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# **Low Cost Design Standards for Rural Roads Projects**

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## **1. INTRODUCTION**

### **1.1 GENERAL**

This “Design Manual for Low Cost Rural Roads in Romania” is the first 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 (this volume)
- Technical Specifications for Low Cost Rural Roads
- Standard Details for Low Cost Rural Roads
- Maintenance Manual for Low Cost Rural Roads

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.

For more complex situations requiring higher levels of investment, including the construction of bituminous surfaced roads, the existing Romanian standards for roads will be applicable. County level engineers should be consulted on their use.

### **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 is to recommend solutions that can realistically be implemented for rural roads projects in Romania. Issues related to the engineering of lightly trafficked earth and gravel surfaced roads are given more prominence than bituminous surfaced roads.

In general, the solutions proposed are suitable for construction by small scale local contractors with basic mechanised plant, such as a grader.



Photo 1.1

**Grader Maintaining a Gravel Road**

## 2. TRAFFIC

### 2.1 GENERAL

The amount and type of traffic is one of the most important factors in the design of a road. Levels of traffic will be used to determine:

- The type of surface needed (earth, gravel or bituminous)
- Pavement thickness
- Geometry of the road

### 2.2 TRAFFIC VOLUMES

The amount of traffic using a road is commonly expressed in terms of the Annual Average Daily Traffic (AADT). This is the total annual traffic in **both** directions, divided by 365 to give an average daily value.

For major investments, such as asphalt surfaced roads, it is usual to base the design of a road on a forecast future value of AADT. This is the AADT predicted in 10 or 15 years after construction of the road. Such an approach ensures that the road will function throughout its lifetime. Future year AADTs are calculated by applying an annual growth factor to the measured AADT, to allow for traffic increases. The method (or an equivalent) may be required for rural roads in specific cases, as discussed in section 4.6. County Engineers should be consulted to decide upon design year and growth factors.

The majority of low cost rural roads will be constructed from earth or gravel. In these cases, it is difficult to predict future traffic growth. The design life and maintenance cycle for such roads is relatively short. As a result, the design of earth and gravel roads should be based on the **existing** AADT.

### 2.3 TRAFFIC COMPOSITION

The life of roads depends not only on the number of vehicles, but also the type and weight of vehicles. Heavy vehicles cause greater damage to a road structure. This is particularly true in the case of asphalt surfaced roads.

For the analytical design of paved roads (see section 4.6), traffic volumes must be converted into an equivalent number of standard axle loadings. As a result, traffic surveys must distinguish between the different types of vehicle.

There are six categories of traffic:

1. Non motorised traffic, such as animal drawn carts
2. Cars, including passenger cars, vans, minibuses (up to 24-passenger seats), taxis, pick-ups, 4WD vehicles etc

3. Buses, including medium and large buses above 24 passenger seats
4. Light trucks, including small and medium sized trucks with 2 axles, agricultural tractors etc.
5. Medium trucks, including larger trucks with 3 or 4 axles, agricultural tractors with trailers etc.
6. Heavy trucks, including trucks with more than 4 axles and articulated trucks

## **2.4 TRAFFIC SURVEYS**

Traffic surveys should be carried out to determine AADT. For major investments the following process should be used:

- Counts should take place over 7 consecutive days
- Counts should be for 12 hour periods during the daytime (usually 7.00 am to 7.00 pm)
- Counts should take place at representative times of the year, when there are no unusual events such as public holidays, extreme weather conditions etc.
- Counts should distinguish between vehicle categories
- Traffic in both directions should be counted

The results from each days count can be converted into 24 hour average daily traffic flows (ADT) by using a conversion factor and then taking an average of the 7 day results. For major investments, one of the daily counts should be continued over a 24 hour period to obtain this factor. Alternatively, the county engineer may be able to provide a local factor. In the absence of any other information, an hourly conversion factor of 1.33 should be applied to 12 hour counts to give ADT.

The value for ADT may also need to be adjusted for seasonal factors to obtain AADT. Again, the county engineer may be able to provide guidance on this. A seasonal conversion factor of 1.0 is assumed if no information is available.

To summarise:

$$12 \text{ hour count} \times \text{hourly conversion factor} = \text{ADT}$$

$$\text{ADT} \times \text{seasonal conversion factor} = \text{AADT}$$

In the case of low cost roads, data collection can be complex and time consuming. For investments in gravel and earth roads, alternative methods might be considered.

One method, which is more appropriately carried out at county level, is to carry out traffic counts at representative locations, and then use correlation with data on population centres to establish traffic estimates for links where no formal surveys have been carried out.

The Moving Observer Count (MOC) is another alternative way in which to collect basic data on traffic on a particular link, and assists in categorising roads into broad flow bands. During the MOC, the surveyor is driven down the road to be surveyed and records traffic in three different categories:

- Vehicles travelling in the opposite direction (x)
- Vehicles travelling in the same direction and overtaking the observer (y)
- Vehicles in the same direction and being overtaken by the observer (z)

The survey should last at least one hour. The hourly traffic (HT) in both directions will then be given by:

$$HT = (x + y - z) / t$$

where t is the study period measured in hours.

The hourly flow can then be converted into daily flows using the following formula:

$$\text{Daily traffic} = HT \times 16$$

An example of the form used for traffic counts is given overleaf.



### **3. GEOMETRIC DESIGN**

#### **3.1 GENERAL**

The layout of a road must be suitable for the traffic that travels along it. The number, speed and type of vehicles on the road will influence the design, which must be both safe and economic.

Roads with very low levels of traffic carry less than 50 vehicles per day. The main concern is that the road exists and provides reliable, all season access. The use of inexpensive standards at minimal cost is appropriate, even if traffic speeds will be limited. This is called a **basic access** approach.

For roads with more than 50 vehicles per day, the increased numbers of vehicles justify the use of a higher standard. The road is designed so that vehicles are able to travel at a reasonably consistent speed. This is called the **design speed** approach.

#### **3.2 DESIGN PRINCIPLES – BASIC ACCESS APPROACH**

For the basic access approach, the geometric layout should allow buses and small trucks to use the road. These are the largest vehicles that commonly use low cost rural roads in Romania.

The standards used will also be dependant upon the terrain, which is generally classified as level, rolling or mountainous (see section 3.3). In particular, it may be uneconomic to construct roads even to the minimal basic access standards for buses and small trucks in mountainous areas. A further reduction in standards may be justified. The road must remain passable to typical vehicles used in the area, such as private cars, light pick-up trucks and agricultural vehicles, although it will be closed to larger vehicles.

#### **3.3 DESIGN PRINCIPLES – DESIGN SPEED APPROACH**

For roads carrying more than 50 vehicles per day, the choice of a design speed depends on a number of factors including:

- terrain
- road classification
- level of traffic
- type of road surfacing

**Terrain** is usually categorized into three classes, based on the average ground slope. The average ground slope can be measured by the number of five metre contour lines crossed per km on a straight line linking the two ends of the road section.



Photo 3.1

**Level Terrain:** (Between 0 and 10 No. five metre contour lines per km). Flat or gently rolling country, which offers few obstacles to the construction of a road. Minimum values of alignment will seldom be necessary. Roads will for the most part follow the ground contours with only small amounts of cut and fill.



Photo 3.2

**Rolling Terrain:** (Between 11 and 25 No. five metre contour lines per km). Rolling, hilly or foothill country where the slopes generally rise and fall moderately and where occasional steep slopes are encountered, resulting in some restrictions in alignment.



Photo 3.3

**Mountainous Terrain:** (Greater than 25 No. five metre contour lines per km). Rugged, hilly and mountainous country and river gorges. This class of terrain imposes definite restrictions on the alignment and often involves long steep grades and limited sight distance.

○

Under Romanian national standards, the **technical and functional classification** of a road is closely related to the **traffic volume** using a road, as shown in the table below:

Table 3.3.A – Road Classification System		
Technical Class	Functional Class	Annual Average Daily Traffic
I	Motorways (dual carriageway, four lanes)	> 21,000
II	Expressways (dual carriageway, four lanes) European class national roads (E) and main national roads (dual carriageway, four lanes)	11,001 to 21,000
III	Expressways and European class national roads (E) (single carriageway, two lanes) Main national roads (single carriageway, two lanes)	4,501 to 11,000
IV	Secondary national roads, county roads (single carriageway, two lanes)	1,000 to 4,500
V	Communal, local roads, (single carriageway two lanes) Communal, local roads (one traffic lane only)	< 1,000

As can be seen from the table, all low cost rural roads fall into Technical Class V, the lowest level in the Romanian system.

