyred rollers can be used for final rolling. |
| Post-construction | • The following properties should be assessed:<br>– Level – level of the asphalt should not vary beyond 10 mm of the specified level at any point.<br>– Shape – each asphalt layer should be true to shape to ensure the final layer is within correct tolerances. Check the shape using a straightedge.<br>– Thickness – depending on the layer thickness, the total thickness should not vary more than 10%.<br>– Density – generally measured by taking cores or by nuclear gauge. Refer to the ARRB *Road Materials Best Practice Guide* for information on density testing.<br>– Ride quality – measures the smoothness/roughness of the surface. Usually required within 3 months after construction of the surface using a roughness meter or laser |

| Key steps | Considerations |
| --- | --- |
| | profiler. Ride quality is generally not measured for short lengths (due to the influence of start and end joints.<br>– Factors that can affect ride quality and how to ensure a smooth pavement are described in Austroads/AAPA Work Tip AP-PWT03-10 *Asphalt Riding Quality*. |

**Figure 4.13: Formation of joints in asphalt**




*Source: NAASRA (1984).*

# 4.12 Post-construction

## 4.12.1 Quality of Construction

The quality of construction and the preparation of pavement should be assessed at the completion of a project. Refer to Table 4.11 and Table 4.12 for properties that should be checked post-construction of a bituminous surface.

## 4.12.2 Site Clean-up

Cleaning up and removal of excess material should be an integral part of each construction operation. On completion of the job, the whole site should be left in a clean and tidy state. This includes:

- Cleaning the site should of all surplus material and rubbish.
- Checking all culverts, cleaning them of debris (e.g. gravel) and clearly marking with guideposts.
- Re-erecting any existing signs at the correct locations and cleaning them.
- Undertaking revegetation of disturbed areas progressively during the construction operation.
- Removing windrows around posts, trees and other fixtures and leaving the area clean and tidy.
- Picking up tree butts, survey stakes, and other construction waste, by hand if necessary, and disposing of at an approved location.

- Leaving all drains clean and ready for use.
- Where appropriate, grading the zone within the construction area level with great care being taken to not disturb native vegetation.
- When the works have been completed and passed, then remove the roadwork signs.
- Removing any material remaining at stockpile sites and reinstating the area to its original condition.

# 5. Operations and Maintenance

## 5.1 Road Maintenance

Sealed roads deteriorate as a result of repeated traffic loading and environmental influences such as climate and soil moisture interactions. Maintenance is carried out to ensure the safety of traffic and road users and to sustain the serviceability and appearance of the road and its associated facilities.

This is why in order to address the many maintenance requirements of sealed roads it is important to recognise that the maintenance need is often a direct consequence of the inadequacy of the many components that make up a road. A road with poor geometric design, poor use of local materials, inadequate drainage and construction methods will result in much greater maintenance demands than one designed and built in accordance with good practices. To ensure that greater value is obtained from the limited funding available for maintenance it is essential that deficiencies causing the problems are identified and remedied as resources become available so that over time greater value is obtained from the funding. Figure **5.1** illustrates the key factors contributing to maintenance.

**Figure 5.1: Maintenance components**


While maintenance of sealed roads is not as involved as unsealed roads, the same objectives for maintenance apply, i.e. a sealed road must be maintained to:

- provide a good riding surface
- carry heavy traffic loads
- meet community expectations
- minimise safety hazards to vehicular traffic
- provide a free-draining surface to the formation.

Information around various maintenance requirements and activities can be found within AUS-SPECs document suite of worksections under *Section 16 – Maintenance and Operations – Road Reserve* (available at www.natspec.com.au).

### *Holistic Approach*

***The importance of a holistic approach to maintenance can be demonstrated with the repair of a pothole.***
*Common practice would involve bringing in material to fill the pothole as and when it appears. A better approach would be to find out why potholes are being formed (normally insufficient crossfall) and to correct the underlying cause so that the problem is overcome, rather than spending good money continuously filling in potholes. This approach may cost more to fix the problem in the short term, but in the longer term provides much higher savings.*

### 5.1.1 Types of Maintenance

Maintenance can vary from on-demand (reactive) maintenance to correct immediate issues to preventative (proactive) maintenance to reduce the occurrence or frequency of defects in future.

The approach adopted will depend on the importance of the road link in the network, available resources and knowledge of the performance of each road link.

### *On-demand vs Preventative Maintenance*

***On-demand (reactive) maintenance***

- *necessary for unforeseen events such as floods.*
- *impacts on road safety or serviceability.*
- *reduces the overall efficiency of maintenance resources.*
- *may result in higher vehicle operating costs for road users.*
- *if defects remain uncorrected for any length of time, it can contribute to more severe pavement deterioration.*

***Preventive maintenance***

- *routine or periodic maintenance.*
- *predicts defects in advance and aims to eliminate or reduce the occurrence or frequency of the defect.*
- *although initial costs are higher, there is the potential for a longer service life for a pavement, reduced vehicle operating costs, increased safety for road users, increased community satisfaction and more efficient use of maintenance resources.*

Good practice also involves the preparation and regular updating of a pavement management strategy, this typically being at a more detailed level than the asset management plan (AMP). The strategy should clearly link the AMP with maintenance contract requirements, outline pavement condition trends and maintenance and renewal intervention standards, describe different maintenance intervention tactics (such as routine maintenance, heavy maintenance, holding maintenance), which can be applied at the treatment-length level, and define the types of treatments and the circumstances for their use. Refer to Section 0 for further asset management information.

### Routine maintenance

Routine maintenance is that group of activities which, due to their extent, timing and means of execution, are not amenable to detailed forward planning. The extent of each individual activity is usually small, and the exact location and timing are difficult to predict. Consequently, the road network must be regularly monitored to detect defects. The repairs required are noted and scheduled for assignment to a routine maintenance crew.

A key requirement of any maintenance management system is that routine inspection programs are established, key performance parameters are clearly described, including those relating to safety and environmental aspects, and records of inspections and any repairs undertaken are kept. This is not only to assist in the future performance assessment of works undertaken and historic trends of costs but also to assist in any possible future litigation claims.

Typical activities included in routine maintenance are for:

- the bituminous surface – pothole patching, crack filling/sealing, sweeping, minor sealing, edge-break repair and ice and snow clearing
- the pavement – patching (excavating and replacing), surface shape correction, (minor) stabilising, shoulder grading
- surface drains – cleaning, replacing, scour checks
- culverts, pipes, pits, subsoil drains, floodways – cleaning, repairing
- vegetation/roadside – mowing, slashing, litter collection, sweeping, repairs to retaining structures, servicing
- signs and road furniture – cleaning, repairing, replacing, painting
- pavement markings – repainting, replacing reflective pavement markers
- signals, lighting – servicing, repairs.

### Periodic maintenance

Periodic maintenance comprises cyclic activities, usually of a more expensive kind than those of routine maintenance. The need for these activities can be predicted and the work planned.

Periodic maintenance is planned to be undertaken at intervals in accordance with the normal life-cycle management process. Such works are intended to reinstate the surface or functional condition of the pavement e.g. waterproofing or skid resistance, without increasing the strength. In some cases, periodic maintenance works may include overlays of a structural nature to at least ensure the original service life and which may extend the life of the pavement.

Typical periodic maintenance activities include:

- asphalt resurfacing
- sprayed bituminous resurfacing
- microsurfacing
- enrichment or rejuvenation treatment
- resheeting of shoulders.

### 5.1.2 Road Defects

Well designed, constructed and maintained pavements are capable of providing many years of service. However, deterioration will occur over the lifetime of the pavement, or when the pavement is subjected to adverse conditions. Such deterioration can lead to a variety of pavement distresses which can impact the road serviceability and/or road user safety, and lead to wider failure of the pavement if left unfixed.

Distresses, or defects, may be associated with pavement aging, traffic loading or may be caused by environmental factors (moisture or temperature related). In some cases, a deficiency in the original design or construction may contribute to the defect. It is essential that the causes of the defect are understood as this may dictate the choice of rectification treatment selected.

Many road and/or local authorities have developed defect classification systems and have set intervention standards for each defect; for standard procedures in addressing defects, it is best to refer to specific documentation for that jurisdiction.

