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
quickly deformed and fines will be scattered by traffic. Heavy grading of gravel is inadvisable without the provision of additional surfacing material if the remaining thickness of gravel is less than 75mm.

The frequency at which grading should be carried out will depend upon the traffic, the climate and the nature of the surface material. Gravels of average quality will probably need grading after 12,000-15,000 vehicle passes and good quality gravels may sometimes be left for 25,000 vehicle passes. For roads that are liable to corrugate, grading may be needed after the passage of only 1,500-2,000 vehicles. Some gravels, particularly those which are self-cementing or which contain large size material, are not suitable for grading as this results in the surface being torn up. Patching or regravelling is needed to repair these. The frequency of grading will also depend upon the daily traffic level as, at high traffic levels, a higher level of service may be expected, requiring more frequent grading. More guidance on the choice of grading frequency is given in Overseas Road Note 1.

6.2.2 Crossfall

Earth and gravel roads require steeper crossfalls than bituminous surfaces if rainwater is to be shed satisfactorily. If the grader operator has been trained on construction work for paved roads, it will probably be necessary to ensure that he understands the different requirements for unpaved surfaces. Crossfall on gravel and earth roads should be between 1 in 25 and 1 in 15 (4-6 per cent). It is very important to ensure correct camber on steep alignments. ‘Flat’ cambers are frequently the cause of the longitudinal gullying commonly found on such alignments.

Crossfall should be checked on site using a simple camber board, such as that illustrated in Fig. 8 which can be carried on the grader. Use of the camber board is illustrated in Fig. 9. It should be placed on its edge across the road with its narrower end pointing towards the centre line. If the level bubble is central, then the camber is correct. Checks should be made at approximately 100 metre intervals along the road and if the camber is too steep or too flat, then the road must be graded again.

6.2.3 Steep hills

Steep hills on unpaved roads, where the longitudinal gradient is steeper than the crossfall, are prone to severe erosion in the wheel paths, particularly when these coincide in the centre of the road. Considerable attention must be paid to maintaining adequate cross-fall in these situations as this will minimise the erosion. If severe damage persists, consideration should be given to paving the gradient either by surface dressing or preferably with a concrete pavement.

6.2.3 Grader operation

The quality of workmanship in maintaining earth and gravel roads depends to a great extent on the skill and judgement of the individual grader operator. Careless operation can cause extensive damage to a road, for example by flattening the crown so that rainwater is not discharged, by cutting too deeply in dry weather or by blading plastic material from side drains on to the carriageway.

The Maintenance Engineer must get to know the ability of each grader operator and should find out the capability of each type of grader in use in his District. The manufacturers of graders publish manuals which explain the correct use of their machines in various applications and these should be obtained and studied by the Engineer. A particularly useful document is Grading Illustrated (Aveling-Barford, undated). With this information he will be better able to explain his requirements to grader operators and to ensure that they are carried out.

Arrangements must be made for graders to be checked mechanically, greased and fuelled before each day’s work. The Maintenance Engineer must make operators understand the need for preventative maintenance of their machines and must try and ensure that equipment is not mishandled, misused or abused by operators in

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Fig.8 Five per cent camber board
Fig. 9 Use of camber board

Fig. 10 Transition of camber on approach to bends
the field. This can only be achieved by proper training and regular site visits by the Engineer. Arrangements may also need to be made to refuel graders on the job if necessary. This may be done either with a refuelling truck visiting the working site, or with an arrangement to refuel at a maintenance camp.

For heavy grading, the grader works on one side of the road at a time, if at all possible, and works in passes of about 200 metres in length. Graders must not stop on junctions or on bends where they will be a danger to traffic. On straight stretches of road the operator should aim to develop a crown on the road. The surface should be cambered to fall away from the crown with a slope of 4-6 per cent. The shape of the road must be maintained across culverts but, on sharp bends, the surface must be superelevated and must be flat from shoulder to shoulder with the outer shoulder higher. Any crown on a bend can be very dangerous to traffic. On the transition from bends in the road to straight sections, the camber on the outside lane should be gradually reduced until the normal cross-section shape is obtained again (see Fig. 10).