The **type of surfacing** will also influence the design speed. Gravel roads may have a lower design speed than the equivalent bituminous surface roads.

Taking into account the terrain, classification, traffic levels and type of surface, the following design speeds are proposed for low cost rural roads:

Table 3.3.B – Desirable Minimum Design Speeds					
Technical class of the road	Average Annual Daily Traffic	Type of road surface	Design speed (in km/h) depending on the terrain features		
			Flat	Rolling	Mountainous
V	< 50	Earth, Gravel, Bituminous	Use <b>basic access</b> approach		
V	50 to 1,000	Gravel	50	40	25
V	50 to 1,000	Bituminous	60	40	25

The values given above are the **desirable minimum** design speeds, which should generally be used where possible. In some specific situations, these values may be reduced to the **absolute minimum** design speeds, as shown below:

Table 3.3.C – Absolute Minimum Design Speeds					
Technical class of the road	Average Annual Daily Traffic	Type of road surface	Design speed (in km/h) depending on the terrain features		
			Flat	Rolling	Mountainous
V	< 50	Earth, Gravel, Bituminous	Use <b>basic access</b> approach		
V	50 to 1,000	Gravel	40	25	25*
V	50 to 1,000	Bituminous	50	40	25*

\* In hairpin turns, design speed may be reduced to 20 km/h

Examples of situations in which the use of the absolute minimum values for design speed may be used are:

- To avoid excessive land take
- To avoid property demolition
- To preserve environmentally important areas
- To avoid excessive costs

This may be a particular issue when upgrading existing roads, where the geometry is already fixed. In these cases, it may not always be possible to meet even the desirable minimum values. Where this happens, further reductions in design speed may be necessary. On sections of road of lower than the absolute minimum design speed warning signs and possible traffic control measures (such as speed bumps) should be used to control traffic speed on the approach to a hazard such as a sharp bend.

Once an appropriate design speed is selected, we can then define appropriate values for the geometrical elements that form the road. This includes the road cross section, the horizontal alignment and the vertical alignment.

### 3.4 CROSS SECTION

The road cross section includes the carriageway, shoulders (for bituminous surfaced roads), drainage features and earthwork profile.

Bus lay-bys and passing lanes may also be including within the cross section. In urban areas the cross section may also include curbs, pedestrian paths and parking lanes.

The main elements of the cross section are shown below:

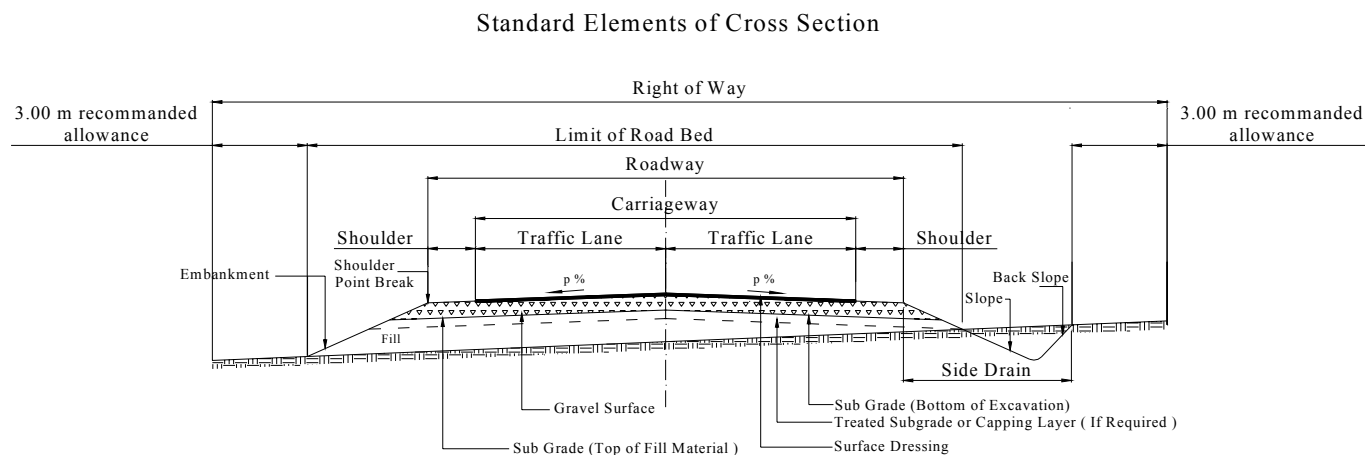


Figure 3.4 A: **Standard elements of rural roads cross section**

It is noted that there are no separate shoulders on a gravel road – the gravel surfacing extends to the edge of the roadway. A bituminous surfaces (including surface dressing) extends only over the width of the carriageway, although it may be extended over the

entire roadway in villages and urban areas, where pedestrian traffic is significant and where the shoulder is used for parking.

The overall width of the cross section will depend on the level of traffic and the technical class of the road. For rural roads, all of which fall into technical class V, the recommended carriageway and roadway widths are as shown below:

<b>Table 3.4.A – Cross Section Elements</b>					
<b>Element of Cross section</b>	<b>Average Annual Daily Traffic</b>	<b>Type of road surface</b>	<b>Width in metres</b>		
			Flat	Rolling	Mountainous
Single-lane Carriageway	< 50	Bituminous Treatment	4.0	4.0	3.0*
Single-lane Roadway	< 50	Gravel	5.0	5.0	4.0*
Single-lane Roadway	< 50	Earth	7.0	7.0	6.0*
Two-lane Carriageway	50 to 1000	Bituminous Treatment	5.5	5.5	5.5
Two-lane Roadway	50 to 1000	Gravel	7.0	7.0	7.0
Two-lane Roadway	50 to 200	Earth	8.0	8.0	8.0

\* passing places of 20 metres in length must be provided at every 300 to 500 metres when the road is also used by larger vehicles such as trucks and buses. This distance shall be reduced where sightlines along the road ahead are shorter to ensure that passing places are visible between each other. Account should be taken of sight distances, the likelihood of vehicles meeting, and the potential difficulty in reversing. Passing bays should be constructed at the most economic locations, such as transitions from cut to fill, rather than at fixed intervals.

The width of the single-lane roadway for earth roads is higher than that for gravels in order to allow for future upgrading to a gravel road.

The width of the carriageway and roadway for roads on flat or rolling terrain with levels of traffic less than 50 vpd may also be reduced to 3.0 (carriageway) and 4.0 metres (roadway) with passing places in order to avoid excessive land take, property demolition, to preserve environmentally important areas or to avoid excessive costs.

The widths of carriageway and roadway should be consistent over sections of a road (apart from at passing places, bus lay-bys etc). Sudden changes in cross section should be avoided as they can be a hazard to traffic and complicate maintenance operations. Any changes in cross section should be introduced over an appropriate transition length, with suitable signing.

Isolated reductions in cross section width may be unavoidable in some cases, such as at existing narrow bridges. Drivers should be warned of the discontinuity using signs and road markings.

The surface of the road slopes away from the centre towards the side ditches. The slope is referred to as the crossfall of the road. It should be sufficient to allow rain to run into the side ditches, without causing a danger to traffic or erosion on unpaved roads.

In flat terrain areas with little possibilities to outflow the storm water collected from the roadway, the roadbed should be raised above the existing ground level minimum 60cm.

The normal crossfall on paved roads should be 2.5%. Cross fall on unpaved (gravel or earth) roads should be 4%. The gravel or earth shoulders on paved roads should also have crossfalls of 4%. In areas with restricted right of way, the roadway drainage may be provided through a single slope crossfall; therefore only one ditch will be needed on the outflow direction side.

