MAINTENANCE MANUAL FOR LOW COST RURAL ROADS IN ROMANIA

Low Cost Design Standards for Rural Roads Projects

4654RO/B.1./3a/3.5/010

Client: Project Management Unit
        Rural Development Project
        Ministry of the Administration and Interior

Funding Agency: International Bank for Reconstruction and Development (IBRD)

Project Manager: The Louis Berger Group, Inc.
                2300 N Street
                NW Washington DC 20037
                USA

MARCH 2005
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1. INTRODUCTION

1.1 GENERAL

This “Maintenance Manual for Low Cost Rural Roads in Romania” is the fourth in a series of manuals commissioned by the Romanian Government as part of a wider rural development project funded through the World Bank. The complete series includes:

- Design Manual for Low Cost Rural Roads
- Technical Specifications for Low Cost Rural Roads
- Standard Details for Low Cost Rural Roads
- Maintenance Manual for Low Cost Rural Roads (this manual)

The manuals were prepared for the Project Management Unit (PMU) of the Rural Development Project, in the Ministry of Administration and Interior. The author of the manuals is The Louis Berger Group of Washington D.C., USA.

1.2 PURPOSE

The aim of this manual is to provide basic advice for engineers and other technical staff working at commune and village level. It had been designed to be used by those with some technical background but with little formal training in road engineering.

1.3 SCOPE

The focus of the manuals is low cost solutions for rural road design, construction and maintenance. Such roads typically have traffic levels below 200 vehicles per day, although the solutions proposed may be applicable to roads carrying up to 500 vehicles per day.

The aim of this document is to recommend solutions that can realistically be implemented for rural roads projects in Romania. The manual focuses on the maintenance of earth and gravels roads, although the maintenance of low cost bituminous surfaced roads is also discussed.

In general, the solutions discussed are suitable for maintenance by small scale local contractors with basic mechanised plant, such as a grader.
2. **GENERAL**

2.1 **OBJECTIVES OF ROAD MAINTENANCE**

For any road network administrator the objectives of road maintenance should be:

- To preserve the investment made in roads, bridges, and associated infrastructure.
- To provide adequate levels of safety, comfort, and convenience for users, consistently and uniformly throughout the road system.

2.2 **ROAD MAINTENANCE CLASSIFICATION**

For the purposes of maintenance management, the most usual way to classify maintenance activities is in terms of their frequency. There are four categories of such activities, presented as follows:

- **Routine** maintenance, required continually on every road whatever its engineering characteristics or traffic volume. Routine maintenance, by definition, has to be undertaken on a regular basis: its frequency does not depend on the character of the road or the amount of traffic, although it may be dependant upon climate and weather conditions. For this reason it is treated as a fixed-cost item in the maintenance budget. Examples of routine maintenance activities include grass cutting; drainage clearance; re-cutting ditches; repair of erosion control measures, culvert maintenance; road furniture maintenance.

- **Recurrent** maintenance, required at intervals during the year with a frequency that depends on the volume of traffic using the road. Recurrent maintenance is treated as variable-cost activity, because the frequency is dependent on the engineering and traffic characteristics of the particular road. Recurrent maintenance activities on unpaved roads include repairing pot-holes and ruts; dragging; grading. On paved roads it includes repairing pot-holes; patching; repairing edges; sealing cracks.

- **Periodic** maintenance, required only at intervals of several years. Periodic maintenance is treated as a variable-cost activity, and usually requires larger scale equipment and skilled labour. Periodic maintenance on unpaved roads includes regravelling. On paved roads it includes surface dressing; regravelling shoulders; road surface marking.

- **Urgent** maintenance is needed to deal with emergencies and problems calling for immediate action when a road is blocked. It may involve removal of debris and other obstacles; placement of warning signs and diversion works.

The further development of a simple maintenance plan, suitable for use at village or commune level, is discussed further in section 7 of this report. Before then, we will look in more detail at the actual maintenance procedures for each element of the road.
3. MAINTENANCE OF ROAD SURFACE

3.1 INTRODUCTION

The correct shape and main features of a gravel road are shown in Figure 3.1. below.

![Standard Elements of Cross Section](image)

**Figure 3.1. Standard elements of a gravel road**

Maintaining this shape, in order to drain water away from the road surface, is essential to the maintenance of gravel and earth roads.

![Photo 3.1](image)

**Photo 3.1** Rural street in Calarasi County. Good shape prevents water ponding and hazard of surface defects
Defects of road surfaces may be primarily classified into surface deterioration and surface deformation. While surface deterioration is related mostly to the qualities of the surfacing materials and the way they respond to the weather or traffic stresses, the surface deformations may have combined causes, due both to direct advanced stresses applied to the surfacing material itself, but also to other factors like subgrade capacity and stability. It is noted that the provision of adequate drainage is critical in both cases.

The following paragraphs will develop these two categories, identifying and describing the main types of defects and suggesting remedial solutions. The focus will be on issues affecting unpaved (earth or gravel roads), although many of the points made are equally applicable to bituminous surfaced roads (which are also discussed separately in section 3.11).

### 3.2 SURFACE DETERIORATION

#### a. Dust

Dust is the result of loss of fine, binder material from road surfaces. Loss of these fines leads to other types of road distress such as loss of cohesion and compaction of the road fill material, and reduced capacity to maintain moisture in the road fill. These deficiencies also tend to feed on themselves, compounding the problem.

In many cases, dust can be reduced on gravel roads by applying chemical additives which draw moisture from the air to improve fine aggregate cohesion; such dust suppressors are presented hereinafter.

**Calcium chloride** absorbs water vapor from the air and liquid water from the road bed. At 25°C and 75% humidity, for example, it absorbs more than twice its weight in water. In addition, calcium chloride solutions attract more moisture to the road than they give up in evaporation.
The road remains dense and compact under almost any level of traffic because calcium chloride keeps materials on the road by keeping moisture in the road.

Calcium chloride is generally sprayed as a 35% solution using a tank truck with a rear-mounted distribution bar that spreads the liquid evenly over the road. One pass will cover an 8- to 12-foot-wide road. Two passes are needed on roads 16 to 18 feet wide.

**Lignin sulphonate** is sprayed on the surface. For stabilization and dust control, it's better to be mixed with the top centimeters of road surface. It is water soluble, environmentally friendly, easy to handle and apply, and very cost-effective.

The benefits include increased load-bearing capacity, a firmer road surface without loose gravel, dust abatement, reduced frost-heave damage, and cost-savings in both construction and maintenance.

The surface will still develop potholes, and the administrator will need to scrape off and remix the top layer after a few months, but the maintenance procedures can be significantly reduced.

**Sugar beet concentrated molasses** could replace calcium chloride as dust control agents. They are very hygroscopic (attaches to and holds water), have a high level of potassium chloride (which can replace calcium chloride), have a near neutral pH level and do not freeze, even at -10°C.

**Bentonite** is naturally occurring sodium montmorillonite clay. Test results indicate that for long-term treatment (two to three years), bentonite is an effective and less expensive alternative to chemical treatments on limestone roads.

Igneous rock gravels have a negative electric surface charge, so bentonite won't adhere to it. Limestone, however, has a positive charge, which allows bentonite to form a bond and adhere to it. For this reason, bentonite works best on crushed limestone.

Unlike calcium chloride and lignin sulphonate, bentonite is blended with road surface material when it is applied and adheres to pieces of surface material like "electrochemical glue." Bentonite's effectiveness is not reduced by grading or other maintenance activities, such as applying another layer of limestone.

The use of dust suppressors must be conditioned by preliminary studies carried out by specialized laboratories, to determine the affinity for the local gravels used for surfacing.

A longer term solution to the problem of dust on gravel roads may be to use a bituminous surface dressing. This also improves the riding quality of the surface and protects the gravel from further damage. Surface dressings are commonly used for roads with higher levels of traffic, and their application is discussed in more detail in Volume 1 of this series “Design Manual for Low Cost Rural Roads in Romania”.

Applying chemical additives to earth road surfaces to draw moisture from the air and improve fine aggregate cohesion is not advisable; this can be an expensive solution that may be not feasible in the cohesive soils cases, where the product cannot penetrate deeply into the subgrade, and the treated thin crust can be removed shortly after the cure process under the traffic or rainfalls. An alternative method to be used in the case of clayey soils is lime stabilization. The lime produces chemical reactions with the clay and the result is a material...
which has more of the granular soils characteristics. It also provides long term stability, as the reactions can continue for years after the application, depending of the quantity of lime used. However, the method is still expensive for rural roads low budgets, and the decision to use it should be carefully considered.

