FEEDLOT DESIGN AND CONSTRUCTION

17. Pen and road surfaces

AUTHORS: Rod Davis and Ross Stafford

Introduction

The design, construction and maintenance of pen and road surfaces are important for their long-term performance. Pen surfacing has a large impact on sustainability, environmental outcomes and long-term maintenance costs while roads are complex engineering structures upon which feed delivery and reliable access to the feedlot depend. The complete surface may include one or more layers (i.e. a base course and sub-base) but must have a strong and stable underlying foundation (subgrade). If the surface sub-layers or the subgrade are weak through inadequate design, poor quality materials, poor construction techniques or poor maintenance practices, the final surface will have reduced life.

Surfaces are generally unbound natural material such as gravel, crushed rock or sand, but bound pavements (asphalt, cement) may be used on some high-usage roads.

The construction of pen and road surfaces comprises the supply and processing (as necessary) of the suitable material, hauling the material to the site of the works, spreading the material on the prepared subgrade (foundation), compacting the material to the required standard (density and moisture content) and shaping the surface of the compacted material to the alignment, grades, cross sections and thickness required.

Design objectives

Pen and road surfaces should be designed and constructed to

- withstand the bearing weight of cattle and pen cleaning equipment
- be durable and resist damage from cattle pawing and licking
- be durable and resist damage from feed delivery vehicles
- have a long life
- require low maintenance
- be easy to clean
- withstand the anticipated traffic loads and frequencies
- allow adequate drainage
- prevent or minimise adverse impacts on groundwater and surface waters.

Mandatory requirements

Compliance with

- National Guidelines for Beef Cattle Feedlots in Australia (MLA, 2012a)
- National Beef Cattle Feedlot Environmental Code of Practice (MLA, 2012b)

The National Guidelines for Beef Cattle Feedlots (MLA, 2012a) state that

- If a groundwater assessment indicates a high potential for contamination of underground water resources because of leaching of nutrients through permeable, underlying rock strata, an impermeable barrier will be needed between the contaminant

and the groundwater. This is required if the permeability of underlying soil/rock strata exceeds 0.1 mm/day.

- Clay liners should have a maximum permeability of 1×10^{-9} m/s (~0.1 mm/day) for distilled water with 1 m of pressure head.

Design choices

The following factors should be considered in determining the final surface design and in the choice of surfacing materials to be used

- climate
- available materials – location in relation to works, workability, durability, permeability
- subgrade variability, strength and drainage
- spectrum of traffic axle loads and frequency
- sequence of earthworks construction
- the presence or otherwise of weak layers below the subgrade level
- the compaction, moisture content and field density specified for construction
- effects of subsurface drainage on moisture content
- cross section chosen for the surface
- use of subgrade or surface stabilisation
- use of staged construction
- the equipment the contractor has available
- ongoing and long-term maintenance requirements
- dust management strategy.

Typically, pen and road surface construction will include the following works

- selection of surfacing material
- conditioning and compaction of the subgrade including the removal and replacement of any unsuitable material
- placement of surfacing material and compaction
- surface finish (e.g. sealing).

Good quality construction materials are essential for feedlot pen and road surface construction and reduced maintenance costs.

Subgrade preparation

The subgrade is the prepared surface (foundation) on which the pen and road surface is constructed and provides support to the pen or road surface. In most feedlot design situations, the subgrade is the layer of soil (cut or fill) prepared during bulk earthworks. Bulk earthworks are discussed in *Section 8 – Bulk earthworks*.

Selection of materials

Generally accepted materials for pen and road surfacing are varied and cover different types of crushed/decomposed rock, crusher product mixed with binder, natural gravels (e.g. pit, ridge, creek or waterworn material) and sand-clay mixes of various quality. Materials such as asphaltic concrete and concrete are unlikely to be used in an open feedlot but may be used in a covered feedlot.

The selection of the materials depends on

- available materials at or close to the construction site
- degree of processing required to obtain conforming material (unbound, bound)
- workability
- durability
- cost.

To produce compliant material, processing may be required. Processing involves crushing, screening and recombining of materials, combining with other materials (including the addition of water as necessary) and any other operation carried out to produce the required final material.

Coarse-graded material used in road construction– larger stones have been graded to the shoulder.

Properties of materials

Typically, the material properties required for pen and road surfaces are those that are to be exhibited by the material after placement and compaction.

