

**ROYAL GOVERNMENT OF BHUTAN**  
**Ministry of Works & Human Settlement**

**DEPARTMENT OF ROADS**



**ROAD MAINTENANCE**  
**MANUAL**

## ***FORWARD***

The “Road Maintenance Manual” has been prepared and produced by the Department of Roads (DoR) through its own in-house capacity. The manual is more user-friendly and practical than the previous one that was published in 1988. It is intended to serve as a guide for the Road Engineers involved in the maintenance of roads in Bhutan.

The manual is simplified in terms of the technical jargons and presentations. Attempt has been made to cover all the Road Routine Maintenance scenarios existent in Bhutan. As far as possible, the text content has been kept at a minimum and more illustrations and photographs are used.

The manual is prepared with an objective to address Road Maintenance issues that are existent at present. Therefore, with the changing times and technology, the manual shall be reviewed from time to time both in its contents and presentation.



**Phuntsho Wangdi**  
**Director**  
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**Thimphu**  
**Date: June 2005**

# ***ACKNOWLEDGEMENT***

The successful publication of the Road Maintenance Manual would not have been possible without the support and assistances of many officials of the Department of Roads.

Firstly, my deep appreciation goes to our Director, Mr. Phuntsho Wangdi, who had initiated the concept of publishing the manual. He had been actively involved during the entire process of this manual publication. Without his support and guidance this manual would not have been realized.

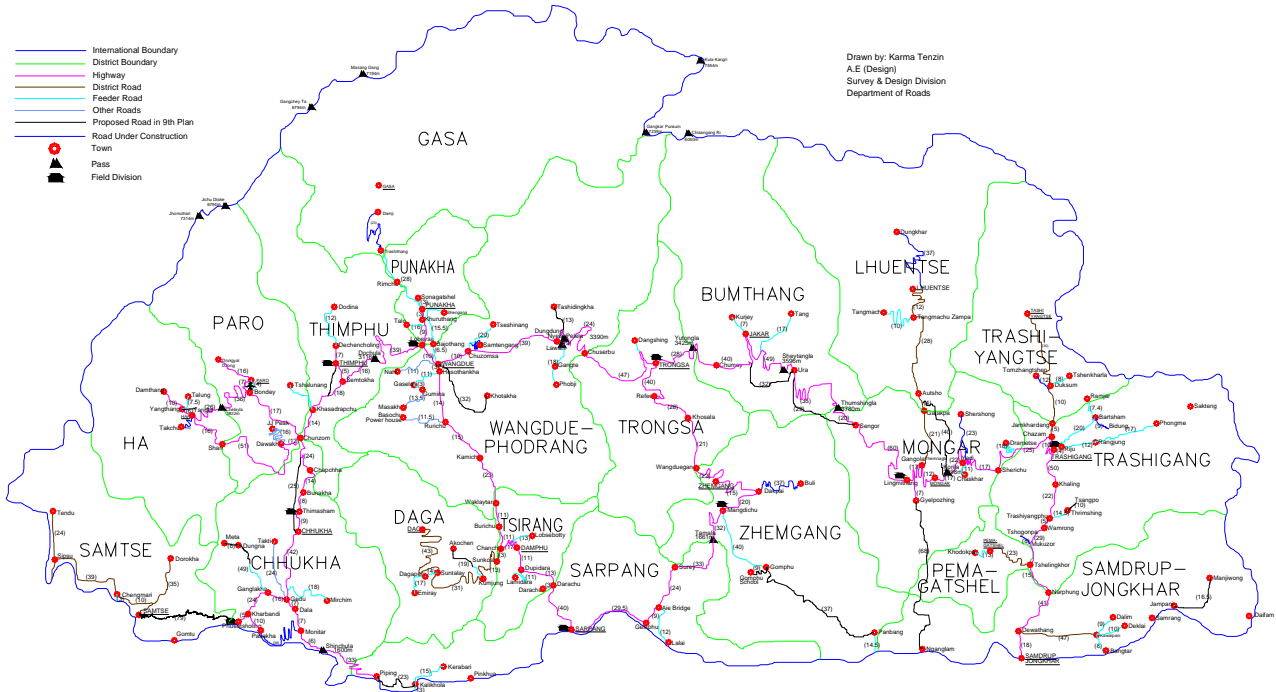
Secondly, my thanks goes to the Superintending Engineers of the DoR, Mr. Kunzang Wangdi, Tshering Wangdi 'B' and Mr. M.N. Lamichaney, for their efforts in editing and providing suggestions and guidance. Thanks are also due to all the technical staff of the Road Division of the DoR for providing useful suggestions and constructive views for the manual and its contents.

The prompt support and financial assistance rendered by EFRC-Support Project for the publication of this manual is highly appreciated and acknowledged.



