FLEXIBLE PAVEMENT MAINTENANCE AND REHABILITATION

1. INTRODUCTION

1.1 Types of maintenance and rehabilitation activities

The maintenance and rehabilitation of flexible pavements involves a range of activities which may be categorised as:

- routine maintenance
- periodic maintenance
- rehabilitation.

Routine maintenance is concerned with minor activities required to slow down or prevent deterioration of a road pavement. It tends to be preventive as well as corrective and includes such activities as:

- crack-sealing
- pothole repair
- minor correction of surface texture deficiencies
- minor shape correction.

Periodic maintenance primarily involves preservation of the asset using thin surfacings to restore texture or ride quality, protect the surface against entry of moisture, or prevent deterioration through ravelling and weathering.

Rehabilitation includes major work carried out to restore structural service levels. As such, the treatments are corrective in nature and include:

- non-structural overlays
- structural asphalt overlays
- reconstruction or recycling of pavement materials, etc.

1.2 Importance of maintenance

An understanding of failures, as well as the ability to identify failure, is a prerequisite of good pavement maintenance. But why is pavement maintenance important?

Australia has a very large road network, made up of various roads from unsealed roads in state forests to national highways.

The magnitude of the road network, much of which is in remote and sparsely populated regions, imposes a heavy burden on all road authorities and is a very valuable asset.

Whilst many organisations are particularly conscious of the importance of high standards of pavement maintenance, roads may still be left in a state of disrepair. The long-term effect of neglect is a wasting of our national asset.

2. WHAT IS A PAVEMENT FAILURE?

In the case of most structures, failure hardly needs defining – it happens suddenly, it is very obvious, and it marks the end of the structure’s useful life.

Consider a suspended concrete slab. Simply support this at each end and then apply an increasing load at the centre. Eventually the concrete snaps and we have a “catastrophic” failure.

Whilst some pavement failures happen suddenly, in most situations a pavement gradually deteriorates. Perhaps a more typical example is a barge board on a house. If the board is left unpainted, gradually the paint deteriorates and cracks to the extent that it has to be scraped back and repainted. If the board is further left unattended, the board will eventually rot away and will be
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difficult and expensive to replace, in that some other components will also have to be removed and replaced.

To settle on a definition, let us refer to the term “pavement failure” as when the deterioration of a section of pavement reduces its serviceability and/or future usefulness such that remedial action is necessary.

Most primary failures result from weakness at one of three points in a pavement. These are:

(a) Surface Failures
Potholes, ageing, etc., which are generally shown by sharp edges or firm pavement without general distortion.

(b) Base Failures
Insufficient strength caused by bad design, overloading, or material change due to moisture or weathering. This failure is characterised by plastic deformation of the pavement. In advanced stages it may also be accompanied by crocodile cracking, followed by leaching of fine materials as deterioration increases.

(c) Bond Failures
Normally occur between bitumen bound layers, between bound layers or between a bitumen bound layer and the base course.

3. IDENTIFICATION OF DEFECTS

3.1 General

Descriptions and possible causes have been taken from the Austroads publication, *A Guide to the visual assessment of pavement condition*. A copy of it should be held by every maintenance engineer.

We now look at the normally experienced types of failures that are found in pavements. We can categorise the defects as:

- deformation cracks
- surface texture deficiencies
- edge defects
- potholes
- patches.

3.2 Deformation

3.2.1 General

Deformation is the change in a road surface from the constructed (intended) profile. Deformation may occur after construction due to trafficking (load associated) or environmental (non-load associated) influences. In some cases, deformation may be built into a new pavement owing to inadequate control.

Deformation is an important element of pavement condition. It may directly influence the riding quality of a pavement (roughness and water ponding leading to loss of skid resistance) and may reflect structural inadequacies. Deformation may lead to cracking of the surface layer. Several types of deformation may occur, the foremost of which are:

- Corrugations (DC)
- Depressions (DD)
- Rutting (DR)
- Shoving (DS).

These are described in detail in the following sections.

The dominant attribute is always vertical displacement. For reasons of standardisation and convenience, the vertical displacement is the maximum depth obtainable under a 1.2m straight edge (usually the depth at the point of maximum curvature).
The name code, as shown above, uses the letter “D” to identify deformation. The general form of the various defect types is illustrated at the end of this section.

3.2.2 Corrugations

(a) Descriptions

Corrugations are also known as ripples, and can be described as transverse undulations closely and regularly spaced, with wave-lengths of less than 2m.

(b) Possible Causes

- Inadequate stability of asphalt surface.
  Remedy: Plane out or grade off the surface and replace with properly designed asphalt.
- Inadequate stability of base course.
  Remedy: Plane out or box out surface and part of or all of the base and replace with suitable pavement material or full depth asphalt and resurface.
- Compaction of Base in wave form.
  Remedy: Remove surface, shape base, recompact base and resurface or correct and overlay.

3.2.3 Depressions

(a) Description

Localised area within a pavement with elevations lower than the surrounding area. May not be confined to wheelpaths and could extend across several wheelpaths.

(b) Possible Causes

- Settlement of service and widening trenches.
  Remedy: Cut traces either side of the settlement and resheet with asphalt, feathering into the traces.
- Consolidation of isolated areas of soft or poorly compacted subgrade or embankment materials.
  Remedy: Cut traces and resheet with asphalt.
- Volume change of subgrade materials due to environmental influences (eg. drying out owing to presence of trees or change in moisture contents of expansive soils).
  Remedy: If the sub grade material continues to change volume, particularly if it is expansive soils, box out and replace base and/or subgrade with better quality material or full depth asphalt. Attempt to eliminate any drainage problems and resurface the pavement.
- Settlement due to the instability of embankment.
  Remedy: Stabilise embankment and resheet depression as above.