Ditches at the side of roads should ideally be wide and shallow, as shown in the figure below:

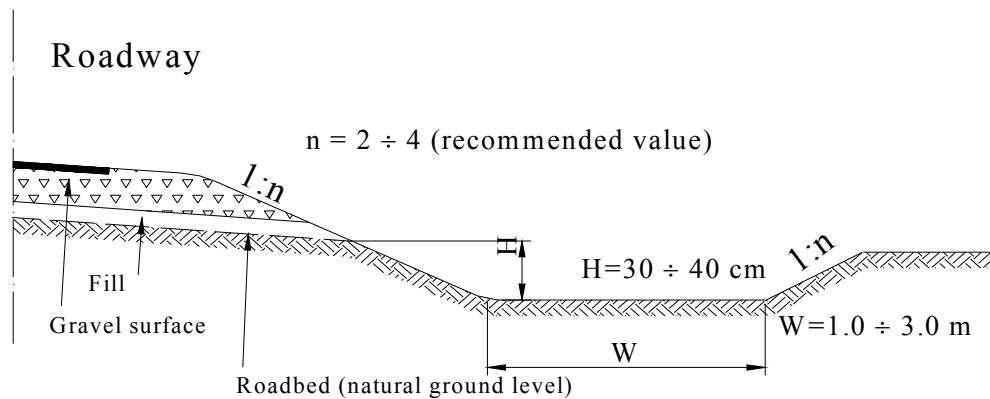


Figure 3.4 B: **Standard ditch cross section**

Minimum depth of ditches should be 0.3 to 0.4 metres below the existing ground level, with a flat bottomed profile. The side slope and back slope should ideally be less than 1:4. Where this is not possible, they should be no less than 1:2.

Lateral clearance between roadside objects and obstructions at the edges of the carriageway (such as road signs, culvert headwalls etc) should normally not be less than 1.5 metres, and as an absolute minimum 1.0 metres.



Photo 3.4

### **Lateral clearance to signs and poles must be maintained**

A minimum vertical clearance of 5.0 metres should be provided.

It is recommended that a 3.0 metre allowance for the right of way must be provided outside the edge of all features of the cross sections, including side ditches and other drainage elements, edge of embankments and cuttings etc. The right of way is a feature of the road cross section and has a number of different functions:

- Ensures sight lines are maintained on the inside of curves
- Provides a corridor for utilities
- Provides working space for maintenance

Adjoining landowners may be allowed restricted use of the right of way area for agriculture.

In addition, there should be a zone outside the highways boundary of 15 metres in which construction is limited. Land may remain the property of the original owners, but they would not be allowed to construct buildings or other structures in this area.

Standard cross sections for each type of road are also shown in Standard Details for Low Cost Rural Roads (see section 1.1).

### **3.5 HORIZONTAL ALIGNMENT**

The horizontal alignment of a road is made up of straights and curves. The curves may be either circular curves (constant radius) or spiral curves (changing radius). Spiral curves may be used as a transition between straight sections and circular curves, but are not generally used for low cost road design due to the additional design and survey work involved.

For the **basic access** approach, the minimum horizontal curve radius depends on the physical characteristics and space requirements of the vehicles using the road. For low cost rural roads, the design vehicle will be a bus or small truck. The minimum curve radius that can be used is 15 metres.

A further reduction in standards may be justified where the road is closed to trucks and buses (see section 3.2), and a minimum curve radius of 8 metres may be used.

For a **design speed** approach, the minimum horizontal curve radius ensures that vehicles can negotiate the curve safely. As a vehicle travels around a curve, it is forced outwards by centripetal force. The faster the vehicle goes, or the tighter the curve, the greater this force.

The minimum radius of a curve is also affected by the amount of **superelevation** on the curve. Superelevation is the removal of the crossfall on one side and steepening of the profile of the road, as shown below:

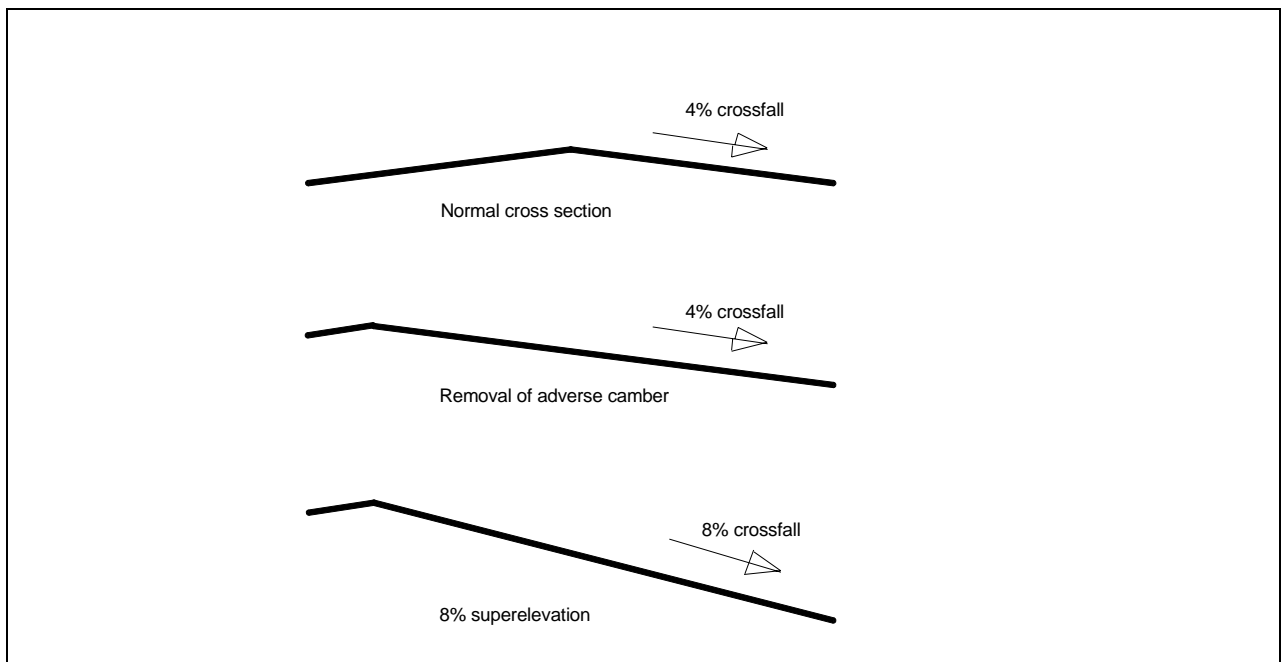


Figure 3.5 A: **Application of Superelevation**

Superelevation assists vehicles to travel around the curve. The highest superelevation rate for highways in common use worldwide is 10%. In areas with snow and ice, as is the case for Romania, maximum superelevation is limited to 8%.

In urban areas traffic is slower moving and it is common practice to utilize a lower maximum rate of superelevation, usually 4% percent. Similarly, either a low maximum

rate of superelevation or no superelevation is employed within important intersection areas or where there is a tendency for vehicles to travel slowly, although adverse crossfall should be removed.

Limiting values of curve radii for design speeds and rates of superelevation are given in Table 3.5.A below:

<b>Table 3.5.A – Minimum Horizontal Curves for Design Speed Approach</b>				
	<b>Design speed</b>			
	<b>60 km/h</b>	<b>50 km/h</b>	<b>40 km/h</b>	<b>25 km/h</b>
<b>Minimum curve radius in metres</b>				
Removal of adverse crossfall	1000 m	700 m	700 m	700 m
Superelevation 4% (maximum in urban areas)	150 m	100 m	60 m	25 m
Superelevation 8%	125 m	85 m	50 m	22.5 m
*Hairpin turns are a special case. Design speed may be reduced to 20 km/h and the minimum curve radius will be 20 metres.				

For the basic access approach, it is also good practice to remove adverse cross fall on curves less than 700 metres where possible. This will mean the road has a single sloping profile from one side to another. On low radius curves, a maximum superelevation of 4% is usually all that is required, due to the low vehicle speeds involved. More than this can cause tipping over of overloaded vehicles.

Superelevation should be introduced gradually on the approach to a curve. 2/3 of the superelevation is applied on the approach, and the remaining 1/3 on the curve itself. It is important to coordinate the change in crossfall with the longitudinal gradient to ensure that this does not cause any flat areas in the road profile where water can collect.

The road should be widened on small diameter curves to allow vehicles to pass safely. Widening should be applied on both sides of the road, and should be introduced gradually over at least 10 metres before the beginning of the curve.

<b>Table 3.5.B – Widening on small radius curves</b>		
<b>Radius of Curve (m)</b>	<b>Curve Widening: Single Lane (m)</b>	<b>Curve Widening: Two Lanes (m)</b>
>250	0.0	0.0
120- 250	0.0	0.6
60-120	0.0	0.9
40-60	0.6	1.2
20-40	0.6	1.5
<20	1.0	2.0

The need for widening applies for both the design speed and basic access approach. For the basic access approach, it is necessary to check if the design vehicle can go around the curve without being obstructed or having to reverse.

On embankments, it is also good practice to widen the fill as well as the carriageway.

