5 MAINTENANCE OF DRAINAGE, SHOULDERS AND SLOPES

5.1 THE DRAINAGE SYSTEM

One of the most important aspects of the design of a road is the provision made for protecting the road from surface water or ground water. If water is allowed to enter the structure of the road, the pavement will be weakened and it will be much more susceptible to damage by traffic. Water can enter the road as a result of rain penetrating the surface or as a result of the infiltration of ground water. The road surface must be constructed with a camber so that it sheds rain-water quickly and the formation of the road must be raised above the level of the local water table to prevent it being soaked by ground water.

Water can also have a harmful effect on shoulders, slopes, ditches and other features. High water velocities can cause erosion which, when severe, can lead to the road being cut. Alternatively, low velocities in drainage facilities can lead to silt being deposited which, in turn, can lead to a blockage. Blockages often result in further erosion.

A good road drainage system, which is properly maintained, is vital to the successful operation of a road. It has four main functions:

(i) to convey rainwater from the surface of the carriageway to outfalls (streams and turn-outs);
(ii) to control the level of the water table in the subgrade beneath the carriageway;
(iii) to intercept surface water flowing towards the road;
(iv) to convey water across the line of the road in a controlled fashion.

The first three functions are performed by side drains and the fourth by culverts, drifts and bridges.

Common drainage problems include:

(i) blocking of drains by debris or vegetation;
(ii) silting: the deposition of silt in the bottom of drains and culverts, often reducing the gradient;
(iii) erosion of the bottom of side drains in erodible soils or on steep gradients, particularly where insufficient turn-outs result in large flows in drains;
(iv) erosion at culvert outfalls, resulting from high discharge velocities;
(v) erosion of shoulders and side slopes.

Even if the drainage system of a new road has been carefully designed, it is likely that for several years after construction it will be necessary to observe its performance closely and to make additions and amendments to it. Reference is therefore made here to design matters where these can be seen as forming part of the maintenance function.

Both in the design and in maintenance of drainage, it is important to interfere as little as possible with the natural flow of water. Culverts on natural water-courses should follow the existing alignment as closely as practicable and re-alignment (often resulting in sharp changes in direction) should be avoided. The surface flows in drains and culverts should also be kept to a minimum by the use of frequent turn-outs where side drains cannot be discharged to existing water courses. In side-long ground, where discharge from the side drain on the high side passes to the low side, it is best to use frequent small culverts rather than occasional large ones. In such cases, the spacing will be governed by the maximum flow acceptable in the side drains and the capacity of the culverts will not usually be a constraint as the minimum requirements for access for maintenance (often taken as 600mm diameter or 600mm x 600mm box) will ensure adequate capacity.

5.2 SIDE DRAINS

The level of the water table beneath the carriageway is a major influence on the strength of the subgrade. The bottom of side drains should normally be main tained at a level at least one metre below formation level (the underside of the sub-base). If side drains have been constructed too shallow and they are not performing properly, they should be deepened as part of the maintenance operation. The performance of side drains should be monitored over time by the Maintenance Engineer to determine designs and dimensions appropriate to local topographical, climatic and soil conditions.

Side drains are usually built to the same gradient as the road. This may result in high velocities and erosion on steep gradients and silting on flat or reductions in gradient. Volumes in the side drains can usually be reduced by constructing frequent turn-outs.

In highly erodible soils, additional measures may be needed to prevent or control erosion. Grass should be encouraged to grow in drainage ditches as this helps bind together the topsoil and inhibits erosion. Where the erosion is only just starting, the most effective control is likely to be to dam the side drain at frequent intervals and to construct additional turn-outs. More severe erosion may need check-dams as shown in Fig. 6.
Fig. 6 Check-dams for sidedrains

- Hand placed rocks up to 200–300 mm
- Fine/medium gravel filter (2-20 mm) placed against upstream side and in bed
- Gabion mattress or rock rip-rap as appropriate to prevent scour downstream
- Steel wire mesh baskets (gabions) filled with rock up to 200–300 mm and set into ditch bottom and sides

About 1 metre

Where small dams are needed, wooden stakes up to 100 mm driven into bed of channel can be used with space between filled with brushwood. Alternatively, a series of stakes across the ditch can be used to make a small dam

This distance such that gradient (A) is about 1 in 70 to 1 in 100

Height 1/2 to 2/3 depth of drain
Fig. 7 Layout of turn-outs
Dumping rock into an erosion gully is not usually effective unless a filter of finer material is also used. Rocks in steel wire mesh baskets or gabions may be more effective. These are shown in Fig. 6. Gabions should be extended well into the sides of ditches to prevent scour around their edges. Protection should also be provided at the foot of check-dams either by rock rip-rap or gabion mattresses as found appropriate. In very steep sections on highly erodible soil, it may be necessary to line the ditch with concrete, masonry or rip-rap. In time, erosion prevention measures may themselves require repair.