A catalogue of different pavement distress examples is given in Figure 5.2 toFigure 5.24, with conditions likely to cause each distress and some basic repair suggestions provided in Table 5.1.

**Figure 5.2: Block cracking – interconnected cracks forming large rectangular-like blocks, typically over a large area of pavement**

**Figure 5.3: Crescent cracking/slippage – half-moon shaped cracks, often parallel to each other and closely spaced**

**Figure 5.4: Crocodile cracking – closely spaced, interconnected cracks forming scale-like polygons**

**Figure 5.5: Diagonal cracking – unconnected cracking stretching diagonally across the pavement**

*Source: Austroads (2019a).*

**Figure 5.6: Longitudinal cracking – longitudinal cracks along the pavement; sometimes alone, in parallel series, or with limited branching**

**Figure 5.7: Meandering cracking – irregular, unconnected cracking in the pavement**

**Figure 5.8: Transverse cracking – unconnected crack stretching across the pavement**

**Figure 5.9: Corrugation – transverse undulations/rows of surface bulges**

**Figure 5.10: Depression/heave – depressions or bulges in the road surface**

**Figure 5.11: Rutting – longitudinal deformation in the wheel path**

**Figure 5.12: Shoving/plastic flow – bulging, horizontal deformation of the road surface (called plastic flow for asphalt surfaces)**

**Figure 5.13: Delamination – discrete section loss of wearing course**

**Figure 5.14: Flushing – excess appearance of binder at the pavement surface**

**Figure 5.15: Patching**

**Figure 5.16: Polishing – smooth, potentially shiny, rounded surface aggregates**

**Figure 5.17: Ravelling/fretting – progressive loss of both aggregate and binder from the pavement surface**

*Source: Austroads (2019a).*

**Figure 5.18: Stripping – aggregate loss from the pavement surface**

**Figure 5.19: Edge break – bituminous surfacing breaking away at the pavement edge**

**Figure 5.20: Edge drop-off – shoulder significantly lower than pavement edge**

**Figure 5.21: Pothole – rough, bowl-shaped pits extending through the wearing course and into the layers below**

**Figure 5.22: Spalling – fracture or disintegration of concrete at a joint**

**Figure 5.23: Faulting – permanent vertical separation of two slabs at a joint**

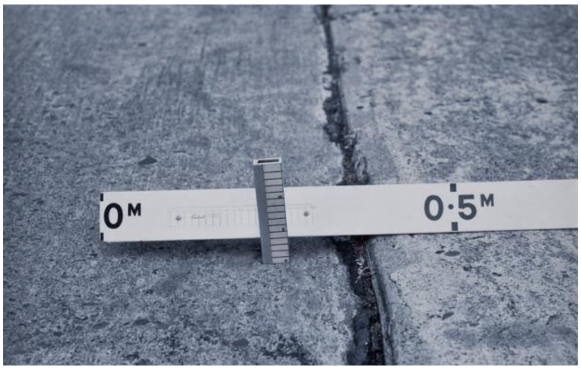



**Figure 5.24: Rocking – rocking movement of a slab under traffic**

Table 5.1: Types, causes and suggested remedies for pavement distresses

| Distress type | Likely causes | Repair strategy options | |
|---|---|---|---|
| **Cracking** | | | |
| Block | • Shrinkage or fatigue of an underlying bound layer<br>• Temperature effects, causing shrinkage in asphalt (can be due to hardening/aging of binder or poor binder choice) | • Crack filling<br>• SAM seal<br>• Reinforced seal<br>• Ultra-thin overlay | • SAMI or geotextile seal + asphalt overlay<br>• Cold plane + overlay<br>• In situ asphalt recycling |
| Crescent/ slippage | • Weak base<br>• Poor bond between surface and underlying layer<br>• Heavy braking or turning stresses<br>• Environmental causes (e.g. reactive subgrade or tree roots)<br>• Asphalt may have been dragged by screed during construction (If cracks are closely spaced/fine) | • Crack filling<br>• SAM seal<br>• Reinforced seal<br>• Ultra-thin overlay<br>• Heavy patching<br>• In situ asphalt recycling | • SAMI or geotextile seal + asphalt overlay<br>• Cold plane + thin overlay<br>• Reconstruct/remove and replace section where poor bonding or weak base is suspected |
| Crocodile | • Inadequate pavement thickness/structural design<br>• Increase in loading<br>• Poor construction<br>• Poor-quality base material<br>• Base or surfacing becoming brittle<br>• Loss of support in lower layers due to poor drainage | If occurring in conjunction with rutting or shoving, suggests pavement weakness requiring correction:<br>• Reconstruct/remove and replace the pavement<br>If no associated deformation: | |
| | | • Crack filling<br>• SAM or reinforced seal<br>• Reinforced seal<br>• Ultra-thin overlay<br>• Heavy patching | • SAMI or geotextile seal + asphalt overlay<br>• Cold plane + thin overlay<br>• In situ asphalt recycling |
| Diagonal | • Bituminous binder hardening/aging<br>• Shrinkage of slab during curing<br>• Construction joints, or reflective cracking from underlying joints<br>• Underground service settlement<br>• Intrusion of tree roots | • Crack seal<br>• SAM or reinforced seal<br>• Ultra-thin overlay<br>• Cold plane + overlay | • In situ asphalt recycling<br>• SAMI or geotextile seal + asphalt overlay<br>• Microsurfacing + geotextile seal<br>• Remove trees/roots |
| Longitudinal | • Reflective cracking<br>• Top-down cracking<br>• Surface layer fatigue or shrinkage<br>• Poor joint construction/location | • Crack seal<br>• SAM seal<br>• Ultra-thin overlay | • In situ asphalt recycling<br>• Microsurfacing + geotextile seal<br>• SAMI or geotextile seal + asphalt overlay<br>• Cold plane + overlay |
| Meandering | • Reflection cracking from bound base shrinkage<br>• Moisture in formation<br>• Inadequate or unstable slab or slab thickness<br>• Settlement of underground services<br>• Intrusion of tree roots | • Crack seal<br>• SAM or reinforced seal<br>• Ultra-thin overlay<br>• Cold plane + overlay | • In situ asphalt recycling + overlay<br>• Microsurfacing + geotextile seal<br>• SAMI or geotextile seal + asphalt overlay<br>• Remove trees/roots |

| Distress type | Likely causes | Repair strategy options |
|---|---|---|
| Transverse | • Thermal cracking (often low-temperature shrinkage)<br>• Top-down cracking<br>• Can be similar to diagonal/ meandering cracking causes | • Crack seal<br>• SAM seal<br>• Ultra-thin overlay<br>• Cold plane + overlay<br>• In situ asphalt recycling<br>• Microsurfacing + geotextile seal<br>• SAMI or geotextile seal + asphalt overlay<br>• Remove tree roots |
| **Deformations** | | |
| Corrugations | • Poor initial construction of base layer<br>• Inadequate asphalt mix or base material<br>• Excessive moisture in subgrade<br>• Local pavement failure | Remove and replace any unstable material before applying treatment:<br>• Asphalt, granular or cold overlay<br>• Seal shoulder to reduce moisture ingress<br>• Microsurfacing + geotextile seal<br>• In situ stabilisation<br>• Heavy patching<br>• Reconstruction |
| Depression/ heave | • Poor compaction allowing material settlement<br>• Inadequate drainage<br>• Moisture movement<br>• Inadequate material quality<br>• Embankment instability | • In situ stabilisation<br>• Heavy patching<br>• Improve drainage<br>• Seal shoulder to reduce moisture ingress<br>• Asphalt, granular or cold overlay<br>• Reconstruct/remove and replace section |
| Rutting | • Insufficient pavement thickness<br>• Weak subgrade, pavement or surfacing material<br>• Inadequate compaction/poor construction<br>• Water ingress<br>• Structural overloading<br>• Pavement at end-of-life/terminal condition | • Microsurfacing<br>• Thin asphalt surfacing<br>• Asphalt or ultra-thin overlay<br>• Granular resheet<br>• Deep lift asphalt<br>• Heavy patching<br>• Drainage improvements<br>• In situ asphalt recycling<br>• Cold plane to remove high points<br>• In situ stabilisation<br>• Reconstruction |
| Shoving/ plastic flow | • Inadequate surfacing or base material strength<br>• Poor bond between pavement layers<br>• Water ingress<br>• Lack of edge support<br>• High horizontal forces (e.g. frequent stopping of heavy vehicles) | • In situ asphalt recycling<br>• Cold plane and replace defective material<br>• Resheet shoulder (if due to unsealed shoulder)<br>• Drainage improvements<br>• Asphalt or granular overlay<br>• In situ stabilisation<br>• Heavy patching<br>• Reconstruction |