An alternative way to reduce dust and the accompanying distress caused by it is to reduce traveling speed. Since signing of speed reductions on unpaved rural roads is rarely effective, this is best achieved by installing physical obstacles (speed bumps), or by convincing the users (mostly members of the local community) to adapt their driving style to the condition of the surface. Such measures are usually only used in villages, where reduction in vehicle speeds also improves safety.

b. Raveling

Raveling is the loosening of coarser aggregates. This is brought about when the coarser aggregates are worn away by traffic after fine, binder aggregates have been lost due to dust or erosion. This also occurs when the initial composition of the surfacing material lacks intermediate size aggregates, or the aggregates are round instead of sharp faced, which would have “locked” the surface if present. Poor grading and shape of surface material is the most frequent cause of raveling and ultimately road failure. This is caused by the erroneous belief of some road administrators that single-sized stone may be a good solution for surfacing. These materials were invariably taken from river beds, and are poor choices for road surfaces.

Raveling may be corrected by grading or blading with the addition of fines or other binder to improve surface gradation and composition. Raveling correction is a highly expensive procedure, since in most of the cases not much of the lost material can be efficiently recovered.

Photo 3.3 Rural street in Dolj County; steep grade aggravated the loss of fines by washing out, followed closely by the loss of large size stones that under the traffic gathered at the toe of the ramp

c. Slipperiness
Slipperiness is caused when the road surface contains excessive fine plastic aggregates (clay or clayey silts, or limestone fines) in proportion to coarser aggregates, especially within the crust (although it is noted that a small amount of plastic fine materials is often beneficial, as it binds the surface together and makes it less permeable). During wet weather, the road surface becomes slippery and may become impassible. Traffic wear can reduce coarse aggregates to finer aggregates, thus disproportioning the original road fill aggregate mix. Slipperiness can be an issue on earth roads.

This problem can be corrected by mixing the surface fines with coarser aggregate by scarifying, grading and/or blading the road surface and compacting back in place. Occasionally, coarser aggregate will need to be hauled in and added to the roadway.

Particular attention must be paid when using limestone gravels. In the regions where available, they tend to be widely used because are cheaper than igneous stone gravels and because they form a crust faster than other materials, even when the gradation is not optimal. Traffic wear polishes this material faster and the rideability appears better in time. The danger appears during wet seasons, when polished limestone and fines, in combination with water can give an exceptionally slippery surface. On the other hand, animal powered traffic, predominant in rural areas in Romania, is less sensitive to this aspect and overall limestone makes a good material for surfacing.

Photo 3.4 Rural road in Tulcea County. Lack of large size stones in the initial formula of the surfacing provide slippery surface during rainy periods
3.3 SURFACE DEFORMATION

a. Rutting

Ruts are longitudinal depressions in the wheel paths caused by high moisture content or inadequate strength in the subsurface soil or base, inadequate surface course thickness, and/or heavy traffic loads.

Rutting can be corrected by adding suitable gravel surfacing material, grading, crowning, and rolling the road surface. Ruts should not simply be filled with single size stone or soil. Filling ruts with stone is no more than a temporary “fix” which can also interfere with grading. The surface must be re-mixed and properly bladed or graded in more severe cases.

Rutting in bituminous surfaced roads is treated by sealing cracks or by surface dressing. If the ruts are more than 15 mm deep they should be patched before surface treatment is applied.

Areas of sustained and repeated rutting may be caused by more fundamental problems such as areas of very weak subgrade. They may require extensive treatment such as an elaborate drain system and/or geotextile fabric foundation beneath the crushed stone road fill. Where possible, an alternative alignment may be a much cheaper solution to avoid endemic rutting areas. Further investigation of the causes is required before making a decision which would require a significant investment.

Photo 3.5 Rural street in Valcea County. Weak subgrade, lack of surfacing, bad profile and inappropriate drainage lead to rutting during rainy season

b. Corrugating

Corrugating or “washboarding” is a series of ridges and depressions across the road surface caused by the lack of surface cohesion. This lack of cohesion is a result of the loss of fines in the road surface which, in turn, is usually a result of very dry conditions within the road
surface. These conditions are aggravated and enhanced by excessive vehicle speeds and high traffic volumes.

Where surface fines are segregated from coarser aggregates, blading with sufficient moisture content can repair the road surface. When the causative problem is of loss of fines, blading alone is not recommended. The problem will only recur shortly thereafter. The problem is best corrected by scarifying the road surface while damp, thereby re-mixing the road surface with a good percentage of fines, regrading, re-establishing the crown, and compacting the surface.

Photo 3.6 Rural road in Arges County. Despite good surfacing formula, the road surface is corrugated due to inappropriate high traffic speed, probably caused by straight alignment and good visibility

c. Depressions

Depressions are localized low areas one or more inches below the surrounding road surfaces caused by settlement, excessive moisture content, and/or improper drainage. These are larger areas not to be confused with potholes.

Depressions should be corrected by filling them with a well-graded aggregate, then grading the affected road surface, and compacting. Underdrains, cross drains or use of geotextiles may be necessary to improve drainage and prevent recurrence. Again, specialist advice should be sought before a major investment.
d. Potholes

Potholes are small depressions or voids in the road surface one or more inches deep which are caused by excessive moisture content, poor drainage, weak subgrade, poorly graded aggregate, or a combination of these factors. Potholes may be corrected by patching with well-graded materials and compacting, and/or spot grading. Large areas of potholed road surface indicate a poor road fill condition over an extended section of roadway, and thus may require the re-grading, re-crowning, and re-compacting of the affected roadway section to mix aggregates into a well-graded road fill and improve road surface drainage. Underdrains may also be necessary in these areas to drain the sub-grade. Repair of potholes must be carried out at early stages of developments, since once they occur at the surface the process of road failure increases exponentially.
Photo 3.8 Rural gravel road in Calarasi County. Potholed road surface, mainly triggered by inappropriate crossfall

### e. Soft-spots

Soft-spots are areas of the road surface and/or sub-grade made weak by poor drainage. These areas depress under vehicular weight and almost always develop into one or more of the other types of surface deformations. These areas can be corrected by improving drainage conditions or replacing the soft spot with more suitable material. Depending on the cost effectiveness and feasibility of each, the following methods may be used to correct soft spots:

(i) Improving the drainage of the road fill and/or sub-grade with under-drains or a layer of granular material acting as a drainage blanket.

(ii) Improving the drainage of the road fill and/or sub-grade by grading road ditches low enough to remove water from beneath the problem area. This may involve piping to move water from one side of the road to the other. This method is outlet dependent.

(iii) Patching the soft spot area with a better quality material of similar permeability (it is important to avoid introducing an area where water may become trapped, such as would be the case if a soft spot in clayey soil were to be filled with gravel with no outlet for drainage. In such cases, it would be better to repair the area up the level of the surrounding subgrade with selected fill to match the existing. Alternatively, a wider area can be replaced with gravel, ensuring that water is able to drain away to the ditches at the side of the road).

A combination of the above may be envisaged. Soft areas identified during construction can be treated in the same way.
Photo 3.9 Rural earth road in Dolj County. Absence of A-shaped profile and no ditches lead to the apparition of softspots

3.4 Shaping/Reshaping

The more a road surface is sloped, the quicker it will shed water and less likely it will become potholed or muddy. Maintenance and safety considerations limit the recommended pitch for the surface of unpaved roads to a range of 4% to 6%. Higher slope values tend to increase the deterioration of the surface, because the water flow increases its speed and washes away the fines from the surface. The surface also becomes slippery in wet weather and vehicles become unstable on the carriageway. If properly maintained, a 4 – 6 % crossfall is adequate to inhibit the formation of potholes and other surface breakdown. By contrast, paved roads generally require only half this pitch, or 2% up to 3%.

For the most part, typical older rural roads have a crown that is gently rounded in the centre whether they are paved or unpaved. Paved roads that have this shape began as gravel roads and were paved by the old fashioned method of mixing the asphalt in place over the gravel rather than having it placed by a modern paving machine. Because of the stabilizing effect of the pavement, this rounded shape usually presents little problem. Gravel roads with this “round crown” present a particularity that cannot be ignored by the administrators when planning the maintenance works.

Looking at the cross section of a road with a rounded crown it becomes obvious that the center of the road is actually flat rather than crowned. The more gentle the crown of the road is, the greater the area that is flat, or nearly flat. If traffic would stay off this centerline area this lack of pitch would not be a problem but that isn’t usually the case with low volume, unpaved country roads.