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**Member**  
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# BHUTAN ROAD NETWORK



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## ROAD NETWORK OF BHUTAN DZONGKHAGWISE AS OF SEPTEMBER 2003

Sl#	Dzongkhag	National Highway (km)	District Road (km)	Feeder Road (km)	Urban Road (km)	Forest Road (km)	Total (km)
1	Sarpang	123.4	0	42.5	0	93.25	259.15
2	Dagana	0	87	31.36	0	0	118.36
3	Tsirang	62	0	37.7	1.5	6.48	107.68
4	Zhemgang	104	38	57.99	1.89	41.6	243.48
5	Trongsa	168	0	36.87	0	10.71	215.58
6	Bumthang	122	0	73.52	0	47.6	243.12
7	Haa	16	25.6	31.523	1.6	36	110.723
8	Samtse	0	89	25.6	8.2	7	129.8
9	Paro	103	36.4	99.57	0	5.19	244.16
10	Chukha	231.89	0	197.79	15.7	30.928	476.308
11	Thimphu	111	0	94.86	71	103.86	380.72
12	Wangdue	150.8	0	110.9	0	19.6	281.3
13	Punakha	9	0	95.82	0	59	163.82
14	Trashigang	141	5	122.31	0	8.5	276.81
15	S/Jongkhar	59	50	60.62	0	29.9	199.52
16	Mongar	177	20	66.26	0	44.8	308.06
17	Pemagatshel	0	23	31.62	0	17.6	72.22
18	Lhunste	0	45	31.95	0	0	76.95
19	Trashiyangtse	0	40	39.87	0	2.2	82.07
20	Gasa	0	0	17.3	0	0	17.3
<b>Total</b>		<b>1578.09</b>	<b>459</b>	<b>1305.933</b>	<b>99.89</b>	<b>564.218</b>	<b>4007.131</b>

### ROADS UNDER DOR AS OF SEPTEMBER 2003

National Highway (km)	District Road (km)	Feeder Road (km)	Urban Road (km)	Total (km)
1056.16	397.00	693.11	86.50	2232.77

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## **1 GENERAL**

### **1.1 Introduction**

Maintenance of roads to a satisfactory standard requires substantial expenditure, often a very significant portion of the government's annual expenditure. Often, lack of right maintenance interventions at the right time, results in higher expenditure than the cost of the maintenance itself. It is of paramount importance that the road engineers are well informed in the field of routine maintenance to discharge their daily duties. This manual is focused on the routine maintenance of roads only.

### **1.2 Types of Maintenance**

Maintenance of Roads is broadly divided into three types which are described below:

#### **1.2.1 Routine maintenance**

Routine maintenance is a group of recurrent activities and which are related to the repair of faults and attention to the road structure and facilities to ensure the preservation of the asset and the convenience and safety of traffic.

Typical activities are:

- Repairing of potholes
- Surface patching
- Drain cleaning
- Grass and scrub cutting
- Maintenance of road structures
- Maintenance of road signs and apparel



- Grading road surface and shoulder

### **1.2.2 Periodic maintenance**

That group of activities which can normally be predicted and planned for by nature, location and extent and are carried out periodically.

Typical activities are:

- Resurfacing works (BT surface dressing)
- Surface dressing (Single Surface Dressing, Double Surface Dressing)
- Overlaying (Asphalt Concrete)

Every stretch of road with 25mm thick Resurfacing is normally due for the next resurfacing in 4 to 5 years and may be lesser in extreme climate areas.

### **1.2.3 Restoration Works/Emergency Maintenance**

The group of activities performed to restore the roadway following damage by events such as monsoon rains resulting in floods or landslides which would be unpredictable.

Typical activities are:

- Clearing of landslides
- Culvert and bridge repairs
- Retaining wall reconstruction
- Construction of diversions
- Floodway repairs
- Restoration of road formation width

## **2 ROUTINE MAINTENANCE**

### **2.1 Objective of Routine Maintenance**

- Keep the road pavement and shoulders in serviceable and safe condition and where possible improve their riding qualities
- Protect and prevent failure, deterioration or loss of road pavement and structures
- Ensure that the drainage system functions at all times
- Prevent the growth of harmful vegetation on formation and drains
- Paint and carry out minor repairs of structures
- Repair and paint road signs & markings.
- Care and control of roadside vegetation (trees, grasses, etc)
- Improve and preserve roadside appearance
- Keep proper records/date of all maintenance activities

### **2.2 Road Maintenance Activities**

The activities of routine maintenance are described in the following paragraphs:

#### **2.2.1 Pavements and Shoulders**

- Grade Water Bound Macadam (WBM) and shoulders to maintain or restore proper shape and cross-section including proper super elevation
- Repair potholes and scours in WBM pavements
- Repair potholes, failed, damaged, or other small defective areas in bitumen surfaced pavements and

## *SECTION 2: ROUTINE MAINTENANCE*

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apply grit/sand should the bitumen bleed in hot weather

- Repair edges and small built-up depressions in bituminous pavements
- Grade and add material as necessary to worn shoulders to bring them flush with edge of pavement
- Maintain smooth junction between pavements and decks of bridges, culverts and causeways/floodways
- Avoid ponding of storm water on the road formation and shoulder
- Sweep the bituminous surfaced road to keep them clean and smooth

### **2.2.2 Drainage**

- Clear drains of rubbish, dry leaves, branches of trees, silt, landslide debris, vegetation, or any foreign matter that may obstruct the flow of water
- Prevent scouring of drains, culverts and culvert aprons and repair the damages promptly
- Deepen the drain if water is stagnant in the drain to avoid damage to the pavement
- Clearing of drains in watershed areas should be given priority over other areas
- Clearing of drains should be given priority over other routine maintenance activities