| Distress type | Likely causes | Repair strategy options |
|---|---|---|
| **Surfacing Defects** | | |
| Delamination | Poor bond between surfacing and underlying layers caused by:<br>• Poor sweeping of granular base before priming<br>• Insufficient prime or tack coat before upper layer placement<br>• Dislodgment of fragments from block or crocodile cracking<br>• Loosening of/weakness in layer underneath seal<br>• Binder adhesion to vehicle tyres<br>• Inadequate surface layer thickness<br>• Water ingress through cracks, weakening interlayer bonds | • Asphalt patching<br>• Cold plane affected layer and overlay<br>• Remove and replace affected areas and reseal |
| Flushing/ bleeding/ fatty surface | • Excess bitumen or cutter in wearing course/seal, prime coat or prior surface<br>• Aggregate penetration into a soft base<br>• Breakdown of aggregate<br>• Inappropriate asphalt grading, type or mix design<br>• Manifestation of underlying, old surface layer flushing<br>• Asphalt/seal laid before primer seal volatiles have evaporated<br>• Poor penetration of prime into granular base<br>• Oil and fuel spillages | • Reseal using specialist techniques such as pre-spraying outside wheel paths, sandwich seal<br>• High-pressure water removal<br>• Solvent treatment and add additional aggregate (for spray seal flushing)<br>• Cold plane, scrabble and groove (for fatty asphalt)<br>• Asphalt overlay |
| Patching | • Expedient patches are from repair of surface deficiencies (e.g. rutting, cracking, stripping, edge break)<br>• Reconstruction patches are from correction of pavement deficiencies, or servicing cuts | Patches do not necessitate further action, but indicate a more considered treatment, which for a systemic problem may be needed in the near future<br>Patches can be removed via structural or non-structural overlay |
| Polishing | • Inadequate polishing resistance of selected aggregate<br>• Naturally smooth aggregate use (e.g. water-worn gravel) | • Reseal<br>• Microsurfacing<br>• Ultra-thin overlay<br>• Asphalt overlay |
| Ravelling/ fretting | • Binder aging/hardening/oxidation<br>• Fuel or oil spill<br>• Poor mix design<br>• Poor compaction/construction defects from cold weather, or dirty/dusty/wet aggregate | • Reseal<br>• Slurry seal or fog seal<br>• Surface enrichment treatment<br>• Cold or asphalt overlay |

| Distress type | Likely causes | Repair strategy options |
|---|---|---|
| Stripping | • Incorrect amount of, or blending of bitumen and/or cutter<br>• Insufficient rolling of surface<br>• Poor binder-stone adhesion (dirty/dusty/wet aggregate or lack of pre-coat)<br>• Moisture ingress from voids in asphalt/primer seal interface<br>• Age hardening of binder<br>• Stone deterioration<br>• Temperature-susceptible bitumen<br>• Inappropriate stone size | • Binder enrichment or rejuvenation (where aggregate loss is limited)<br>• Reseal<br>• Remove and replace section |
| **Other** | | |
| Edge break & edge drop-off | • Inadequate road alignment/width resulting in trafficking of pavement edge<br>• Erosion of shoulder<br>• Vegetation growth at seal edge<br>• Omitted shoulder resheet following overlay | • Local pavement widening<br>• Seal shoulders<br>• Bitumen stabilised shoulders<br>• Resheet shoulders |
| Potholes | • Small defect worsening by water infiltration into base material<br>• Surfacing loss from other defects (e.g. ravelling, stripping, cracking, and/or delamination)<br>• Poor base material<br>• Load-associated disintegration of base<br>• Binder-adhesion and pick-up onto vehicle tyres | • Patching<br>• Reseal<br>• Asphalt overlay |

*Note: Some of the listed distresses can occur in either flexible or rigid pavements, namely: block, diagonal, meandering, longitudinal, and transverse cracking, and depressions. Rigid-pavement-specific distresses are given in Table 5.2.*

*Source: Adapted from Austroads (2019a).*

Table 5.2: Types, causes and suggested remedies for distresses specific to rigid pavements

| Distress type | Likely causes | Repair strategy options |
|---|---|---|
| **Cracking** | | |
| Spalling | • Infiltration of incompressible materials into joint or crack<br>• Weakened joint edge from overworking of surface<br>• Misaligned dowels<br>• Corrosion of rebars or dowels<br>• Subbase movement<br>• Poor-quality concrete aggregate | • Resealing<br>• Re-saw, or rout, + reseal<br>• Saw cut, or rout, + patch with thin bonded concrete<br>• Slab replacement |
| **Deformation** | | |
| Faulting | • Pumping of fines from subbase/subgrade<br>• Poor subbase/subgrade support<br>• Rocking | • Moisture control<br>• Slab undersealing<br>• Resealing joints<br>• Grinding/profiling<br>• Cross-stitching/ replacement<br>• Routing + sealing of cracks |
| Pumping | • Moisture ingress through cracks or joints with moisture sensitive subbase with high fine content | • Improve drainage<br>• Full-depth patch |
| Rocking | • Pumping of fines<br>• Poor subbase/subgrade support<br>• Differential support | • Rubblise/crack and seat + overlay<br>• Slab undersealing + overlay<br>• Reseal joints<br>• Grind surface<br>• Reconstruction |

## 5.1.3 Pavement Assessment Options

For maintenance work to be planned or scheduled and resources organised, the road and associated facilities are routinely inspected, and any defects noted.

While not all defects are serious, if the safety of traffic and road users or the serviceability of the road are impacted by any defects, corrective action should be taken immediately. If safety and serviceability are not in question, maintenance may be postponed.

The magnitude of a defect is generally measured in terms of the extent and severity of the defect's attributes (e.g. the width and depth of a seal edge break). Within their maintenance standards, authorities may define the magnitude (i.e. intervention level) at which maintenance should be undertaken for each type of defect and the time within which work should be undertaken. This facilitates the prioritising, planning and organisation of maintenance activities.

### Assessment process

A typical approach to assessing a pavement is given in Table 5.3.

Table 5.3: Pavement assessment stages to determine appropriate treatment

| Stage | Notes |
|---|---|
| 1 | Gain an understanding of the overall, current pavement condition by conducting programmed assessments of the road as part of routine network inspections:<br>• Identify and note roads clearly not in need of attention (this will assist in focussing resources on roads that warrant attention).<br>• Identify and note the presence of any defects on roads that may require attention. |
| 2 | Report recorded distressed pavements to the network manager or pavement engineer for their opinion on the apparent pavement distress. |
| 3 | Where defects are deemed to be of concern in stage 2, conduct a more detailed investigation on those pavements. This process would likely involve:<br>• pavement engineer/team visiting and investigating the site<br>• assessment of the type/s of defects present<br>• an understanding of the potential root cause/s of the defects<br>• deciding whether or not a treatment needs to be applied. |
| 4 | If the pavement engineer believes action should be taken and the root cause or appropriate treatment type is not immediately obvious then they should supply a detailed investigation for the distressed section to determine the mechanism causing the distress (this will help avoid application of ineffective/inappropriate treatments). |
| 5 | Based on the testing program outcomes, the pavement engineer will provide the necessary treatment program details for the distressed section. |

As mentioned in stage 4 above, determining the likely cause of the deterioration is an essential step in selecting and budgeting for the most appropriate maintenance treatment. Testing is used to establish the quality of the pavement and/or subgrade materials, and whether the pavement is adequate for the prevailing conditions.

## Assessment types

Assessment of a pavement typically begins with a visual inspection, wherein the typical pavement conditions and aspects (including the environment in which the road operates), along with the type and severity of any defects, are noted.