### **3.6 VERTICAL ALIGNMENT**

Vertical alignment has two aspects:

- Vertical curvature
- Gradient of the road

Vertical curves are required to provide smooth transitions between gradients. They may be crest curves (at the top of slopes) or sag curves (at the bottom of slopes) as shown below:

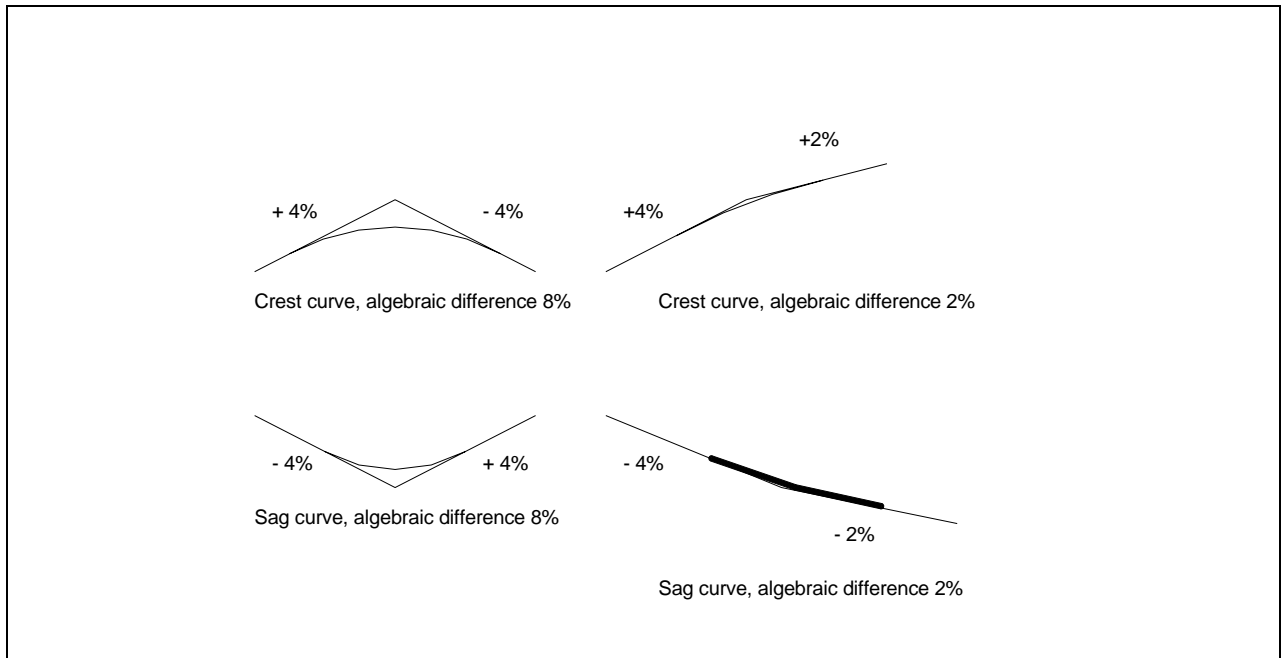


Figure 3.6 A: **Sag and Crest Curve**

Vertical curves are designed to provide enough distance for approaching vehicles to see each other and to stop safely. They are specified in terms of their length.

The minimum length of curve is defined from the equation

$$L = KA$$

where L = length of vertical curve (in metres)

A = algebraic difference in approach and exit grades

K = a factor depending on design speed, and related to the time required for vehicles to stop safely

The values of K will be different for crest curves and sag curves, and for single lane and two lane roads. They are given in the tables below:

<b>Table 3.6.A – K values for Design</b>				
	<b>Minimum K Values for Crest Curves</b>		<b>Minimum K Values for Sag Curves</b>	
<b>Design Speed (km/h)</b>	<b>Two lane road</b>	<b>Single lane road</b>	<b>Two land road</b>	<b>Single lane road</b>
25	3	6	3	6
40	5	10	8	16
50	10	20	12	24
60	18	36	18	36

For the basic access approach, the K values for a 25 km design speed should be used where possible, to ensure adequate sight distance at the crest of hills.

The second issue to be considered for vertical alignment is the maximum gradient. Recommendations for maximum gradients using the design speed approach are given below:

<b>Table 3.6.B – Maximum Gradients for Design Speed Approach</b>				
	<b>Design speed</b>			
	<b>60 km/h</b>	<b>50 km/h</b>	<b>40 km/h</b>	<b>25 km/h</b>
Maximum Gradient	6.5%	7%	8%	9%*
*Gradient in hairpin turns must be reduced to a maximum of 6%				

For a basic access approach, maximum gradients can be increased as shown in Table 3.6.C below:

<b>Table 3.6.C – Maximum Gradients for Basic Approach</b>		
	<b>Roads open to all vehicles</b>	<b>Roads open only to cars and pickup trucks</b>
Maximum Gradient	15%	18%

With gradients of 10% or greater, it may be advisable to pave the road, to provide traction for vehicles and to reduce maintenance. This should be assessed on a case by case basis. As a general guideline, all roads with a gradient between 6% and 10% should at least have a gravel surface. Above 10%, if the road is not already to be surface dressed, other solutions for earth and gravel roads such as brick, block paving or localised surface dressing should be considered.

### **3.7 STOPPING SIGHT DISTANCE**

Simply put, sight distance is the distance visible to the driver of a passenger car. For highway safety, the designer must provide sight distances of sufficient length that drivers can control their vehicles and avoid striking any unexpected objects on the road.

The minimum values of stopping sight distance should be provided in all cases. Sight distances should be checked during design. On the inside of curves, it might be necessary to widen the curves or remove buildings, trees or other sight obstructions. If the minimum sight distances cannot be obtained, then additional land must be acquired or the geometry of the road changed. In exceptional circumstances, a reduction in design speed may be necessary (see section 3.4), but the minimum stopping sight distance must be provided for the new design speed.

On single lane roads, stopping sight distances need to be increased as vehicles will be travelling toward each other on the same carriageway.

Minimum stopping sight distances are shown in Table 3.7.A below:

<b>Table 3.7.A – Minimum Stopping Sight Distance for Design Speed Approach</b>				
	<b>Design speed</b>			
	<b>60 km/h</b>	<b>50 km/h</b>	<b>40 km/h</b>	<b>25 km/h</b>
Minimum Stopping Sight Distance two lane road	85 m	55 m	45 m	25 m
Minimum Stopping Sight Distance single lane road	200 m	140 m	120 m	80 m

For the basic access approach, most roads will be single lane only. Traffic will be travelling at slower speeds and drivers will make allowances for lower standards. A minimum stopping sight distance of 50 m is suggested.

### **3.8 JUNCTIONS**

A junction is where two or more roads join. A disproportionate number of traffic accidents occur at junctions. From a traffic safety aspect junctions require attention and careful design. The layout and operation of the junction should be obvious to the driver, with good visibility.

Differing junction types will be appropriate under different circumstances depending on traffic flows, speeds, and site limitations. Types of junctions include:

- 1) T-Junctions
- 2) Cross-Junctions
- 3) Roundabouts

The basic junction layout for rural roads is the T-junction with the major road traffic having priority over the minor road traffic.

The junction should be sited so that the major road approaches are readily visible. The angle of skew of the junction should be no more than 20 degree from perpendicular.

The right of way should be obvious from the junction layout.

The types of junctions used throughout the whole road network should be similar.

The use of road signs is necessary. Road markings and other road furniture may also be required.

All traffic lanes should be of adequate width and radius for the appropriate vehicle turning characteristics. To accommodate truck traffic, turn radii shall be 15 meters minimum.

For rural roads, there should be a minimum spacing between junctions of 20 metres.

At all junctions, adequate visibility must be provided. For conditions where the minor road yields to the major road traffic, drivers of vehicles on the major road must be able to see traffic on the minor road, and vice-versa, as indicated in yield conditions in **Figure 3.8.A** and **Table 3.8.A**.

For conditions where the minor road stops before proceeding to the major road, drivers must have a sight distance for stop conditions as indicated in **Figure 3.8.B** and **Table 3.8.B**.