For heavy grading, it is important to cut to the bottom of surface defects and, if the road surface is hard, the grader's tines should be used to loosen the material. The grader should start from the edge of the road and work towards the centre. Gravelled shoulders should be treated as part of the running surface. The first and second passes cut to the bottom of the surface irregularity and deposit a windrow just beyond the centre line. If water is to be added, then the water tankers should spray the road at this point. The windrow is then spread back across the road depositing all the material on the carriageway to give the correct camber. The material may need to be sprayed again with water during this operation. After the camber has been checked, the other side of the carriageway is graded in a similar way to complete the work and leave a smooth even surface. This is illustrated in Fig. 11.

It is essential that the grader does not make a final pass down the centre of the road with the blade horizontal. This flattens the centre of the road and causes water to pond. This leads to rapid deterioration of the surface. Windrows must not be left in the middle of the road overnight as this is a danger to traffic.

If compaction equipment is available for use, it must follow up closely behind the grader but must only work on sections where grading has been completed to avoid interference with the grading operation. Rolling should start at the edge of the road and work towards the middle. Providing that the work is carried out in the wet season, watering of the road will not be necessary before rolling. Otherwise water should be added, as necessary, during the rolling operation to give the correct moisture content for compaction. The rollers should aim to progress from section to section at the same rate as the graders.

In the dry season, grading is essentially a dragging operation to remove loose dry material from the surface of the road and to fill in potholes and ruts (see Section 6.3).

6.2.4 Grading gang

For heavy grading, the grader needs to be powerful enough to cut to the bottom of the deformation in the road and a minimum size of 135 horse power is usually recommended. However, if the wearing course does not contain an excessive amount of oversize material, a tractor-towed grader could be used instead. The operator will normally be assisted by a machine attendant who helps direct traffic and grader turning, and removes large stones and other unwanted material from the path of the grader. He should work well ahead of the grader to stop it being delayed. The grader should carry a camber board and traffic signs as indicated in Section 3.2. Rollers should be used if available and water tankers should be used in conjunction with rollers if necessary.
For light grading, up to three graders can be used as this is more efficient for supervision, maintenance and refueling. The graders can be less powerful than those needed for heavy grading. Traffic signs should be used as described in Section 3.2.

All graders should be fitted with yellow flashing warning lights, and these plus headlights should be switched on when the graders are working.

6.3 DRAGGING AND BRUSHING

Regular and frequent dragging can be used, in the dry season, to delay the formation of corrugations on earth and gravel roads by removing loose material from the surface. Dragging will not remove severe corrugations once they have formed, nor will it restore camber or lost material. These defects must be corrected by heavy grading.

6.3.1 Design of drag

Typical drag units are shown in Fig. 12. The first consists of a metal ‘A’ frame constructed from 100 x 65 x 3mm channel on to which are bolted used grader blades. The leading one of these is angled to the direction of travel. The second unit is constructed from 100 x 75 x 3mm channel, but has additional blades for re-distributing the windrow. The approximate weights of these units are 250 and 375 kg respectively and they are relatively cheap to manufacture. Many other forms of drag have been used in various countries, such as railway rail, rolled steel joists, tolards, timber baulks, etc. However, the two types illustrated in Fig. 12 are recommended because of their proven performance in quantified field trials and their ease of manufacture. They should be towed at speeds from 5-8 kilometres per hour and are capable of maintaining roads carrying up to about 100 vehicles per day. They are also effective for dealing with corrugations.

6.3.2 Brushing

Brushing is generally effective only on very lightly trafficked roads with surfaces containing loose material. Typical tractor drawn brushes constructed from locally available material are shown in Fig. 13. The actual brushes used on the first type illustrated are made from brushwood tied tightly together. These must not be made out of old steel cable which is dangerous if broken off and left lying on the road. The tyre sledge illustrated consists of old tractor or heavy lorry tyres cut in half around their circumference and bolted or chained together. It is important that all the tyres are in contact with each other, as in the illustration, to ensure proper distribution of the loose material. Brushes made out of trees dragged behind a vehicle are not very effective for redistributing loose material on the road.

6.3.3 Method of operation

The basic method of operation for both dragging and brushing is the same.

The frequency with which dragging should be carried out depends on the traffic loading, the rate of development of corrugations and the soil type. A road carrying 100 vehicles per day may need to be dragged every two weeks using the metal drags illustrated in Fig. 12. One dragging pass will probably be necessary every 3 to 4 weeks for roads carrying 50 vehicles per day and every four to six weeks for traffic levels of 25 vehicles per day. Simple experiments should be carried out by the Maintenance Engineer to determine the optimum frequencies for different conditions.

