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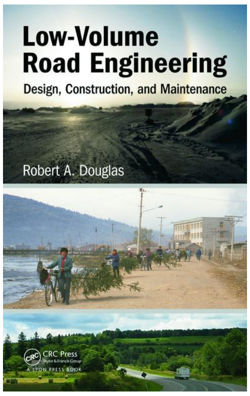

Low-Volume Road Engineering: Design, Construction, and Maintenance

Robert A. Douglas

Road maintenance

Publication details
https://test.routledgehandbooks.com/doi/10.1201/b19036-17
Robert A. Douglas
Published online on: 08 Dec 2015

How to cite :- Robert A. Douglas. 08 Dec 2015, *Road maintenance from:* Low-Volume Road Engineering: Design, Construction, and Maintenance CRC Press
Accessed on: 05 Jun 2023
https://test.routledgehandbooks.com/doi/10.1201/b19036-17

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Chapter 14

Road maintenance

14.1 INTRODUCTION

As noted in Chapter 1, agriculture, business, commerce, and communications all depend heavily on low-volume roads. The roads must be well maintained or these functions will suffer. Trips to schools, shops, and hospitals all depend on well-maintained roads [14.1]. In addition, an efficiently managed road network is a requirement for successful trading countries. Vast quantities of agricultural, mining, and manufacturing products are carried by trucks on roads, and the expectation of users is that the roads will be maintained to cope with the inevitable deterioration. Further, there is the expectation that any disruption to service will be minimal *during* maintenance operations.

Maintenance management has been called a matter of "doing the correct thing at the correct time in the correct place" [14.1].

14.2 MAINTENANCE ADMINISTRATION AND PLANNING

14.2.1 Administration

An agency's overall efforts to protect the capital investment in road infrastructure is distributed among reconstruction, rehabilitation (or remedial maintenance), and maintenance (or preventive maintenance) [14.2]. Reconstruction is a matter of completely replacing the existing pavement, rehabilitation is carried out to restore the existing road to its original condition, and maintenance is done to stop or retard—rather than reverse—deterioration. The typical distribution of effort between these three is presented in Table 14.1. The figures are approximate and highly dependent upon the individual circumstances of the agency. Note that roughly half the effort is devoted to pavements, with typically about a fifth of the effort put into road maintenance.

Road maintenance itself can be divided a number of ways.

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Table 14.1 Distribution of a road authority's work to protect road assets

Item	*Range (%)*	*Typical (%)*
New facilities pavement	10–60	30
Reconstruction	5–40	20
Rehabilitation	0–20	10
Maintenance	10–50	20
Bridge maintenance	0–10	5
Traffic management	0–10	5
Organizational management	5–20	10

Source: Lay, M.G., *Handbook of Road Technology*, 4th edn., Spon Press, New York, 933pp., 2009.

Giummarra [14.3], in Australia, identifies on-demand and preventive maintenance. Applied when a defect arises, on-demand maintenance is reactive. Defects are predicted well in advance, and actions recommended to reduce or to eliminate them in preventive maintenance. The approach used depends on the importance of the road to the network. Usually on-demand maintenance results in higher user costs (and inconvenience), whereas preventive maintenance usually requires higher initial costs [14.3].

Giummarra [14.3] also divides maintenance into routine and periodic maintenance. For the former, permanent patrols perform such work as light grading or clearing blocked drains and culverts. For the latter, teams are assembled, for example, for regravelling, recompacting, and reshaping projects.

Lay [14.2], in the United Kingdom, considers three types of maintenance:

1. Periodic, programmed maintenance
2. Routine maintenance
3. Service restoration

Periodic, programmed maintenance is predictable and planned. It includes operations such as mowing grass, cleaning ditches, repainting lines, grading shoulders, sealing joints, and filling cracks in the pavement. Routine maintenance is not amenable to detailed planning but can be assessed in advance. It includes operations such as repairing potholes and patching road surfaces. It typically has a high benefit–cost ratio. Finally, service restoration deals with work such as ice and snow removal, and cleanup and repair of flood and wind damage.

Periodic and routine maintenance are usually done by patrols of workers with general skills, whereas service restoration requires workers with skills in that particular type of maintenance [14.2]. For the former, the patrols usually consist of 3 or 4 workers equipped with the required tools and a truck. A patrol will operate over a defined part of the road network, say 100 km (60 miles) of road. A supervisor is assigned to up to about 10 patrols. The patrols are in many ways self-managing, and "pride of patch" is a strong motivator.