Samples of the material that is intended to be used as surfacing material should be tested before it is selected and delivered to the construction site. Soil aggregates should be of uniform quality and free from organic matter, lumps of clay and any other deleterious material.

A materials quality test should be conducted in accordance with relevant Australian Standards. Generally, the tests outlined in Table 1 should be conducted as a minimum.

Table 1. Recommend engineering tests for soil samples

	Australian Standard	Performance criteria required for pens	Performance criteria required for roads
Particle size distribution (grading)	AS 1152	Grading C or D are recommended for pen surface materials. Refer to Table 2 for suggested grading limits.	Grading A and B are suited for bottom course of roads. Grading C or D are recommended for top course for roads. Refer to Table 2 for suggested grading limits.
Soaked CRB value	AS 1289.6.1.1-1998	The National Guidelines for Beef Cattle (MLA, 2012a) state a minimum standard CBR wet and dry of 20% for pen surface. Refer to *Section 8 - Bulk earthworks*, Table 2 for typical range of CRB values for different soils types.	Preferable CBR is between 30 and 45 with a minimum of 15.

If a sample fails any of the preliminary tests, the material should be rejected as unsuitable for the works.

Grading requirements

The material used for surfaces should be a uniformly blended mixture of coarse and fine aggregate (an even grading). The material should be free from cobbles greater than 75 mm and free from clods, stumps, roots, sticks, vegetable matter or other deleterious materials.

In the absence of technical specifications or experience, the grading limits for 'coarse-grained' pen and road surface material (i.e. material having 10 mm or greater nominal maximum size) are suggested in Table 2.

Table 2. Suggested grading limits for pen and road surfaces materials

AS 1152 sieve size (mm)	Percentage (by weight) passing sieve			
	Grading A	Grading B	Grading C	Grading D
75.0	100			
53.0	80–100	100		
37.5	60–100	85–100	100	
19.0	40–75	55–90	80–100	100
9.50	30–55	40–70	55–90	80–100
4.75	20–45	28–55	40–70	55–90
2.36	15–35	20–45	30–55	40–70
0.425	5–20	10–25	12–30	20–40
0.075	3–12	4–15	5–20	8–25

Grading A and B is a coarse grading suitable as a bottom course for roads but not as top course (surface) material. Grading C or Grading D are recommended for use as pen surface materials and/or as a top course for roads.

Even grading material on turnaround results in little displacement of coarse material.

Stabilisation

Stabilisation is a technique that can be used to increase the strength and durability of pen and road building materials. Stabilisation can be used on both the subgrade as well as the surface materials. *Section 10 – Pen and road stabilisation* provides further information on pen and road stabilisation.

Road cross section

Roads are usually designed and then constructed with careful consideration given to correct shape of the cross section. The design objective is to keep water drained away from the roadway. A road cross section has three components – a crowned driving surface, a shoulder area that slopes away from the edge of the driving surface and a drain to remove the water away from the road.

Figure 1 shows a typical cross section of an unsealed gravel road.

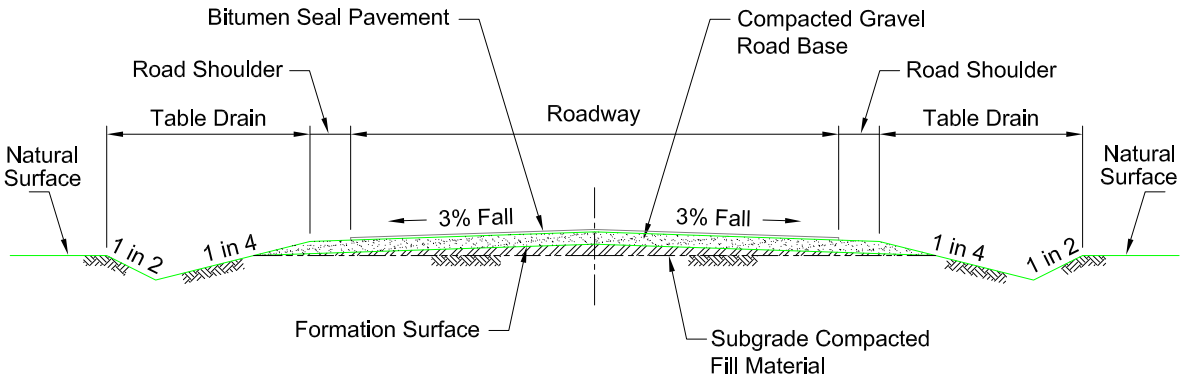

Figure 1. Typical unsealed road cross section

Figure 2 shows a typical cross section of an unsealed feed road in a sawtooth or single row pen layout. The fall is away from the feed bunk.