### **2.2.3 Roadside and traffic aids**

- Clear bushes, scrub, weeds and long grasses which interfere with sight distance

## ***SECTION 2: ROUTINE MAINTENANCE***

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- Remove fallen trees or branches or any branches overhanging the roadway
- Maintain the sign posts, guide posts, parapet & guard rails and road markings
- Clear up the roadside of any rubbish and dispose or burn them at suitable locations

### **2.2.4 Landslides clearance of up to 1.5 m<sup>3</sup>**

- All landslides of individual volume up to 1.5 m<sup>3</sup> should be cleared manually
- The landslide debris should be disposed off at a suitable location
- Priority should be given to clearing of landslide debris over other activities where the debris has blocked the drainages or traffic

### **2.2.5 Snow clearance**

- If snow is expected, a light spray of de-icing salt should be spread on the road surface to avoid formation of ice and accumulation of snow
- Snow/ice on the road surface should be cleared immediately after occurrence

## **2.3 Emergency Closure of Roads**

In the event of road becoming blocked by flooding, landslip or bridge collapse, immediate action is to be taken to place temporary warning signs and barriers as may be necessary to ensure the safety

## *SECTION 2: ROUTINE MAINTENANCE*

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of traffic. If an alternate route is available, the traffic should be directed along the alternate route.

### **2.4 Routine Maintenance Calendar**

The planning of routine maintenance activities should be guided by the Routine Maintenance Calendar (Figure 1 and Figure 2).





### **3 BITUMINOUS SURFACES**

#### **3.1 Common Defects in Bituminous Surfaces.**

The common defects in Bituminous Surfaces are as described below:

##### **3.1.1 Deformations**

These comprise changes in the profile of the surface from that originally constructed. Deformations manifest themselves in the following forms and types:

Rutting  
Shoving  
Depression  
Corrugation

##### **3.1.2 Cracks**

Cracks are fissures resulting from fracture of the pavement or surfacing. The causes of cracking of a bituminous surface are:

- 1.2.1. Deformations
- 1.2.2. Fatigue life of the surfacing is exceeded due to hardening of the bitumen
- 1.2.3. Shrinkage of the pavement or the sub-grade
- 1.2.4. Reflection of cracking in the underlying layers

As cracks allow entry of water, they are a primary cause of a range of secondary defects such as potholes. A careful examination of crack patterns is useful in assessing the causes of pavement failure.



### **3.1.3 Surface Texture Deficiencies**

These are faults in the bituminous surface itself such as loss of stone aggregates and fines or too much or too less bitumen in the surface. Types of surface texture deficiencies are:

- 1.3.1. Raveling
- 1.3.2. Polishing
- 1.3.3. Delamination
- 1.3.4. Flushing/Bleeding
- 1.3.5. Stripping

### **3.1.4 Potholes and Patches**

Potholes are depressions in the surface resulting from loss of wearing coarse material of the surface as well as the pavement.

## **3.2 BITUMINOUS SURFACE REPAIR METHODS**

Repair methods for bituminous surfaced pavements will normally be one of the following: crack sealing, skin patches, patches repair, pothole repairing, surface sanding, and surface treatments.

### **3.2.1 Crack Sealing**

Crack sealing in bituminous surfaced pavements is used to prevent the intrusion of water into base-course and sub-grade.

***Materials:***

Bitumen 80/100 or Emulsion and sand

***Method:***

Apply sand mixed with bitumen or spray of bitumen and light spray of sand in the crack

**3.2.2 Skin Patches**

A skin patch is usually placed on the bituminous surface without removing any damaged surface.

***Materials:***

Bitumen 80/100 or Emulsion, 10mm aggregates

***Method:***

- The area should be cleaned with brooms and if necessary compressed air. A tack coat should be applied to the area.
- A shallow trench with a vertical face is made around the patch to help hold it in place.
- The skin patch should be placed with hot mix of bitumen and 10mm and below densely graded aggregates or cold mix (aggregates with bitumen emulsion) may also be used. Coarse particles should be removed.
- This material should be compacted with any available equipment. When necessary, compaction

can be accomplished with the wheels of trucks or tippers also.

### **3.2.3 Patch Repairs**

Patch repairs are used to replace the damaged portion of the bituminous surface.

#### *Materials*

Bitumen 80/100 or Emulsion, 10mm aggregates

#### *Method*

- The edges of the patch should extend at least 30 cm into satisfactory surface of the pavement. The patch should be square or rectangular with vertical edges. The cuts should be made with a crow bar.
- A tack coat of hot bitumen or bitumen emulsion should be applied to the cleared area. Tack coat should be allowed to cure till it becomes tacky to touch.
- Enough hot mix of bitumen or emulsion with densely graded 10mm down size aggregates should be spread into the depression so that when compacted, it will bring the depression back to the original grade. If the material has been carefully spread, allowance of approximately 20 to 25 percent overfill should correct for compaction. If edges of the patch are feathered, coarse aggregates must be removed from the edges prior to compaction.
- After the material has been placed, it will be thoroughly compacted using a hand tamper or roller. If none of these are available, compaction can be

achieved by truck wheels. Surface elevation shall be checked by thread.