### *Visual Investigation*

*Visual assessment is the first step in assessing a pavement and should be used to short-list the likely causes of any evident faults or distresses.*
*Without a short-list, considerable resources can be wasted undertaking inappropriate pavement investigations.*

Along with a visual assessment, during a pavement distress evaluation it is important to consider the following:

- *Pavement type* – structure and materials (pavement/surfacing types); this includes the material properties (e.g. CBR, grading, moisture content, durability, density, viscosity, mix design, and Atterberg limits).
- *Pavement history* – construction practice/notes, prior maintenance and any prior rehabilitation.
- *Load factors* – pavement strength/stiffness, potential material breakdown/instability, design traffic loading, and any changes in trafficking conditions (including any record of use in detours that may have increased trafficking temporarily).

- *Environmental factors* – surrounding planting, surrounding land use and development, climate conditions, drainage systems and moisture/seasonal effects (including records of any sporadic events such as flooding).

Typical aspects to note when visually assessing a road are listed in Table 5.4.

**Table 5.4: Pavement aspects to consider during a visual inspection**

| Aspect | Considerations/notes |
|---|---|
| Binder aging/oxidation | • Aged/oxidised binder in the surfacing can be a major cause of pavement distress (especially for residential pavements).<br>• Old surfacings are more likely to be adversely affected by oxidation. |
| Cracking | • The type of cracking will assist in determining the cause of distress.<br>• The extent and severity of cracking should be noted visually, although can be assessed using automated survey devices.<br>• Unless severe, cracking will often not affect the ride characteristics of a pavement. |
| Deformation | • Deformations will generally influence the ride characteristics pf a road.<br>• Typically, deformations are measured manually by determining the maximum vertical displacement. |
| Drainage & services | • Drainage of moisture, both above and below the pavement surface, is essential in prolonging pavement life.<br>• It is important to note:<br>– kerb and channel/gutter condition<br>– pavement and shoulder crossfall<br>– existing surface drainage structures such as culverts or pipes<br>– condition and functionality of these structures<br>– existing subsurface drainage systems<br>– number of outlets<br>– table-drain fall<br>– any poorly backfilled/reinstated trenches, and/or leaking water mains.<br>• Defects due to drainage are not indicators of pavement failure, but rather of substandard work practices; as such, steps should be taken to ensure practices are improved. |
| Edge defects | • Edge defects are often noted where an unsealed shoulder is present.<br>• The magnitude of edge defects is measured manually. |
| Nature of road use/traffic | • Type and volume of traffic over the pavement life will assist in identifying the cause of distress.<br>• It is useful to note (e.g. make a 30-minute observation) the amount, and type of traffic using the road. This can be used with any available traffic data to assess if the traffic loading of the road has changed.<br>• Understand the time of day that traffic uses the road and the speed of traffic as this can have an affect (e.g. slow-moving or stationary traffic on spray seals in the afternoon when pavement temperatures are at their highest can cause flushing and pick up).<br>• Obtaining accurate traffic data (e.g. using traffic counters or classifiers) for a small expenditure is often a good investment, although care should be taken to ensure traffic counts are not affected by seasonal factors (e.g. grain-haulage operations). |
| Patches & potholes | • Patches and potholes can be indicators of the presence of services.<br>• These can also indicate the presence of previously poor performing pavement, or a badly oxidised surfacing. |

| Aspect | Considerations/notes |
| --- | --- |
| Road geometry & cross-section | • Road geometry may contribute to:<br>– the trafficking of unsealed shoulders<br>– the trafficking of the pavement edge<br>– channelised traffic flow (including at the centre of the road due to narrowness of the street or presence of side-of-street parking).<br>• Road geometry must be noted as it can disqualify potential treatments (e.g. steep crossfall and a pronounced crown can limit placement of overlays/resheets). |
| Shoulder condition | • Condition of the shoulder should be noted for its potential effect on:<br>– performance of the adjacent sealed pavement<br>– lateral support<br>– drainage.<br>• Aspects to note include:<br>– deformations (particularly rutting and shoving)<br>– crossfall<br>– material build-up<br>– erosion and edge drop. |
| Surface texture | • Assessment of surface texture should include:<br>– loss of surfacing materials<br>– level of macrotexture (Section 2.4.1) notes.<br>• Surface texture is not an indicator of pavement structural condition but can be useful in selecting a rehabilitation treatment where skid resistance is a major factor. |
| Surface/ pavement type | • Different types of pavements/surfacings can behave differently and, as such, certain behaviours can lead to particular defects. Knowing the type of pavement/surfacing can help short-list the possible causes of a given defect.<br>• The type of surfacing can influence the selection of rehabilitation treatments. |
| Topography | • Take note of surrounding topography (e.g. swampy areas, deep fills, cuts) to assist in determining the cause of distress. For example:<br>– distress at cut-to-fill locations may indicate poor subsurface drainage, or<br>– distress and deformation often occur in rock cuttings due to subsurface water being pushed into unbound layers. |
| Trees | • Make note of surrounding trees and other plantings near the pavement including tree types, sizes and proximity to the pavement. |
| Neighbouring land use | • The surrounding type and level of development can influence the choice of treatment. The presence of houses may mean that noise generated from the surfacing will be an issue. Industrial areas or areas where construction is taking place may mean a surfacing with a high resistance to shear stresses in needed. |

It is important to note that visual inspection, while a useful starting point, is limited. Though testing beyond visual assessment may appear costly, visual assessment can be very subjective and does lack insight into the material properties below the surface.

In some cases, there may be more than one defect coexisting together, or several causes of the apparent distress. As such, the use of automated road surveys, and in situ or laboratory testing may be necessary where pavement distress is extensive. Table 5.5 provides a consolidated list of pavement evaluation tests and surveys. Figure 5.25 to Figure 5.32 give visual examples of the different survey types.

**Table 5.5: Tests and survey types for pavement evaluation**

| Test/survey type | Property being assessed | Vehicles/tests involved | Suitable road type |
|---|---|---|---|
| Ride quality survey | Roughness | Ride quality testing (RQT) vehicle | Sealed/unsealed roads |
| Dilapidation survey | Video imagery<br>Roughness<br>Rutting<br>Surface texture<br>Cracking (ACD) | Network survey vehicle (NSV) with automatic crack detection (ACD) – optional | Sealed roads |
| Road network survey | Video imagery<br>Roughness<br>Rutting<br>Surface texture<br>Cracking (ACD)<br>Road geometry (GIPSITRAC) | NSV with ACD – optional | Sealed local roads |
| Strength testing | Deflection<br>Remaining pavement life<br>Pavement design overlay | Benkelman beam/deflectograph/ PaSE<br><br>Falling weight deflectometer (FWD),<br><br>Intelligent pavement assessment vehicle (iPAVe) | Sealed roads<br><br>Sealed/unsealed roads<br><br>Sealed arterial roads |
| Unsealed road testing | Video imagery<br>Roughness | Unsealed roads vehicle | Unsealed roads |
| Skid resistance testing | Skid resistance measured in Bp number<br><br>Skid resistance measured in SFC<br><br>Skid resistance measured in grip number (GN) | British pendulum<br><br>SCRIM<br>Intelligent safe surface assessment vehicle (iSSAVe)<br><br>Grip tester | Sealed roads |
| Surface texture measurement | Surface texture | Sand patch<br><br>NSV | |
| Visual condition assessment/ footpath survey | Video imagery | All-terrain survey vehicle (ATSV) | Footpaths |
| Materials testing – laboratory and field | Refer to the *ARRB Road Materials Best Practice Guide* | | |

Figure 5.25: Field measurements

Figure 5.26: Visual measurement of rutting

Figure 5.27: Multi-laser profiler for ride quality assessments

Figure 5.28: Pavement material testing

Figure 5.29: Sand patch testing (texture)

Figure 5.30: Travel speed deflectometer (iPAVe)

*Source: Victoria DoT.*

Figure 5.31: Intelligent safe surface assessment vehicle (iSSAVe)

Figure 5.32: Falling weight deflectometer


## 5.1.4 Pavement Maintenance Options

A number of techniques which are commonly used to repair various defects are described in Table 5.6. Before choosing a treatment, it is important to understand the defect being dealt with in order for the treatment to be most effective. Defects and suitable treatments are described in Table 5.1). For information on the specific materials used in each treatment, refer to ARRB *Road Materials Best Practice Guide*. For more detailed information on the treatments and techniques, refer to Austroads (2018b).