The drag should be designed where possible so that its width adequately covers half the road. This enables the maintenance to be carried out with a single pass in each direction.

For the best results, four main adjustments can be made according to the conditions; namely depth of cut, angle of cutting blades relative to direction of traffic, towing angle of drag and weight of drag. The drags illustrated in Fig. 13 have height adjustments at each end of the cutting blades and the position of the blades on the drag can also be changed to obtain the required volume of windrowed material. Varying the towing angle between tractor and drag can also achieve different volumes of windrows, but this is more difficult to control. The depth of cut can also be varied by weighting the drag. The level of surface roughness and size of the gravel wearing course will largely dictate the optimum weight of drag. However, the designs in Fig. 13 can still be utilised by changing the thickness of the channel sections.

The tractor or grader towing the drag should always work in the same direction as traffic and should not stop on junctions or on bends. Drags should be towed at speeds of 5-8 km/h depending on the type of drag and on the condition of the road surface. Care must be taken not to drive too fast or tile drag will skip over the surface irregularities and will also generate a lot of dust. With brushes made of thorn scrub or brushwood, the operator must ensure that pieces which may break off the drag are not left lying on the road surface where they will be a danger to following traffic. Pass lengths should be as long as possible, preferably of the order of several kilometres.

6.3.4 Dragging gang

Dragging can be carried out by a small crew of a tractor driver and/or grader operator and a machine attendant, depending on the availability of equipment. It is most
Fig. 12 Metal cutting drags
Fig. 13 Types of brush drag

(a) BRUSHWOOD DRAG

Wooden sub-frame

Frame from steel angle or channel

Hinged draw-bar

Bundles of sticks secured with wedges of binding wire

12 x 20 lorry tyres

Metal connecting plates bolted into tyres

Towing eye

(b) TYRE SLEDGE
efficient to use several graders working in a team, one behind the other, spreading across the whole width of the road.

Machinery should, where possible, be fitted with flashing yellow warning lights, and these plus headlights should be switched on when working. If warning lights are not available, machinery should carry flags. Traffic signs should be used as described in Section 3.2.

6.4 REGRAVELLING

6.4.1 The task

The surfacing material of gravel roads is worn away by traffic, eroded by rain and blown away as dust. Where this occurs the subgrade will be exposed particularly in ruts and depressions. Before all the material has been lost and the subgrade loses shape and gets damaged, the road requires regravelling. Regravelling is also used to correct loss of shape, ruts, potholes and erosion gullies, when these have become severe.

Before regravelling work is carried out, it is important to make any necessary repairs or improvements to the drainage system of the road. If this is not done, the new gravel surface will deteriorate very quickly.

6.4.2 Quality of gravel

Most Roads Departments have standard specifications for gravels for surfacings (and for bases, where these are used). In practice, what is used will depend largely on what is available, and it may be necessary to use lower-grade material than is commonly specified. In dry climates, a fairly high proportion of clay binder is desirable to prevent the surface from ravelling and becoming corrugated. In wet climates, the presence of clay in the material is a disadvantage since it makes the surface slippery and prone to soften and rut under traffic. Suggested specifications in terms of grading and plasticity characteristics are given in Tables 3 and 4.

6.4.3 Organisation and equipment

Regravelling will be the major item of expenditure on the maintenance of gravel roads and its organisation should be carefully planned to ensure maximum efficiency.

The following will provide a basis for an estimate of the plant required for regravelling:

Gravel production: 1 bulldozer
1 loading shovel
1 grader
8 tipping lorries
6 labourers

Regravelling: 1 grader
1 6/8 tonne steel-wheeled roller and
1 pneumatic-tyred roller

TABLE 3
PARTICLE SIZE DISTRIBUTION FOR GRAVEL SURFACINGS

<table>
<thead>
<tr>
<th>B S sieve size</th>
<th>Percentage passing (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37.5mm</td>
</tr>
<tr>
<td>37.5</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>80-100</td>
</tr>
<tr>
<td>9.5</td>
<td>55-80</td>
</tr>
<tr>
<td>4.75</td>
<td>40-60</td>
</tr>
<tr>
<td>2.36</td>
<td>30-50</td>
</tr>
<tr>
<td>425µm</td>
<td>15-30</td>
</tr>
<tr>
<td>75µm</td>
<td>5-15</td>
</tr>
</tbody>
</table>

(*) Not less than 10% should be retained between each pair of such successive sieves specified for use, excepting the largest pair.