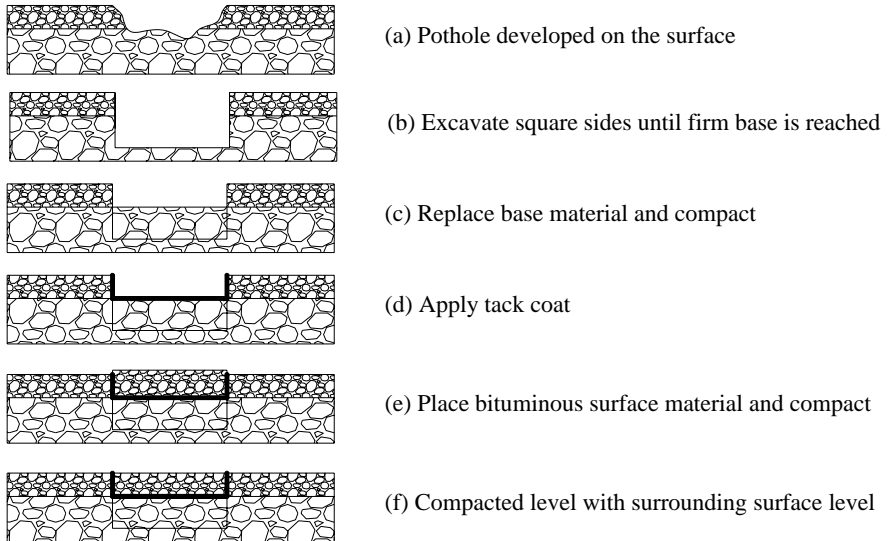
### **3.2.4 Potholes Repairs**

#### *Materials*

Bitumen 80/100 or Emulsion, 10mm aggregates

#### *Method*

- Potholes repairs require proper preparation and backfill. All material for filling these holes must be of the standard equivalent or higher than the original material used during construction.
- First the hole should be cut and deepened to hard, firm base. It is important that the sides be cut vertical and the bottom rest on hard firm base/soil.
- Base material should be replaced with equal or better material than that removed or by bituminous paving material. This material will be thoroughly compacted by use of mechanical or hand tamps.
- The hole will be applied with a tack coat including the sides and base of the holes and allowed to cure until the bitumen becomes tacky. The last step is to replace the bituminous surface material. The hole will be overfilled approximately 25% the required thickness of the bituminous surface to allow for compaction and should be followed by seal coat if necessary.



**Figure 3: Method of Pothole Repair**

### 3.2.5 Applying sand

This method is normally used where bleeding/flushing of asphalt has occurred.

#### *Materials*

Sand (Crushed or river sand) or 10mm aggregates

#### *Method*

- The surface should be cleaned of all loose debris or aggregates if any by brooming

- If possible sand should be heated and placed on the area at a temperature of 135°C or above
- Spreading may be done at the rate 0.0075 m<sup>3</sup>/m<sup>2</sup>
- Spreading may be accomplished by using tail gate spreaders or by hand made spreaders or by hand if small area is involved.
- A rubber tired roller will be used immediately to seat the hot sand into the softened binder.
- After the surface has been cooled, any loose material will be swept off.
- The treatment may be repeated if the condition has not been permanently remedied.

### **3.2.6 Fog/Surface Seal emulsion**

Seal/Fog Seal can be a light application of bitumen emulsion diluted with water. Most Surface Seals/Fog Seals are used on sound bituminous surfaces that weathered, oxidized, fine cracks, and have become brittle (as soon as finer particles starts dislodging, say after two years or so if it's new construction/overlay) at rate of 0.40kg/sqm to 0.80kg/sqm Bitumen Emulsion.

#### ***Materials***

Bitumen Emulsion

#### ***Method***

- The surface should be thoroughly cleaned by compressed air or hand brooms.
- Slightly damp surface is beneficial if Bitumen Emulsion is used.

### *SECTION 3: BITUMINOUS SURFACES*

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- If necessary sand should be applied on top of the bitumen spray.



**Figure 4: Polishing**

**Table 1: TYPES OF DEFECTS AND THEIR REPAIRS**

**DEFORMATIONS**

Sl.#	Defect	Description	Probable Causes	Type of remedies
1	Corrugations	Transverse undulations closely and regularly spaced wave action on the surface	Inadequate stability of the premix surface or pavement	Patch repair
2	Depressions	Localized area in a pavement which is lower than surrounding area	Consolidation of isolated areas of poorly compacted sub-grade. Settlement due to instability of embankment	Pothole repairs
3	Rutting	Longitudinal deformation in a wheel path of a road	Inadequate pavement thickness. Poor compaction of pavement or sub-grade	Patch repairs, potholes repairs
4	Shoving	Bulging of road surface and horizontal displacement of surfacing materials	Inadequate strength in pavement	Patch repairs