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Another way to organize the maintenance effort is to have "lengthmen" responsible for a particular stretch of road [14.2]. Lengthmen have the necessary hand tools but no vehicle and are usually supported by patrols.

O'Flaherty [14.1] classifies maintenance by the pavement defects involved:

- Whole carriageway (roadway) minor deterioration—potholes, crazing, surface fretting, loss of chips, and excess bitumen
- Whole carriageway major deterioration—cracking, loss of aggregate
- Loss of skidding resistance
- Wheel track rutting
    - In the foundation (subgrade)—requires reconstruction
    - In the surface course—dealt with using surface work, such as overlays or mill and replace
    - Should check other defects, cracking, for example
    - Surface irregularities (deformations)

There are other items requiring maintenance, including road signs, road markings, bridges, culverts, and drainage structures.

14.2.2 Planning

Maintenance planning is needed to ensure constant levels of service, standards, methods, and procedures [14.2]. Lay [14.2] has developed a chart of the flow of maintenance management decisions and communications (Figure 14.1), depicted as a loop.

The loop begins with management setting policy and establishing funding. Standards are then set to meet policy. A maintenance program is planned, emphasizing the annual program. The plan is checked to determine if it is within the established budget. If it is, the next step is the scheduling of the work. If the plan exceeds the budget, there is a need to reassess the funding allocation and confirm or alter it. With the work program within the funding allocation, the work is scheduled, distributed, and executed. The next step is to monitor and assess the effectiveness of the plan. Whether the road needs were met is evaluated. Next year's needs are then developed, and the budget needed estimated again, back at the beginning of the loop.

14.2.3 Maintenance activities

Maintenance activities range from repairing subgrade failures to spraying roadside weeds. Jordan et al. [14.4] cited by Lay [14.2] have laid out a comprehensive list of activities, grouped by theme, Table 14.2. Note that in Table 14.2, Items 110 Paved Carriageways/Pavement Structure and 210 Unpaved Carriageways/Existing Surface have been expanded to show all Task Definitions, as examples. All the others can be expanded similarly. See Lay [14.2] for the full treatment.