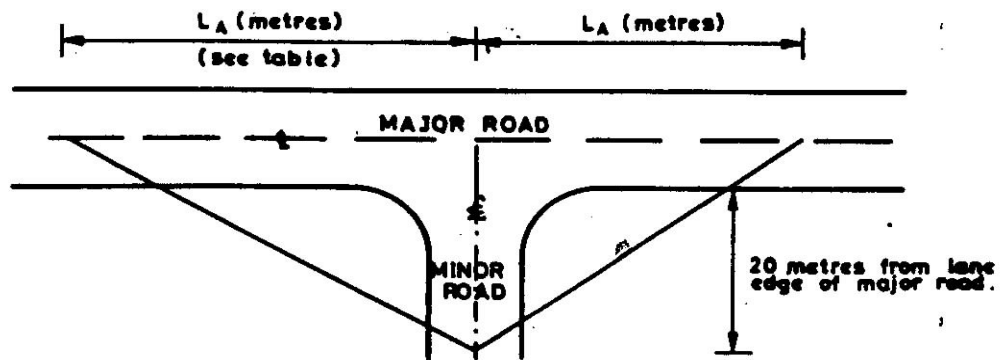


Figure 3.8.A: Visibility Splay for “Yield” Conditions

Table 3.8.A: Visibility Splay for “Yield” Conditions							
Junction Design speed (km/h)	40	50	60	70	85	100	120
Approach Length, $L_A$ (m)	110	135	160	185	225	260	310

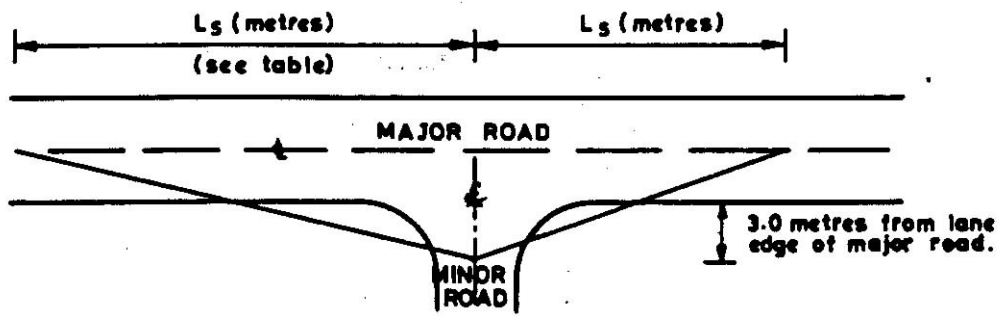


Figure 3.8.B: Visibility Splay for “Stop” Conditions

Table 3.8.B: Visibility Splay for “Stop” Conditions							
Junction Design speed (km/h)	40	50	60	70	85	100	120
Stop Length, $L_s$ (m)	120	145	185	230	315	400	500

The other common type of junction is the **private access**, leading to somebody’s home or property. A private access shall have entry and exit radii of 6 meters or greater, depending upon the turning characteristics of the expected traffic. The minimum width shall be 3m. A typical access is show in **Figure 3.8.C**. The location of the access must satisfy the visibility requirement for “stop conditions” given in **Figure 3.8.B**.

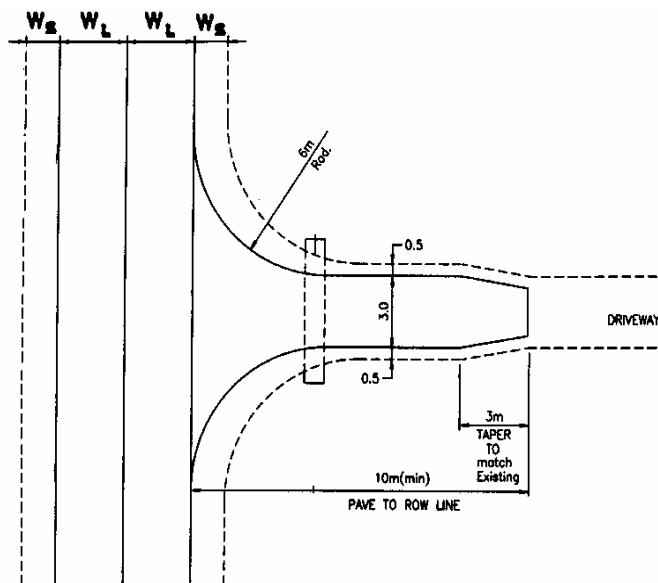


Figure 3.8.C: Private Access

## **4. PAVEMENT DESIGN**

### **4.1 GENERAL**

The emphasis in this section is on appropriate low cost solutions which are cost effective and appropriate for the range of climates and environmental conditions found in Romania. The focus is on earth and gravel roads, although alternative surfacing options such as surface dressing are also discussed. These are generally bituminous based products, applied in a thin layer to a gravel road to seal the surface.

Roads constructed with an asphalt pavement are already adequately covered under the existing national standards in place in Romania. County Engineers should be consulted during the design of such roads, due to the high levels of investment required.

### **4.2 DESIGN PRINCIPLES**

Road pavements are designed to limit the stress at the weaker, lower, subgrade levels by the traffic travelling on the pavement surface. The aim is to ensure that the subgrade is not subject to significant deformations. At the same time, the pavement materials themselves should not deteriorate to such an extent as to affect the riding quality and functionality of the pavement.

Pavements do deteriorate, however, due to time, climate and traffic. Therefore, the goal of the pavement design is also to limit deteriorations which affect the riding quality. In the case of asphalt pavements, this entails reducing cracking, rutting, potholes and other such surface distresses to acceptable levels. For earth and gravel roads, deteriorations will commonly include rutting, potholes, corrugations and other distresses.



Photo 4.1

### **Deterioration of flexible pavement, Dolj County**



Photo 4.2

### **Deterioration of gravel road, Dolj County**

The design method should produce a pavement which will reach a relatively low level of deterioration at the end of the design period, assuming that routine and periodic maintenance are performed during that period.

The main steps involved in designing a new road pavement are as follows:

- estimate the amount of traffic that will use the road (see section 2.4);
- estimate the strength of the subgrade soil (see section 4.3);
- determine the availability of materials
- calculate relative costs
- select an appropriate pavement structure (see section 4.5.4, 4.6.2).

### **4.3 SUBGRADE STRENGTH**

Once any vegetative or topsoil layer has been stripped away, the **subgrade** is the natural soil used as the base for the road.

The type of subgrade soil depends on the location of the road. Where the soils within the possible corridor for a new road vary significantly in strength from place to place, it is better to use the stronger soils if this does not conflict with other constraints.

In many cases, the alignment of rural roads is already fixed by an existing route and changes are limited. In this case, the road has to be designed based on the existing subgrade materials. These can be checked for strength (CBR) in the same way as for new roads, by excavating through any gravel surface where necessary.

The strength of the road subgrade for pavements is commonly assessed in terms of its California Bearing Ratio (CBR). The CBR is dependent on the **type of soil**, its **density**, and its **moisture content**. It is calculated by testing samples in a soils laboratory.

The density of the soil is controlled by the amount of compaction (and by the moisture content). In the laboratory, this is simulated in the CBR test by compacting a sample a certain number of times with a hammer of a known weight in a standard sized mould.

The moisture content of the subgrade soil is governed by the local climate and the depth of the water table below the road surface. It is important to measure the CBR under the appropriate conditions. In temperate countries such as in Romania, the long term (or equilibrium) condition will usually be when the water table is relatively close to the surface and the soil is saturated. As a result, CBR should be measured on laboratory samples which are first compacted and then immersed in water for 4 days before testing.

Determination of CBR by testing representative samples in a laboratory is the preferred method, and is the recommended approach. This approach (or an equivalent analytical approach), is essential for all major investments including all bituminous surfaced roads.

In some cases, it may not be possible to carry out testing. Some guidance on design CBR for different types of soil is given in Table 4.3.A below. It is stressed that these values are given for guidance only. Where available, the relatively low cost of laboratory testing will be likely to be economic for even for the lowest cost roads.

<b>Table 4.3.A – Estimates of Design CBR Values</b>			
<b>General Material Description</b>	<b>Detailed material description</b>	<b>Suitability as subgrade material</b>	<b>Estimated Design CBR</b>
Gravels	Gravels or gravel/sand mixtures	Excellent	30 – 60
	Silty gravels, gravel/sand/silt mixtures	Good	20 – 40
	Clayey gravels, gravel/sand/clay mixtures	Good	20 – 40
Sands	Sand or sand/gravel mixtures	Good	10 – 40
	Silty sands or sand/silt mixtures	Fair	10 – 30
	Clayey sands or sand/clay mixtures	Fair	5 – 20
Silts and Clays	Silts and silt/clay mixtures of low plasticity	Poor to fair	5 – 15
	Sandy clays and clay/sand mixtures of low plasticity	Poor to fair	5 – 15
	Silty clays and clay/silt mixtures of low to medium plasticity	Poor	3 – 10
	Heavy clays of high plasticity	Poor	2 – 5
Organic soils	Peat, organic clays and silts	Not suitable	-

## **4.4 DESIGN OF EARTH ROADS**

### **4.4.1 INTRODUCTION**

The most basic general class of roads are unimproved earth roads. 'Earth' in this context is any natural material. To be suitable for use as a road surface it will invariably need to have a high proportion of natural gravel (see section 4.4.3).