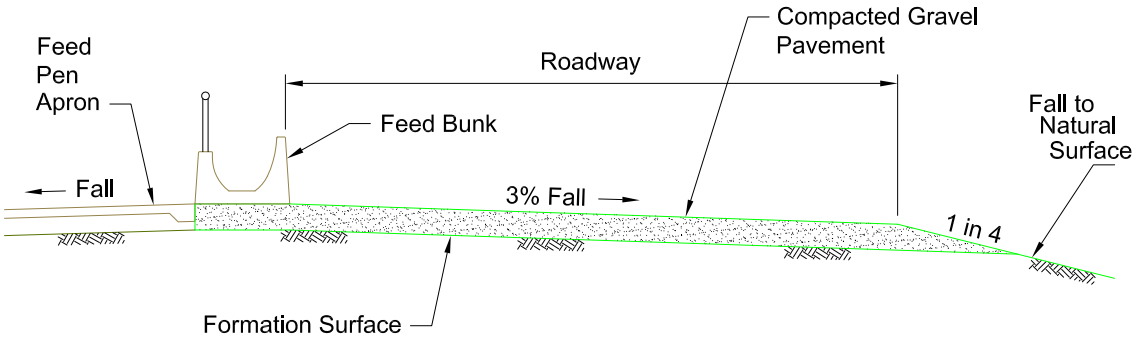

Figure 2. Typical unsealed feed road cross section in a sawtooth or single row pen layout

The cross-fall on the finished compacted gravel surface should be about 3% in dry regions and 3–6% in wet regions. Steeper cross-falls may result in erosion by rain.

Most feedlot roads are unsealed gravel. Sealed roads, whilst a higher capital cost, allow the roadway to keep its shape for a longer period of time and reduce maintenance and dust generation. However, they are more expensive to repair if the subgrade/pavement or seal does eventually fail.

With unsealed roads, gravel tends to be displaced from the surface to the shoulder area during dry weather and they tend to rut more easily in wet weather. Unsealed roads should be constructed and maintained to ensure that there is no standing water within the cross section.

In order to maintain an unsealed road properly, grader operators must clearly understand the need for a crowned driving surface and a shoulder area that slopes directly away from the edge of the driving surface to allow water to drain away.

Figure 3 and Figure 4 show typical cross sections for an unsealed feed road in a back to back pen layout. In a back to back pen layout, the design choices for feed road cross sections include a cross-fall towards the centre or no cross-fall. All configurations must have a longitudinal fall along the length of the road.

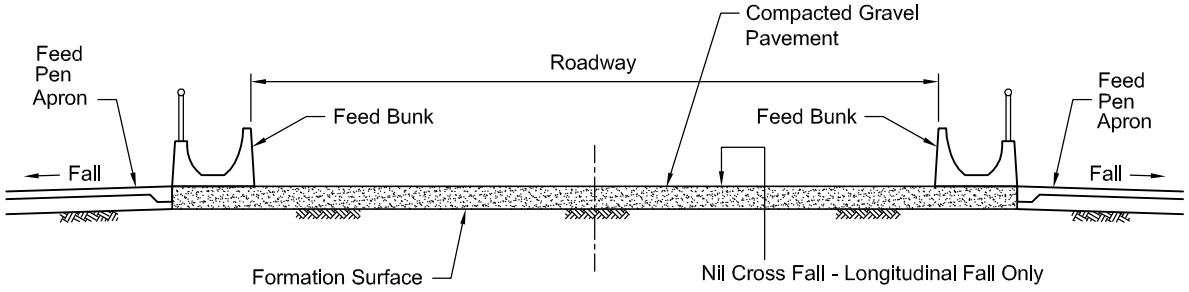

Figure 3. Typical unsealed feed road cross section with no cross-fall in back to back pen layout.

Figure 3 illustrates a feed road cross section with no cross-fall. In this arrangement water is shed along the road and not concentrated along a centre drain. This cross section is easier to maintain with grading machinery when feed roads are narrow.