Many gravel roads have started as wagon paths and have had little done to them except to add gravel and, perhaps, have a ditch cut on each side. Most are no more than a lane and a half in width. This means that most cars always drive with one set of wheels (the left ones) in the
center of the road. When a vehicle approaches from the opposite direction, both drivers simply veer slightly to accommodate the other and then return the left wheels to the center of the road. Even if the road was built as two full lanes, poor ditch maintenance or the involuntary sense of safety often pushes drivers toward the centerline.

This scenario means that the centre of the road receives twice the traffic of the ditch side if every car’s left wheels travel this section. In conjunction with a lack of crossfall to shed water, centerline potholes are inevitable. Proper crossfall on the part of the road closer to the ditch can certainly help the passenger side, but considering that cars almost always have drivers on the left side, it would make sense to ensure a smooth ride for them also. These combined reasons are arguments in favor of A-shaped crown, but the achievement of this goal is often made difficult by the erroneous training achieved over the years by most of the grader operators.

With most gravel roads, especially in the case when they have a single traveling lane, the minimum 4% crossfall should continue over the entire road width which means the surface needs to be pitched at this grade across the entire carriageway from one side to the other. There is no separate shoulder There are a few situations, such as curves on higher volume roads, that warrant maintaining this crossfall in just one plane across the entire road, making the whole surface drain toward the inside of the curve because the outside of the road is higher. Most roads, however, break the pitch in the middle, requiring the “A” shaped or “tepee” crown and not the rounded crown that is so common.

The edge of the road surface should be continuous with the level of the shoulder. Having a drop at the edge of the surfacing presents a safety hazard and reduces support at the edge of the road. A edge higher than the running surface prevents water draining into the ditch. Channels are formed at edge of the road, which can quickly erode to form secondary ditches. Water can then infiltrate the subgrade causing more extensive failure.

Photo 3.10  Rural road in Valcea County. High banks next to the road surface prevent the outflow of the storm water to the natural terrain. The result is a fill profile with secondary channels
The elimination of high edges should be a priority during maintenance. If the material on the high edge is gravel, it can be reused on the roadway. If it is unsuitable as surfacing, it must be removed. Mowing or cutting vegetation beforehand will make the task of removing high edges much easier.

3.5 TYPES OF MAINTENANCE FOR UNPAVED ROAD SURFACES

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 labor-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.

3.6 USING THE APPROPRIATE EQUIPMENT

The most versatile and efficient tool for maintenance of earth or gravel roads is the motor grader. Among the reasons for its extensive use are the following:

- Capacity to work at high speeds and cover long road sections in short periods of time
- Possibility to mount a wide range of specific tools and therefore increase the number of operations
- The reduced necessity of qualified personnel (practically, one operator!)
- The increased maneuverability, which makes the grader able to perform in adverse conditions and adapt to various road and roadside configurations

There is a well developed contracting sector in Romania, and the use of mechanized methods is common.

Essential considerations for effective grader operation are outlined below.

a. Grader Operating Speed

Operating speed in road maintenance operations must not be high. Excessive speed inevitably causes problems on unpaved roads. Depending also on the nature and condition of the processed material, like aggregate size grade, fines content, moisture content, it is virtually impossible to do good work beyond a top speed of 4 to 8 km/h. When the machine begins to rush or recoil, it will cut depressions and leave ridges in the road surface. The higher speeds of up to 8 km/h can be adopted for earth roads made of silty clays having moisture content close to optimal value; lower speeds of the order of 4 to 6 km/h are required for graveled roads at low moisture content, because high speed can increase the segregation of the material. However, in virtually any condition, it is difficult to exceed 8 km/h and still do a good job, but this limit speed is more than enough to cover long road sections in one-day of work. Efficiency must be obtained not by increasing the speed of the tool, but by better
scheduling the succession of operations. For example, the grader performance is much increased if preparatory works like scarification, hauling or disking of additional material are properly executed.

b. Moldboard Angle

Another critical aspect to good road maintenance is the horizontal angle of the moldboard. While this angle is fixed on some grading devices, on motor-graders it can be easily adjusted. For the operator, it is important to keep the angle within 30 to 45 degrees, depending also on the material to be processed. The main concern for the grader operator is to recover loose aggregate from the shoulder of the roadway without spilling material around the leading edge (toe) of the moldboard. Operating without enough angle is a primary cause of this spilling.

![Figure 3.2 Moldboard Cutting Angles](image)

Figure 3.2 Moldboard Cutting Angles

c. Moldboard Pitch

Along with correct angle, it is important to understand the effect of providing proper pitch or “tilt” of a moldboard. The grader operator must recover the material loosened by the traffic towards the shoulders, mix it again and restore the surface shape and fill the potholes and unevenness. This mixing action is part of routine maintenance. If the moldboard is pitched back too far, the material will tend to build up in front of the moldboard and will not fall forward and move along to the discharge end of the blade. This also causes excess material loss from the toe of the moldboard. It also reduces the mixing action that is desirable when recovering material from the shoulder and moving it across the roadway, leveling and smoothing it in the process.
d. Motor Grader Stability

Despite the solid construction, it can sometimes be hard to keep a grader stable, especially while carrying a light load of material. Counteracting machine recoil or sprint requires experience in knowing the cause and then finding a solution. When a motor grader begins to rock from side to side, it is usually caused by blade angle that closely matches the angle from corner to corner of the tires on the rear tandems. The solution is generally to stop, change angle slightly on the moldboard and slowly resume blading. Simply reducing speed will often eliminate the loping effect of a machine. Experimenting with different tire inflation pressures can also help stabilize a machine as well as leaning the front wheels in the direction that material is being moved. Filling tires with liquid ballast to about 70% capacity is sometimes done to increase traction, weight and stability of the grader. The ballast often used is a solution of calcium chloride and water.

e) Motor Grader Maintenance

For safety and maximum service life of the grader, it is necessary to ensure correct maintenance. The starting point is a walk around inspection, to check for:

- Loose or missing bolts
- Damaged tires
- Damaged hydraulic lines or hoses
- Oil, fuel and coolant levels
- Condition of the blade.

Some of the main areas to check are shown in Figure 3.4
3.7 Grading

Light grading is a light trimming of the surface of the road which should be carried out on a routine basis to control roughness and corrugations. When undertaking light grading in dry conditions, the 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 wetter conditions, material should be graded towards the centre of the road.

Light grading may be carried out by motor graders, although 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 utilized. Heavy grading operations must always be carried out at the end of summer to ensure that the road has the correct profile for effectively shedding water during the rains. Heavy grading must also be carried out at the end of spring 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, when conditions are dry, 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 earth roads and roads that are liable to corrugate, grading may be needed after the passage of only 1,500-2,000 vehicles. Some gravel and earth roads, 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.

As already stated in this document, 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 4-6 per cent. It is very important to ensure correct camber on steep alignments. ‘Flat’ cambers are frequently the cause of the longitudinal gulling commonly found on such alignments.

Crossfall should be checked on site using a simple camber board, such as that illustrated in Fig. 3.5 which can be carried on the grader. Use of the camber board is illustrated in Fig. 3.6. 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 20 meter intervals along the road and if the camber is too steep or too flat, then the road must be graded again.
a. 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 with the centre of the road. Considerable attention must be paid to maintaining adequate cross-fall in these situations as this will minimize the erosion. If severe damage persists, consideration should be given to paving the gradient either by surface dressing or with a concrete pavement.

b. Grader operation

The quality of workmanship in maintaining earth and gravel roads depends to a great extent on the skill and judgment 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.

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. Graveled shoulders are continuous with and 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.

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 material does not dry out excessively, 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. This should be close to the optimum moisture content of the material to be compacted. This can be measured with simple on-site tests, although it is possible to tell from experience how much water is required. The aim is to water the gravel sufficiently to ensure all of the particles are moistened, but not so much as to make the material heave under the action of the roller or to cause the fines to separate. The rollers should aim to progress from section to section at the same rate as the graders.

In the summer months, 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 3.8).

c. Grading gang

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

d. Junctions

At junctions and driveways, the main line road should maintain its crown through the junction, as shown below:
Note the need for the driveway or minor road to match the edge of the main road. Excess material extending from the driveway is often a problem and should be removed during maintenance.

3.8 Dragging and Brushing

Regular and frequent dragging can be used, in the summer months, 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.

a. Design of drag units

Typical drag units, to be towed by a tractor, are shown in Fig. 3.8. 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 redistributing 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, timber baulks, etc. However, the two types illustrated in Fig. 3.8 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 kilometers per hour and are capable of maintaining roads carrying up to about 100 vehicles per day. They are also effective for dealing with corrugations.
b. Tire Sledges

Sledges are generally effective only on very lightly trafficked roads with surfaces containing loose material.
The tire sledge illustrated consists of old tractor or heavy lorry tires cut in half around their circumference and bolted or chained together. It is important that all the tires are in contact with each other, as in the illustration, to ensure proper distribution of the loose material.