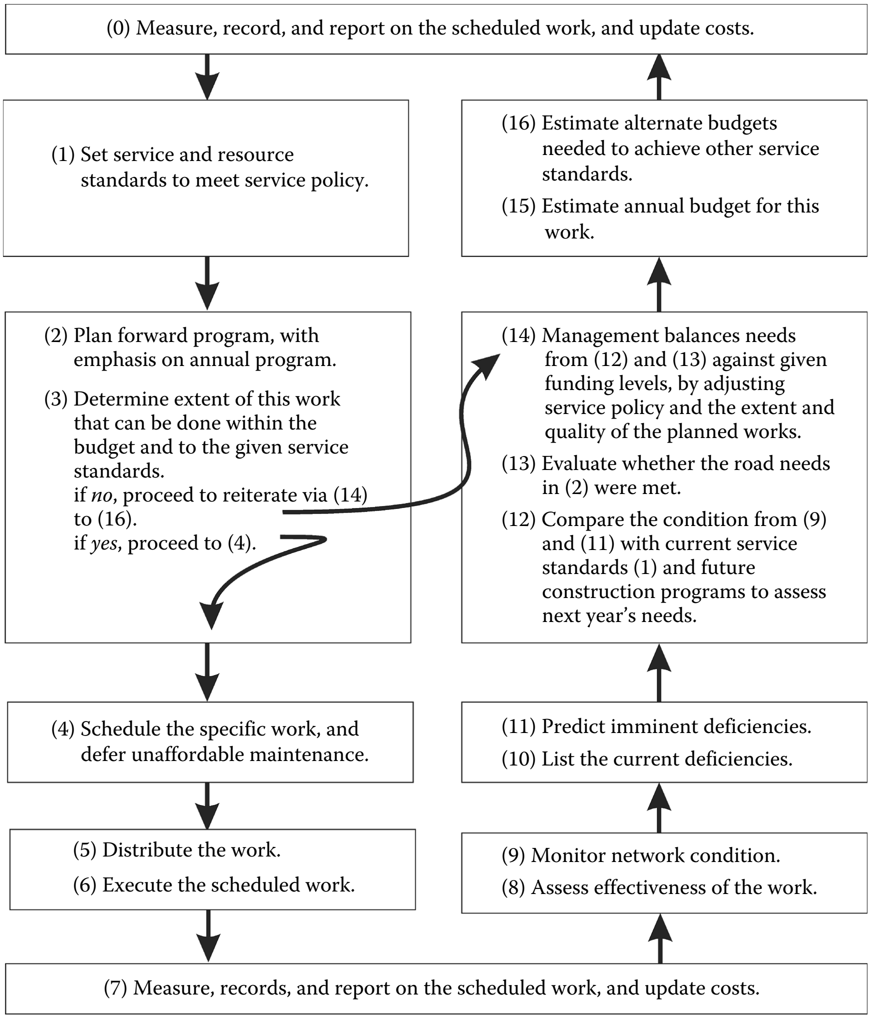

Figure 14.1 Maintenance management flow chart. (From Lay, M.G., *Handbook of Road Technology*, 4th edn., Spon Press, New York, 933pp., 2009; Jordan, J.R., Logue, G., and Anderson, G.M., Review of NAASRA study of road maintenance standards: Costing and management, *Proceedings of 10th ARRB Conference,* 10(2), 232 1980.)

14.3 CONCRETE PAVEMENTS

Concrete (rigid) pavements behave differently from bituminous (flexible) pavements, so their maintenance is different. Failures include spalling (pieces breaking off the surface) at joints, surface scaling, and cracking

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Table 14.2 Road maintenance activities

Categories	*Task definition*
100	**Paved carriageway (roadway)**
110	*Pavement structure*
111	Repair localized subgrade failures
112	Repair localized pavement failures
113	Reconstruct short sections of up to 500 m^2 (5400 ft^2) in area
114	Clean joints in slabs and fill and seal cracks in pavements
115	Lift and fix displaced concrete slabs
120	*Pavement surface*
130	*Pavement edges*
140	*Unpaved shoulders*
150	*Paths*
160	*Access*
200	**Unpaved carriageways (roadways)**
210	*Existing surface*
211	*Grade to restore shape (dry maintenance)*
212	*Provide dust suppressants*
213	*Rip excess material*
214	*Remove loose material*
215	*Patch soft spots*
216	*Add new material*
217	*Compact with water (wet maintenance)*
218	*Spray weeds with herbicide*
220	*New surface*
300	**Drainage**
310	*Surface drains*
320	*Pits and sediment traps*
330	*Culverts and bridges with spans less than 6 m*
340	*Underground drains*
350	*Roofwater outlets in road reservation (right of way)*
400	**Roadside**
410	*Vegetation within road boundary (right of way)*
420	*Motorists' services*
430	*Litter control*
440	*Earthworks*
450	*Property/boundary fences and gates*
460	*Other service agencies within the road boundary (right of way)*
470	*Roadside hazards*
480	*Sites of environmental significance*

(Continued)

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Table 14.2 (*Continued*) Road maintenance activities

Categories	*Task definition*
500	**Traffic facilities**
510	*Signs and markers*
520	*Road furniture*
530	*Road markings*
540	*Traffic signals*
550	*Roadside telephones*
560	*Lighting*
570	*Communications links*
600	**Structures**
610	*Bridge substructures*
620	*Waterways maintenance*
630	*Bridge superstructures*
640	*Bridge decks*
650	*Miscellaneous*
700	**Restoration**
710	*Traffic accidents*
720	*Storm and flood damage*
730	*Fire damage*
740	*Road openings due to utilities operating in the road reserve*
750	*Permanent reference points*
800	**Overheads**
810	*Administration of maintenance activities*
820	*Roadway inspection*
830	*Inspection and supervision of work*
840	*Depots and camps*

Source: From Lay, M.G., *Handbook of Road Technology*, 4th edn., Spon Press, New York, 933pp., 2009; Jordan, J.R., Logue, G., and Anderson, G.M., Review of NAASRA study of road maintenance standards: Costing and management, *Proceedings of 10th ARRB Conference*, 10(2), 232, 1980.

Note that for brevity, only Items 110 and 210 have been expanded as examples of showing the complete Task Definition. All other Task Definitions can be expanded similarly—see Lay [14.2] for the full treatment.

[14.1]. Because of their movement, jointed concrete slabs require periodic maintenance of the joints. Seals must be replaced because a loss of seal leads to water penetration, subsequent weakening, and deterioration of lower pavement layers. Base, subbase, and/or subgrade problems can sometimes be repaired by grouting. If this is not successful, it becomes necessary to remove the affected slab; repair the deteriorated base, subbase, or subgrade; and pour a new slab [14.1].