Table 5.6: Pavement repair techniques/treatments

| Repair technique/treatment | Description and considerations |
|---|---|
| **Pavement/subgrade repairs** | |
| Excavations/removal | • Excavation is removal of the pavement or subgrade layers.<br>• Excavate to the depth required to remove all unsatisfactory material and the sides of the excavation squared up and trimmed vertical.<br>• Where utility services could be intersected by the excavation, the service should be located using hand excavation.<br>• If the base of the excavation is wet or yielding, consideration should be given to the type of further treatment required, e.g. further excavation, use of a geotextile, stabilisation, or provision of a working platform made from rock fill or open granular with an impermeable capping layer.<br>• On completion of the excavation, all loose material should be swept from the base and the edges of the excavation and the adjoining surface and the base of the excavation compacted. |
| In situ stabilisation | • Treat deficient pavement by stabilising rather than excavating. Ensure it is the basecourse that needs repair and not a weak subgrade.<br>• For detailed information on the application of stabilised treatments refer to the ARRB *Road Materials Best Practice Guide.*<br>• Stabilisation is covered by AUS-SPEC Worksection *1113 – Stabilisation.* |
| Granular overlays/resheets | • Gravel or crushed rock overlays may be employed as a maintenance treatment for short sections of pavement which have deteriorated badly, as well as a rehabilitation treatment for longer sections. Removal of the existing surfacing is recommended to allow the movement of moisture through the pavement. |

| Repair technique/treatment | Description and considerations |
|---|---|
| **Asphalt or granular surface repairs** | |
| Cold planing (milling) (Figure 5.33) | • Technique used to remove surface layers to allow for excavation and overlays.<br>• Accurately and rapidly removes a specified thickness of an irregular pavement surface caused by distress such as rutting, shoving, surface corrugation or surface cracking.<br>• Most commonly, it is used to remove asphalt surfacing, but modern equipment can now mill heavily bound cementitious layers and plain concrete.<br>• Cold planing is covered by AUS-SPEC Worksection *1136 – Cold Milling of Asphalt and Base Course* |
| Asphalt or cold mix patching (Figure 5.34) | • Area to be repaired is removed to form a vertical face to the required depth along the edge of the existing surfacing material. The asphalt is then placed in the hole and compacted. Asphalt should be placed in layers between 3–5 times the nominal size of the mix being used e.g. 30–50 mm for a 10 mm mix.<br>• Any soft or yielding base material should be removed and replaced.<br>• The base and the edges of the area to be patched should be lightly and uniformly tack-coated with bitumen emulsion before filling with asphalt.<br>• To produce a smooth joint, the edges should be compacted first, with the compactor overlapping the existing surface. |
| Mechanised pothole and edge patching | • Patch using machinery specific for pothole and seal edge repairs. The machinery blows debris from the pothole, fills it with the patching material and compacts. |
| Crushed rock and gravel patching | • Replace excavated pavement materials.<br>• The gravel or crushed rock is placed in layers of usually no more than 100 mm and compacted and final layer trimmed if required to be flush with adjoining surface.<br>• The material should be brought to the optimum moisture content for the compaction equipment being employed.<br>• The surfacing materials should be selected so that the surface of the patch is as close as possible to the existing surface in texture and appearance. |
| Scarifying and reshaping or rip and remake | • When a sealed granular pavement becomes badly potholed or badly out of shape, it may be necessary to scarify and reshape it, adding more pavement material if required.<br>• The additional material may be added as an overlay or mixed into the existing material.<br>• The minimum compacted depth of material treated should be 75 mm. |
| Asphalt resurfacing/overlay | • Undertaken in order to correct surface deficiencies or to strengthen the pavement or used to upgrade a seal to an asphalt.<br>• It will partially restore surface evenness provided any underlying pavement or subgrade deformation has ceased.<br>• The thickness of asphalt applied is usually 40 mm or less. Overlays with a thickness greater than 40 mm which add significantly to the structural capacity of the pavement should be designed appropriately.<br>• Existing asphalt may be profiled before asphalt overlay is placed.<br>• An example of this type of treatment could be a thin asphalt overlay such as a small sized (7 or 5 mm) SMA or gap graded mixes.<br>• Asphalt resurfacing is covered by AUS-SPEC Worksection *1144 – Asphalt (Roadways)* |

| Repair technique/treatment | Description and considerations |
| --- | --- |
| **Sprayed seal repairs** | |
| Crack sealing (Figure 5.35) | • Cracks that are up to 20 mm wide or less are filled with a bitumen sealant either in a hot or emulsified form (modified or unmodified).<br>• For wider cracks, hot sealant is typically used.<br>• Dry filler is sometimes used to plug deep cracks over which crack sealing is undertaken.<br>• Polymer modified bitumen sealants are more expensive than the unmodified product but are less brittle and less likely to crack in cold weather. Also, they are less likely to soften and bleed in hot weather.<br>• Crack sealing of areas with a high intensity of cracking (e.g. crocodile cracks) should be avoided as this can be a costly option and the close proximity of the crack sealant can cause water ponding which presents a safety hazard. Patching or resealing should be considered instead. |
| Resealing | • Undertaken primarily to prevent further surface deterioration, such as potholing or stripping of aggregate from the surface.<br>• Particularly in rural areas, site establishment costs can be a significant part of the total cost of resealing. Consequently, the unit cost of resealing can often be substantially reduced if the work can be programmed so as to carry out a substantial length or number of reseals concurrently as a package or in conjunction with the sealing of new construction.<br>• Bitumen may be applied as a hot binder or an emulsion. For emulsions, two coats of aggregate (e.g. rack-in coat) may be required rather than a single coat.<br>• SAM or a reinforced seal to be used where cracking is extensive.<br>• Straight bitumen, cutback bitumen, emulsion, polymer modified binder, crumb rubber binder can be used, as well as geotextiles and fibre reinforced seals (described below).<br>• Refer to Austroads (2018b) for selection and design of re-seals.<br>• Resealing is covered by AUS-SPEC Worksection *1143 – Sprayed Bituminous Surfacing* |
| Geotextile reinforced seal | • Geotextiles are rolled out after applying a tack coat (unless self-adhesive) and covered by a 1 or 2 coat bituminous seal.<br>• For small maintenance jobs, e.g. less than 200 m in length, the geotextile may be applied manually. For larger jobs, the geotextile is placed using a roll dispenser attached to a loader or self-propelled multi-tyred roller. |
| Fibre reinforced seal (FRS) | • An emulsion PMB is sprayed onto the pavement, followed by a layer of chopped glass fibre and then a second layer of binder. The fibre and binder are locked in with an aggregate scatter coat.<br>• FRS can be used as a SAM or SAMI treatment. |
| Surface enrichment | • A light application of bitumen emulsion or a low-viscosity cutback bitumen is sprayed onto a surface which is lacking in bitumen or where the bitumen has deteriorated due to ageing.<br>• Generally, no cover aggregate is applied.<br>• Enrichment is not a suitable process for treating seals with a low texture depth.<br>• Surface enrichment is covered by AUS-SPEC Worksection *1147 – Pavement Preservation Surfacing* |
| Rejuvenation treatment | • Similar to enrichment, this process consists of applying a commercially available rejuvenator designed to improve the condition of an oxidised or hardened binder in an asphalt or bitumen sealed surface.<br>• The surface must be porous enough to allow the rejuvenator to be absorbed.<br>• Rejuvenation is also covered by AUS-SPEC Worksection *1147 – Pavement Preservation Surfacing* |