![Figure 3.9 Brush Drags](image)

**Figure 3.9 Brush Drags**

c. Method of operation

The basic method of operation for both drags and sledges 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. 3.8. 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 to determine the optimum frequencies and effectiveness 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. 3.8 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. 3.9 can still be utilized 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 the drag will skip over the surface irregularities and will also generate a lot of dust. Pass lengths should be as long as possible, preferably of the order of several kilometers.

d. Dragging gang

Dragging can be carried out by a small crew of a tractor driver and a machine attendant, depending on the availability of equipment.

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.

3.9 REGRAVELLING

a. 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.

b. Quality of Gravel

Although maintenance should be based on standard specifications for gravels for surfacing, 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.

The materials for gravel wearing course should satisfy the following requirements that are often somewhat conflicting:

a) They should have sufficient cohesion to prevent ravelling and corrugating (especially in dry conditions)

b) The amount of fines (particularly plastic fines) should be limited to avoid a slippery surface under wet conditions.

Material for surfacing shall consist of hard durable angular particles of fragments of stone or gravel. The material shall be free from vegetable matter and lumps or balls of clay, although a small amount of plastic fines (clay material) is desirable to bind the surface together.
The grading of the gravel should be continuous, with no single size dominant. Rounded aggregates, commonly found in river beds, are not usually suitable. The individual stones do not lock together and the road soon becomes deformed.

Suggested specifications in terms of grading, according to British Standard recommendations, are given in Table 3.1. Further information on specifications is given in the “Technical Specifications for Low Cost Rural Roads in Romania”.

Table 3.1 – Particle Size Distribution for Gravel Surfacing

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percentage passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal maximum size</td>
<td>40 mm</td>
</tr>
<tr>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>80-100</td>
</tr>
<tr>
<td>10</td>
<td>55-80</td>
</tr>
<tr>
<td>5</td>
<td>40-60</td>
</tr>
<tr>
<td>2.5</td>
<td>30-50</td>
</tr>
<tr>
<td>.5</td>
<td>15-30</td>
</tr>
<tr>
<td>.075</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.

Another important aspect is the quality of the fines passing the 0.5 mm sieve. For a good surfacing material it is required that the fines should be largely of clay origin, like silty clays or clayey silts, which can bind together the larger size particles of the gravel. The laboratory tests should assess the plasticity index of the fines. For fines passing the .5 mm sieve, the plastic characteristics are given in Table 3.2

Table 3.2 – Preferred Plasticity Characteristics for Gravel Surfacing

<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>Cold Areas</td>
<td>35</td>
<td>4-9</td>
<td>2-5</td>
</tr>
<tr>
<td>Warm Areas</td>
<td>45</td>
<td>6-20</td>
<td>3-10</td>
</tr>
</tbody>
</table>

Higher limits are acceptable for concretionary gravels that have a structure that is not easily broken down by traffic. Lower limits are appropriate for some other gravel, like limestone ones, that are easily broken down.

c. Organization and Equipment
Regravelling will be the major item of expenditure on the maintenance of gravel roads and its organization 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 laborers

Production can be estimated as 450-500m³/day on a 5 kilometer average haul. If the haul exceeds 5 kilometers, additional lorries should be provided so that the other plant is fully utilized.

Regravelling:  
1 grader  
1 steel-wheeled roller and  
1 pneumatic – tired roller  
2 water tankers, if water is available  
1 water pump  
1 lorry  
20 laborers

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

To provide 100 mm of gravel on one kilometer of road 7.5 meters wide will require 750 m³ of gravel (compacted volume) so that the above team could regravell about half a kilometer 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 regravelling site. If it is necessary to keep the road open during gravelling, a bulldozer or grader should open up a diversion track adjacent to the road. 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. If it is not necessary to open a diversion, ‘lane closed’ signing must be used.

d. 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. A 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 road is open and no
diversion is in place, 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.

The moisture content of new gravel should be adjusted to optimum for compaction. 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. Finally, the camber should be checked with the camber
board and, if the required standard has not been reached, the grading should be repeated.

e. Compaction

Compaction should not be left to the action of traffic as this quickly becomes concentrated in
the wheel tracks 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 organized to finish at the same time as the grader finishes
the next section. It is essential to check the thickness of the compacted layer.

f. 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
if a road closure is not possible.
3.10 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 be used to repair pot-holes, ruts, soft-spots and erosion gullies and can be performed even without special equipment. 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 3.1 and 3.2), or should be selected material of similar permeability to the subgrade where the repair is to extend below surfacing level. 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. 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 overnight.

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.

For general maintenance work for filling and patching 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 labor intensive methods or equipment.

A suggested basic gang size for labor-intensive work is given below, but this will need to change for different operations and situations, and the gang should develop to meet local circumstances.

Personnel

1 Gang leader
1 Driver
Several laborers

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 laborer used on compaction work
1 Pick-axe for every two laborers
1 Broom for every two laborers
1 Shovel or hoe for every two laborers plus extension rods for culvert clearing
1 Rake for every two laborers
1 200 liter drum for water
1 Bucket or watering can
1 Axe
Safety equipment as recommended.

3.11 MAINTENANCE OF PAVED ROADS

Major repairs to paved roads require a high level of investment and lie outside the scope of this study. Detailed information can be found in the relevant national standards. The exception to this is for the maintenance of surfaced dressed roads, which are commonly used in rural areas and are discussed in this section. Nevertheless, it is thought worthwhile to include a brief description of maintenance activities for paved roads, particularly for small scale failures to existing roads which may be repaired at village or commune level.

Maintenance of paved roads can be divided into operations to repair local failures and those used to repair the whole carriageway.

For both surfaced dressed and asphalt roads, local surfacing failures can be repaired by local sealing. Localized structural failures should be repaired by patching. Repair of the gravel subbase by patching is as previously discussed for gravel roads.

Local sealing is limited to relatively small areas of surfacing failure. It is often carried out using the manual application of binder, which limits the range of binders used to bitumen emulsions and low viscosity cut-back bitumen. Small sized aggregate of 6mm or less (chipping or coarse sand) are then lightly rolled in as a cover.

Patching may be carried out as a separate activity, or prior to surface dressing (see below). The cause of the failure will need to be investigated and treated – this is usually related to problems with drainage. For all patching, it is necessary to remove all of the failed area and cut back the road to sound material. The sides and bottom of the patch should be trimmed to provide a firm and regular surface, which should then be brushed, moistened with water and then painted with bitumen emulsion to provide a bond. Material should then be compacted in the excavation in layers of 50-70 mm. The infill material should match the layer being repaired – gravel of similar quality should be used in the lower layers against the existing gravel base course, whilst cold mix asphalt will be used in bituminous layers.

For asphalt roads, crack sealing may be used to repair reflection cracking, by filling cracks with bituminous binder.

Whole carriageway maintenance involves either surface dressing or slurry sealing. Where there is extensive structural failure, the road will need to be overlaid or reconstructed.
Surface dressing consists of spraying the road surface with a film of binder, followed by the application of a layer of stone chippings, which is then rolled. Surface dressing has three main purposes:

- To seal the road surface against ingress by water
- To prevent disintegration of the surface
- To provide a non-skid wearing surface

Surface dressing will not restore the riding quality of roads, nor will it significantly strengthen the road structure. The design of the surface dressing should take into account the type of the existing road surface, the traffic, the available chippings and the climate. The quantity of chippings must be sufficient to cover the entire binder film – this is best guaranteed by spreading a slight excess. Chipping is applied by a mechanical spreader which closely follows the sprayer.

The road must be prepared for surface dressing by patching and filling in depressions in the road surface. The bitumen film is delivered by a mechanized, truck mounted distributor system. The spray bar must be able to be adjusted by the operator. The rate of spray may be determined by the tray test. Rubber tired rollers are generally used for rolling the chippings.

Further information on surface dressing can be found in Volume 1 of this series of manuals, “Design Manual for Low Cost Rural Roads in Romania”.

Slurry seals are mixtures of fine aggregates, bitumen emulsions and added water. The principal application is as a maintenance treatment for old bitumen surfaces. Costs are higher than for surface dressing.

### 3.12 Recycled Asphalt

The use of recycled asphalt as a road surface may be an option in certain cases, where a source becomes available from, for example, reconstruction of a national road.