Earth roads are invariably the lowest cost solution in terms of initial construction cost, and may be adequate for the purpose of providing basic access where:

- Traffic levels are very low
- Subgrade conditions are good
- Adequate drainage is provided
- Maintenance is provided

### **4.4.2 DESIGN METHOD**

Earth roads should be considered when traffic levels are less than 50 vehicles per day. Above this level, upgrading to gravel roads may be more economic, due to the increasing need for maintenance.

Depending on the natural material, unimproved earth roads can provide good levels of service up to 70 to 100 vehicles per day and beyond, as long as drainage is good and regular maintenance is carried out.

### **4.4.3 SUBGRADE**

In terms of the strength of the subgrade, a minimum CBR of 10% is required for an earth road. As discussed in section 4.3, the design CBR should be based on saturated samples of material.

It is noted that the CBR requirements mean that subgrades suitable for use as earth roads will require high proportions of sands and gravels in the natural soil. Where the requirements for subgrade CBR cannot be met, a gravel surface will be required even where traffic levels are below 50 vehicles per day.

Isolated areas of poor subgrade can be gravelled or replaced using a spot improvement approach. The gravel should extend the entire width of the road and there should be a crossfall on the underlying subgrade to allow water to drain from the subgrade/gravel interface.

The subgrade can also be improved by lime stabilisation (for clay soils) or cement stabilisation (for granular soils). This involves mixing the existing subgrade material with

lime or cement to provide a stronger subgrade. Careful control of mixing and material quantities is needed, and specialist advice should be sought from the county engineer if such an approach is to be used.

#### **4.4.4 CONSTRUCTION**

Advice on best practice for the design and construction of earth roads follows. Many of the principles outlined will be equally applicable to low cost gravel and bituminous surfaced roads as well.

- The level of the surface of the earth road should be higher than the surrounding ground level, to allow drainage of the road surface and to prevent flooding.
- Where the topography allows, wide, shallow longitudinal drainage for earth roads are preferred. They minimise erosion, and will not block as easily as narrow ditches. The ditches grass over in time, binding the soil surface and further slowing down the speed of water, both of which act to prevent or reduce erosion.
- The two requirements above can be used together to provide a cost effective and technically appropriate approach to construction. Material is excavated from the proposed longitudinal drainage areas and used to construct a roadway to raise the road above the surrounding ground level. The surface of the roadbed should be at least 30 cm above the bed of the drain, and at least 60 cm above the ground level in flat areas..



Photo 4.3

**Road raised above surrounding ground level by use of material from wide side ditches, Dolj County**

- Although there is no requirement for a pavement design, the surface of earth roads shall be graded and compacted to provide a durable and level running surface for traffic.
- The road surface shall be sloped at a minimum of 4%, to ensure water runs off the surface and into the side drains
- Areas where there are specific problems (usually due to water or to poor condition of the subgrade) may be treated in isolation, by localised replacement of subgrade, gravelling, installation of culverts, raising the roadway or by installing other drainage measures. This is the basis of a spot improvement approach.
- Water should be drained away from the carriageway side drains by installing lead off drains, to divert the flow into open space.
- Culverts should be installed perpendicular to the route where there is a need to transfer water from one side to another, for example where the road crosses a watercourse. In flat areas, smaller diameter, parallel culverts may be preferable to single large culverts, in order to ensure discharge is at ground level. The inlet and outlet of the culvert must be protected against erosion.

Standard cross sections for earth roads are shown in the Standard Details for Low Cost Rural Roads (see section 1.1).

## 4.5 DESIGN OF GRAVEL ROADS

### 4.5.1 INTRODUCTION

Gravel road pavements are generally used for roads where AADT is less than 200. Improvements of gravel roads at traffic volumes above this level should be assessed on a case by case basis. This section sets out the standards for gravel roads.

A generalised drawing of a gravel road is shown below in Figure 4.5.1.A

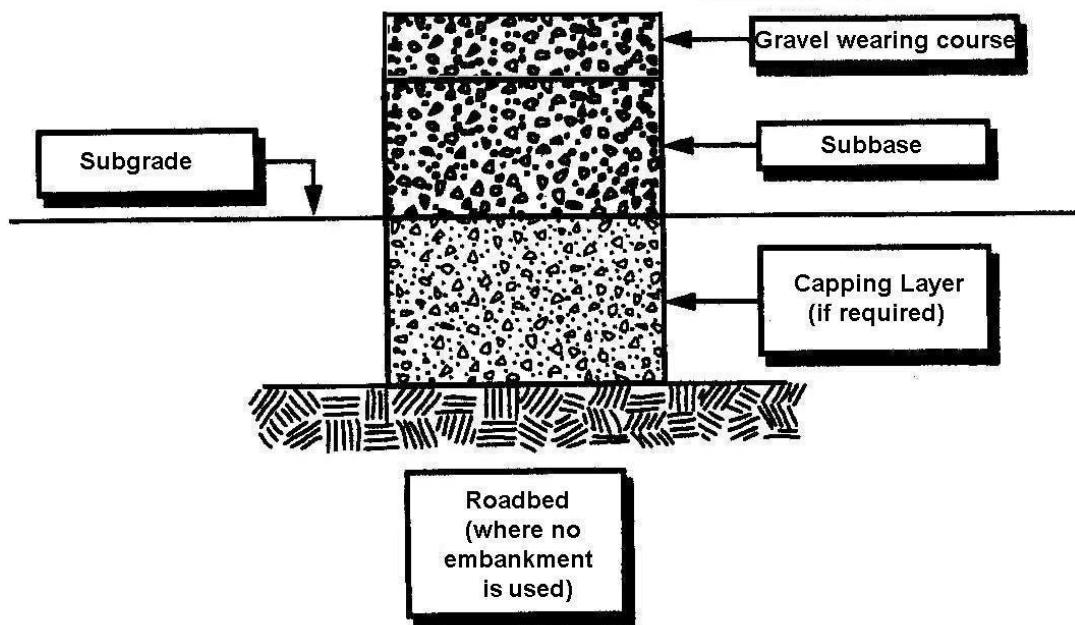


Figure 4.5.1.A – Generalised section, gravel road

### 4.5.2 DESIGN METHOD

The following factors will need to be considered during the design process:

- Traffic
- Subgrade classification and material strength
- Thickness design
- Materials specification

### **4.5.3 SUBGRADE**

Depending on the CBR of the subgrade, improved subgrade layers shall be constructed as required, on which the gravel wearing course is placed. Where the subgrade is replaced, these layers are called capping layers.

In general the use of improved subgrade layers has the following advantages:

- Provision of extra protection under heavy axle loads;
- Protection of underlying earthworks;
- Provides running surface for construction traffic;
- Assists compaction of upper pavement layers;
- Provides homogenous subgrade strength;
- Acts as a drainage filter layer;
- More economical use of available materials.

Soils used for improved subgrade layers shall be non-expansive, non-dispersive and free from any organic matter.

### **4.5.4 PAVEMENT AND MATERIALS**

Material specifications for gravel roads are given in The Technical Specifications for Low Cost Rural Roads (see section 1.1). A summary is given below:

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. Grading limits are given in the Technical Specifications.

Rounded aggregates, commonly found in river beds, are not usually suitable. The individual stones do not lock together and the road soon becomes deformed.

It is recommended that pavement and improved subgrade for gravel roads shall be constructed in accordance with Figure 4.5.4.A. As noted in section 2.2, the design of gravel roads should be based on the **existing** AADT.