3.2.4 Rutting

(a) Description

Longitudinal deformation in a wheelpath. The length-to-width ratio would normally be greater than 4 to 1. May occur in one or both wheelpaths of a lane.

(b) Possible Causes

- Inadequate pavement thickness.
  Remedy: Redesign pavement considering the economy of total reconstruction against the required thickness of asphalt overlay.
- Inadequate compaction in surface or base.
  Remedy: If the rutting is as a result of inadequate compaction of the surface and if the surface is 4 years or older (ie. limit of traffic compaction), correct and properly compact rut and overlay.
If the rutting is as a result of inadequate compaction of the base, proof roll, correct and overlay.

- Inadequate strength (stability) in surfacing or base.
  
  **Remedy:** If inadequate stability in surfacing the surface would also show signs of shoving and this mode of failure is covered later.

If inadequate strength in base the pavement would have to be redesigned and the economies of reconstruct as against sufficient thickness of asphalt overlay would have to be considered. Alternatively if the rutting was seasonal over one season, the drainage would have to be looked at.

### 3.2.5 Shoving

#### (a) Description

Bulging of the road surface generally parallel to the direction of traffic and/or horizontal displacement of surfacing materials, mainly in the direction of traffic where braking or acceleration movements occur. Transverse shoving may arise with turning movements.

#### (b) Possible Causes

- Inadequate strength in surfacing or base.
  
  **Remedy:** If inadequate stability in surfacing, remove affected areas and replace with properly designed surface.

- If insufficient strength in base, remove surfacing and base and resurface with adequately designed and good quality base and surface.

- Poor bond between pavement layers.
  
  **Remedy:** If the bond is between two layers of asphalt or between asphalt and seal. Remove the upper layer, texture the surface and replace the asphalt.

- If the bond is between the surface and the base, this may be due to too much slurry on the base or too much prime or an inadequate bond because the type of base or an insufficient matrix of bond by the tack coat to the stone. In this instance, take up the surface, tighten up the surface of the base with multi tyred roller, sweep thoroughly, apply tack coat and replace surface.

- Lack of containment of pavement edge.
  
  **Remedy:** Contain edge and replace.

- Inadequate pavement thickness.
  
  **Remedy:** Redesign road and look at the economy of reconstruction against adequate asphalt surface.

### 3.3 Cracks

#### 3.3.1 General

Cracks are fissures resulting from partial or complete fractures of the pavement surface. Cracking of road pavement surfaces can happen in a wide variety of patterns, ranging from isolated single cracks to an interconnected pattern extending over the entire pavement surface.

The detrimental effects associated with the presence of cracks are manifold and include:

- Loss of waterproofing of the pavement layers
- Loss of load-spreading ability of the cracked material
- Pumping and loss of fines from the base course
- Loss of riding quality through loss of surfacing
- Loss of appearance.

The loss of load-spreading ability and waterproofing will usually lead to accelerated deterioration of the pavement condition. Factors which lead to cracking include:
Crack patterns, alone or linked with deformation, are useful in assessing causes. As cracks promote water entry, they can be the primary cause of a range of secondary defects (deformation and potholes).

The name code, as shown above, uses the letter “C” to identify cracking. The general form of the various defect types is illustrated below.

### 3.3.2 Block cracks
(a) Description

Interconnected cracks forming a series of blocks, approximately rectangular in shape. Commonly distributed over the full pavement. Cell sizes are usually greater than 200mm and can exceed 3000mm. Joints in pavement layers may reflect through the surface layer and appear as rectangular blocks, particularly joints in concrete pavements overlaid with asphalt.

(b) Possible Causes

- Joints in underlying concrete layer.
  - Remedy: Thoroughly clean and heat the crack and apply a rubberised and/or latex modified bitumen based filler.
- Shrinkage and fatigue of underlying cemented and high compressive strength material.
  - Remedy: Thoroughly clean and heat the crack and apply a rubberised and/or latex modified bitumen based filler.
- Shrinkage cracks in asphalt surfacing owing to daily temperature cycles.
  - Remedy: Thoroughly clean and heat the crack, and apply a rubberised and/or latex modified bitumen based filler.
- Fatigue cracking in embrittled asphalt wearing course.
  - Remedy: Thoroughly clean and heat the crack and apply a rubberised and/or latex modified bitumen filler, which can be expected to form a stress relieving membrane band at the surface, then overlay.

### 3.3.3 Crescent shaped crack (slippage or shear cracks)
(a) Description

Half moon or crescent shaped crack, commonly associated with shoving, often occurring in closely spaced, parallel group. Mainly associated with asphalt.

(b) Possible Causes

- Poor bond between wearing course and underlying layers.
  - Remedy: Same as 3.2.5, Shoving.
- Low modulus base course.
3.3.4 Crocodile cracks

(a) Description

Also known as alligator cracks. Interconnected or interlaced cracks forming a series of small polygons resembling a crocodile hide. Usually associated with wheelpaths and may have a noticeable longitudinal grain. Cell sizes are generally less than 150mm across but may extend up to 300mm.

(b) Possible Causes

- Inadequate pavement thickness.
  Remedy: If localised problem remove pavement and replace with full depth asphalt. If evident on the majority of the road design an adequate overlay or, if overlay is uneconomical, look at insitu emulsion stabilisation or reconstruct.