TABLE 4
PREFERRED PLASTICITY CHARACTERISTICS FOR GRAVEL SURFACINGS

<table>
<thead>
<tr>
<th>Climate</th>
<th>Liquid Limit not to Exceed (%) (*)</th>
<th>Plasticity Index range (%) (*)</th>
<th>Linear Shrinkage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moist tropical and wet tropical</td>
<td>35</td>
<td>4 – 9</td>
<td>2 – 5</td>
</tr>
<tr>
<td>Seasonal wet Tropical</td>
<td>45</td>
<td>6 – 20</td>
<td>3 – 10</td>
</tr>
<tr>
<td>Arid and semi-arid</td>
<td>55</td>
<td>15 – 30</td>
<td>8 - 15</td>
</tr>
</tbody>
</table>

(*) Higher limits may be acceptable for some laterites or concretionary gravels that have a structure that is not easily broken down by traffic. Lower limits may be appropriate for some other gravels that are easily broken down by traffic. Any variation from these limits should be based on carefully collated local experience.

Production can be estimated as 450-500m$^3$/day on a 5 kilometre average haul. If the haul exceeds 5 kilometres, additional lorries should be provided so that the other plant is fully utilised.
2 water tankers, if water is available
1 water pump
1 lorry
20 labourers

Production can be estimated as 300-350m³/day.

To provide 100mm of gravel on one kilometre of road 7.5 metres wide will require 750 m³ of gravel (compacted volume) so that the above team could regravel about half a kilometre of road per day.

Well in advance of the work, a start should be made to stockpile gravel at the borrow pit or quarry. In addition, arrangements must be made to obtain water close to the regraveling site. Whenever possible, a bulldozer or grader should open up a diversion track adjacent to the road. If a traffic diversion can be opened adjacent to the work site, it will enable the job to be carried out more efficiently and more safely. If traffic is heavy, the diversion may need to be gravelled and a grader assigned to keep the surface in good condition. After the diversion has been completed and before the work starts, warning signs, barriers and cones must be erected around the work area as described in Section 3.5. If it is not possible to open a diversion, 'lane closed' signing must be used as described in Section 3.3.

6.4.4 Spreading gravel

It is advisable to reshape the existing surface before placing additional material. If this is not done it is likely that existing deformation will be reflected in the new surface. A hard surface should be scarified with a grader to a depth of about 50 mm to ensure a good bond between the new and existing material. The edges of the road should be 'boxed-out' to provide support for the new material. The camber of the graded surface should be checked to ensure that it is between 4 and 6 per cent.

At the quarry, the tippers should be loaded for transport to site. The supervisor at the quarry should ensure that gravel is taken from the right place and that the trucks are loaded correctly. Tippers circulate continuously between the quarry and the site. Usually the gravel is supplied in advance and tipped in heaps on one side of the road at the correct spacing to give the required thickness of material when spread across the road. If the diversion has not been opened, material must be tipped onto the shoulder and warning signs placed at either end. If the gravel is fairly moist, this will not cause any serious problems, but dry gravel is likely to segregate during the loading, tipping and subsequent spreading operations. A better method of spreading gravel is to use a spreader box towed by a lorry. This is much faster than spreading using a grader, but does require a continuous feed of lorries or the method becomes very inefficient.

Ideally, the moisture content of new gravel should be adjusted to optimum for compaction. In practice, this may be impracticable in view of the cost of providing, transporting and applying large amounts of water. However, it is usually possible to take advantage of the climate and to carry out regraveling work at the beginning of the dry season when the natural moisture content of gravel from borrow pits is close to optimum. It is important that the work is planned to obtain maximum benefit in this way. If additional water is required and available, the tankers should spray the road initially, before the new gravel is spread. The new gravel is then spread right across the road using the grader. The new material is alternately spread by the grader and watered by the tanker until its moisture content is correct for compaction. The tankers circulate continuously between the site and the source of water.

Once the material has been spread evenly across the road and it is at the correct moisture content, it should be graded to shape as described in Section 6.2.3. Finally, the camber should be checked with the camber board and, if the required standard has not been reached, the grading should be repeated.