14.4 ASPHALT PAVEMENTS

14.4.1 Deterioration

Asphalt roads deteriorate in a number of characteristic ways, including the following [14.1]:

- Polished aggregate—the smooth texture of the particles leads to a reduction in skidding resistance
- Loss of surface texture—the road surface itself becomes smoother, also leading to a reduction in skidding resistance
- Deformation of the surface due to traffic—rutting and other deformation leads to water ponding on the road surface, contributing to the risk of hydroplaning, where a thin film of water builds between the pavement surface and the tread face of tires, resulting in a loss of vehicle control
- Cracking and surface deterioration caused by oxidation and embrittlement of the asphalt cement
- Fatigue strain of the foundation (subgrade) causing structural deterioration of the pavement

Maintenance treatments are decided once the type of deterioration is identified and understood.

14.4.2 Maintenance treatments

Maintenance treatments should be selected to take into account whole-life costs and should include user costs [14.1]. Treatments may be grouped as follows [14.1]:

- Surface dressings (treatments), thin surfacings
- Resurfacing
- Strengthening

Surface dressings are applied by spraying one or two layers of asphalt cement on the existing road surface, and then spreading and rolling-in single-sized chips which can be coated or uncoated. The treatment can be unpopular with users, when flying chips crack windshields and damage vehicle paintwork. Many other (often) proprietary thin surfacings can also be applied. They can restore skid resistance; treat narrow, stable cracks; improve impermeability; and restore the road's cross-sectional profile if not too bad [14.1].

Resurfacing represents a more substantial set of treatments than surface dressings. Approximately 40–50 mm (1.5–2.0 in.) of new asphalt is placed

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on the pavement. It may be placed directly on the road surface, or placement may come after a similar depth of the existing asphalt is milled and removed. The old material can be recycled in either hot-mix or cold-mix asphalt. The new surface may have better properties than the old surface had. For example, it may have better noise reduction, or improved skid resistance, or be less conducive to water spray from tires. Milling and replacing the old surface is usually more expensive than placing a simple overlay, but it may be that the rise in surface level ("grade raise") of the overlay cannot be tolerated at abutting pavements or curbs and gutters [14.1].

Strengthening pavements implies reconstruction or the placement of a structural overlay. It is usually done when the problem is more than surface deep. Suggested references for assistance with pavement and structural overlay design are shown in Table 14.3. As it is in most countries, UK practice is to design pavements to last typically 20 years, when a structural overlay is placed on the pavement [14.1]. Sufficient space is allowed under bridges and overhead signs to accommodate the future thickness of the pavement.

Ontario (Canadian) practice is to perform a pavement condition survey, observing and recording the severity and extent of 12 distresses. The distresses include two types of surface defects, three types of surface deformations, and seven types of cracking. The severity of a distress is how bad it is, and the extent is how much of the road segment exhibits the distress. The treatment of the pavement is then related to the dominant distress type, its severity, and its extent. Table 14.4 [14.5] presents the approach for the case where wheel path rutting is the dominant distress.

Table 14.3 Selected pavement design and overlay references

Country	*References*	*Remarks*
United States	[14.12] AASHTO 1993 *Guide for Design of Pavement Structures*	Guide is replaced by *Mechanistic Empirical Pavement Design Guide* (MEPDG) literature, but the "old" guide is in many ways more appropriate for LVR
Canada	[14.13] Adaptation of AASHTO Pavement Design Guide for Ontario Conditions	Interprets the AASHTO guide and provides regional inputs to pavement design routine
	[14.14] MTO Pavement Design and Rehabilitation Manual	Comprehensive treatment of materials, design, and rehabilitation—known as "the Blue Book"
United Kingdom	[14.15] TRRL Report LR833	Covers new design and overlays
Australia/New Zealand	[14.3] Unsealed Roads Manual together with the N.Z. Supplement	Focuses on only *unsealed* roads (gravel, earth-surfaced) but provides full treatment

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Table 14.4 Example treatment list for a particular dominant distress—Rutting

Pavement condition evaluation		
Severity	*Density (extent)*	*Recommended treatments*
Very slight	Few	None
	Intermittent	
	Frequent	
	Extensive	
	Throughout	
Slight	Few	None
	Intermittent	
	Frequent	
	Extensive	
	Throughout	
Moderate	Few	None
	Intermittent	Machine chip seal Machine patching
	Frequent	Machine chip seal Machine patching
	Extensive	Machine chip seal Machine patching
	Throughout	Machine chip seal Machine patching Cold mill with hotmix resurfacing
Severe	Few	Machine patching
	Intermittent	Machine patching
	Frequent	Machine patching
	Extensive	Cold mill with hotmix resurfacing Hotmix resurfacing
	Throughout	Same alternatives as for "extensive"
Very severe	Few	Machine patching
	Intermittent	Machine patching
	Frequent	Machine patching
	Extensive	Rehabilitation candidate
	Throughout	Rehabilitation candidate

Source: Chong, G.J., Phang, W.A., and Wrong, G.A., *Manual for Condition Rating of Flexible Pavements*, SP-024, Ministry of Transportation of Ontario, Toronto, Ontario, Canada, 111pp., 1989 © Queen's Printer for Ontario, 2015. Reproduced with permission.