- Low modulus base
  Remedy: If localised problem remove pavement and replace with full depth asphalt. If evident on the majority of the road, design an adequate overlay or if overlay is uneconomical look at insitu emulsion stabilisation or reconstruct.

- Brittle Wearing Course.
  Remedy: Overlay.

3.3.5 Diagonal crack

(a) Description

An unconnected crack which generally takes a diagonal line across a pavement.

(b) Possible Causes

- Reflection of a shrinkage crack or joint in an underlying cemented material.
  Remedy: Thoroughly clean and heat crack. Fill with rubberised and/or latex modified bitumen filler.

- Differential Settlements between embankments, cuts or structures.
  Remedy: Thoroughly clean and heat crack. Fill with rubberised and/or latex modified bitumen filler.

- Tree Roots.
  Remedy: Bearing in mind environmental ramification, attempt to remove the tree or root, and treat crack as previously mentioned. If the road has heaved, the root will have to be removed and the area reinstated. If it is not possible to remove the tree and the root, keep on filling the crack with rubberised binder.

- Service Installation:
  Remedy: Fill the crack as previously mentioned. If there is a depression, fill the crack, then correct the depression with asphalt remembering to key in the sides for feathering.
3.3.6 Longitudinal cracks

(a) Description
Crack running longitudinally along the pavement. Can happen singly or as series of almost parallel cracks. Some limited branching may occur.

(b) Possible Causes
(i) Occurring singly:
- Reflection of a shrinkage crack or joint in an underlying base (commonly portland cement concrete, cemented base or asphalt base)
- Poorly constructed paving lane joint in asphalt surfacing
- Daily temperature cycles or asphalt hardening
- Displacement of joint at pavement widening

(ii) Occurring as a series of almost parallel cracks
- Volume change of expansive clay subgrade
- Cyclical weakening of pavement edge
- Differential settlement between cut and fill.

Remedy: In all the above, thoroughly clean and heat the crack and then fill with a rubberised and/or latex modified bitumen filler. In the base where the crack is reasonably wide (10mm plus) and extends for a long distance (100m plus) it is possible to cut out the crack (150mm wide) and fill with a mixture of rubberised hot bitumen and hot aggregate to provide the movement required and eliminate the crack.

3.3.7 Meandering crack

(a) Description
Unconnected irregular crack, varying in direction, usually singly.

(b) Possible Causes
- Reflection of a shrinkage crack in underlying cemented material, or portland cement concrete, or certain fine grained granular materials
- Weakening of the pavement edge through moisture entry
- Differential settlements between embankments, cuts or structures
- Tree roots.

Remedy: In all the above thoroughly clean and heat the crack and fill with rubberised or latex modified bitumen filler. In the case of water ingress from the side of the road, remove that possibility (covered later in edge defects).

3.3.8 Transverse crack

(a) Description
Unconnected crack running transversely across the pavement.

(b) Possible Causes
- Reflection of a shrinkage crack or joint in an underlying base (commonly portland cement concrete or cemented materials).
- Construction joint or shrinkage crack (due to low temperature or bitumen hardening) in asphalt surfacing.
- Structural failure of portland cement concrete base.

Remedy: In all the above thoroughly clean and heat the crack and fill with rubberised or latex modified bitumen filler. In the case of water ingress from the side of the road, remove that possibility (covered later in edge defects). In the case where there has been a structural failure in the portland cement concrete base, remove the failure and replace with full depth asphalt.
3.4 Edge Defects

3.4.1 General

These defects occur along the interface of a bituminous surface pavement and the shoulder, and are most significant where the shoulder is unsealed. For convenience they are considered to be a defect of the bituminous surfacing and not of the shoulder material. They may occur locally or may be continuous over a length of road. These defects frequently happen on one side of the roadway, or on corners, or where the edge of the pavement is vulnerable to tyre wear and attrition. The detrimental effects of edge defects include:
- Reduction of pavement width
- Loss of quality of ride and possible loss of control of vehicle
- Channelling of water at the edge of the pavement leading to erosion of shoulder
- Water entry into base.

The principal defect types which are documented in the following are:

- Edge Break (EB)
- Edge Drop-Off (ED)

The name code, as shown above, uses the letter “E” to identify edge defects.

3.4.2 Edge break

(a) Description

Edge of the bituminous surface fretted, broken or irregular.

(b) Possible Causes

- Inadequate pavement width.
  
  Remedy: Carry out recount of traffic volume. If the volume warrants widening, then do so. If the volume does not warrant widening there are a number of options available as follows:
  
  (i) Patch edge with asphalt or cold mix or seal.
  
  (ii) Backfill shoulder to existing road surface level.
  
  (iii) Cut 150 mm wide by 100 mm to 150 mm deep, keying trench along the existing edge (trimming back to a true line of existing material). Back fill trench with full depth asphalt or plant manufacture (high quality) cold mix forming an edge beam. Then re-work shoulder to the correct level.

- Alignment which encourages drivers to travel on pavement edge.
  
  Remedy: Check the design alignment as well as superelevation. If the alignment is satisfactory or viable to be altered, erect physical barriers such as kerbing or road edge post and erect sign prior to the alteration, to draw public awareness to the changes.

- Inadequate edge support.
  
  Remedy: Construct shoulder and surface to correct alignment and/or construct edge beam.

- Weak seal coat, loss of adhesion to base.
  
  Remedy: Cut back seal to sound surface, repair base and reseal.