6.4.5 Compaction

Compaction should not be left to the action of traffic as this quickly becomes concentrated in the wheeltracks and leads to deformation of the road. Rollers should be used if available as, even though it may not be possible to achieve full compaction, the limited compaction obtained will improve the quality of the surface. Four passes of a roller will give a worthwhile degree of compaction at optimum moisture content, while eight or more will be needed to bring relative compaction up to that required.

Compaction should start as soon as the grader has finished a section. The rollers should start at the edge of the road and work towards the centre and continue rolling until full compaction has been achieved. This should be organised to finish at the same time as the grader finishes the next section. It is essential to check the thickness of the compacted layer.

6.4.6 Continuous working

The work should continue along the road in sections. As each section is completed, the traffic signs, cones and barriers are moved along the road to the next section. This opens the road at the completed
end for traffic, and closes it at the other end to allow new gravel to be dumped. As the work proceeds, it will be necessary to open new diversions.

6.5 FILLING AND PATCHING

These are manual operations which can be used for repairs to the surface where defects develop on a small scale and heavy grading or regravelling is not justified. They can also be used when equipment is not available. They can be used to repair pot-holes, ruts, soft-spots and erosion gullies. The operations are sometimes known as spot regravelling. Patching may also be needed on self-cementing gravels or gravels containing large lumps of material as, in these cases, grading will only cause more damage to the surface. Filling and patching are not satisfactory methods of repairing corrugations and dragging or grading is needed to remove these. Where there are large numbers of pot-holes, the road will need heavy grading and possibly regravelling.

The quality of the material used should be the same as that used for regravelling (Tables 3 and 4). It should be stockpiled at the nearest maintenance camp or dumped by the side of the road near where it will be used.

Before work starts, signs must be set up as described in Section 3.3. Loose material and standing water should then be brushed from the area to be repaired. Large or deep pot-holes should have their sides cut back to be vertical and should be deepened to reach sound material. If the material is dry, the area to be repaired should be sprinkled with water and it is then also useful to mix the patching material with water as well. The patch should then be filled in layers of about 50-70mm at a time. Each layer should be compacted with hand rammers or with small vibrating compactors. It is not advisable to roll with the wheels of the truck or tractor as insufficient compaction can be obtained in this way. The layers of the patch should be built up in this way and, finally, the patch is filled with gravel to approximately 30mm above the level of the road surface and is spread and raked to the correct shape. The patch is then compacted to give a surface which is slightly above the level of the surrounding road. Both large and small areas are repaired in the same way.

Patching work started must not be left unfinished over-night. At the end of each day, tools and traffic signs should be taken back to the maintenance camp and the site must be left clean and tidy with no stockpiles of material left on the road.

Details of the maintenance gang and equipment needed for filling and patching work are given in Section 5.8. The District Engineer will need to modify this basic unit to meet his own local conditions and for different situations.

6.6 DUST PREVENTION

6.6.1 The dust problem

In the dry areas of many developing countries, unpaved roads are often affected by dust. This may have been generated by the interaction between vehicular tyres and the unbound surface or by the effect of wind. Dust is a maintenance problem because it results in the loss of material from the road surface which has to be replaced. It is a contributory factor to road accidents because of the reduction in visibility and it also pollutes the atmosphere close to the road.

It has been shown that well constructed and adequately maintained unpaved roads carrying 100 vehicles per day in dry areas can lose over 25 tonnes of dust per kilometre each year. In addition, it has been found that, when the wearing course contains an excessive amount of material finer than 10mm, the annual dust loss can be greater than 33 tonnes per kilometre. Losses on older roads with lower levels of maintenance will be much higher. This loss of material increases the permeability of the surface layer and results in the early development of pot-holes, all of which accelerate the need for regravelling.

6.6.2 Remedial treatment

The major types of remedial treatment for dust proofing unpaved roads are as follows:-

(i) application of a bituminous seal

(ii) chemical stabilisation and coating with deliquescent salts

(iii) application of waste local materials such as oiled gravels, sulphur liquors, molasses, palm oil, vegetable oil, bamboo oil, lime, charcoal, etc

(iv) addition of water.

With the exception of the bituminous seal, all of these treatments provide only temporary improvements. Many of the additives are soluble in water and will require renewal at the end of the rainy season. Apart from the use of local materials, most treatments are also expensive.

If dust treatment is being considered, careful costings should be carried out to ensure that the costs of repeated applications of the additive over several years are cheaper than the more permanent treatment by surface dressing.