14.5 SURFACE-TREATED PAVEMENTS

Surface-treated pavements are also known as chip-sealed and tar and chip pavements. Because they are sealed, surface-treated pavements behave in a similar fashion to asphalt pavements. However, because the sealing layer

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is thin and depends on a well-built granular base for structural strength, surface-treated pavements also behave in some ways like gravel-surfaced roads. Following are discussions of the typical distresses exhibited by surface-treated pavements and the relevant maintenance treatments.

14.5.1 Deterioration

The deterioration of surface-treated pavements is manifested in distresses such as surface defects, surface deformation, and cracking. These can be broken down further as follows:

- Surface defects
  - Loss of cover aggregate
  - Streaking
  - Flushing
  - Potholes
  - Pavement edge breaks
- Surface deformation
  - Rippling
  - Wheel track rutting
  - Distortion
- Cracking
  - Longitudinal cracking
  - Transverse cracking
  - Pavement edge cracking
  - Alligator cracking

Chong et al. [14.6] provide detailed discussion of each of the distresses. A summary is given here.

Surface defects focus on potholes, edge breaks, and defects in the aggregate or asphalt cement component of the pavement sealing “system” (aggregate held in place by asphalt cement). Cover aggregate can be pulled off the surface under traffic, leaving the asphalt cement unprotected. During construction, alternating lines of lean and heavy asphalt cement may have been put down, parallel to the direction of traffic. If too much asphalt cement was placed during construction, or a new sealing layer is placed over an old one with excess asphalt cement, flushing may occur where free asphalt cement may migrate upward to the surface. If flushing occurs, it often happens in the wheel tracks. It is more common during hot weather.

As with gravel pavements, potholes can form where cross fall is lacking and water stands on the pavement, or if construction technique and quality control are poor, especially permitting aggregate segregation.

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Frost action, poor edge support, poor drainage, or poor alignment where traffic runs close to the edge of the seal can lead to edge breaks.

Surface deformations can lead to poor riding quality. Rippling (washboarding) can occur when the pavement surface is pushed into regular undulations by traffic braking or accelerating. It is often accompanied by flushing. Wheel-track rutting can occur under repeated traffic load when the underlying granular layers deform. The base or subbase may be unstable due to excess pore water pressures. Other pavement distortions may occur as a result of settlement, frost action, lack of subgrade support, or embankment slope failure.

Cracking of a number of types can be identified. Longitudinal cracking can result from traffic loading, poor construction techniques, or environmental effects such as frost action or moisture changes. Transverse cracking can be caused by shrinkage in cold temperatures or frost action. Pavement edge cracking can happen if the pavement is subjected to frost action, has poor edge support, poor drainage, or traffic coming close to the edge.

Alligator cracking is seen when a surface-treated pavement is coming to the end of its structural life. Alligator cracking—cracks forming a network of polygonal blocks looking like the skin of an alligator—results from a softening of the pavement structure, normally caused by excess moisture. Alligator cracking is progressive.

14.5.2 Maintenance treatments

Maintenance treatments for surface-treated pavements usually seek to reestablish the seal, smooth the deformation, or address the cause of the bump or hole. Table 14.5 presents a summary of maintenance treatments for surface-treated pavements.

14.6 GRAVEL- AND EARTH-SURFACED ROADS

The condition of gravel* and earth-surfaced roads can change much more rapidly than the condition of sealed roads, and so they require regular maintenance at frequent intervals. An advantage of these unsealed roads, however, is that they can be easily "healed," with minor damage easily repaired simply by grading and/or recompaction.

* To avoid getting too cumbersome with the terminology, "gravel" is used here to denote roads surfaced with crushed rock, crushed gravel, or pit-run sandy gravel. When it is important, the distinction between the three different materials will be made explicit. "Sealed roads" include those surfaced with asphalt, concrete, or a surface treatment such as chip seal. "Unsealed roads" include roads surfaced with crushed rock, crushed gravel, pit-run sandy gravel, or earth.