3.4.3 Edge drop-off

(a) Description

The vertical distance from the surface of the seal at the edge to the surface of the shoulder. Not usually considered a defect if the drop-off is less than 10 to 15mm.

(b) Possible Causes

- Inadequate pavement width.
  
  Remedy: Carry out recount of traffic volume. If the volume warrants widening, then do so. If the volume does not warrant widening, there are a number of options available as follows:
(i) Patch edge with asphalt or cold mix or seal
(ii) Backfill shoulder to existing road surface level
(iii) Cut 150mm wide by 100mm to 150mm deep, keying trench along the existing edge (trimming back to a true line of existing material). Back fill trench with full depth asphalt or plant manufacture (high quality) coldmix forming an edge beam. Then re-work shoulder to the correct level.

- Shoulder material with inadequate resistance to erosion and abrasion.
  Remedy: In situ stabilise existing shoulder material with emulsion or replace material with good quality material.
- Resurfacing of pavement without resurfacing of shoulder.
  Remedy: Tyne and add additional material and regrade and compact, preferably with an asphalt edge beam at the same time.

3.5 Surface texture deficiencies

3.5.1 General
Surface texture deficiencies cover loss of surfacing materials, loss of surfacing materials, loss of surface macrotexture and microtexture. While such defects do not usually indicate pavement structural inadequacy, they have a significant influence on the serviceability of a pavement (especially with regard to skid resistance and quality of ride). Some defects, if not corrected, may lead to subsequent loss of pavement structural integrity. Flushing may lead to binder pickup in hot weather.

The principal defect types, as documented in the following pages, are:
- Delamination (SD)
- Flushing (SF)
- Polishing (SP)
- Ravelling (SR)
- Stripping (SS).

“Delamination” describes a condition where distinct areas of generally uniform thickness of the wearing course are lost. It has the appearance that the wearing course is detaching from the underlying layer. The defect can occur in both sprayed seals and asphalt surfacings.

“Flushing” is a condition where the stone is immersed in the bitumen. It is a condition normally, though not necessarily, associated with sprayed seals and is characterised by a black smooth surface with very little texture. Stripping may also have this appearance, but the stone will be lost from the pavement rather than immersed. Flushing reduces contact between tyre and stone with a consequent loss of skid resistance. In hot weather it may lead to pickup of bitumen by tyres.

“Ravelling” has been used to define a condition where there has been a progressive loss of both binder and stone. The defect will have the appearance of the fretting away of both aggregate and binder. It is normally associated with asphalt surfacings. Ravelling may not be clearly distinguishable from delamination in sprayed seals.

The term “stripping” has been used to define the condition where the stone has been lost but the binder is intact. The defect is normally associated with sprayed seal surfaces. Pickup of bitumen by tyres may happen in hot weather.

The name code, as shown above, uses the letter “S” to identify a surface texture deficiency. The general form of the various defect types is illustrated below.

3.5.2 Delamination
(a) Description
Loss of a discrete and large (1–2 M²) area of the wearing course layer. Usually there is a clear delineation of the wearing course and the layer below.

(b) Possible Causes
- Inadequate cleaning or inadequate tack coat before placement of upper layers.
Remedy: If the surface is on a previously sealed surface, remove the surface, clean, tack and replace.

- Seepage of water through asphalt (especially in cracks) to break bond between surface and lower layers.
  Remedy: Consider crack sealing in line with section 3.3. However, failed areas should be removed, cleaned, tacked and replaced.

- Weak loose layer immediately underlying seal.
  Remedy: Remove underlying layer and fill with full depth asphalt.

- Adhesion of surface binder to vehicle tyres.
  Remedy: Overlay or remove and replace with a more stable surfacing material.

- Polished or heavily painted host surface.
  Remedy: Remove affected area, texture surface and replace with new surface.

3.5.3 Flushing

(a) Description
Immersion, partially or completely, of the aggregate into the bituminous binder causing low texture depth and inadequate tyre-to-stone contact.

(b) Possible causes
- Excessive application rate of binder, with respect to stone size
- Excessive prime coat being incorporated into the seal
- Excess binder in underlying surface (patch or flushed area)
- Penetration of aggregate into base (low strength base)
- Primer seal covered before volatiles in primer binder have evaporated.
  Remedy: There are a number of options available listed as follows:
  (i) Spread and compact hot aggregate (170° plus) to affected area
  (ii) Overlay with high void dense or open graded asphalt
  (iii) Remove and replace
  (iv) In cases where the aggregate has penetrated the base, (i) and (ii) are options. However, if you are to choose option (iii) the base will also have to be removed and replaced.

3.5.4 Polishing

(a) Description
Smoothing and rounding of the upper surface of the roadstone, usually occurs in the wheel tracks. Identified partly by relative appearance and feel of trafficked and untrafficked areas. Polished areas will feel relatively smooth and will sometimes be noticeably shiny. The quality of polishing cannot be quantified by observation.

(b) Possible Causes
- Inadequate resistance to polishing of surface aggregates, particularly in areas of heavy traffic movements, or where high stresses are developed between surface and tyres (eg. corners, grades).
- Use of naturally smooth uncrushed aggregate (eg. waterworn gravel).
  Remedy: Resurface bearing in mind that the surface may require texturing prior to overlay or reseal.
3.5.5 RAVELLING
(a) Description
Also known as fretting. Progressive disintegration of the pavement surface by loss of both binder and aggregates.