Removal of silt should form part of the routine maintenance programme. Silt should be thrown at least two metres clear of the side drains away from the road. It must never be used to repair road surfaces. If silting of side drains persists, it may be advisable to realign the ditches to increase water velocities, if this is possible.

The discharge from side drains should, wherever possible, be taken to existing natural watercourses. Where this is not possible, the side drains should be interrupted at intervals by dams, and the flow discharged to turn-outs (see Fig. 7). Here the water will be dispersed by seepage, evaporation, or by surface flow. Turn-outs should be built so that they have a longitudinal gradient of about 1 in 50 to 1 in 100 (ie. nearly parallel to the contours) and of such length that they run out to zero depth. The spoil from turn-outs should be thrown to the low side. The junction of the side drain and the turn-out should have a radius of at least five metres. This avoids the tendency for scour to occur at this point. Spacing of turn-outs depends on several factors including the erodibility of the soil, the width and gradient of road and cross-slope of the ground. On highly erodible soils, the spacing may initially be based on those indicated in Table 2. Spacings may be increased on soils with greater resistance to erosion. Observation of the performance of the side drains and turn-outs in practice will indicate if any changes are necessary.

<table>
<thead>
<tr>
<th>TURN-OUT SPACING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gradient</strong></td>
</tr>
<tr>
<td>1 in 100 or less</td>
</tr>
<tr>
<td>1 in 100 to 1 in 50</td>
</tr>
<tr>
<td>1 in 50 to 1 in 20</td>
</tr>
<tr>
<td>1 in 20 to 1 in 10</td>
</tr>
<tr>
<td>more than 1 in 10</td>
</tr>
</tbody>
</table>

In agricultural areas, the construction and maintenance of turn-outs can cause difficulty with farmers. The matter should be discussed at the outset with the farmer as it is often possible to integrate road and farm drainage. In the last resort, it may be necessary to ask for the assistance of the Civil Authorities. Compensation may need to be paid.

Turn-outs should receive the same attention as side drains during maintenance. Both can be maintained by hand or with a grader. The cross-section of the ditch or turn-out determines the most appropriate method of maintenance.

The use of cut-off drains should be avoided as they some times cause small land-slips. Because they are often difficult for maintenance crews to locate, they are often neglected and become ineffective.

**5.3 FORDS AND DRIFTS**

Fords and drifts are often used on lightly trafficked roads at watercourses with seasonal flows. They may be covered by deep water for short periods when traffic may not be able to pass, or by shallow water for longer periods. For much of the year they may be dry.

Maintenance of fords and drifts should be carried out after flooding and much of it consists of maintenance to carriageway, earthworks and culverts as for a normal length of road. In addition, warning signs, marker posts and depth indicators should be checked, and repaired or replaced as necessary. The crossing should be checked to ensure that the carriageway has not scoured or washed out, and any damage should be repaired. Erosion downstream of the ford is a common problem and, if necessary, a masonry or concrete apron should be constructed. An alternative may be to use stone gabions or mattresses. Any silt or debris must be cleared from the carriageway.

Some drifts have a culvert passing under them. These can cause the deposition of silt up-stream of the drift which tends to block the entrance to the culvert, making it ineffective. If culverts are used in drifts, they should be large enough and steep enough to be self-cleaning.

**5.4 CULVERTS**

Culverts are provided to convey water from the upstream side of the road to the downstream side. They may be built on the line of existing watercourses or to carry the build-up of water which results from the presence of the road. In either case, silting, choking by debris or structural collapse will usually result in over-topping and damage to the road. Maintenance comprises keeping the waterway clear, controlling scour and repairing structural damage.
Erosion of outlet channels from culverts is a common problem and if not dealt with promptly is likely to result in damage to the culvert and the road. This is caused by high discharge velocities from the outlet, and solutions which do not take account of this are not likely to be permanently effective. If the discharge velocity cannot be reduced by increasing the area of cross-section of the culvert and reducing its gradient, perhaps with a drop-inlet, then some type of energy-dissipating outlet should be used. As a first step, a fan discharge constructed with masonry or concrete should be tried. Stone gabions or mattresses downstream of the outlet may be a cheap alternative. Drop outlets are good, but on many sites there is insufficient height to construct these.

The checking and removal of debris from culverts can be difficult, particularly if the culverts are small. Long-handed shovels or shovels attached to rods are useful for clearing out culverts which are too small for a man to get inside. Trees or branches blocking culvert entrances should be sawn into convenient sized pieces to help their removal and carting away. Culverts which get regularly blocked by debris should have a grill constructed at their upstream entrance.