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Table 14.5 Maintenance treatments for surface-treated pavements

Treatment	*Description*	*Application*
Manual patching	Spreading and compaction of premixed asphaltic materials (hot, cold, or recycled mix), and compaction manually or by machine	Repairs potholes, depressions
Machine patching	Machine spreading and compaction of premixed asphaltic materials (hot, cold, or recycled mix)	Repairs major surface distresses such as potholes, depressions, alligator cracking, rutting, and distortion—note, does not solve the problem if root cause is structural weakening
In situ recycling with manual chip seal	Machine removal of surface defects followed by manual chip seal	Removes distortion
Manual spray patching	Manual application of emulsified binder, followed by spreading of aggregate	Repairs potholes, cracking
Manual chip seal	Manual application of emulsified binder with a manual spray bar, followed by spreading of aggregate with a chip spreader and mechanical compaction	Repairs localized distresses
Machine chip seal	Machine application of emulsified binder followed by machine spreading of aggregate	Repairs localized distresses
Fog seal	Machine application of a slow-setting emulsified binder diluted with water, may be followed by machine spreading of sand	Seals small cracks and surface voids
Manual burn and seal	Elimination of excess surface binder by open-flame burning, sealed with heated aggregate or manual chip seal	Eliminates excess surface binder

Source: Chong, G.J., Phang, W.A., and Wrong, G.A., *Manual for Condition Rating of Surface-Treated Pavements*, SP-021, Ministry of Transportation of Ontario, Toronto, Ontario, Canada, 73pp., 1989 © Queen's Printer for Ontario, 2015. Reproduced with permission.

The main requirement is to maintain the cross fall (camber) to shed water [14.1–14.3]. As much as 6% cross fall has been recommended [14.2] although 4% is more typical. A greater cross fall than the 2% usually recommended for sealed road surfaces (asphalt, surface treated, concrete) is usually specified for the following reasons:

- Unsealed roads have rougher surfaces which impede surface drainage
- Unsealed roads develop ruts between grading operations, which can also impede surface drainage

- The grading operation itself, if poorly performed, can result in a flattening of the road cross section—*specifying* 4% or 5% may actually *result* in only 2% or 3% in reality

To keep gravel and earth-surfaced roads in good condition, more gravel needs to be added where weaknesses appear. It is important to add gravel where there are ruts or weaknesses rather than to redistribute the gravel already on the road by cutting high spots and filling low spots. Such a practice weakens the high spots.

14.6.1 Deterioration

The defects of gravel and earth-surface roads can be classified as surficial or structural. Surficial defects tend to affect road user safety and comfort, whereas structural defects are more a concern of agency costs [14.3]. Surficial defects are caused by climatic conditions, unsuitable material, inappropriate grading, or poor compaction [14.3]. Except for unsuitable material, the defects can usually be removed with careful grading, and compaction if needed. Structural defects are more deep seated and are often caused by overstressing of the base, subbase, and/or subgrade. Before determining a repair strategy, the cause of the structural defect should be determined. It may be a lack of drainage, poor compaction, inappropriate material, or insufficient pavement* layer thicknesses.

Corrugations (washboards) are the displacement of material due to tractions on the road surface, such as braking, accelerating, or climbing grades. The road surface develops parallel ridges at right angles to the direction of travel, with a spacing of approximately 0.5–1 m (18 in. to 3 ft) and depths to 0.15 m (6 in.). Granular materials with particle sizes greater than 5 mm (0.2 in.), low plasticity, and limited fines are susceptible to corrugation. Grading too fast can also cause corrugations to form [14.3].

Potholes affect riding comfort and can cause serious damage to vehicles if left to grow large enough. Those affecting vehicles are 0.25 m (10 in.) or more in diameter, and more than 50 mm (2 in.) deep [14.3]. Roads most vulnerable to potholing have no longitudinal grade and have flat cross sections. Water may lie on the surface. Approaches to bridges, which have much flatter cross sections than gravel roads should have, can be problem areas. The formation of potholes is triggered by the stripping of surface material and infiltration of water into the road structure. Fines are pumped away, and the pavement

* "Pavement" is *any* material placed on the natural subgrade at the site. It is not restricted to asphalt or concrete. Thus, even suitable earth dug from the ditches immediately adjacent to the road and placed on the road constitutes "pavement."