| Repair technique/treatment | Description and considerations |
|---|---|
| Slurry seals/microsurfacing (Figure 5.36) | • Involves the application of a mixture of fine aggregate and bitumen emulsion to the road surface by means of a specially designed vehicle which both mixes and spreads the material. In microsurfacing, the emulsion is polymer modified.<br>• The treatments will provide a smooth-textured surface similar to asphalt in a much thinner layer but will only correct minor evenness deficiencies.<br>• Slurry seals/microsurfacings are covered by AUS-SPEC Worksection *1146 – Microsurfacing* |
| **Concrete pavement repairs** | |
| Concrete pavement repairs | • Where a slab has settled, it may be raised by slabjacking, i.e. by using special equipment, and forcing a mortar consisting of loam, cement and water under the slab to raise it.<br>• Severe cracks may be repaired by cross-stitching, i.e. the insertion of tie bars into holes drilled at an angle to the surface into the concrete, which are then refilled with mortar.<br>• Joints between concrete slabs are sealed to reduce the infiltration of water and the entry of stones and other incompressible material, which causes spalling.<br>• Badly damaged areas, e.g. at slab corners, can be cut out using pneumatic tools and replaced with new concrete. The minimum area replaced should be one square metre. Also, any defective subbase or subgrade material should be replaced.<br>• Badly worn or damaged surface concrete can be replaced with new concrete after cutting back to provide a minimum depth of 20 mm. To achieve a good bond between the new and old concrete, the cutback surface is coated with a neat cement grout.<br>• Slippery concrete surfaces can be retextured using a cold-planing machine, scabbled, grooved or sealed with a bituminous seal.<br>• For further details of the defects and repair processes for concrete pavements, refer to *CCAA Concrete Pavement Maintenance/Repair* (2009).<br>• Concrete pavement repairs are also covered by AUS-SPEC Worksections *1621 – Concrete Pavement Repairs* and *1622 – Concrete Slab Stabilisation*. |
| Segmental pavement repairs | • Repairs usually consist of lifting the blocks over the affected area to restore the underlying layers and reinstating the blocks and replacing any of which are broken or damaged.<br>• Where the deformation is caused by tree roots, a root barrier should be installed, if possible.<br>• For further details, refer to CMAA (2014) and AUS-SPEC Worksection *1145 – Segmental Paving*. |

**Figure 5.33: Reclamation operation**

*Source: Victoria DoT.*

**Figure 5.34: Tack coating asphalt patch**

*Source: Victoria DoT*

**Figure 5.35: Crack sealing**

*Source: LGAM (2020).*

**Figure 5.36: Slurry seal**

## Unsealed shoulder maintenance

Many sealed roads have unsealed shoulders. Where unsealed shoulders are trafficked to any significant extent, they will require periodic grading and resheeting. Deficiencies in unsealed shoulders which may require maintenance include:

- an excessive drop-off at the seal edge due to attrition or erosion of the shoulder material
- a build-up of grass and dirt at the seal edge which impedes runoff of water from the sealed pavement
- ruts, shoving and potholes which will hold water
- scour channels
- loose or segregated shoulder material
- excess or insufficient crossfall.

Unsealed shoulder profile defects can be repaired by grading (Figure 5.37). The following should be taken into account when grading shoulders:

- Should be undertaken when the shoulder material has sufficient moisture to enable it to be compacted.
- Preferably a minimum 4% crossfall should be maintained on shoulders to facilitate drainage and keep excess moisture away from the pavement edge.
- When the shoulder is too dry, watering will be required prior to grading.
- Compact shoulder to help shed water and reduce infiltration and reduce grading intervals.
- Care should be taken in grading shoulders to avoid damaging the adjoining bitumen surface.

Resheeting of unsealed shoulders:

- Used where there are insufficient materials or when removal or replacement of the shoulder is required.
- When resheeting the shoulders, all grass and other vegetation should first be graded off and the existing material scarified if less than 75 mm is to be added.
- Water and compact shoulders.
- Care should be taken in resheeting shoulders to avoid damaging the adjoining bitumen surface.

**Figure 5.37: Grading of unsealed shoulder**


*Source: Victoria DoT.*

### Excavation and backfilling for maintenance of utilities

To install, inspect or repair a public utility service, a trench or 'road opening' (Figure 5.38) may be required.

In urban areas, reinstatement of trenches often represents the greatest cause of road roughness. Consequently, all road openings should be carefully backfilled, compacted and sealed by a competent and experienced works crew in accordance with local regulations.

As part of the administrative procedures of the service authority, the maintenance organisation should be advised of a proposed road opening. Many authorities require that such works be subject to an inspection and approval process to ensure that the work has been adequately carried out. Provision must be made for traffic flow while the work is in progress.

The general process for excavation and backfilling for maintenance of utilities is as follows:

1. Establish the location of the utility and any services in the vicinity (Section 4.6.1).
2. Trenches through an asphalt surfaced or concrete pavement are commenced by cutting the surface with, for example, a skid steer profiler or possibly a concrete saw or cutting disc before breaking out the pavement. Excavation in the vicinity of existing services should be by hand.
3. Where the excavated material is suitable for backfilling, it should be stacked in a neat and tidy manner and so that it does not block or wash into drainage lines. Unsuitable or excess material should be removed from the site. Expansive clay soils which shrink and swell with a change in moisture content are normally unsuitable for backfilling.
4. Backfill should be compacted in layers of no more than 100 mm compacted thickness using vibrating plate compactors, a small vibrating roller or handheld tampers. The material should be brought to the optimum moisture appropriate for the compaction equipment being employed. Asphalt should be compacted in layers between 3 and 5 times the nominal mix aggregate size.

Figure 5.38: A road opening

### 5.1.5 Reconstruction

Reconstruction is usually carried out when there are no alternative treatments available with which to repair the pavement economically or where maintenance and rehabilitation costs are excessive. Pavement reconstruction may be undertaken when existing pavements are severely distressed over significant lengths and/or the degree of structural or functional repair required with respect to overlay/resheet thickness is high enough to warrant a pavement reconstruction.

Reconstruction of an existing pavement will result in more significant disruption to residents than other rehabilitation treatments due to the duration of works required.

In considering reconstruction the following must also be assessed:

- provision for traffic (e.g. available detours)
- maintaining access to properties
- provision for residential parking
- services
- dust control
- maintaining drainage
- appropriateness of the pavement type
- available work area (more an issue in the construction of rigid pavements)
- weather effects
- completion time for each pavement type
- cost.

Issues which must be addressed in considering reconstructing a pavement include:

- costs associated with maintaining the existing pavement condition
- costs of reconstructing the pavement
- shorter-term treatments options
- how the costs of long- and short-term treatments compare.

If reconstruction is chosen it may be appropriate to also consider any other works that can occur concurrently such as:

- traffic calming
- improved stormwater
- additional service maintenance or provisions (telecommunications, gas)
- improved horizontal and vertical geometry and cross-section shape.

### 5.1.6 Drainage and Minor Culvert Maintenance

A road's drainage system, if not functioning as designed, can have significant adverse impacts on the pavement, roadside vegetation and/or local receiving waters. To minimise or mitigate the impacts on the surrounding environment, drainage systems must be maintained; however, maintenance must be conducted appropriately to avoid further impact on the environment.

Table 5.7 outlines some key aspects and activities to consider when maintaining different drainage systems. Examples of different drainage types are depicted in Figure 5.39 to Figure 5.44.

**Table 5.7: Drainage and minor culvert maintenance activities and considerations**

| Drainage type | Activities and considerations |
|---|---|
| Unlined surface drains (table drains, catch drains, diversion drains) | • Maintenance often involves scour repair and removal of vegetation, silt and debris.<br>• Scours in table drains require prompt attention to prevent serious damage. However, cleaning of table drains should only be done when necessary as it will promote sediment generation.<br>• It is preferable to leave the drains flat bottomed, wide and rough/irregular shaped (as opposed to smooth and steep batters).<br>• Remove silt and debris with a backhoe, excavator or grader.<br>• Material should be disposed of where it cannot cause silting or damage to roadside vegetation.<br>• Do not tip material onto fill batters (can cause slips).<br>• Vegetation in grassed drains should be controlled by mowing or slashing only, in situations where scour might occur from grass-cover removal.<br>• Scoured drains can be repaired by backfilling and revegetating.<br>• Synthetic woven fabric or jute mesh may be used to retain soil/mulch until vegetation is established.<br>• Concrete/stone-pitched/bituminous linings may be required to stabilise repaired drains.<br>• Placing obstructions (e.g. rocks) in a scour can undesirably increase the scour.<br>• Use geofabric mattresses in extreme scouring locations. |
| Lined surface drains | • Clear kerb and channels/gutters by sweeping.<br>• Check concrete, steel, stone-pitched and bituminous drain linings for any deficiencies and scours beyond the lining when cleaning. |
| Culverts | • Carry out culvert inspections prior to the wet season and following heavy rainfall.<br>• Maintain clear inlet and outlet conditions.<br>• Remove any silt and debris.<br>• Check for structural defects and subsidence (note for further investigation) not only in the culvert but also in the overlying pavement as this can be a sign of deterioration at the joints in the culvert units. |