<b>Table 4.5.4.A: Pavement and Improved Subgrade for Gravel Roads for existing AADT &lt; 200</b>			
	<b>AADT</b>		
<b>Strength of Subgrade</b>	<b>&lt;20</b>	<b>20-50</b>	<b>50-200</b>
<b>CBR &gt; 15</b>	Earth road	Earth road	200 mm GW
<b>CBR 5 – 15</b>	200 mm GW	150 mm GW 100 mm G20	175 mm GW 100 mm G20
<b>CBR 2- 5</b>	150 mm GW 300 mm G7	150 mm GW 200 mm G20 200 mm G7	200 mm GW 200 mm G20 250 mm G7
<b>CBR &lt; 2</b>	Obtain specialist advice		

G20 is upper sub-base level  
 G7 is lower sub-base level  
 GW is gravel wearing course

(see Section 1.1 for reference to Technical Specifications for Low Cost Rural Roads)

For roads with AADT > 200, consideration should be given to using surface dressing (see section 4.7)

Typical profiles for gravel roads are given in the Standard Details for Low Cost Rural Roads (see section 1.1). The cross section is constant and there are no separate shoulders. The profile is an ‘A’ shape, making sure that the centre meets at a point and is not flattened. The crossfall for gravel roads shall be 4% (or up to 8% if superelevated). This is to ensure that potholes do not develop by rapidly removing surface water and to ensure that excessive crossfall does not cause erosion of the surface. Provision of drainage is extremely important for the performance of gravel roads.

## 4.6 DESIGN OF BITUMINOUS PAVEMENTS

### 4.6.1 INTRODUCTION

Heavily trafficked roads, carrying more than 500 vehicles a day, may require a more substantial pavement structure, constructed from asphalt concrete. This requires a substantial level of investment. Existing Romanian standards should be used for the design of such pavements, which are outside the scope of this manual.

Between 200 and 500 vehicles per day AADT, an asphalt concrete structure is unlikely to be justified. At the same time, the increased levels of traffic cause rapid deterioration of the surface of gravel roads. It is this deterioration of the surface that leads to failure.

One way of reducing the rate of deterioration of the surface is with the use of a **surface treatment**.

A **surface treatment** comprises a thin film of bituminous binder, which is sprayed onto the gravel road surface and then covered with a layer of stone chippings. The thin film of binder acts as a waterproofing seal preventing the entry of surface water into the road structure. The stone chippings protect this film of binder from damage by vehicle tires, and form a durable, skid-resistant and dust-free wearing surface. In some circumstances the process may be repeated to provide double or triple layers of chippings.



Photo 4.4

### Surface Dressing

A surface treatment can provide an effective and economical running surface for newly constructed road pavements. For sealing new roadbases, traffic flows up to 1000 AADT are appropriate, although this can be higher if the roadbase is very stable or if a triple seal is used. Roads carrying in excess of 2000 AADT have been successfully surfaced with multiple surface treatments.

A correctly designed and constructed surface treatment should last at least 5 to 10 years before resealing with another surface treatment becomes necessary. If traffic growth over a period of several years necessitates a more substantial surfacing or increased pavement thickness, a bituminous overlay can be laid over the original surface treatment when the need arises.

A surface treatment is also a very effective maintenance technique, which is capable of greatly extending the life of a structurally sound road pavement if the process is undertaken at the optimum time. Under certain circumstances a surface treatment may also retard the rate of failure of a structurally inadequate road pavement by preventing the ingress of water and preserving the inherent strength of the pavement layers and the sub-grade.

Existing gravel roads can be upgraded by regravelling and then surface dressing to protect the running surface.

#### **4.6.2 DESIGN METHOD (EMPIRICAL)**

The design method outlined for gravel roads in section 4.5.4 is based on experience. The surface dressing protects the surface of a gravel road from deterioration, but does not contribute to the strength of the pavement. The pavement thicknesses outlined in section 4.5.4 remain valid for traffic of up to 500 AADT, due to the relatively low numbers of heavy goods vehicles using the road. The exception to this is if there are very high levels of heavy goods vehicles or high predicted traffic growth rates – in such cases, it may be more appropriate to use an analytical-empirical method of pavement design (see section 4.7.3). It may also be used for gravel roads where there are similar concerns over traffic growth or high levels of heavy goods vehicles.

Pavement thicknesses and materials suitable for Romania are summarised below:

<b>Table 4.6.2 A: Pavement for Gravel Roads with Surface Dressing</b>	
	<b>AADT</b>
<b>Strength of Subgrade</b>	<b>200-500</b>
<b>CBR &gt; 15</b>	200 mm GW with double surface dressing
<b>CBR 5 – 15</b>	175 mm GW with double surface dressing 100 mm G20
<b>CBR 2- 5</b>	200 mm GW with double surface dressing 200 mm G20 250 mm G7
<b>CBR &lt; 2</b>	Obtain specialist advice

G20 is upper sub-base level  
G7 is lower sub-base level  
GW is gravel wearing course

(see Section 1.1 for reference to Technical Specifications for Low Cost Rural Roads)

For improvement or rehabilitation of existing gravel roads, additional gravel can be added to the existing lower layers to bring them up to the required thicknesses, before adding a new surface gravel layer and applying surface dressing. Alternatively, the analytical method of pavement design can be used, as described in the following section 4.7.3.

#### **4.6.3 DESIGN METHOD (ANALYTICAL-EMPIRICAL)**

In some cases, such as where there are very high levels of heavy vehicles, a more rigorous approach to pavement design may be required, using an analytical – empirical approach. It may also be appropriate when designing rehabilitation of existing pavements. There are several advantages to the method:

- Properties of existing pavements can be assessed by non-destructive methods, which is useful for maintenance planning and design
- Properties of materials can be measured for all climatic conditions
- Stresses and strains can be calculated for all combinations of axle loads, tyre configuration and tyre pressure
- Deterioration of a pavement can be related to deterioration of each layer
- Prediction of gradual deterioration becomes possible

This method is used for the design of unbound gravel materials. As noted before, the surface dressing acts to protect these layers but does not directly contribute to the strength of the pavement, and hence is not considered during the pavement design process.

Professional advice should be sought on the application on the use of the analytical-empirical method. For information, a brief description follows.

The design method has two steps. The first step is the calculation of the permissible stresses in each layer of the pavement. The second step is the calculation of the actual stress occurring in each pavement layer, using the theory of elasticity.

In the first step, the modulus of elasticity,  $E$ , is measured using a falling weight deflectometer (FWD) or by a static load test such as a plate bearing test. The FWD is preferred as it more closely simulates the dynamic loading of heavy traffic. For new roads, it is not usually possible to use the FWD, and design is instead based on CBR values.

The maximum permitted vertical stress on a layer is calculated from an empirical equation of the form

$$\sigma_{\text{permissible}} = 8.34 \text{ CN}_{\text{esa}}^{-0.307} (E/160)^\alpha$$

where  $\text{CN}_{\text{esa}}$  is the cumulative number of 100 kN standard axles

$E$  is the modulus of elasticity

$\alpha$  is 1.16 for  $E < 160$  MPa, and  $\alpha$  is 1.00 for  $E > 160$  MPa

The constants used in the equation are based on the AASHTO road test and Danish experience. The equation would need calibration to apply to Romanian conditions, where the standard axle is 115 kN.

The cumulative number of standard axles is the number of standard axles over the predicted design life of the road, which is usually 10 years for bituminous surfaced rural roads. Different vehicles do differing amounts of damage to a road. The structural damage caused by cars is insignificant when compared to that caused by trucks, and it is the levels of heavy goods vehicles that are critical in pavement design.

The number and types of vehicles using the road are measured by traffic counts (see section 2). The results from the counts are converted into an equivalent number of standard axles using the following conversion factors for Romania:

Table 6.3. A: Vehicle type – ESAL weighting factors (Romanian codes)						
Type of Vehicle	Two axle trucks	Three and four-axle trucks	Articulated vehicles	Buses	Special vehicle trailers	Trailers
$f_{ek}$	0,4	0,6	0,8	0,6	Special calculation procedure	0,3

The number of standard axles are determined by calculating the number of each type of vehicle that are predicted to use the road over the lifetime, taking account of existing vehicles, the design life of the road and the predicted traffic growth rates. The factor  $f_{ek}$  is used to convert this total number of vehicles in each category to an equivalent number of standard axles.

The next step in the design process is to calculate the stresses that actually occur at the top of each layer of the pavement. These are calculated using elastic theory, assuming a homogenous, linear elastic and isotropic material.

$$\sigma_z = \sigma_0 \left(1 - \frac{1}{\left(1 + \left(\frac{a}{z}\right)^2\right)^{3/2}}\right)$$

where  $\sigma_z$  is the stress at depth  $z$  within the pavement

$\sigma_0$  is the stress at the surface of the pavement

$z$  is the depth below the surface of the pavement

$a$  is the radius of the wheel in the contact area, which is related to the tyre pressure and wheel load

The thickness of pavement layers are varied to provide the most economic combination where  $\sigma_z$  remains less than  $\sigma_{\text{permissible}}$  for all layers.