**CRACKS**

Sl.#	Defect	Description	Probable Causes	Repair methods
1	Block	Interconnected cracks forming a series of blocks approximately rectangular in shape and usually distributed over the full pavement	Shrinkage cracks in the asphalt surfacing. Fatigue cracking in hardened asphalt wearing course.	Crack Seal
2	Crescent	Half moon or crescent shaped cracks	Poor bond between wearing course and pavement layers. Thin wearing course.	Patch repair
3	Crocodile	Interconnected cracks resembling the skin of a crocodile generally in the wheel paths of a road.	Inadequate pavement thickness. Hardened wearing course.	Fog Seal if less severe Patch repair if highly severe
4	Diagonal	Unconnected cracks on diagonal across the road.	Differential settlement at embankments and cuttings.	Crack Seal
5	Longitudinal	Cracks running along the road in same direction as vehicles.	Differential settlement sometimes along the shoulder edge.	Crack Seal
6	Meandering	Unconnected irregular crack varying in direction.	Weakening of pavement edge. Entry of moisture. Reflection shrinkage crack. Differential settlement.	Crack Seal
7	Transverse	Unconnected crack running across the road	Construction joint or shrinkage crack in asphalt surfacing	Crack Seal

**SURFACE TEXTURE DEFICIENCIES**

Sl.#	Defect	Description	Probable Causes	Repair methods
1	Delamination	Surface lifting seal break	Inadequate cleaning or insufficient tack coat on pavement before placing premix carpet.	Patch repair
2	Flushing	Black spot, fatty surface, excess bitumen on surface	Too much bitumen with respect to aggregate size.	Apply heated sand and roll
3	Polishing	Smoothing/rounding stone aggregates on wheel paths.	Stone aggregates too soft therefore polishing and rounding. Use of naturally smooth uncrushed stone aggregates.	Apply aggregate and sand seal coat
4	Raveling	Disintegration of pavement surface by loss of bitumen and stone aggregates.	Deterioration of binder and/or stone aggregates. Inadequate compaction, construction during wet weather, insufficient binder, excessively open graded mix, fracture of stone aggregates during rolling.	Patch repair, Fog Seal
5	Stripping	Loss of stone aggregates in sprayed seal leaving only bitumen.	Insufficient bitumen application. Inadequate rolling of sprayed seal.	Patch repair
6	Potholes	Steep deep sided holes in pavement and wearing course.	Loss of surface dressing. Water entering pavement through cracks.	Pothole repair



## SECTION 3: BITUMINOUS SURFACES

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**Figure 5: Crocodile Cracks**



**Figure 6: Pothole created by seepage of drain water**

## SECTION 3: BITUMINOUS SURFACES

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**Figure 7: Pothole**



**Figure 8: Pothole and Longitudinal Cracks**

## SECTION 3: BITUMINOUS SURFACES

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**Figure 9: Flushing/Bleeding**



**Figure 10: Flushing/Bleeding and shoving**

## **4 DRAINAGE**

### **4.1 Introduction**

Drainage is the most important consideration in the construction and effective maintenance of all types of road pavements. Its main objectives are:

- Interception and removal of water on and under the roadway
- To prevent inconvenience to traffic
- To ensure that the road pavement and its structures are not unduly weakened or damaged

Poor drainage conditions such as blockage of culverts or drains and ponding of water can cause damage to roads in many ways such as:

- Scouring of WBM on unsealed roads, shoulders and drains
- Loss of pavement and surface materials
- Softening of sub grade or soil formation resulting in distortion and failure of pavement
- Causing landslides on both cuttings and embankments

The results of bad drainage conditions are not always immediately apparent, and considerable damage and unnecessary expense can be caused through neglect.

Inspections should be made immediately after a heavy rainfall to check if all the drainage components of the road are working to their full capacity and if not the matter should be attended to immediately.

### **4.2 Types of Drainage:**

## SECTION 4: DRAINAGE

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The following means are adopted to protect the road from damage or deterioration by surface water:

### 4.2.1 Surface Drainages

#### 4.2.1.1 Road Cross Section

The cross section of the road pavement is maintained with sufficient crown during construction so that water is quickly shed to the sides.

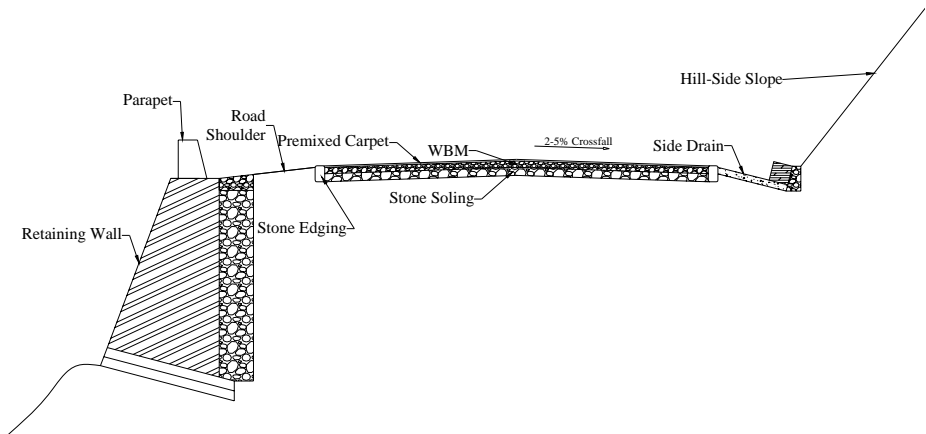


Figure 11: Road Cross Section

The following are essential in the maintenance of the road cross section:

- As far as practicable water is not to be allowed to flow longitudinally along the pavement or shoulders, particularly at the junction between the pavement and shoulder.