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disintegrates [14.3]. If the cross fall and longitudinal gradient are sufficient, water doesn't accumulate, and potholes usually do not form.

Rutting is the formation of deformations in wheel paths. The ruts collect water which softens the pavement materials. Ruts are caused by the following:

- Poor grading of material
- Poor compaction
- Inadequate pavement thickness
- Poor surface drainage
- Excessive fines
- Overloaded vehicles
- Vehicle tracking

Slippery surfaces can be caused, in wet weather, by excessive fines in the wearing surface, or a lack of cross fall [14.3], or of course subfreezing temperatures. In dry weather, they can be caused by the accumulation of loose stones on the road surface [14.3].

Surface scour can be longitudinal or transverse, and is caused by the concentrated flow of water over the surface of the road. It can present a dangerous surface and an uncomfortable ride [14.3].

Soft surfaces may result from the selection of unsuitable material [14.3] or insufficient pavement thickness.

14.6.2 Maintenance treatments

Corrugations can be dealt with in the short term by grading—cutting below the trough of the corrugations and reshaping the road surface. For a more permanent solution, depending on circumstances, a clay binder might need to be blended in to the surfacing material, or a high quality crushed aggregate may need to be imported [14.3]. In the worst cases, it may be necessary to seal the affected stretch of the road.

Potholes require the restoration of the road's cross-sectional shape, especially the cross fall, to prevent water from infiltrating in flat spots [14.3]. Severe potholes may require scarification and reshaping the road. The aprons to bridge decks may need to be sealed if severely potholed.

Rutting solutions depend on the cause. Routine grading can replace gravel lost from the ruts. A thicker road section can be constructed if the pavement design is inadequate. Inappropriate materials can be subexcavated and replaced with more suitable material. Truck loads can be regulated more stringently.

Slippery surfaces can be improved by subexcavating inappropriate materials and replacing them with high quality crushed aggregates.

Surface scour can be ameliorated by directing surface water away from the road surface and improving surface drainage adjacent to the road. In an extreme case, it may be necessary to realign the road.

14.6.3 Gravel road maintenance practices

A wealth of practical experience is available in a PIARC (Permanent International Association of Road Congresses) publication [14.7]. It is important to tailor the maintenance practices to local conditions because they are so variable across the globe. An excellent publication on grading practices in the United States has been produced by one of the US LTAP (Local Technical Assistance Program) centers [14.8]. The publication provides details on the operation of motor graders for light and heavy maintenance operations, drainage, the selection and use of good road surfacing gravel, the use of dust palliatives, and innovations.

14.6.4 Dust suppression

Dust generated on gravel- and earth-surfaced roads can have an effect on the economics, health, and the environment on land adjacent to the road [14.3]. McCrea [14.9] cited in Jones [14.10] mentions a case where the health of sheep was adversely affected because their teeth wore down in the dusty environment next to a gravel-surfaced road. Numerous reports cite reduced crop yield in dust-covered fields near gravel roads. Dust can also be an issue of safety for road users.

Dust is caused by the loss of fines from the road surface [14.3]. The fines are loosened by traffic under the right weather conditions, and with the loss of fines, the road surface becomes more permeable, water intrudes, and the road structure weakens. At the same time, there is a loss of binding material for the larger particles in the road surface. They loosen and are kicked off by traffic, and the road surface fabric unravels.

To control the loss of fines as dust, the most effective to least effective treatments are listed as follows [14.3]:

1. Good construction and maintenance practices, including the selection of appropriate surfacing material
2. Mechanical stabilization—adjusting the particle size distribution of the surface course—to form a hard crust
3. The use of chemical dust suppressants, as an adjunct to the first two treatments

The use of chemical dust suppressants can only ever be a short-term mitigation, and should never be considered the sole treatment [14.3].

Good surfacing gravel reduces or eliminates the dust problem. The characteristics of good surfacing gravel are covered in depth in Chapter 6, so it will not be covered here. On the understanding that they are the third category of dust abatement measures, and can only be considered temporary, dust palliatives are covered in the rest of this section.

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Effective dust palliatives have the following characteristics [14.3]:

- They prevent particles from becoming airborne
- They resist traffic wear
- They remain in the pavement—they are not leached out, and don't evaporate
- They resist aging
- They don't damage the environment
- They are applied easily with commonly available equipment
- They are workable and responsive to maintenance treatments
- They are inexpensive

There are a number of classes of dust palliatives [14.3]. Table 14.6 lists them, with comments.