Culverts made with corrugated metal pipes can be abraded by water carrying silt and sand which can wear away the protective zinc coating. This will result in the culvert pipe rusting away. If the culvert is large enough for a man to enter, the rust can be removed with a wire brush and the pipe coated with a thick layer of hot bitumen or tar. Alternatively, a flat concrete invert can be constructed.

Culverts made from concrete rings can be subject to differential settlement. This is a construction fault and major settlement problems can only be corrected by reconstruction. Minor mis-alignments should be repaired by grouting the joints in the pipes with concrete to provide a waterproof seal.

5.5 BRIDGES

Bridge inspection and maintenance requires specialist knowledge and skills, some of which will only be held by a qualified bridge engineer. The maintenance of large bridges is beyond the scope of this Note. However, some repairs to small bridges can be accomplished by a normal road maintenance unit and notes on these are included here.

The maintenance of the waterways under bridges involves the same principles as that for culverts. The main operations involve keeping the waterway clear, controlling scour and repairing structural damage. Maintenance methods are similar to those described under the maintenance of side drains, fords, drifts and culverts (Section 5.2 to 5.4). Debris should be removed as soon as possible after floods, and eroded and scoured areas should be repaired. These should be filled with compacted gravel and then protected with rip-rap, concrete or gabions. Deposits of silt and sand should be removed where necessary to restore the original channel.

Simple repairs can be carried out to the decks of timber bridges. Loose plans can be re-fixed using screws or nails whose length is two or three times the thickness of the planl. Defective planks should be replaced with new planks of the correct thickness, length and width, which should be treated with wood preservative. All nail heads should be driven flush with the surface. Whenever planks are replaced, the condition of the timber underneath should be checked.

Small painting jobs can be undertaken such as the repainting of railings or, occasionally, steel beams. All dust, dirt and old paint scale should be removed, where possible with an oxy-acetylene burner, and then with a wire brush. The steelwork should be given coats of primer, undercoat and topcoat. Only good quality paint should be used and it should be brushed thoroughly into the steel. Ample time should be allowed between coats for the paint to dry. Brushes should be washed thoroughly after use with thinners, petrol or kerosene. The colour of the topcoat should be as bright as possible for better visibility and safety.

5.6 SHOULDERS

Shoulders provide lateral support for the carriageway. They also provide accommodation for stopped vehicles and, on narrow roads, provide room for passing vehicles. Besides being used by vehicles, they are also used by pedestrians, cyclists and for animal driving. Shoulders may be paved, gravel, earth or may be grassed.

Paved shoulders are subject to the same type of defects as paved carriageways and are repaired using the same methods as described in Section 7 (Maintenance of paved roads). It will usually be convenient to carry out repairs to this type of shoulder at the same time as the repairs to the carriageway with the same maintenance gang. Periodically, it is necessary to resel shoulders and this should be carried out in the same way as for manual surface dressing (Section 7.6).

Similarly, maintenance of earth and gravel shoulders is essentially the same as for unpaved roads. Most defects are corrected by grading, although ruts and pot-holes can be repaired manually (see Section 6.5). One of the objects of grading is to retrieve gravel lost to the shoulder and place it back on to the carriageway. On no account, must sediment from the ditch be graded on to the shoulder. The grader should cut to the bottom of all defects in the shoulder and spread the material so that, when compacted, it is level with the carriageway edge and slopes away to the ditch at a
steeper crossfall than the carriageway. For unpaved roads, this grading should be carried out at the same time as grading of the carriageway and in the same way (see Section 6.2).

If shoulders are worn away by the action of traffic and the level falls below that of the carriageway at the edge, water can collect at the edge of the road and infiltrate the base. This considerably weakens the structure of the road and usually results in severe deformation of the carriageway. In the case of paved roads, the edge starts to disintegrate and break away. This type of edge damage is difficult to repair effectively, but must be patched using methods similar to those described in Section 7.4. Edge repairs must be accompanied by the placing and compacting of new material on the shoulder or the repairs will be ineffective. Periodic regravelling of the shoulders should be carried out in a similar way to that described in Section 6.4.

Grassed shoulders can cause problems if the grass traps material washed off the road, leading to the shoulder level building up and trapping water at the edge of the carriageway. If this occurs, the shoulders should be graded-off as described above. Where there are bushes and high grass growing on the shoulder which interfere with lines of sight, these should be cut back as short as possible. This can be done using a tractor-mower or by hand using scythes and cutlasses. Where there is much road side furniture, hand cutting will be easier than using a machine.

When there is extensive damage to shoulders as a result of erosion or washouts, repairs are needed urgently and should be carried out as described in Section 5.7.