- It is essential that the surface of the road be maintained free of depressions and to correct cross fall.
- Except during construction and at super-elevated curves, shoulders are not to be higher than, or extend over, the edge of the pavement, as otherwise impounded water may soak down and soften the shoulder material.
- Shoulders should have slightly more cross fall than the adjoining pavement.

#### **4.2.1.2 Side Drains**

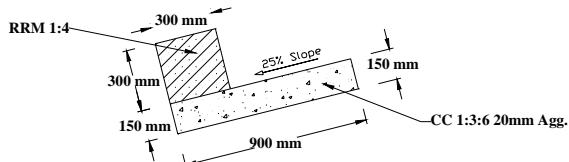
Side Drains are provided along the pavement on the hillside to intercept surface water from catchments and road surface. The DoR has encouraged the construction of L-shaped drains along all types of roads. The following are important considerations in the maintenance and construction of side drains:

- The drains are to be graded to ensure free flow of water to culverts or water courses.
- Particular attention is also to be given to drains along the higher sides of the super-elevated curves to prevent water spilling over the pavement and in locations where the grade is only slight, such as on level sections along the road, on sags in the longitudinal grade. In such places, it is often necessary to deepen the drain in order to secure satisfactory drainage conditions. Such sections are to be checked after every storm and remove silt as necessary.

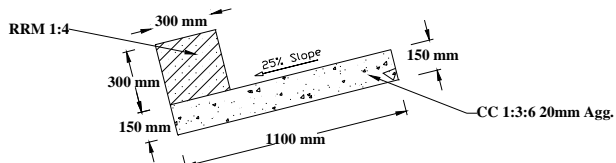
## SECTION 4: DRAINAGE

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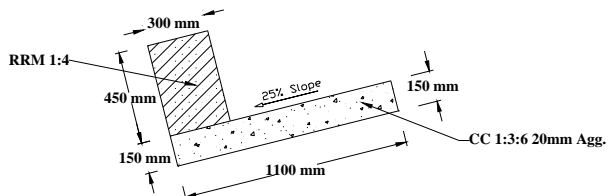
As far as practicable, these drains are to be kept free of debris or any foreign matters at all times. Soil debris from the drains should be disposed off properly.



LOW RAINFALL AREA



HIGH RAINFALL AREA



HIGH RAINFALL AREA (As per site conditions)

**Figure 12: Side Drains**

### **4.2.1.3 Cross Drainages**

The water from the drains are collected and drained into culvert, bridges and open storm water crossings.

- These cross drainages are to be kept free of silt, debris, stones and all the drains are to be connected thereto in a satisfactory manner.
- The culvert or crossing should receive all the drainage from the catchments for which it was designed, otherwise structures further along the road may be seriously overtaxed resulting in flooding and damage to road or private property.
- Attention is also to be given to open storm water crossings after each rain, removing any obstructions tending to pond water.
- Particular attention is to be given to prevention of water lodging on or near the pavement. Should any repair be considered necessary to the crossings, excessive scouring be taking place, it should be attended promptly.

### **4.2.2 Sub-Soil Drainage**

This drainage is required to prevent the water from entering into the sub-grade soil and softening the soil and rendering it unstable and resulting in failure or distortion of the pavement. The sub-grade soil softened by the water is unstable to withstand the loads transmitted to it.



## *SECTION 4: DRAINAGE*

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The entrance of water into the sub-grade soil could be due to one or more of the following situations:

1. Water directly percolating through the road surface from above or through the shoulders
2. Seepage from higher ground or natural springs
3. Water rising from below by capillary action in low lying grounds or swamps
4. Leakages from water pipes and irrigation channels and spillages from paddy fields

### *Measures*

*Situation 1:* By making the pavement more impervious and proper maintenance of shoulders.

*Situation 2&3:* It is necessary to lower the level of ground water by sub-soil drains or deep side ditches, or alternatively, raising the level of the road. In some cases it is usually cheaper to construct and maintain deep side drains than to install sub-soil drains.

*Situation 4:* The fourth case can be best overcome by repairing the pipe or irrigation channel. However, when leak can not be exactly located, especially in case of underground pipes, it may be necessary to install sub-soil drains in order to collect the water from leakages.

## **5 SHOULDER MAINTENANCE**

### **5.1 General**

Shoulders provide support to the pavement and can be used by the traffic in an emergency. Shoulders can be constructed of the same material as the pavement, but in Bhutan are of lesser quality, smaller size of stone and not as thick as the pavement.

Stone aggregates (50-20mm) make suitable material for road shoulders.