From the Australian perspective, Giummarra [14.3] gives guidance on the selection of dust palliatives. A selection flow chart is presented, along with a map of Australian climatic zones as an input in the selection process.

There are cautions on the use of palliatives [14.3]. Chlorides and lignin sulfonates tend to leach out of the road structure in the rain, reducing their effectiveness, and polluting the adjacent ground. They can also become slippery when wet. Chlorides keep the road surface damp but have no cementing action [14.3]. Calcium and magnesium chlorides are deliquescent—they dissolve in moisture absorbed from the air—whereas sodium chloride is, however, hygroscopic—absorbing moisture from the air. Sodium chloride needs high relative humidity (>70%), so is of little use in arid areas. Calcium chloride and magnesium chloride cannot absorb moisture and dissolve at humidity less than 30%–40%, so are also of little use in very dry climates.

The satisfactory applicability of the various treatments depends on a complex relationship between the soil, the weather and climate, and the suppressant itself (Figure 14.2 [14.3]). In any individual case, trials are recommended to determine the best treatment and the recommended application rate.

14.7 MAINTENANCE EQUIPMENT

Many road authorities have manuals on the details of the selection and operation of the myriad pieces of equipment that can be used for road maintenance. An example is the US Washington State Department of Transportation manual [14.11], which details the use of the following:

- Graders, drags, rakes, underbody blades
- Loaders, backhoes, excavators, Gradalls®

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Table 14.6 Road dust suppressants

Treatment	*Description*	*Remarks*
Surfactants	Wetting agents: soaps or detergents	Reduce the surface tension of the moisture in the soil—the increased moisture provides a better binding action in the soil
Chlorides	Salts such as NaCl, $CaCl_2$, and $MgCl_2$	Absorb moisture from the air if the humidity is high enough—increased moisture promotes binding action in the fines
Adhesives	Lignin sulfonates	Organic nonbituminous binders which are by-products of pulp and paper production—they make clay fines more plastic at low water content, increasing the binding action—obviously clay particles must be present in the surface course material for this approach to be successful
Electrochemical stabilizers	Sulfonated petroleum or enzymes	Highly ionic, expelling adsorbed water, decreasing air voids, and increasing density
Petroleum products	Recycled waste motor oil	Causes an agglomeration of soil particles—no longer acceptable environmentally because of the pollution by the oil and the possibility that the oil contains heavy metals
Others		Include microbial binders and polymers—constantly evolving

Source: Giummarra, G. (ed.), *Unsealed Roads Manual, Guidelines to Good Practice*, ARRB Transport Research Ltd., Vermont South, Victoria, Australia, 2000.

- Rotary traveling mixers, hammer mills, portable pug mills
- Water trucks, towed rollers, self-propelled pneumatic rollers, self-propelled steel-wheel rollers, self-propelled vibratory steel-wheel rollers

In recent years, a modification of the excavator bucket called the chuck blade has come into use in North American LVR construction and maintenance. This is a relatively flat blade 1.8 m (72 in.) or more wide, which is connected to an excavator boom. It provides a useful tool for earthworks including the formation of the road subgrade and ditches, particularly in heavy soils.

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	Traffic Volumes, Average Daily Traffic			Subgrade Types 2			Surface Material Fines Content					Climate			Environ-mental impacts 5
							Passing 75 μm sieve								
	Light <100	Medium 100–250	Heavy >250 7	Clay	Silt	Granular	<5%	5 – 10%	10 – 20%	20 – 30%	>30%	Rainy	Moderate	Dry: >20days <40%RH	
Surfactants											3	1,3			
Salts: $CaCl_2$, $MgCl_2$											3	1,3		8	
Lignosulphonates			6								3	1			
Petroleum products			6							4	4	3			

Dust suppressant performance: Good / Fair / Poor

Notes:

1. May leach out in heavy rain.
2. Subgrade may mix with surface material and have an impact on the quality of fines.
3. May become slippery in wet weather.
4. Difficult to coat all particles and to prevent "dust pockets."
5. Any product listed may have adverse environmental impacts if used improperly.
6. Hard surface crust can encourage the formation of potholes and break-up under heavy traffic.
7. Products may require greater amounts or more frequent applications under heavy traffic.
8. $CaCl_2$ is likely to behave poorly under these climate conditions.

Figure 14.2 Dust palliative effectiveness. (From Giummarra, G. (ed.)., *Unsealed Roads Manual, Guidelines to Good Practice*, vermont South, Victoria, Australia: ARRB Transport Research Ltd., 2000. Used with permission of ARRB group Ltd.)

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