| Drainage type | Activities and considerations |
|---|---|
| Pipes and pits | • Maintain clear inlet and outlet conditions.<br>• Remove any silt and debris.<br>• Check pipes for structural defects and subsidence (note for further investigation).<br>• Pits should be cleaned at least annually (before the start of a wet season).<br>• This can be done with a gully eductor/pump; this may result in the accumulation of silt, debris and polluted water which must be disposed of appropriately (consult state/territory regulations).<br>• Pipes can be purged of silt by using high-pressure water jetting to an access pit where it can then be removed by an eductor. |
| Cattle grids | • Check whether the landholder is financially/physically responsible for such work.<br>• Maintain clear inlet and outlet conditions.<br>• Remove any silt, dirt and debris.<br>• Repair/reweld of any loose grid bars (may require specialist welding techniques if rail lines have been used). |
| Subsoil drains | • Periodically check subsoil drain outlets.<br>• Check during wet periods whether the drains are operating.<br>• Vegetation, debris and silt should be removed from outlets.<br>• Replace any damaged or missing vermin-proof flaps/screens on the outlets.<br>• If drains have to be replaced or extended, the filter material should be checked against relevant standards. |

**Figure 5.39: Table drain**

*Source: LGAM (2020).*

**Figure 5.40: Catch drain**

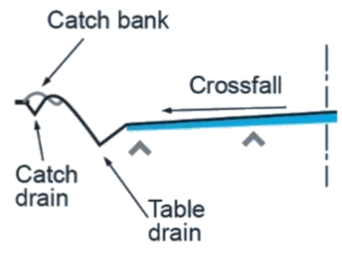



**Figure 5.41: Kerb and channel/gutter**

*Source: LGAM (2020).*

**Figure 5.42: Culvert/pipe drain**

*Source: LGAM (2020).*

**Figure 5.43: Drainage pit**

*Source: LGAM (2020).*

**Figure 5.44: Cattle grid**

*Source: LGAM (2020).*

### 5.1.7 Environmentally Sensitive Maintenance

Road maintenance includes all operations that are conducted along a roadside to maintain the riding surface of the road and to maintain the safety and aesthetics of the road. Care should be taken to ensure maintenance operations do not degrade the conservation value of the roadside and the surrounding environment. Environmental guidelines, suggested through roadside management plans, should be considered during road maintenance activities. Refer to Table 3.4 for environmental considerations for sealed road and roadside maintenance.

Table 5.8 gives some examples of routine maintenance activities with respect to the environment.

Table 5.8: Example routine maintenance activities with respect to the environment

| | Potential environmental risks | Example management guidelines |
|---|---|---|
| **1** | **Shoulder maintenance – unsealed shoulder grading and repair** | |
| 1.1 | Spoil can be dumped on, and smother nearby native vegetation. | Remove excess spoil and dispose to a designated dump site. |
| 1.2 | Grading in areas where there is excessive weed growth can lead to spreading of weeds. | Spray weeds prior to grading. |
| 1.3 | The fines within loose uncompacted materials (or windrow) left behind after grading can be transported via surface drains into nearby waterways. | Spread graded material over the road shoulder; undertake compaction and watering to eliminate windrow or remove excess materials from the roadside. |
| 1.4 | Siting and management of stockpiles has potential to affect runoff quality and waterways. | Stockpiles need to be bunded and sited away from remnant vegetation and waterways |
| 1.5 | Operation of machinery along road reserve. | Take care when moving plant. To avoid damaging native vegetation, do not move outside the 'maintenance envelope' zone. |
| **2** | **Drainage maintenance – restoring surface drainage grades; flows and positioning of discharge points; cleaning/installing/repairing surface drains, culverts and side-entry pits; repairing inlet/outlet scours; cleaning floodways etc.** | |
| 2.1 | Disruption of natural flows during drainage maintenance can divert flows away or into environmentally sensitive areas such as wetlands. | Minimise alteration to natural drainage patterns in establishing and maintaining road drains. |
| 2.2 | Diversion of sediment-laden runoff can affect water quality and erode watercourses, with consequent effects on aquatic biota. | Apply sediment control measures where sediment-laden drainage water will leave the worksite and have materials for additional erosion and sediment controls readily available. |
| 2.3 | Disturbance and reshaping surface drains can increase water velocity and scour, leading to sedimentation in nearby waterways. | Reshape table drains only when necessary and ensure drainage water is discharged safely into a stable environment and does not directly discharge to a waterway. |
| 2.4 | Spoil can be dumped on and smother nearby native vegetation and should not be disposed near waterways. | Direct spoil towards the road pavement and/or remove to a designated dump site. Do not spread onto native vegetation. |
| 2.5 | Any soil disturbance along the road reserve can affect remnant vegetation, spread weed seeds and encourage weed invasion. | Avoid using machinery outside the 'maintenance envelope'; avoid changing the ground level around existing native vegetation. |
| **3** | **Mowing and slashing – to restore sight clearances, drainage capacities etc.** | |
| 3.1 | Incorrect timing of mowing (e.g. late spring) can impede seeding of ground flora and destroy seedling trees and shrubs. | Where mowing is necessary in areas with native ground layer vegetation, schedule works for either early spring or late summer. |
| 3.2 | Machinery can spread weed seeds and pathogens. | Clean machinery prior to moving into areas of native vegetation, however, be careful where washdown water is discharged as this will contain weed seeds and sediment. |

| | Potential environmental risks | Example management guidelines |
|---|---|---|
| **4** | **Clearing and vegetation control – to maintain sightlines to signs and intersections, restore safety clearances etc.** | |
| 4.1 | Spray drift and/or runoff containing herbicides can damage native vegetation and waterways. | Avoid spraying on windy days; apply herbicide so that spray drift is contained. Any chemical spillage to be cleaned up and clean-up materials should be readily available on site. |
| 4.2 | Incremental clearing to retain sight distances can cause loss of habitat. e.g. loss of hollows as fauna nesting sites, soil disturbance, general loss of biodiversity due to tree and shrub removal or pruning. | When clearing is necessary, mark the limits of vegetation to be removed and clearly identify vegetation to be retained. Avoid felling trees into undisturbed areas. Avoid clearing vegetation in or near waterways. |

*Source: Adapted from ARRB (2003b).*

## 5.2 Safety and Maintenance Works

It is important to take into consideration the ongoing wear and tear on roads and changing surface conditions as these can be contributing factors leading to crashes. This section provides guidance on practical and low-cost techniques for improving road safety and reducing potential litigation. In the management of its road network, a prudent road agency will be able to demonstrate a duty of care, and that it has acted reasonably in addressing road safety issues.

### 5.2.1 Low-cost Safety Improvement Measures

Table 5.9 illustrates some low-cost countermeasures that can be considered to address safety concerns for hazardous locations. These are generally aimed at assisting motorists to drive to the conditions. These countermeasures are not exhaustive and may not always be appropriate for given situations. Sound engineering judgement needs to be employed when considering countermeasures to address hazards in the road network.