(b) Possible Causes
- Deterioration of binder and/or stone
- Inferior asphalt mix design
- Inadequate compaction, construction during wet or cold weather
- Hydrophilic aggregates.
  Remedy: Clean and correct prior to resurfacing. Severe areas may require removal prior to resurfacing.

3.5.6 Stripping
(a) Description
Removal of the coarse aggregate of a sprayed seal leaving the binder exposed to tyre contact – can happen as the loss of individual stones, or as the complete loss of stone in a localised area.

(b) Possible Causes
- Low binder contents.
- Poor binder to stone adhesion (dirty or hydrophilic aggregates, without effective precoating with adhesion agent or wet stone etc.).
- Ageing or absorption of binder.
- Stone deterioration.
- Incorrect blending of binder.
- Inadequate rolling before opening the seal to traffic.
  Remedy: Clean out, correct bad areas and resurface. If failures are isolated, treat those areas only.

3.6 Potholes
3.6.1 General
Potholes are bowl-shaped depressions in the pavement surface resulting from the loss of wearing course and base course material. They generally have sharp edges and nearly vertical sides at the top of the hole. Potholes are produced when traffic abrades small pieces of the pavement surface (cracking, delamination etc.) allowing the entry of water. These spots disintegrate because of the weakening of the base course or poor quality surfacing. Free water collecting in the hole and the underlying base accelerates its development.

Only one defect type is recognised in this category. The symbol “HO” is used to code potholes.

3.6.2 POTHOLES
(a) Description
A steep sided or bowl shaped cavity extending into layers below the wearing course.

(b) Possible Causes
- Loss of surface course.
- Moisture entry to base course through a cracked pavement surface.
- Load-associated disintegration of base.
- Pickup of bitumen wearing surface caused by binder adhesion to tyres.
3.7 Patches

3.7.1 General
A patch is a repaired section of pavement. It may or may not be associated with either a loss of serviceability (apart from a loss of appearance) or structural capacity. The extent and frequency of patching can be useful indicators of the structural adequacy of the pavement.

Patching usually takes one of the two following forms.

- Expedient patches
- Reconstruction patches.

Expedient patches are surface repairs without digout. The deficiency could include deformation cracking, stripping, edge creak, etc. An expedient patch will usually not be straight sided.

Reconstruction patches are where material has been removed and reconstructed. The repair may be confined to the surfacing course or extend to all courses. Reconstruction patches will usually be straight sided. The reasons for the reconstruction patch could vary from the need to correct a pavement deficiency, to the provision of a trench for services.

Defects can occur within a patch, or the patch can be a further defect where it is raised or depressed below the level of the pavement. When a defect happens within a patch, the cause of the defect may not be attributable to unpatched areas. Where such a defect occurs it is important that the description identifies that the defect is within a patch.

A two letter name code “PA” is used to identify patches.

Where a distinction is sought between expedient and reconstruction patches, the codes PE (expedient) and PR (reconstruction) could be adopted.

3.7.2 Patch

(a) Description
An area of pavement surface where the original has been replaced. Expedient patches (PE) are identified as irregularly sided, usually small patches (a few square metres or less). Reconstruction patches (PR) are usually straight sided.

(b) Possible Causes

- Correction of surface deficiencies (PE)
- Correction of structural deficiencies, within surface course, pavement or subgrade. (PR)
- Excavation for services. (PR)

Remedy: A patch can only be considered a failure in itself when it fails or is carried out incorrectly. If so, re-do the patch correctly.

4 PATCHING TECHNIQUES

4.1 Introduction
Probably the most common maintenance activity and the least supervised is routine patching.

Regular and detailed pavement inspection should be made to enable patching to be carried out as early as possible to minimise the size of patch required.

4.2 Patching Materials
There is a wide range of materials available. Each has its purpose, advantages, and limitations. Some of these materials are:
4.2.1  Hot mix asphalt

Hot mix asphalt is generally superior to cold placed products for pavement repair. Its strength, serviceability, and durability is dependent on the quality of the mix, adequate layer thickness, and sufficient compaction whilst still hot. Under these conditions its full strength is quickly achieved and it will not pick up or move under traffic.

4.2.2  Cold mix

Cold mix may be dense graded, semi-dense graded or open graded using cutback bitumen, fluxed bitumen or bitumen emulsion binder.

Cold mix binders enable the mixture to be workable at ambient temperatures and remain effective after storage in stockpiles for long periods. After initial compaction, it depends mainly on a physical interlocking of the matrix, as well as support from the sides of the patch to maintain shape. As the binder cures, the mix assumes properties similar to hot mix. However, the rate of curing is dependent on the thickness, ambient air temperatures, and type of binder and it may take several months for the mix to harden in situ. Consequently, cold mix is suitable for pothole patching and large emergency patching. In the latter case, it should be replaced as soon as possible with hot mix asphalt.

4.2.3  Bitumen emulsion

This is normally readily available. Pot hole patching may be undertaken by building up layers of aggregate and bitumen emulsion. This is a useful technique where plant mixed materials are not available. A particular form of emulsion patching is undertaken using specialised patching machines that apply a controlled mixture of bitumen emulsion and aggregate. Bitumen emulsions may also be used for crack sealing as well as sprayed seal work.

Bitumen emulsion may be either anionic or cationic, depending on the electrical charge of the emulsified droplets. Anionic emulsions are more suited for acid aggregates, such as limestone, whereas cationic emulsions are suitable for alkaline aggregates, such as basalts, dolerite, etc. Emulsions used for crack sealing generally contain rubber or polymer modifier.