### **5.2 Maintenance**

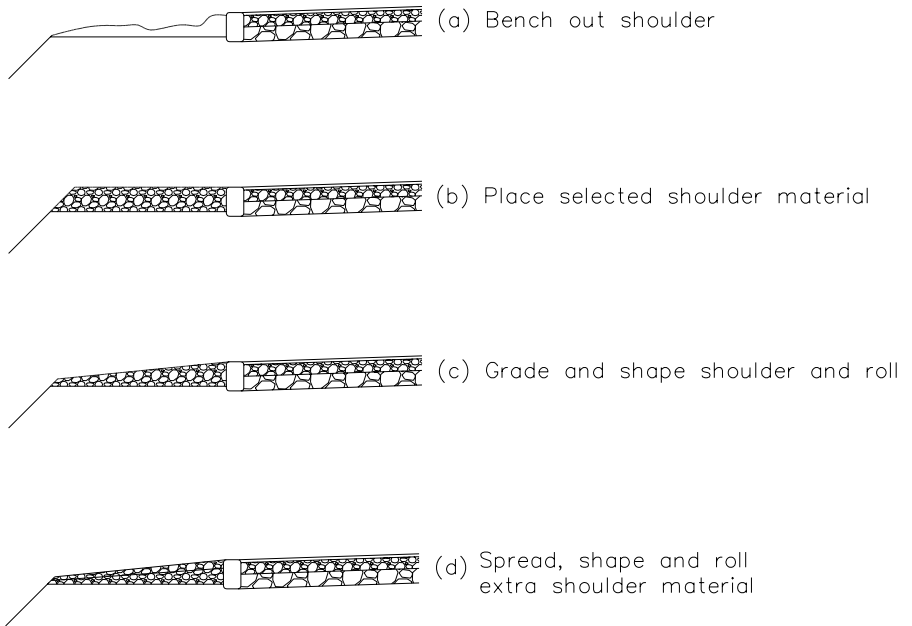
The maintenance of shoulders involves:

- Keeping the shoulders even or flush with the pavement edge and at slopes which permit drainage of surface water away from the pavement.
- Shoulders are maintained by grading, replenishing and compacting the shoulder material. The frequency of these operations depends on the level of deterioration of the shoulders.
- Grading of shoulders can be done either by use of motor grader or manually. While using a motor grader care should be taken not to damage the pavement by the grader blades and any loose material that goes to the pavement surface should be cleaned off immediately.

The action of rain and traffic causes the shoulder material to be lost and new materials will be required to be spread and compacted to bring the shoulder flush with the edge of the pavement.

## SECTION 5: SHOULDER MAINTENANCE

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**Figure 13: Method of Shoulder Restoration**

## **6 UNSEALED WBM ROADS**

### **6.1 General Maintenance**

All the Feeder Roads and few stretches of National Highways and District Roads are constructed without bituminous surfaces (unsealed). Satisfactory maintenance of surfaces on these pavements involves:

- Regular attention to corrugations, potholes, depressions and scours, by grading or patching
- The elimination of loose, harsh or slippery conditions
- Occasional reshaping so that water will quickly shed to avoid excessive softening
- Strengthening of weak sections
- Attention to shoulders
- Attention to drainages

### **6.2 Method of Maintenance**

The Water Bound Macadam (WBM) pavement consists of crushed rock particles of 20-50mm size with voids filled with finer materials (binding materials). Such courses are constructed as a base course and are usually 100mm in thickness.

#### **6.2.1 Patching potholes and weak areas**

If the surface is adequately maintained by grading, patching of the pavement is usually required at isolated points only. Where there is a depression too large to be eliminated by grading and not due to weakness in the pavement or sub-grade, it is to be filled with material similar to that in the adjoining pavement. If necessary

the existing pavement is to be lightly scarified to bond with the new material. Compaction and smoothing are then effected by traffic and normal grading.

### **6.2.2 Shallow holes**

- Shallow holes in the WBM pavements are preferably patched after rain, when the patch gets more readily bound into the adjacent pavement.
- After removal of loose material the holes should be cut square and filled with material similar to that in the existing road.
- The filling material should be covered with damp binding material and then tamped until firm.
- The tamping could be done using the mechanical rammer, rollers, heavy hand tampers or by truck wheels.

### **6.2.3 Large Holes**

Large potholes and areas damaged because of weaknesses in the pavement or the sub-grade are to be repaired by excavating and placing pavement as follows:

- Mark out a rectangular area large enough to cover the whole of the pothole or other weakness, then excavate and remove all unsatisfactory material. Cut the sides vertically into firm pavement. Provide necessary subsoil or shoulder drainage to avoid pockets of water in sub grade, remove inferior sub grade and replace with sound material such as gravel, sand, loam and fine crushed rock. Before adding new material, the bottom of the excavation is to be well rammed.

- All pavements are to be restored in layers not exceeding 100mm depth. The new material is to be similar to that in the existing pavement or of superior quality.
- All the patching materials must be compacted in layers so that the final surface is smooth and conforms to the level of adjoining sound pavement. A motor grader or drag will generally be required to level large patches particularly in fine grained materials. Where the compaction is to be effected by traffic, the surface is to be kept about 15mm above the adjacent pavement, kept under observation and topped up and smoothed as necessary.

#### **6.2.4 Reshaping**

The WBM surfaces become irregular (cross fall, grade and alignment) due to wearing away of the materials by traffic and the effect of weather. Restoration of the surfaces to the correct shape is required to be undertaken from time to time. This process should normally be undertaken when moist conditions prevail in the pavement.

Reshaping is normally carried out using a motor grader for large areas or by hand made wooden drags for small areas. After correct shape has been obtained, it is often required to roll adding binding materials and water until a smooth and dense surface is obtained. In all cases of pavement reshaping, care must be taken to avoid disturbing large stone in the base-course and bringing into the pavement inferior materials from the shoulders and side drains. Shoulders adjacent to the reshaped pavement must be built up or reshaped as necessary.