**Table 5.9: Low-cost countermeasures to address safety concerns**

| Issues | Contribution to crash | Possible countermeasures |
|---|---|---|
| Tight horizontal curves | • Most are well below the minimum radius for the prevailing operating speed.<br>• Inappropriate superelevation.<br>• Loose surface materials.<br>• Inadequate horizontal sight distance.<br>• Drivers often cut into the inside of a curve to help increase its radius and thereby maintain the desired speed. | • Place curve warning signs on all approaches to high-risk sites.<br>• Where a speed control sign is necessary then use a regulatory sign that has been approved, including vehicle activated signs.<br>• Provide guide posts and/or roadside vegetation around the outside of a curve to assist the driver to gauge the sharpness of the curve.<br>• Provide the required horizontal sight distance by removing or slashing roadside vegetation within prescribed limits.<br>• In some cases, batters may need to be cut back to provide sight lines.<br>• Consider sealing the inside edge of the curve. |

| Issues | Contribution to crash | Possible countermeasures |
|---|---|---|
| Sharp crests/ sag curves | • Inadequate vertical sight distance over a crest or sag to enable a driver to see and stop should there be a hazardous object on the road.<br>• Crests on single-lane two-way roads where drivers have little warning of an oncoming vehicle are particularly critical locations. | • Place standard crest road signs at critical locations where lowering the grade to provide the required sight distance is cost prohibitive.<br>• For single-lane two-way roads widen the roadway over the crest to provide a driver with greater manoeuvring space in case of encountering an oncoming vehicle. |
| Roadside hazards | • Roadside hazards on rural roads often include table drains and roadside vegetation consisting of large trees with diameter > 100 mm.<br>• Light poles or other utilities can pose a hazard if they are placed too close to the traffic lane. | • Check the clear zone requirements for the road.<br>• Provide a safety barrier.<br>• Drainage ditches should aim to have flatter slopes and rounded inverts to reduce the chance of rollover if a vehicle hits them.<br>• Provide adequate guide posts where there are deep table drains close to the roadway to provide better delineation of the roadside edge. |
| Sudden surprises | • Sudden surprises or inconsistencies along a road may catch a drive off-guard.<br>• These include features such as sudden dips, causeways, and a sharp curve at the bottom of a down grade or at the end of a long straight.<br>• Changes to road surface conditions or operations such as water on the road, loose gravel after grading or gravel testing trial sites etc. need to be known to a driver if it may affect behaviour or route choice. | • Install appropriate warning signs to alert drivers to changing road circumstances (including vehicle activated signs).<br>• Where a road suddenly narrows, these locations need to be clearly delineated to ensure drivers adjust to the road situation in time.<br>• Placement of road advisory signs may be necessary to alert a driver to changing circumstances. |
| Intersections | • Drivers may have a low expectation of meeting other vehicles and so tend not to slow down or look carefully for other vehicles when approaching an intersection.<br>• Inadequate sight distances and road signs to indicate an approaching intersection. | • Ensure that at all intersections the required sight distances and necessary road signs (including vehicle activated signs) are provided on approaches including advance warning if there is inadequate sight distance.<br>• In some cases, it is desirable to eliminate a crossroad by providing two staggered T-intersections to ensure that drivers do slow down when approaching the intersection. These can often be constructed within the existing road reservation at little cost.<br>• At T-intersections ensure that the intersecting angle is > 70°. |

| Issues | Contribution to crash | Possible countermeasures |
|---|---|---|
| Bridges/ causeways | • Road widths on bridges and causeways are often much narrower than the approaches; this can lead to a hazardous situation unless appropriately signed.<br>• The road alignment leading to a bridge/causeway can often be inconsistent with the preceding road standards and may cause drivers to not anticipate the changing circumstances.<br>• This can also be compounded by poor sight distances when approaching a bridge/causeway.<br>• Lack of the necessary signs to alert a driver to the approaching bridge/causeway can lead to difficulties in negotiating the crossing. | • Ensure that on all narrower bridges/causeways there are the required road signs to indicate a narrowing roadway and who has precedence if it is a one-lane two-way bridge.<br>• Ensure that there are adequate bridge barriers and guardrails where warranted.<br>• Good sight distances need to be provided on both bridge/causeway approaches to enable a driver to adjust to road alignment conditions.<br>• Particular attention is required at causeways/floodways so that the roadside edge has guide posts and, when necessary, a depth gauge for crossing the roads that are subject to flooding. |
| Maintenance activities | • Foreign materials on the road such as fallen trees, dead animals.<br>• Loose or slippery roads surface.<br>• Deformations in the road such as potholes, corrugations, rutting.<br>• Overgrown vegetation overhead restricting vertical clearances.<br>• Vegetation on the side of a road restricting driver sight lines around curves.<br>• Missing or damaged road signs, guardrails, guide poles, safety barriers.<br>• Loose gravel not adequately compacted during maintenance grading. | • As part of a road agency's asset management plan, regular road inspections should be undertaken to assess road conditions and identify safety hazards.<br>• Reports from the public on road conditions should be taken into account as they provide a valuable and ongoing way of monitoring network conditions.<br>• Intervention levels should be set for each road condition/hazard depending on the road classification and available resources.<br>• The list of works required should be prioritised and a maintenance program prepared based on the available resources.<br>• During grading operations ensure the appropriate 'grader ahead' signs are placed or other signs when roadworks are being carried out.<br>• If loose gravel is left on the road an appropriate sign should be placed on the road sections where this occurs until the road can be swept. |

### 5.2.2 Signs and Delineation

***Roadworks Signage***

***During maintenance and roadwork operations, traffic control devices necessary for warning, guiding and protecting the public and maintenance staff are essential.***

- *It is important to have good and consistent signage.*
- *Immediately following completion of the works, all temporary signs and safety devices must be removed from the site.*

### *Maintenance of Delineators*

*It is important to ensure guide posts (delineators on the posts) are maintained in a good condition as this is often the only delineation provided for road users.*

Table 5.10 outlines typical activities and considerations for the inspection and maintenance of road signs, line markings and delineating road furniture. The table does not provide in-depth instructions on any maintenance activities that may need to be carried out but is aimed at giving a general overview of some aspects and to be considered in planning and carrying out maintenance on these road features.

**Table 5.10: Maintenance activities and considerations for road signs and delineators**

| Road feature | Maintenance activities and considerations |
|---|---|
| Signs | • Inspect regularly and maintain signs to ensure visibility and legibility:<br>– inspect reflective signs at night for legibility.<br>• Prune any plants/branches obscuring visibility of the sign.<br>• Straighten signs and sign supports if required.<br>• Clean signs:<br>– flush dirt/abrasive particles from the sign with water before further cleaning<br>– avoid excessive rubbing as it can damage any reflective coatings.<br>• Repair or replace damaged signs (e.g. when illegible due to fading or are damaged by crashes or vandals).<br>• The location, height and orientation of signs should be checked against the requirements of AS 1742.3 *Manual of uniform traffic control devices*, or against state/territory manuals.<br>• Some minor damage to signs can be repaired in the field:<br>– holes in metal signs can have pressure-sensitive adhesive sheeting applied or filled with plastic filler<br>– holes in timber signs may be plugged with putty or wood filler<br>– dents may be removed by beating, using a hammer and dolly (or rubber mallet for reflective signs).<br>• Temporary signs must be removed when they are no longer needed e.g. warning signs once a road has been treated. |
| Road furniture | • Road edge guideposts should be inspected regularly and straightened, cleaned, repainted, and/or replaced as required.<br>• Delineators should be cleaned or renewed as required.<br>• Periodic night-time inspection of delineators to check reflectivity is desirable.<br>• Maintenance of fencing (including safety barriers) should include:<br>– repainting (if fencing is painted)<br>– replacement (if damaged from a crash ). |
| Pavement markings | • Road-centre markings, edge lines, transverse lines, chevrons, arrows, legends and painted medians should be renewed periodically.<br>• Markings may need to be restored as a result of patching or other maintenance activities.<br>• Road markings should be restored to the standard of the original markings and applied to a clean surfacing.<br>• Symbols should be restored using a template.<br>• Use reflective glass beads to enhance night-time visibility.<br>• Protect newly placed markings with traffic cones until dry. |

| Road feature | Maintenance activities and considerations |
|---|---|
| Raised markers | • The surface to which the marker is applied must be clean (remove all dirt and oil) and dry for good adhesion.<br>• Markers must be placed with full support over the whole of the base to avoid breakages. |
| Temporary markers | • Use temporary markers for delineation of lanes when existing line marking has been obliterated by resurfacing or patching (until permanent lane marking can be carried out). |
| Marking removal:<br>Markings are difficult to remove, and removal can alter the surface texture of the road (i.e. may leave a visible mark that could mislead road users). As such, removal should be carried out over a greater width than the marking to avoid confusion.<br>Removal can be performed by:<br>• grinding or milling on surfaces such as asphalt.<br>• chemical stripping for final cleaning of rougher surfaces.<br>• sand blasting. Note this is a slow process and produces hazardous dust that must be controlled.<br>It should be noted that these techniques can damage the road surface and shorten the life of the pavement. The preferred method of removal is to resurface the entire affected area. | |

*Note: Preparation of surfaces for paint and its application should be carried out in accordance with the paint manufacturer's instructions. Typically, this involves washing the surface, removing flaking paint/other loose material, wiping down with a dry cloth, and stopping up cracks/spot priming cracks and bare spots.*

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