4.2.4  Crack filling materials

Cracks in pavement can be filled by a number of proprietary products. Some material can be poured and/or handled at ambient air temperatures; others require heating. Normally they are a blend of bitumen, liquid latex, rubber and a filler. It is important to remember that regardless of what is used to fill the cracks, the cracks must be cleaned out properly in the first instance.

4.3  Patching Techniques

The patching operation must be carried out correctly. This involves four steps:

• Preparation
• Priming
• Placing
• Compaction.

The areas of patches vary in size from small potholes to several hundred square metres covering the full width of the roadway. The technique and equipment used will depend upon the size of the patch but the principles are the same.

4.3.1  Preparation

Holes should be cleaned of all loose aggregate and dust. The edges of the hole are cut back to sound material and the side cut vertically, in order to provide shoulders against the movement of the patch, and the bottom is squared. If the base is unsuitable or soft it should be removed and replaced with stable material (preferably with similar or better materials to those in the original construction). The surface shape of the patch should be squared up to provide a neat appearance to the public and also to promote pride of workmanship in the maintenance crew.
4.3.2 Priming

The sides and bottom of the hole are then lightly primed with bitumen emulsion or cut back bitumen, whichever is available. Too much prime should be avoided, as it may lead to shoving of the patching mix.

4.3.3 Placing

Premixed patching material is then placed in the hole. If the patch is more than 50 mm deep it should be filled in two or more layers and each layer tamped or rolled.

For thin patches, the depth of the patch should be at least three times the normal size of the premix. Sufficient material should be placed in the hole so that the surface of the compacted patch is slightly higher (normally about 3 mm to 6 mm for deep patches) than the adjacent area, to allow for further traffic compaction.

When placing cold plant mix, it should be thoroughly aerated (without segregation) before compaction to remove some of the flux oil. (In general, the amount of flux oil should be reduced by about 50% of that in the cold mix as produced.)

Depending on the size of the patch, levelling can be done either by hand raking, or with a grader, a pull type drag, or even a paver. Around the edges of the patch, all aggregate larger than the feather edge should be removed so that the edges of the patch can be raked and rolled to a smooth junction with the old surface.

4.3.4 Compaction

Compaction of the patching material is very important. Small holes can be hand tamped and at least compacted by rolling with the wheel of the truck delivering the mix. A vibrating plate compactor is excellent. Larger patches should be compacted by a roller.

When using cold mix, some authorities finish up with a light application of sand or lime to close the top of the patch and prevent the mix picking up under traffic.

4.4 Surface Rehabilitation

From time to time bituminous pavements require resurfacing, since bitumen oxidises with prolonged exposure to air and light and so hardens progressively until cracking occurs.

4.4.1 Resheeting

The application of a new surface course of asphalt. It is normally machine laid and so automatically improves the surface shape and well as providing a dense skid-resistant surface. The total pavement is strengthened by adding thickness. By proper assessment of the existing pavement strength and loading conditions the thickness of the overlay can be designed to provide the required additional pavement strength to extend the life of the total pavement. Life of asphalt can be expected at about 20 years and with some careful mix design in low volume roads this life could be stretched to 30 years.

4.4.2 Resealing

Normally refers to resurfacing with spray seal, usually a single coat of bitumen followed by one or two applications of aggregate. Generally hot bitumen is used, but emulsion can be used. Asphalt should be used to correct pavements prior to resealing.

Life: 
- Hot Bitumen: 9–12 years
- Emulsion: 7–10 years

4.4.3 Slurry sealing

The application of a cold slurry mix of fine aggregate, slow setting bitumen emulsion, and water, usually about 10mm thick. It is designed to fill up surface cracks in a pavement with a sound base to postpone the need for more costly surface treatment.

Life may be expected to be from three to ten years, depending on traffic intensity.
4.4.4  Surface enrichment

Surface enrichment involves a light application of bitumen emulsion, cutback bitumen or proprietary (typically 0.5 L/m²) without cover aggregate. In some cases, a light covering of sand or clean grit may be used to prevent pick-up. Surface enrichment is used on aged and oxidised surfaces to replace binder in sprayed seals or extend the life of asphalt surfacing.

4.4.5  Hot-in-place recycling

Asphalt is heated, scarified and mixed with rejuvenating agent, with or without additional asphalt material, to treat to aged asphalt pavements. Success of treatment depends on the asphalt materials being recycled, added materials and control of the recycling process.

4.4.6  Pavement profiling

The use of pavement profiler to remove worn, oxidised, aged or out-of-shape pavements is now very common for correction of poor surface conditions and making the pavement suitable for resheeting or resealing.

4.5  Drainage

It is not within the scope of this course to cover drainage. However, the importance of proper drainage to the performance of flexible pavements cannot be over emphasised and may well be a significant factor in any repair treatment.

5  CONCLUSION

The cost of pavement maintenance is normally considered in direct terms – the indirect cost of inadequate maintenance is measured in terms of public inconvenience, fuel usage, vehicle maintenance, and road safety. These costs are not insignificant and add weight to the need for timely and proper pavement maintenance.

Patching must be done promptly and properly – it requires skill, close supervision, and good quality patching materials.