Conventional recycling consists of removing an existing pavement; crushing the reclaimed material if necessary; mixing the recycled material with additional aggregate, asphalt and a recycling agent in a hot mix process; and placing the recycled mix with a paver and compacting.

Additional aggregates and binders are added to the mix for a number of reasons:

- Gradation: The addition of new aggregate allows the gradation of the recycled mix to be optimised
- Aggregate quality: Overall aggregate quality can be improved by adding additional material
- Filler: filler material may be excessive, and needs to be balanced by the addition of larger sized aggregate.
- Binder. The existing binder may have been oxidised and requires modification with a low viscosity asphalt or recycling agent in order to avoid brittleness.
A mix design is carried out to determine the percentages of reclaimed asphalt mixture, new aggregate, recycling agent and binder. The maximum amount of recycled material used is generally in the range 50 to 60%.

Most recycled asphalt is produced with a drum mixer rather than a batching plant.

As can be seen from all of the above, the conventional use of recycled asphalt is a complex and can be costly. Specialist technical expertise will be required for the mix design. Specialised plant and equipment is required. It may not be an economic alternative for low cost rural roads.

In the case of low cost rural roads, there may be a cheaper alternative that can be considered. This uses recycled material without further treatment. When using recycled asphalt in this way, the bituminous portion becomes the binder. When placed, the material will form a weak pavement, which has a number of drawbacks. Potholes will be formed easily, but it will not be possible to maintain the surface with a grader. A better option may be to cold mix the recycled asphalt with gravel, in a 50/50 proportion. This should produce a material that still has a good binding characteristic, whilst remaining workable for maintenance and reshaping.

### 3.13 Recycled Concrete

A further alternative that may be considered for low cost rural roads is recycled, crushed concrete, if a source is available. It often provides a poor running surface, but may be used in the lower layers of the road. If the crushed concrete is contaminated with other material it may still be acceptable - up to 15% of other hard material such as brick and glass may be present, up to 3% of softer materials such as plastic and plaster, and up to 1% of wood or other vegetative matter.

Suggested limits for grading are given in the table below:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% passing by mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>100</td>
</tr>
<tr>
<td>19.0</td>
<td>71 to 100</td>
</tr>
<tr>
<td>4.75</td>
<td>36 – 65</td>
</tr>
<tr>
<td>0.075</td>
<td>2 – 14</td>
</tr>
</tbody>
</table>
4. **Ditches**

4.1 **General**

Roadway ditch location, profile, shape, lining and outlets effect how efficiently water will be removed from the roadway. Ideally ditches should resist erosion, be self cleaning, and discharge onto nearly level vegetated areas, thus maximizing the length of time between regrading, thereby reducing maintenance costs.

Recommendations on the design of ditches and other drainage features are provided in the “Design Manuals for Rural Roads in Romania”, volume 1 in this series.

4.2 **Ditch Profile and Grading**

a. General

Roadway ditches must be excavated at a bottom elevation of a minimum of 30 to 60 cm below the road base. The ditch bottom should be cut as a trapezoidal section (the preferred section as it provides highest capacity) or as a “V” shape (also has good flow characteristics and can be cut and maintained with a grader). U-shaped ditches must be avoided as they have up to 30 percent less drainage capacity than other shapes and they tend to look messy. Their steep sides make maintenance difficult and the sides tend to cave in, compounding maintenance problems and adding to erosion and sedimentation.

Where possible, “turn-outs” ("tail-ditches") must be installed, to help maintain a stable velocity and the proper flow capacity within the road ditches by timely outleting water from them. See Figure 4.2 below. These structures are critical elements in establishing and maintaining a stable unpaved roadway drainage system. It is imperative that landowners adjacent to these roadways allow water to be discharged in this manner at crucial points. Correspondingly, these turn-out points must be stabilized to prevent creating worse erosion problems such as gullies. In many cases, the discharged runoff can be spread to reduce the erosive energy of concentrated flows.

![Figure 4.1 Typical Locations for “Turnouts” (“Tail Ditches”)](image-url)
Ditches which have a channel slope less than 5% shall be lined with grass, and those having a 5% or greater channel slope must be lined with geo-fabric or aggregate filter underlain riprap or other material.

Concrete lining for ditches is not recommended on unpaved roads due to initial cost and difficulties during later maintenance. Concrete lined ditches are also prone to cracking if there is even minor ground movement.

Ditches must be lined as soon as possible to prevent erosion and to maintain the ditch profile. Whenever possible, ditches must be excavated only as far as lining can catch up before the next expected or potential rainfall event. Alternatively, the gradient of ditches may be adjusted by introducing steps or check dams.

All ditches should have appropriate outlets which allow water to completely drain from them. Standing water in ditches against road fill weakens the roadway. The preferred equipment for creating or maintaining ditches is a rubber-tired excavator with an articulated bucket. Alternatively, “V” shaped ditches can be excavated with a grader. In flat areas, the road level can be built up above that of the surrounding ground and lifted clear of areas prone to flooding by excavating wide channels at the sides of the road and using the material excavated as a road platform. The channels can then double as drainage ditches. Well designed and constructed road ditches can be cleaned with a grader or excavator making maintenance quicker, easier, and less costly.

b. Other Applications

Diversion ditches and berms may be used as structures to intercept, consolidate, and direct or redirect runoff at the top of a slope to prevent gullies and rills on slopes, or across the slope to break up the slope length or redirect water flow. These ditches and berms should be located where the outlet will empty onto a stable disposal area. Ditches and berms may be used in combination where runoff is significant and/or hard to control.

c. Cleaning and Maintenance

All ditches, including “tail-ditches” and “turn-outs”, must be checked after major storm events, as the storms may have caused obstructions, erosion, or bank collapse. A post-storm plan for checking for damage and determining maintenance needs must be set within the maintenance management system.

When they become clogged with sediments or debris, ditches must be cleaned out to prevent ponding, bank overflows, and road washouts. Ditches must be re-graded only when absolutely necessary and lined with vegetation or stone as necessary. Re-grading of ditches should be limited to late spring or summer, after spring rains have diminished and drier weather has set in, and when vegetation can re-establish itself. Other times may be suitable depending on weather patterns, work to be performed, and exigency of work to be done. The main concern is to limit disturbance to the ditches during times of high erosion potential.

Removal of silt should be part of the routine maintenance programmed. Material should be disposed of and spread well away from the sides of the ditch, to prevent it being washed back in again.
Ditch cleaning and maintenance is one of the most important elements to maintaining good drainage along any type of road. For unpaved roadways, a well-designed ditch can be cleaned with either a grader or a backhoe with a grading bucket, but production under normal conditions is generally higher with a grader. Here are some important tips about ditch maintenance:

- Inspect ditches regularly and schedule cleaning every few years. The bottom of the ditch should remain compact.
- Clean ditches when they become clogged with sediments or debris to prevent overflows and washouts.
- Check ditches after major storm events as fast moving water may have developed obstructions, erosion, or bank collapse.
- Re-grade ditches only when absolutely necessary and line with grass (or stone) as soon as possible. Seed, mulch, and fiber mats can assist re-vegetation.

d) Routine Maintenance and Inspection Checklist

- **Spring and Summer**

  Clean and remove fallen brush, leaves, trash, sediment and other debris from the ditch. Reshape the ditch to improve flow capacity.
  Re-establish and/or improve the cover type:

  - Earth – Seed, mulch, and apply erosion control matting to prevent erosion
  - Grass – Re-seed mulch and apply erosion control matting. Mow and trim out brush
  - Stone – Add stone to slopes and low spots, if necessary. Place or form stones to fit ditch shape.

  Patch broken or washed out areas to prevent further damage and erosion

- **Fall and Winter**

  Remove accumulated debris.
  Keep critical sections free from snow and ice to prevent spring flooding.
5. **CULVERTS AND DRAINAGE STRUCTURES**

5.1 **GENERAL**

Recommendations on the design of culverts and other drainage features are provided in the “Design Manuals for Rural Roads in Romania”, volume 1 in this series.

5.2 **CLEANING AND MAINTENANCE**

Culverts and other drainage structures must be inspected often, especially in the spring and autumn, and after storm events, checking them for signs of corrosion, joint separation, bottom sag, pipe blockage, piping, fill settling, cavitation of fill (sinkhole), sediment buildup within the culvert, effectiveness of the present inlet/outlet inverts, etc. Inlet and outlet channels must be checked for signs of scour, degradation, aggradation, debris, channel blockage, diversion of flow, bank and other erosion, flooding, etc.