Figure 4 illustrates a feed road cross section with cross-fall to the centre of the roadway. Water is shed to the centre of the roadway and then longitudinally along the centreline of the roadway with the gradient fall. This drain needs to be kept clean to prevent blockages

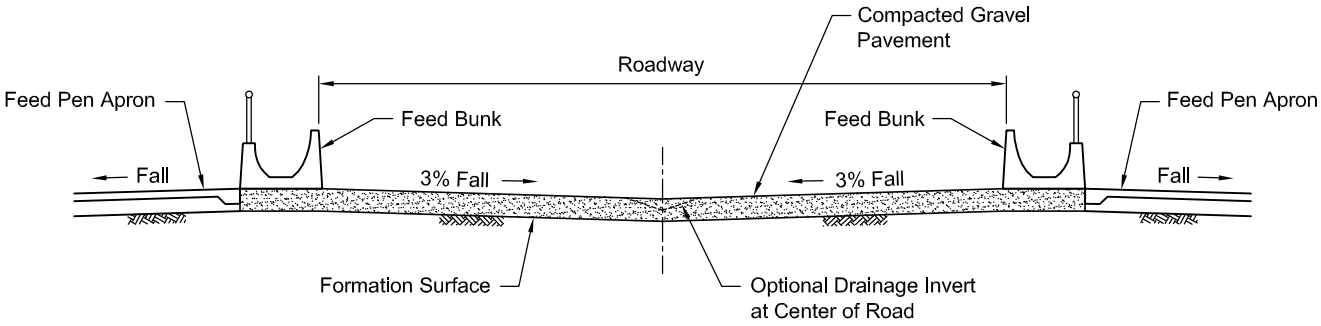

Figure 4. Typical unsealed feed road cross section with back to back pen layout and fall to centre

while a concreted v drain in the centre of the roadway would minimise erosion. The roadway needs to be wide enough for grading machinery to grade each cross-fall section individually. This design is best suited to sealed feed roads and allows water to be shed quickly off the pavement, minimising moisture penetration into the subgrade.

Road cross section – back to back layout with cross-fall to centre of the feed lane and longitudinal fall along the road

Surface material loss

Surface material is lost from the unsealed road surface through the action of rain, traffic wear, and as dust. The rate of loss partly depends on the rainfall and traffic characteristics. Alignment, gradient, surface cross-fall, road width, material quality, compaction and maintenance practices can be expected to all significantly influence rates of material loss. Surface material loss is specific to the material used and the location. Surface material loss and dust may influence other environmental considerations.

Structural thickness

Thickness design is not normally used for gravel surfacing for roads and/or pens at feedlots, but the surface must be thick enough to spread the load of the traffic so that the underlying subgrade is not stressed.

In the absence of roads specifications or recommendations based on experience, the thicknesses outlined in Table 3 are suggested.

Table 3. Recommended compacted gravel thicknesses for pens and roads

Subgrade strength – in-situ soil	Roads – Design traffic - ESA[1]		Pens – Design vehicle - FEL[2]	
	1 x 10^6 (mm)	2 x 10^6 (mm)	Loaded 14.0t (mm)	Unloaded 7.25t (mm)
Strong foundation – CBR >15 – Well-drained sand (SW,SP) (Little traffic damage if earth road is properly shaped to drain rainwater away)	200	225	150	150
Intermediate foundation CBR = 4–5 – silty clay - poorly drained	380	420	250	180
Weak foundation CBR = 2–3 heavy plastic clay – poorly drained	630	670	360	260

[1]*ESA – Equivalent Standard Axles – Defined as a single axle with dual wheels that carries a load of 8.2t.*

[2]*FEL – Front end loader*

Constructions

Surface material should be placed and compacted on a pre-shaped (cambered) and compacted subgrade. Water should be added if necessary to obtain good compaction (as close as possible to optimum moisture content).

If two or more materials are to be combined to produce the required final material, the mixing (including the addition of water) should preferably be carried out in a processing plant. Alternatively the component materials may be uniformly spread and mixed in place on the subgrade unless specified otherwise in the earthworks specifications.

If the specified compacted thickness of the base or sub-base is 150 mm or less, the material should be spread and compacted in one layer.

If the specified compacted thickness of the base or sub-base is more than 150 mm, the material should be spread and compacted using more than one layer. The compacted thickness of each layer should not be less than 75 mm or more than 150 mm.