## **7 SNOW CLEARANCE**

### **7.1 General Maintenance**

Keeping road open during and after snow falls require:

- Snow clearing by machines or men
- Spreading of chemicals (salt) to remove ice
- Spreading of grit (fine stone chippings) to provide traction for vehicles

### **7.2 Snow Clearance**

The mechanical way of clearing snow is by blading it over the side of the road. The equipments used for snow clearing are:

- Motor grader
- Front end loaders

While deploying these machines for snow clearing, care must be taken not to damage the pavement by the blades.

### **7.3 Ice on the surface**

A film of ice forms on the surface of the road when snow freezes or due to low temperatures and frost. The ice on the road surface reduces the friction between the wheels of the vehicles and the road surface and vehicles tend to loose control and slip off the road.

Ice on road requires treatment with chemicals (salt) to melt ice or by spreading grit (fine stone chippings) to provide traction for the wheels.

### **7.4 Use of Chemicals for melting ice**

Sodium Chloride (Salt) or Calcium Chloride may be used to melt ice on road surfaces. De-icing salt works by creating a brine solution that has a lower freezing temperature than the temperature of the surrounding snow and ice. This brine gets in between the road surface and ice, preventing a bond that would make removal difficult. When salt is spread before snow fall or drop in temperature, it can prevent snow accumulation or ice formation. Application of salt is done by throwing by hand. Though Calcium Chloride also has the same effect as Sodium Chloride, most countries use the later for melting ice as it costs lesser than the Calcium Chloride.

It is to be noted that salt should not be used on roads under construction where bitumen sealing is to be carried out in the future, as the salt may damage the seal.

### **7.5 Use of Grit**

Where the use of salt as de-icing agent is not permissible, or the temperature is so low that a complete melt is not possible with salt application, grit should be spread to increase traction. The grit may be spread by hand if the area is to be treated in small.



**Figure 14: Snow Clearance by machine**



## **8 LANDSLIDES**

### **8.1 General**

Clearing landslides is a major task confronting maintenance crews throughout Bhutan. Many factors contribute to the instability of the formation cutting which causes earth and rock to fall and block the roadway.

While a lot of landslides occur for which little can be done, many slides can be prevented. Some factors to be considered on the causes and prevention of landslides are:

#### **8.1.1 Angle of repose of the natural material**

Rock and firm earth have a steep angle of repose while decomposed material and sandy gravel have a flat angle. This means when a formation is constructed through rock, quite steep batter angles can be tolerated and will remain stable. However, the same cuttings through softer material will slip down on the roadway. Because much of the terrain in Bhutan have steep side slopes it is often not possible set back a flat batter in the soft material to produce a stable batter slope. However, where it is reasonably economic to lay back the batter and obtain additional width of road, while doing maintenance, this should be done.

#### **8.1.2 Drainage**

Seepage of water during monsoon causes almost all the landslides that occur in Bhutan. Attention must therefore

be given by maintenance engineers at all times to the drainages. Catch drains are often required at the top of the formation cuttings to divert the water towards valleys and natural springs.

### **8.1.3 Vegetation**

Top soiling of batters and planting grass, shrubs, bushes and trees will the surface of the cuttings and make them stable during rain. Local species of vegetation should be planted as this will have the best chance of growing.

### **8.1.4 Retaining Structures**

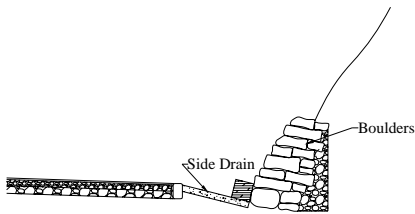
Retaining Structures of different types are common and they are effective ways to retain the batter and the formation. Construction of small breast walls and retaining walls, crib walls and boulder walls may be carried out to retain unstable slopes.



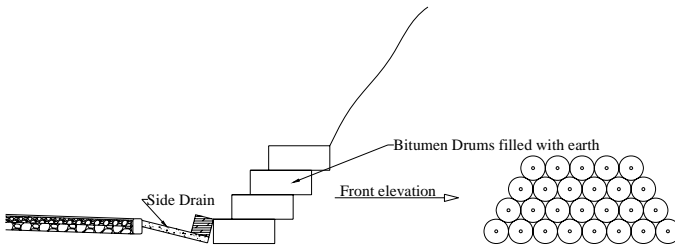
**Figure 15: Bitumen Drum Wall**

**SECTION 8: LANDSLIDES**

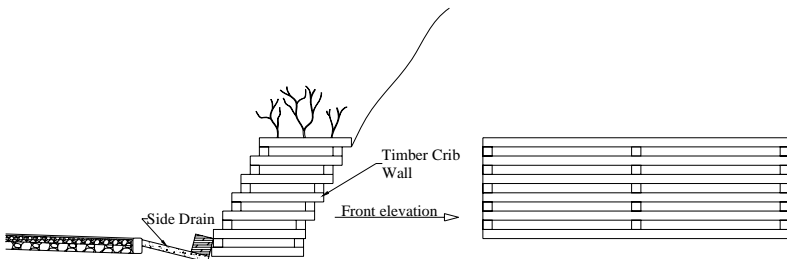
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Boulder Wall



Bitumen Drum Wall



Crib Wall

**Figure 16: Types of Retaining Structures that can be taken up as Routine Maintenance**



**Figure 17: Pay Loader clearing landslide**



**Figure 18: Boulder Wall**

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