Preventive maintenance must be enforced to avoid clogging of pipes and other situations which may damage the culvert or diminish its design function. If a culvert is plugged with sediment, it must be flushed from the outlet end with a high pressure water hose. Measures must be taken to reduce downstream sedimentation and debris and sediment cleaned from the outlet ditch afterwards.

Checking and removal of debris from small culverts can be difficult. Long handled shovels or shovels attached to rods may be useful. Trees blocking culverts can be sawn up to make removal easier. Grilles should be installed where culverts are subject to repeated blockage.

When replacing damaged culverts which handle the flow adequately, the same size, shape, and type of pipe must be used. Changing any of these criteria may adversely affect the established stability of the ditch, stream, and/or roadway.

5.3 **OUTLET STRUCTURES**

Outlet structures are used to reduce and/or control energy from ditch or culvert discharge, and release the discharge downstream under controlled, stable conditions. Their design is discussed in Volume 1 in this series, “Design Manual for Low Cost Rural Roads in Romania”

Outlet structures reduce the velocity of water carried by road ditches and culverts, therefore helping to control sedimentation. Water should outlet to areas with moderate slopes and vegetative filter strips or riparian areas before entering surface waters. This will allow for most of the sediments and other pollutants to be removed before runoff enters surface waters. If erosion occurs, additional outlet structures may need to be repaired or constructed as part of the road maintenance.

Outlet structures should be located where concentrated, turbulent, and/or high velocity flows are discharged onto areas which can be erosive, or where the discharged water requires filtration or settling of sediments. This can be outlets for swales and road ditches, flumes, runoff management culverts within the road ditch system, or culverts used at stream crossings.
All disturbed areas at outlets shall be mulched and vegetated. Silt fences or other appropriate erosion control measures may be used to prevent or reduce erosion and sedimentation until stabilizing vegetation is established.

Photo 5.1 Rural street in Dolj County. The absence of a plunge basin or any other erosion protective measure lead to uncontrolled erosion development

5.4 GENERAL MAINTENANCE AND INSPECTION

- Avoid clogging, collapsing, washouts, and settlement by practicing preventative maintenance.
- Replace culverts with the same size pipe if it has been handling flow satisfactorily.
- Pay special attention to water action at the culvert inlet.
- Use high pressure flushing to effectively clear most plugged culverts.
- Flush culverts from the outlet end.
- Be sure to clean the outlet ditch after flushing.
- Thaw frozen culverts using steam, high-pressure water, ice augers, or calcium chloride.
- Inspect culverts every chance you get, but at least every spring and fall and following heavy storms.
- Mark all drainage culverts to insure that they are not skipped during inspections. · Monitor culverts with running water during freezing weather and take action if they start to freeze.
5.5 **Routine Seasonal Maintenance**

a) **Spring**

- Inspect culverts for winter damage.
- Remove obvious blockage (trash, fallen brush, etc.)

b) **Summer**

- Clean/flush inside pipe.
- Repair/improve/install headwalls, end sections, and splash pads.
- Mow, trim and remove brush from around the culvert ends.
- Reestablish vegetation around culvert ends to prevent erosion.
- Add cover material if necessary.
- Remove obvious blockages.

c) **Fall**

- Mark culvert ends for winter.
- Remove obvious blockages.

d) **Winter**

Thaw culverts as necessary to maintain flow during warm spells.
6. **OTHER ROAD FEATURES**

6.1 **SLOPES**

Bank or slope failure occurs when a section of the bank slides. There are many potential causes, in particular too steep of a slope gradient for the strength of the soil. Other causes of slope failure have to do with improper soil compaction, slope toe erosion, groundwater pressure, and excessive artificial loads placed on the slope, such as building construction, automobile parking, etc.

Proper long term stabilization of banks along roadways and drainage ways will significantly reduce if not prevent costly maintenance, and will contribute significantly to the reduction and prevention of considerable amounts of sediment delivery into streams and waterways. Stable road banks also decrease public disenchantment, improves motorist safety, improves traffic flow, and protects adjacent land.

Bank construction and maintenance procedures in relation to compaction (for fills), slope gradient, and surface grading is critical to establishing a long term, stable slope. For landslides, material should be carried away and dumped well clear of the road. Ditches should be cleared of all fallen material. Fill slopes should be repaired by benching new material into the stable slope (see figure 5-3), and compacting in horizontal layers to a density commonly stable for the soil material used. Smooth and even grading of the slope surface will enhance aesthetics and will also improve the ability to establish a good vegetative cover and maintain it. Slope grades should be straight and true without humps, bellies, dips or ridges. This will reduce concentration of runoff on slopes and promote sheet flow which is less erosive and enhances infiltration of water needed for plant growth. Vertical tracking (up & down slope) with a dozer will also enhance infiltration.

6.2 **ROAD FURNITURE**

Signs should be inspected and cleaned twice per year. Guard rails and parapets (if any) should be repaired promptly if damaged and repainted regularly if required.

6.3 **SMALL BRIDGES**

Maintenance is similar to that of culverts and comprises keeping the waterway clear, controlling erosion (particularly at outlet channels) and repairing structural damage.

On the approaches to bridges, the crown of the gravel road needs to be gradually removed over 30 or so meters from the bridge. The level of the road should match the level of the bridge deck at the interface between the two. Potholes and depressions often form in this area – they should be filled in, although care should be taken not to spill gravel across the deck itself.
7. MAINTENANCE MANAGEMENT

7.1 MANAGEMENT TASKS

Maintenance work should be carried out in a structured and planned manner. The engineer responsible for maintenance of a network of roads may want to consider approaching the work in a series of steps:

- **Inventory**: This involves the preparation of a catalogue with a record of the basic characteristics of sections of road to be maintained.
- **Inspection**: Road sections should be examined to determine condition.
- **Determination of maintenance requirements**: This will include an analysis of the root cause of defects, followed by proposals for maintenance for correction and to protect the road against further deterioration.
- **Estimate resources**: Maintenance activities should be costed.
- **Prioritization**: Identification of the most critical areas for action.
- **Implementation**: Contract, implement and supervise maintenance.
- **Monitoring**: Check long term effectiveness of maintenance work.

These steps will form the basis of the maintenance plan.

Further discussion of the inspection, determination and resource usage and prioritisation stages are given in the following sections.

7.2 INSPECTION

When the maintenance system is introduced, it will probably only be possible for the inspector to assess the severity of defects by observation. As the system is developed, physical measurement of defects should be gradually introduced into the inspection procedure; but the quality of visual assessment can be improved by having first-hand knowledge of the physical measurement techniques.

Most defects require either the area or the length of deterioration to be measured. The area or length of deterioration must first be identified and classified using the method outlined in the following paragraphs. As each sub-section should be approximately 100-200 meters long, it is probable that several occurrences of the same type of deterioration will be found within the subsection. These should be added together to give the total extent for each sub-section.

**a) Side drains and turnouts (all roads)**

The level of the water table beneath the road has a major influence on the strength of the subgrade. To keep water out of the pavement structure, side drains should be maintained at an appropriate depth below the road surface. The depth of side drains should be measured at approximately 25 meter intervals using a straightedge and measuring tape.
b) Loss of material (gravel roads)

An estimate can be made of the thickness of gravel on the road by examining pot-holes or by digging a small hole in the road surface until subgrade is reached and probing the depth with a measuring tape. Material should then be replaced and compacted with a hand tamper.

Ideally, thicknesses should be measured immediately after grading. But in view of the difficulty of timing such measurements and the need to carry out surveys on a routine basis, the following approach may be more appropriate. The survey team should take measurements on each sub-section or at 200 meter intervals along the road. At each survey point, the team should identify any obvious ruts and should dig two holes: one in the rut and the other at the peak between ruts. The gravel thickness should be recorded as the average of the two measurements.

c) Deformation (all roads)

Ruts are measured using the deformation gauge. Initially, measurements will be made at only one point on each sub-section or at 200 meter intervals along the road, but as the survey procedure is improved and extended, more frequent measurements should be taken until recordings are made every 25 meters.

Rut depths are measured by placing a two meter straightedge transversely to the road edge over the wheel path. The deepest part of the depression beneath the straight edge is measured and recorded as the rut depth using a calibrated wedge. The depth of rut indicated is the value recorded. In some cases, a bump may have formed at the edge of a wheel path owing to shoving of material in the pavement. The condition should then be reported as a comment on the form and an indication of the seriousness of the condition obtained by placing one end of the straightedge on the bump and the measuring the maximum rut depth in the wheel path. Measurements of rutting are made in the two wheel tracks nearest the edge on both sides of the road, and the higher of the two rutting values is recorded.