The principal concerns during construction of a road or pen surface should be

- The formation or foundation for the surfacing material should be properly shaped and compacted beforehand. The drainage system must be adequate and functioning properly.
- Surface material quality should be carefully controlled, and an appropriate level of testing carried out, if feasible.
- Layer thickness control is essential; simple pegs or profile boards may be used for this purpose. Initial checks should be made on number of loads delivered loose per unit length of road. Regular checks should be made by excavating through the compacted gravel surface.
- Large (oversize) particles should be removed by screening or grading to the outside/shoulder.
- The laid surface material should be at a moisture content suitable for compaction. If necessary, water should be added.
- Compaction by vibrating roller will considerably improve durability of the surface material. The loose surface material must be spread evenly before compaction to ensure a uniformly dense and even surface.
- Finished compacted cross-fall (2–6%) should be checked using a camber board or template, or strings stretched longitudinally, transversely and diagonally between the setting out pegs.

Road constructed from even grading material—well maintained by regular cleaning and grading.

Surfacing

Pens

Various materials can be used for the pen surface. These include overlaying the subgrade with a gravel capping, compacting in-situ material (clay/gravelly clay) to obtain the required standard, or lining the subgrade (clay/gravelly clay) with imported material to obtain the required standard. Some features of gravel and clay pen surfaces are

- gravelled pen surfaces are harder on cattle hooves; large, sharp angular gravel should be removed
- gravel pen surfaces are more durable and can withstand higher loading
- gravel is removed if manure is cleaned back to the gravel surface; manure will require screening before utilisation
- clay pen surfaces may need to be stabilised to improve trafficability

Final trim operations result in a well-prepared pen surface.

- clay pen surfaces are more erodible
- clay pen surfaces are more difficult to manage in wet weather
- clay pen surfaces require more repairs.

Table 2 provides grading requirements for materials for pen surfaces. Grading C or D should be used.

Irrespective of the material chosen for the subgrade and surfacing of the feedlot pens, the construction must ensure that the permeability requirements set out in the National Feedlot Guidelines are achieved.

Roads

The main reasons for bound surfacing of feedlot roads is not for structural purposes, but for dust suppression, improved water shedding, reduced maintenance or reduced wear on vehicles. The bound surfacing most applicable to a feedlot development can be classified as

- sprayed bituminous seals
- asphalt (hot mix).

The cross section of the road is important when roads are to be bound surfaced.

Sprayed bituminous seals

Sprayed sealing has relatively low cost and is faster than other forms of pavement surfacing. However, it is less able to resist the effects of heavy traffic, particularly when vehicles are turning.

Common materials used in sprayed sealing are

- bitumen – Class 170 (approximately equivalent to 85/100 penetration)
- cutback bitumen – used for sealing, generally C170 mixed with cutter as required or priming/primer sealing
- cutter oil – a light solvent such as lighting kerosene or aviation turbine fuel
- bitumen emulsion – generally Australian Standard grades of cationic emulsions, with specialty grades developed for priming
- aggregate pre-coating materials – oil- or bitumen-based or a specialty grade of bitumen emulsion
- adhesion agents – to promote wetting and adhesion in damp conditions, and for aggregates with poor affinity to bitumen.

For spray seals the quality of the aggregate is critical, with the nominal size of aggregate related to the various conditions of the site. A single-sized aggregate is preferred because this provides maximum tyre contact and macro texture for surface drainage. With the expected traffic volume of feedlot roads, typical aggregate sizes should be no greater than 10 mm for single seals.

Gravel material may be available on site but should be tested to determine if it is suitable for use as a seal aggregate. On-site material, whilst cost effective, may be of a lower grade and may not be able to adequately support heavy loads, resulting in a loss of texture early in the seal life.

Poorly graded material being used in pen repairs – note the large percentage of fines.

Watering roads will maintain surface integrity, reduce corrugations and reduce dust.

Gravel loss and structural issues are most common on road curves where shear stresses from vehicle loadings are the highest. Bitumen seal on road curves reduces road maintenance but potholes can form easily at the transition with the unsealed section.

Rutting on a sealed road with poorly prepared subgrade.

Manure stockpile areas need an impervious base with good site drainage to withstand heavy loads and equipment.

For roads carrying heavy vehicles, more expensive crushed rock material may have to be imported as the surface material. The sprayed treatments are broadly separated into prime and seal. A prime and seal is the preferred treatment for all new work as it improves the bond, provides flexibility and reduces the risk of early seal failure.