REFERENCES

ARRB Transport Research, *Sealed Local Roads Manual; guidelines to good practice for the construction, maintenance and rehabilitation of pavements*, ARRB TR, 1995

Rutting  Shoving
Depression  Corrugation

Edge break  Edge drop off

Block  Edge  Corner  Longitudinal
ROAD
Meandering  Diagonal  Transverse
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#### Diagrams of Pavement Defects

<table>
<thead>
<tr>
<th>Meandering</th>
<th>Transverse</th>
<th>Longitudinal</th>
<th>Diagonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>Crocodile</td>
<td>Crescent shaped</td>
<td></td>
</tr>
</tbody>
</table>

Source of diagrams: Austroads ‘Guide to visual assessment of pavement condition’
## APPENDIX  GENERAL PAVEMENT REPAIRS

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>REMARKS/ACTION/TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNSEALED PAVEMENTS</strong></td>
<td></td>
</tr>
<tr>
<td>Erosion of material by wind</td>
<td>Moistening such areas with a water cart will give passing relief and reduce public nuisance, traffic hazard, damage to crops as might apply.</td>
</tr>
<tr>
<td>and slip stream, dust</td>
<td>Application of a water-bitumen emulsion mixture can have more lasting effect particularly on lightly trafficked roads. Recommended dilution of 1 litre of slow break emulsion to 5 litres of water, or more depending on porosity of surface.</td>
</tr>
<tr>
<td>nuisance, etc.</td>
<td></td>
</tr>
<tr>
<td>Potholes/scour</td>
<td>Causes include use of poor materials, segregation while working on material, insufficient compaction due to improper moisture content, insufficient rolling or too light a roller.</td>
</tr>
<tr>
<td><strong>SEALED PAVEMENTS</strong></td>
<td></td>
</tr>
<tr>
<td>Potholes/failed areas</td>
<td>Identify and remove the cause. Basic practices must normally be:</td>
</tr>
<tr>
<td>For sprayed seal surfaces</td>
<td>(a) Excavate to level of sound material.</td>
</tr>
<tr>
<td></td>
<td>(b) Ensure sides of the hole are vertical and compact bottom</td>
</tr>
<tr>
<td></td>
<td>(c) Make up with pavement material to within 25 mm to 40 mm of surface properly moistened.</td>
</tr>
<tr>
<td></td>
<td>(d) Apply bitumen emulsion tack coat to sides of hole.</td>
</tr>
<tr>
<td></td>
<td>(e) Spread and compact cold mix or asphalt to surface level. Alternatively, where cold mix is not available, bring the compacted material up to seal level and apply a one-coat hot seal with stone cover or a two-coat bitumen emulsion and stone seal.</td>
</tr>
<tr>
<td></td>
<td>(f) Use of cement modified water bound material where time limit demands to provide a quick set.</td>
</tr>
<tr>
<td>For asphalt surfaces</td>
<td>(a) Excavate to level of sound material.</td>
</tr>
<tr>
<td></td>
<td>(b) Ensure sides of the hole are vertical and compact bottom</td>
</tr>
<tr>
<td></td>
<td>(c) Make up with pavement material if excavation is more than 50 mm approximately below underside of asphalt surfacing.</td>
</tr>
<tr>
<td></td>
<td>(d) Apply bitumen emulsion tack coat to sides of hole.</td>
</tr>
<tr>
<td></td>
<td>(e) Spread and compact cold mix or asphalt to surface level. Mix should normally be pieced in two layers if hole exceeds 50 mm in depth to achieve a good final surface shape.</td>
</tr>
</tbody>
</table>

Source of diagrams: Austroads ‘Guide to visual assessment of pavement condition’

free draining to side or table drains. The problems should be identified and corrected. Grader drivers should understand their role and be made to form to correct profiles.
Edge Breaking/ Fretting

General causes stem from lack of shoulder support to the seal edge or deformation of asphalt pavement edge due to excessive moisture content. Wear and scour are commonly responsible for the erosion and water bonding which readily identify the condition. However, poor shoulder profile and bed drainage, while more controllable, can cause the most serious damage of deformation. Restrict the causes with correctly-graded profiles and effective drainage. Deformation leads to costly reconstruction. Early action will enable the repair of damage with cold mix/asphalt make-up. The procedure should be generally as above - see (a) to (e) above. Such asphalt in depth at edges will support a pavement in scouring conditions.

Wear and tear on shoulders and pavement edges can be considerably reduced through the influence of painted edge lines.

Cracks or Crazing

Causes are numerous. viz:

(a) Ageing of bitumen binder - reduces ductility and reduces brittleness. Identified in advanced stages as crazing with possibly some stone loss. Earlier detection possible by prising of stones from the surface and visually assessing bitumen ductility.

(b) Shrinkage of sub-grade and/or pavement material - reduced ductility of bitumen will be seen as cracks of any length in even a permanently good seal, say upwards of three years approximately. Readily identified by slick of mud which sluiced from the pavement in wet conditions. In an advanced stage will be recognised (and felt) as actual depression in the surface where seal recedes into the crease formed by material loss. Calls for multiple layer asphalt treatment - a coarse open mix to insulate and a dense wearing course to seal.

(c) Reflection stresses from sub-surface structures, eg: concrete culverts, bridge abutments, lintels, etc. Expansion and contraction behaviour with temperature will induce cracking which requires sealing at earliest.

(d) Deformation of pavement – induces fracture cracks recognisable as close spaced longitudinal cracking or tight crazing often accompanied by distortion of pavement shape. Caused by insufficient pavement strength or subgrade nearing capacity for loads being carried. Often results from faulty drainage system, or inadequate sub-soil drainage. Keep agricultural pipes cleared and table drains formed.

Treatment to contain deterioration until re-surfaced with asphalt or bitumen as applicable or as funds permit.