Corrugations on unpaved roads are measured by placing the straightedge longitudinally in the wheel paths spanning the corrugation crests. Corrugation depths are measured at the deepest point of the troughs using the calibrated wedge. The highest value of depth from any trough in any wheel path is the value that should be recorded.

d) Cracking (paved roads)

A crack can have the appearance of a line in the surfacing (particularly for asphalt) without two clearly defined edges. This condition indicates an early stage in the deterioration process, when the surfacing still remains waterproof. For the purpose of condition measurement surveys, it is more practical to define a crack as being visible from standing height. Such a crack would, on close inspection, have two clearly defined edges at the surface. It should be remembered that this condition is much further along the deterioration path than that described above. Water may be penetrating into the pavement through cracks of this severity whether the road is surfaced in asphalt or surface dressing.

In bright sunlight, it is often very difficult to see even quite wide cracks. A method of shading the area under observation should be used. The width of cracks in asphalt can change
markedly between early morning and mid-day owing to thermal expansion. In some cases, cracks can close completely and not be seen at all. Surveys are best carried out in the morning or during cloudy weather conditions, particularly when the road is drying out after rain.

During surveys, cracking should be recorded in two classes: wheel track cracking and non-wheel track cracking. In each case, the total length of road affected by cracking should be recorded regardless of the area or severity of cracking across the road.

e) Pot-holes (all roads)

The number of pot-holes in the sub-section should be counted and recorded.

f) Edge damage (paved roads)

This is measured at the edge of the paved area of the road at the same chainage where rutting is measured. Excessive edge damage is recorded if the edge is eroded by more than 150 mm from the original position. The measuring wedge, which is 150 mm long, provides a simple means of measuring this defect.

g) Edge step (paved roads)

This is measured at the same chainages as the rutting. Measurements are taken on both sides of the road at the point where the carriageway meets the shoulder. The measuring wedge should be placed on the shoulder with its 'toe' against the edge of the carriageway. If the step is greater than the 50mm marker, an excessive edge step should be recorded.

On certain roads, particularly where an overlay has been applied, there may be an edge step which is a construction feature. In this case, measurement of the step should still be made in the same way. If the measurement exceeds 50mm, a defect should be recorded.

h) Frequency of inspection

The maintenance engineer should have the entire length of the road network inspected at least once a year - and he should aim to improve on this frequency if it is at all practicable. In regions where there are distinct wet and dry seasons, a total inspection ought to be made in each part of the year. The wet season inspection will be particularly useful in detecting cracking in bituminous surfaces (since this defect is more easily visible when the road surface is drying after rain) and in assessing the efficiency of drainage. In Romania the wet season could be considered the period November – April, while the dry season could be considered the period May – October.

The day-to-day supervision of inspection work can be delegated to trained technicians. But a maintenance county engineer should visit the inspection teams, especially at locations where detailed assessments are required.

The network inspection will need to be completed in time for its results to be fed into the preparation of the following year's budget estimates. Since most organizations prepare their estimates in the second half of the financial year, the maintenance engineer has to make sure that the inspection programme is undertaken early enough to produce the necessary input.
I) Managing condition surveys

In assessing the condition of the road, it is advisable to adopt a two–stage process of inspection:

(i) In the first stage a trained but relatively unskilled team uses standard procedures and simple equipment to measure and record defects in the road. It is led by a technician who determines routine and recurrent maintenance needs and identifies locations where further examination is necessary. Occasional monitoring of these surveys by the maintenance engineer is recommended.

(ii) The second stage involves a more experienced team, led by an county engineer, whose task is to determine the requirements for periodic work by making such additional investigations, measurements and analyses as are required.

The advantages of this approach are that it provides a double check on the state of the road and the scale of maintenance requirements, and it uses professional resources in a cost-effective way by directing them specifically to locations that call for skilled inspections and treatment.

J) Recording results

Appendix A shows how standard pre-printed forms can be used to record the results of inspection surveys. Each road should be divided into sub-sections and a separate form used for each sub-section. Different forms are needed for paved roads, unpaved roads and for structures and road furniture. Note that the form for unpaved roads includes space for the results of monitoring surveys that should be carried out at a later date to gauge the effectiveness of the maintenance programme.

Pre-printed forms are especially useful in providing a check-list that tells the technician what items are to be examined during an inspection, and so reduces the possibility that significant information may be omitted. The examples of forms shown here are intended only as a guide. In some cases the maintenance engineer may receive an issue of standard forms from his organization. In other cases, he may find it more useful to draw up his own form, designed to suit the particular road conditions in his area.

Whatever form is used, it should be easy to understand and to complete. The technician responsible for the inspection should fill in the results on site, recording them accurately and legibly. The forms should then be retained in the office so as to provide a permanent record of inspection results. There is no need to make fair copies of forms completed on site: this wastes time and involves the risk of errors when information is transcribed.

It may, however, be useful to summarize key results in the form of statistical tables or diagrams - for example, graphs that show rates of deterioration over time.
7.3 **DETERMINATION OF MAINTENANCE REQUIREMENTS**

The tables on the following pages give guidance on maintenance standards and intervention requirements, based on the results of the inspection discussed in the previous sections.

<p>| Table 7A – Maintenance Standards for Unpaved Roads |
|-----------------------------------|-----------------|-----------------|-------------------|-------------------|</p>
<table>
<thead>
<tr>
<th>Defect</th>
<th>Level</th>
<th>Extent</th>
<th>Action</th>
<th>Programme</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel thickness</td>
<td>&lt; 50 mm</td>
<td>&gt; 20%</td>
<td>Regrave</td>
<td>Periodic</td>
<td></td>
</tr>
<tr>
<td>Camber, roughness, rutting, corrugations, potholes</td>
<td>-</td>
<td>-</td>
<td>Grading or dragging</td>
<td></td>
<td>All gravel roads must be graded or dragged at the end of the summer and in spring, when conditions are most favourable. Additional grading or dragging may be required based on traffic levels. A grading frequency chart is given overleaf.</td>
</tr>
</tbody>
</table>


Grading Frequency Chart for Unpaved Roads
(Source: “Overseas Road Note 1: Maintenance Management for District Engineers (2nd Edition)”, Transport and Road Research Laboratory, UK, 1997)
<table>
<thead>
<tr>
<th>Defect</th>
<th>Level</th>
<th>Extent</th>
<th>Action</th>
<th>Programme</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local surfacing failures</td>
<td>Any</td>
<td>&lt;10%</td>
<td>Local sealing</td>
<td>Recurrent</td>
<td></td>
</tr>
<tr>
<td>Local surfacing failures</td>
<td>Any</td>
<td>&gt;10%</td>
<td>Surface dressing</td>
<td>Periodic</td>
<td>Extensive potholing may be caused by an ongoing problem. The cause should be identified and appropriate action taken</td>
</tr>
<tr>
<td>Potholes</td>
<td>Any</td>
<td>-</td>
<td>Patch</td>
<td>Recurrent</td>
<td></td>
</tr>
<tr>
<td>Potholes</td>
<td>Any</td>
<td>Any</td>
<td>Patch</td>
<td>Recurrent</td>
<td></td>
</tr>
<tr>
<td>Edge damage</td>
<td>Erosion from original edge &gt;150 mm</td>
<td>&gt;20%</td>
<td>Patch road edge and repair</td>
<td>Recurrent</td>
<td>If failure is severe or reoccurs, determine causes and reconstruct shoulder</td>
</tr>
<tr>
<td>Edge step</td>
<td>&gt; 50 mm</td>
<td>&gt;50%</td>
<td>Reconstruct shoulder</td>
<td>Periodic</td>
<td></td>
</tr>
<tr>
<td>Wheeltrack rutting (surface dressed roads)</td>
<td>Any</td>
<td>&lt;5% in wheeltrack &lt;10% on whole road</td>
<td>Seal cracks</td>
<td>Recurrent</td>
<td>If rutting is &gt;15 mm ruts to be patched before treating. Further investigation is required if rut development is fast or extensive</td>
</tr>
<tr>
<td>Wheeltrack rutting (asphalt)</td>
<td>Any</td>
<td>&gt;5% in wheeltrack &gt;10% on whole road</td>
<td>Surface dressing</td>
<td>Recurrent</td>
<td>If rutting is &gt;15 mm ruts to be patched before treating. Further investigation is required if rut development is fast or extensive</td>
</tr>
<tr>
<td>Wheeltrack rutting (asphalt)</td>
<td>Any</td>
<td>&lt;5%</td>
<td>Seal cracks</td>
<td>Recurrent</td>
<td>If rutting is &gt;10 mm ruts to be patched before treating.</td>
</tr>
<tr>
<td>Wheeltrack rutting (asphalt)</td>
<td>Any</td>
<td>5-10%</td>
<td>Surface dressing</td>
<td>Periodic</td>
<td></td>
</tr>
</tbody>
</table>