There is no typical formal design method, and the selection of a suitable grade of cutback bitumen primer is based on experience within the local area, construction practices, type and compaction of surfacing material and the seal to follow. The primer should be allowed to dry and cure for a minimum of three days before being sealed.

Specialist advice should be obtained on bitumen seal from a designer suitably qualified and experienced in the area of road pavement design.

Asphalt

Asphaltic surfacing is more expensive than sprayed sealing.

Asphaltic surfacing is an engineered product composed of about 95% stone, sand, and gravel by weight, and about 5% asphalt cement, which is a petroleum product. Asphalt cement acts as the glue to hold the surfacing together. Asphaltic surfacing is often referred to as 'hot mix'.

Asphaltic surfacing is typically placed with a minimum thickness of around 20–25 mm. The main characteristics of asphaltic surfacing are the use of a heavy tack coat or sprayed seal to form an integral bond with the underlying surface, and the adoption of coarse gap-graded mixes to provide good surface texture. Asphalt requires a well-prepared surface before installation. The clay content, plasticity and grading of the surface material is more selective than that required for spray seal.

Asphaltic surfacing is often preferred in colder climates but avoided in hotter climates, where the asphalt can become soft and prone to ruts and bumps.

Typically, asphalt surfaces are not placed during cooler weather. Mixing and placing asphalt should not be permitted when the surface of the road is wet or is at a temperature less than 10°C, or there is a likelihood of cold winds chilling the mix to an extent that spreading and compaction are adversely affected.

Specialist advice should be obtained on surfacing options from a designer suitably qualified and experienced in the area of road pavement design.

Rutting

Even when shaped properly, unsealed roads may fail when exposed to heavy loads as a result of weak subgrade strength and marginal gravel depths. On sealed roads, rutting also may occur in the asphaltic mixture near the surface. Even proper maintenance will not address rutting if the design of the surface is poor.

Manure stockpiling and composting areas

As feedlots pens have to be cleaned regularly, harvested manure has to be stored and processed before it can be utilised.

The main design considerations for the manure stockpile and composting areas are

- an impervious base
- good site drainage
- sufficient area.

Solid waste storage areas must have an impervious base that can handle heavy traffic. The soils used for lining this area must have the same properties as those for holding pond clay liners (see *Section 12 – Holding pond design*).

The base of the solid waste storage should

- be constructed to achieve a maximum permeability of 1 × 10-9 m/s (0.1mm/day) for distilled water with 1 m of pressure head
- have sufficient depth so that the integrity of the structure is maintained throughout general operations, including the movement of heavy loads and equipment
- remain durable and effective when subjected to the physical effects of machinery and water flow, or be overlain by a suitable depth of a durable material (e.g. gravel) that can adequately protect the lining material under these conditions.

The manure stockpiling or composting area should sit within the controlled drainage area, with diversion banks (or the natural topography) diverting external 'clean' runoff away from the area. Runoff caught within the area must be directed to the holding pond, with any spills from the manure stockpiling area to be handled in accordance with licence conditions.

Good drainage with an even slope of 1–3% within the manure stockpiling or composting area will prevent formation of wet patches that can destroy the integrity of the base. Manure windrows should be orientated with the long axis down the slope to promote drainage.

The area for manure stockpiling or composting needs to be large enough to store and process the expected amount of manure, and to allow for contingency storage. The required area will depend on the amount of manure harvested from the pens, the length of time the manure is stored and the processing method.

Composting areas also need an impervious base and an even slope of 1–3%.

Quick tips

- A strong and stable underlying subgrade is the key to a successful surface.
- A weak subgrade or surface sub-layer either through inadequate design, poor quality materials, poor construction techniques or poor maintenance practices, will reduce the surface life.
- Weak subgrade or surface sub-layers may need to be stabilised to improve strength and workability.
- Material used for road and pen surfaces should be a uniformly blended mixture of coarse and fine aggregate and free from cobbles greater than 75 mm, clods, stumps, roots, sticks, vegetable matter or other deleterious materials.
- Proper shaping of roads to provide a crowned surface will facilitate draining of water from the road and reduce maintenance requirements.
- Seek specialist advice on bitumen sealing of roads as sub-layer material needs to be more selective when compared to unsealed roads.

Further reading

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