(a) Advanced ageing cracks and shrinkage and reflection cracks are best treated with latex doped bitumen emulsion which exhibits a high degree of elasticity and can cope with the continuing movement at such cracks. Early signs of ageing can be offset with emulsion or bitumen cutback dusted off with sand to prevent stick or slick.

(b) Distortion cracks call for pavement repair and re-seat normally, but if cause can be arrested before serious distortion occurs the above method of track sealing will often prevent further surface deterioration.

Aggregate Stripping, Ravelling

(a) Bitumen seals

Aggregate stripping can occur from one or more of the following causes:
1. Acidic stone which may not stick to bitumen readily. This can be prevented by precoating or use of adhesion additives to bitumen.

2. Vesicular stone which can absorb bitumen thereby reducing thickness of binding film. Precoating of stone will provide some assistance in the problem to pre-fill finer holes but extra bitumen can be sprayed to allow for that effect.

3. Absorption by pavements of sprayed bitumen thereby reducing thickness of binding film. Surface enrichment with successive coats of prescribed diluted emulsion may succeed in supplementing the depleted binder to hold stone in place.

4. Insufficient residual binder application for size or grading of stone can result from poor specification, under spraying 'missing' spray jets.

5. Improper atmospheric conditions for particular binder being applied, ie: bitumen fluxed for anticipated high air temperature will not so readily stick to stone it sprayed in significantly lower temperatures - firm intelligent supervision should be provided to make flux recommendations and to control procedures.

6. Wet stone or over damp pavements unless chemical additives in bitumen have been added to cope.

7. Insufficient controlled rolling of surface treatment allowing subsequent speeding traffic to shear stone off seal.

8. Aged or brittle bitumen allowing stone to break away enrichment or re-surfacing needed.

9. Dusty stone where bitumen sticks to dirt instead of stone - stone should be adequately precoated.

10. Insufficiently swept or wet pavement where binder with stone strips off pavement.

**Treatment** – Re-spray with binder at below normal rate and apply aggregate afresh or surface with open graded asphalt as well absorb free bitumen without itself becoming over bitumenised.

(b) Asphalt mix

Stone strips or erodes from hot asphalt mixes due to one or more of the following causes:

1. Insufficient compaction of the mix in place.

2. Rolling at too low a temperature which prevents sufficient compaction.

3. Aged asphalt where binder has become brittle and fractured.

4. Use of poor quality stone which crushes under traffic and breaks down with age.

The life of ageing asphalt can be prolonged with surface enrichment if carried out as soon as erosion is first apparent. If neglected, aged asphalt can reach a stage of high permeability where water admitted explodes the asphalt under tyre pressure to cause rapid disintegration. A thin overlay of asphalt should be applied when above symptoms are apparent to preserve asset.
(c) Cold mix

Cold asphalt mix ravel if not contained and accurately compacted. It is not good enough to just throw a shovel-full of cold mix into a surface depression or saucer shaped pothole. The material ends up anywhere but where it is needed. Maximum stone size and grading of mix should be related to depth of hole being patched. Maximum stone dimension should be not less than 1/3 to 1/4 of hole depth and should be 50% of mix.

Fat or bleeding areas

These occur as a rule where an excess of bitumen has been applied for the grading of stone cover. However, some result from stone wear when the condition is apparent as slickness. Correction is difficult. In small areas stone or grit preheated to approximately 95°C can be rolled in successfully on a hot day. Alternatively stone can be bound to road with binder sprayed at a rate less than normal, or ideally the area should be surfaced with open graded asphalt to absorb bitumen excess and provide a skid proof surface.

Joint reflection cracks

Bituminous surfaces fatigue rapidly at joints in concrete pavements, bridge decks, on bridge approaches and at culverts. etc. Special action can be taken to contain the problem as under:

1. Anticipate the crack(s) before they occur.
2. Locate the source with referable measurements.
3. Saw cut the asphalt over the joint. If expansion has to be accommodated make two parallel cuts.
4. Fill a single cut with rubber/bitumen emulsion
5. Fill a slot with, say, a hot-poured polymer modified bitumen joint sealer.

Re-surfacing

Need of re-surfacing treatments should be recognised and attended to before costly repairs are necessary and permanent reduction in riding qualities occur or surfaces become hazardous through lack of skid resistance.

Treatments can take the form of:

- Enrichment
- Spray reseal
- Slurry seal
- Asphalt

in that order of increasing cost (normally), but in the opposite order, probably, of economic performance.

Their general effects are as under:

Enrichment

- enriches (and supplements) ageing (or insufficient) binder to hold existing wearing course together for interim control.

Spray reseal

- reseals the road surface.
- provides binding medium for new stone
- aggregate wearing surface.
- does not improve surface shape.

Slurry seal

- provides new wearing surface.
- fills interstices in coarse surface to provide
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- finer texture.
- Provides only minor improvement in surface shape.

Asphalt
- provides new wearing surface of open or dense texture as specified in depths of up to 250 mm in one lift.
- corrects surface shape.
- increases load bearing capacity - may be laid in substantial thicknesses with very high strength.

Surface patching
Pavement deformation demands correction at the earliest to minimise damage to adjacent areas through impact of traffic. Areas should be overlaid or excavated and replaced depending on their nature, eg: due to secondary sub-grade settlement or pavement consolidation or alternatively caused by poor drainage or sub-grade properties when excavation might be necessary.

Large or continuing areas should be corrected with good quality asphalt, laid preferably by asphalt paver.

Small areas can be hand corrected with suitably designed quality cold mix of a grading and flux content which can be tailored for the purpose by way of maximum stone size, density of grading and degree of flux content.