If extent is > 10% then investigate cause before maintaining.
<table>
<thead>
<tr>
<th>Defect</th>
<th>Level</th>
<th>Extent</th>
<th>Action</th>
<th>Programme</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris on road</td>
<td>Any</td>
<td>-</td>
<td>Remove</td>
<td>Urgent</td>
<td></td>
</tr>
<tr>
<td>Side drains silted or too</td>
<td>Ditch depth</td>
<td>Any</td>
<td>Clean out</td>
<td>Routine</td>
<td>Ditches should be cleaned out at the end of summer and in the spring. Other drainage faults need to be addressed at the same time.</td>
</tr>
<tr>
<td>shallow</td>
<td>less than 0.5</td>
<td>metres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side drains scoured</td>
<td>Erosion channels</td>
<td>Any</td>
<td>Build check dams or line ditches</td>
<td>Routine</td>
<td></td>
</tr>
<tr>
<td>Side drains have standing</td>
<td>Any</td>
<td>-</td>
<td>Realign to correct gradient</td>
<td>Routine</td>
<td></td>
</tr>
<tr>
<td>water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert silted up or blocked</td>
<td>Any</td>
<td>-</td>
<td>Clean out</td>
<td>Routine</td>
<td>Culverts should be cleaned out at the end of summer and in the spring. Other drainage faults need to be addressed at the same time.</td>
</tr>
<tr>
<td>Outfalls scoured</td>
<td>Any</td>
<td>-</td>
<td>Construct additional scour control works such as rip rap protection</td>
<td>Routine</td>
<td>Scour can develop rapidly and cause severe damage. It must be repaired as soon as possible.</td>
</tr>
<tr>
<td>Road furniture dirty</td>
<td>Any</td>
<td>-</td>
<td>Clean</td>
<td>Routine</td>
<td></td>
</tr>
<tr>
<td>Road furniture damaged,</td>
<td>Any</td>
<td>-</td>
<td>Repair or replace</td>
<td>Routine</td>
<td></td>
</tr>
<tr>
<td>corroded or missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder and side slopes</td>
<td>Any</td>
<td>Visual</td>
<td>Reconstruct or repair</td>
<td>Routine/</td>
<td>periodic</td>
</tr>
<tr>
<td>deformed</td>
<td></td>
<td>assessment</td>
<td></td>
<td>periodic</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>Interferes with</td>
<td>Any</td>
<td>Cut</td>
<td>Routine</td>
<td></td>
</tr>
<tr>
<td>sight lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.4 Prioritization and Use of Resources

Despite the critical importance of maintenance in protecting an investment, there will rarely be sufficient financial resources available at commune and village level to carry out all of the activities required. As a result, the engineer will often have to make a decision as to which activities may need to be carried out. In order to provide guidance, the following list of maintenance activities is listed in order of importance:

1. Urgent or emergency maintenance work. This may include emergency repairs to blocked or impassable roads.

2. Routine drainage work. This work is always a priority, as poor drainage will lead to rapid deterioration of the road structure itself. In particular, it will be a waste of time to correct surface defects if the underlying causes of the defect (ie the drainage) is not also corrected. Routine drainage work includes:
   - Cleaning out and recutting ditches and turnouts
   - Cleaning out culverts
   - Repairing areas of scour or erosion
   - Building check dams and scour controls
   - Repair of drainage structures

3. Recurrent repairs to road surface. These include:
   - Grading, dragging or filling gravel roads
   - Patching or local sealing of paved roads

4. Periodic repairs. These are more extensive activities such as:
   - Regravelling of unpaved roads
   - Surface dressing for paved roads

5. Other routine maintenance.
   - Grass cutting
   - Repairs to road signs and other road furniture
8. INSTITUTIONAL ARRANGEMENTS

There are a number of options available for the institutional organisation of a road maintenance programme for rural roads. Traditionally, the local council or other representative authority has carried out maintenance directly. In many cases there has been an emphasis on execution, rather than planning and management.

A selection of different options are summarised below:

- **Direct labour.** The local authority plans, manages and executes maintenance using their own staff and equipment. This requires high levels of capital investment in equipment, and a large number of permanent staff resulting in high overhead costs. The level of use of the equipment will be dependant upon the activities required – plant may stay unused for a substantial portion of the year. This option tends to be expensive in comparison with other options, although it provides the shortest response time and provides the most flexibility. Some of the capital investment costs can be split between different authorities if they are prepared to share equipment.

- **Maintenance by local community.** This is the cheapest option available, and generally relies on labour based methods. In Romania, equipment based approaches are more common and are generally more efficient.

- **Maintenance by private contractors.** The use of the private sector for maintenance activities has grown in recent years. In most cases, the authority limits themselves to the planning and management of the work, contracting out the implementation to others. These may be single contracts for a specific item of work, such as regravelling a particular section of road, or term contracts covering routine maintenance activities such as ditch clearance for a fixed period of years. This method may be more economic for the maintenance authority – the capital costs are borne by the private contractor, who by utilising equipment on other contracts can make more efficient use of plant and labour.

Different combinations of the above methods can be used – for example, the local community could be entrusted with labour intensive work such as ditch and culvert clearance, private contractors might be used for periodic maintenance, whilst the local authority maintains a small team for emergency maintenance which requires an immediate response.

In Romania, there is a well developed private contracting sector, and competition keeps tender prices low. Mechanised equipment is generally used for construction activities. Taking these factors into account, it is recommended that private contractors be used as much as possible to carry out maintenance activities for rural roads. Local authorities should focus on the planning, management and monitoring of the maintenance activities. There may be a need for capacity building to improve expertise in works supervision and management.

There may be other institutional issues relating to overlapping responsibilities (or gaps) between national, county and commune levels. This may result in:

- Lack of institutional focus
- Duplication of effort
• Inconsistent application of standards
• Inefficient use of financing

It is suggested that the county level may be the best level for the management of rural road maintenance programmes. It is often the case that the necessary technical and management skills are lacking at commune level. Asking each commune to plan and manage its own maintenance programme introduces further duplication of effort, although they can be involved with the supervision and monitoring of works, under the direction of the county engineers.

The county organisations are likely to have the most appropriate technical skills for the management of rural road maintenance programmes. They are able to take a broader view, and have budgetary authority. They can let contracts covering several different communes, which may prove more attractive to local contractors, allowing them to make more efficient use of their equipment.

At county level, the rural road maintenance function can be carried out by either the existing roads department as part of their general duties, or a separate rural roads maintenance unit can be set up within the roads or rural development sections. Due to the specific technical requirements for rural roads, a dedicated unit is generally preferred.
9. **MAJOR REFERENCES**

“Design and Appraisal of Rural Transport Infrastructure: Ensuring Basic Access for Rural Communities”, World Bank Technical Paper No.496, Lebo and Schelling

“Overseas Road Note 1: Maintenance Management for District Engineers (2nd Edition)”, Transport and Road Research Laboratory, UK, 1997

“Overseas Road Note 2: Maintenance Techniques for District Engineers (2nd Edition)”, Transport and Road Research Laboratory, UK, 1997

# APPENDIX A – EXAMPLES OF INSPECTION FORMS

<table>
<thead>
<tr>
<th>PAVED ROAD INSPECTION REPORT</th>
<th>DATE</th>
<th>SECTION NO.</th>
<th>DISTANCE (m)</th>
<th>LEFT</th>
<th>RIGHT</th>
<th>SIT</th>
<th>SHOULDER</th>
<th>SOUR</th>
<th>VEGETATION</th>
<th>CRACKING</th>
<th>WHEELMARK</th>
<th>OTHER</th>
<th>STRIPPING/PEELING</th>
<th>EROSION</th>
<th>SETTING UP/TEARING</th>
<th>LANE MARKING</th>
<th>EDGE DAMAGE</th>
<th>SHOULDER</th>
<th>SOUR</th>
<th>SIT</th>
<th>SIDE DRAIN/SPUR</th>
<th>NOTES/COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td>0</td>
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**LOUIS BERGER GROUP INC.**

**MAINTENANCE MANUAL FOR LOW COST RURAL ROADS IN ROMANIA**

**PAGE 55**