5.7 SLOPES

For all slips and settlements of cut and fill slopes which affect the road, the maintenance gang should place warning signs, cones and barriers around the site according to the layouts described in Section 3. Severe damage, where the road is cut by a landslide or a washout will usually have to be repaired by special gangs often needing heavy construction equipment. Less severe damage can often be repaired by the maintenance gang. Although slips and settlements can occur as a result of slopes being too steep, they are much more usually associated with the presence of water in the soil.

In the case of landslide material blocking the road, all the material should be removed and carted away on a tipper truck or on wheelbarrows and dumped where it cannot affect the road. Roadside ditches should be cleared of all debris and ditch shapes should be reinstated. When shoulders have been cleared, their levels should be checked to ensure that water can flow from the carriageway uninterrupted into the drain. When the failed slope is not to be reinstated, the sides of the slip area should be rounded off.

Where there has been severe erosion or slips which have removed part of the carriageway or shoulder, or if erosion of slopes threatens the road structure, repairs are needed urgently. Loose material must be removed and the damaged area should be cut back to sound material. New material must be placed and compacted in 50-7 mm layers using small vibrating rollers or hand tampers. It may be necessary to add water to the fill material to assist compaction. When reinstating slopes in these cases, gabions can be used for all or part of the repair work. In all cases, protection measures should be taken to stop the slip occurring again. Thin will probably involve improvements to the drainage system and may require paving of the slope itself using rip-rap, masonry or concrete. The use of gabions for filling material removes the need for slope protection. Establishing grass or other vegetation on the slope may be a cheaper form of protection. It may also be necessary to surface the shoulder with gravel or with a bituminous surface dressing.

5.8 MAINTENANCE GANG

For general maintenance work to drainage features, shoulders and slopes, the detailed composition of the maintenance gang will depend on whether the work is to be carried out by labour-intensive or equipment-intensive methods. A suggested basic gang size is given below, but this will need to change for different operations and situations, and the Maintenance Engineer should develop his own gang compositions to meet his own local circumstances.

Personnel
1 Overseer/Gang leader
1 Driver
Several labourers

Vehicles and equipment
1 Small truck or tractor-and-trailer
1 Hand-held vibrating roller (0.25 Mg) plus a plank to help load onto truck or trailer, or one hand rammer for each labourer used on compaction work
1 Pick-axe for every two labourers
1 Broom for every two labourers
1 Shovel or hoe for every two labourers plus extension rods for culvert clearing
1 Rake for every two labourers
1 200 litre drum for water
1 Bucket or watering can
1 Axe
Safety equipment as recommended in Section 3.
6. MAINTENANCE OF UNPAVED ROADS

6.1 TYPES OF MAINTENANCE

The principal operation in maintaining earth and gravel roads is grading. Dragging or brushing may also be carried out with the objective of controlling the development of corrugations, and light or routine grading is also carried out for this reason. Heavy grading is used to reshape the road surface and to restore it to its correct camber or crossfall and to provide a smooth running surface. Heavy grading can be combined with regravelling to restore the thickness of the gravel surface. Filling or patching are labour-intensive operations to deal with the worst defects on low-volume roads for which the expense of grading or other machine activities cannot be justified.

6.2 GRADING

6.2.1 Types of grading

Light grading is a light trimming of the surface of the road which should be carried out on a routine basis particularly in the dry season to control roughness and corrugations. When undertaking light grading in the dry season, loose material should be bladed towards the edge of the road. If several graders are available, it is more efficient to use them together on the same job. In this case, they should work one behind the other covering the whole width of the road. In the wet season, material should be graded towards the centre of the road. Light grading maybe carried out by motor graders, but a more cost-effective technique is to use tractor-towed graders which are capable of similar outputs and standard of work on properly constructed roads.

Heavy grading consists of scarifying and cutting to the bottom of deformations and then reshaping the surface. It usually requires the use of a 135 horse power motor grader but, in some cases, the tractor-towed grader could also be utilised. Heavy grading operations should always be carried out at the beginning of the wet season to ensure that the road has the correct profile for effectively shedding water during the rains. When possible, it should also be carried out at the end of the wet season when the moisture content of the surfacing material is still high enough to help recompaction and prevent loss of fines. This is particularly important when heavy grading is needed to remove ruts and potholes. Scarifying to the depth required to remove these will result in the production of a considerable depth of loose materials and, in the dry season, this cannot be recompacted unless large amounts of water are added. The surface will then be

Materials

Patching materials as indicated in Tables 3 and 4 for unpaved shoulders and slopes and as indicated in Tables 5-7 for paved shoulders.

Cement, sand and ballast may be needed for making concrete for repairs to culverts and paved ditches. Water, if not obtainable on site, must be carried.

Grass cutting work can be done by this same gang equipped with scythes and cutlasses or by a specially-equipped tractor mower. Shoulder grading should be carried out with a grader of at least 135 horse power working in conjunction with compaction equipment wherever possible.