Computer programmes are often used to assist with the calculation

#### 4.6.4 PAVEMENT AND MATERIALS

Surface treatments can be constructed in a number of ways to suit site conditions. The common types of surface treatments are illustrated in Figure 4.6.4.A

A **single surface treatment** would not normally be used on a new roadbase because of the risk that the film of bitumen will not give complete coverage. It is also particularly important to minimise the need for future maintenance and a double dressing should be

considerably more durable than a single dressing. However, a ‘racked-in’ dressing (see below) may be suitable for use on a new roadbase which has a tightly knit surface because of the heavier applications of binder which is used with this type of single dressing.

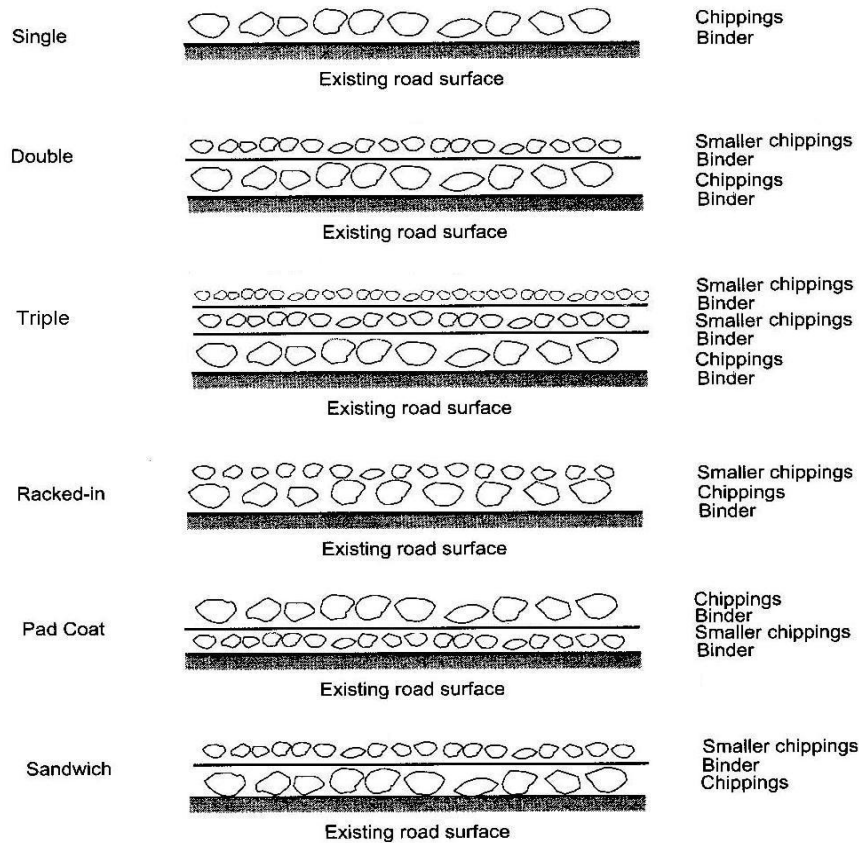


Figure 4.6.4.A: **Types of Surface Treatments**

When applied as a maintenance operation to an existing bituminous road surface a single surface treatment can fulfil the functions required of a maintenance re-seal, namely waterproofing the road surface, arresting deterioration, and restoring skid resistance.

**Double surface treatments** should be used when:

A new roadbase is surface-treated.

Extra ‘cover’ is required on an existing bituminous road surface because of its condition (e.g. when the surface is slightly cracked or patched).

There is a requirement to maximize durability and minimize the frequency of maintenance and resealing operations.

The use of a double surface treatment is recommended for most instances in Romania. The quality of a double surface treatment will be greatly enhanced if traffic is allowed to run on the first treatment for a minimum period of 2-3 weeks (and preferable longer) before the second treatment is applied. This allows the chippings of the first treatment to adopt a stable interlocking mosaic, which provides a firm foundation for the second treatment. However, traffic and animals may cause contamination of the surface with mud or soil during this period and this must be thoroughly swept off before the second treatment is applied. Such cleaning is sometimes difficult to achieve and the early application of the second seal to prevent such contamination may give a better result.

A **triple surface treatment** may be used to advantage where a new road is expected to carry high traffic volumes from the outset. The application of a small chipping in the third seal will reduce noise generated by traffic and the additional binder will ensure a longer maintenance-free service life.

A **racked-in surface treatment** is recommended for use where traffic is particularly heavy or fast.

‘Sandwich’ surface treatments are principally used on existing binder rich surfaces and sometimes on gradients to reduce the tendency for the binder to flow down the slope.

These last three treatments are unlikely to be applicable at traffic levels on low cost rural roads, but are included for information.

Information on materials and specifications for surface treatments are given in the Technical Specifications for Low Cost Rural Roads (see section 1.1).

## **5. DRAINAGE DESIGN**

### **5.1 GENERAL**

For low cost roads, the most critical aspect of the design is the provision of drainage. This protects the road from surface water and ground water. Inadequate drainage is the most common reason for road failure.

### **5.2 DESIGN PRINCIPLES**

The drainage system for a road is made up of a number of elements:

- Longitudinal side ditches
- Cut off ditches
- Culverts
- Inlet and outlet structures

These work together to divert water away from the road. Erosion within the system and at outlets must be minimised.

Whilst there are a variety of analytical methods for the hydrological design of drainage systems, these require detailed knowledge of the hydrology of the surrounding area and complex calculations. Such information is unlikely to be available at commune or village level, but the information given in this chapter should serve as a guide to good practice. For specific problems, such as major water crossings, it is recommended to consult county level engineers.

### **5.3 LONGITUDINAL DRAINAGE**

Longitudinal drains are required along the side of the roadway to collect and transport water running off the crossfall of the road surface. They should ideally resist erosion, be self cleaning and discharge onto level areas.

Ditches along the side of a road are required in all cases except where the natural fall of the ground away from the road exceeds 4%.

Ditches at the side of roads should ideally be wide and shallow, as shown in the figure below:

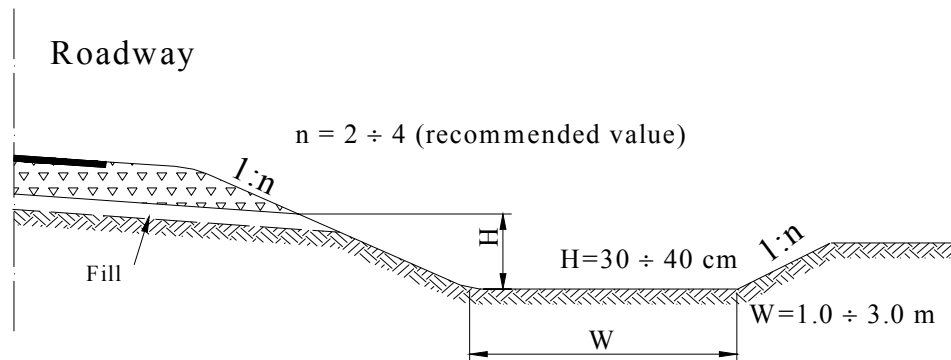


Figure 5.3.A: **Ditch cross section**

Minimum depth of ditches should be 0.3 to 0.4 metres below the roadway, with a flat bottomed profile. As an alternative, a ‘V’ shaped ditch can be constructed on gentle sloping terrain where a motor-grader is used to construct the road – the ‘V’ shape is cut with the blade as shown in the picture below:



Photo 5.1

### ‘V’ shaped ditch cut with grader

The drawback with the ‘V’ shaped ditch is that it is more prone to erosion, and the bottom of the ditch may need to be protected with stone pitching even at shallow gradients.

For both flat bottomed and ‘V’ shaped ditches, the side slope and back slope should ideally be less than 1:4. Where this is not possible, they should be no less than 1:2.

The minimum longitudinal gradient for ditches should usually be 2%. In very flat areas this may be difficult to achieve. In such cases, wide and shallow ditches are excavated and the material used to build the road level up above the surrounding land, as described in section 4.4.4.

The maximum gradient for unlined ditches should be 5%. A grass cover will assist in protecting against erosion.

In areas where the slope is greater than 5%, a number of options are available. Channels may be lined with pitched stones, small individual concrete slabs or other materials such as geotextiles. The use of poured concrete as ditch lining is not recommended, as it is prone to cracking and difficult to repair. Alternatively, the slope of the ditch may be made less steep by building a series of steps in the base of the ditch, using check dams, as shown in Figure 5.3.B below. The check dams are usually constructed of stone, although other materials such as wooden stakes may also be used.

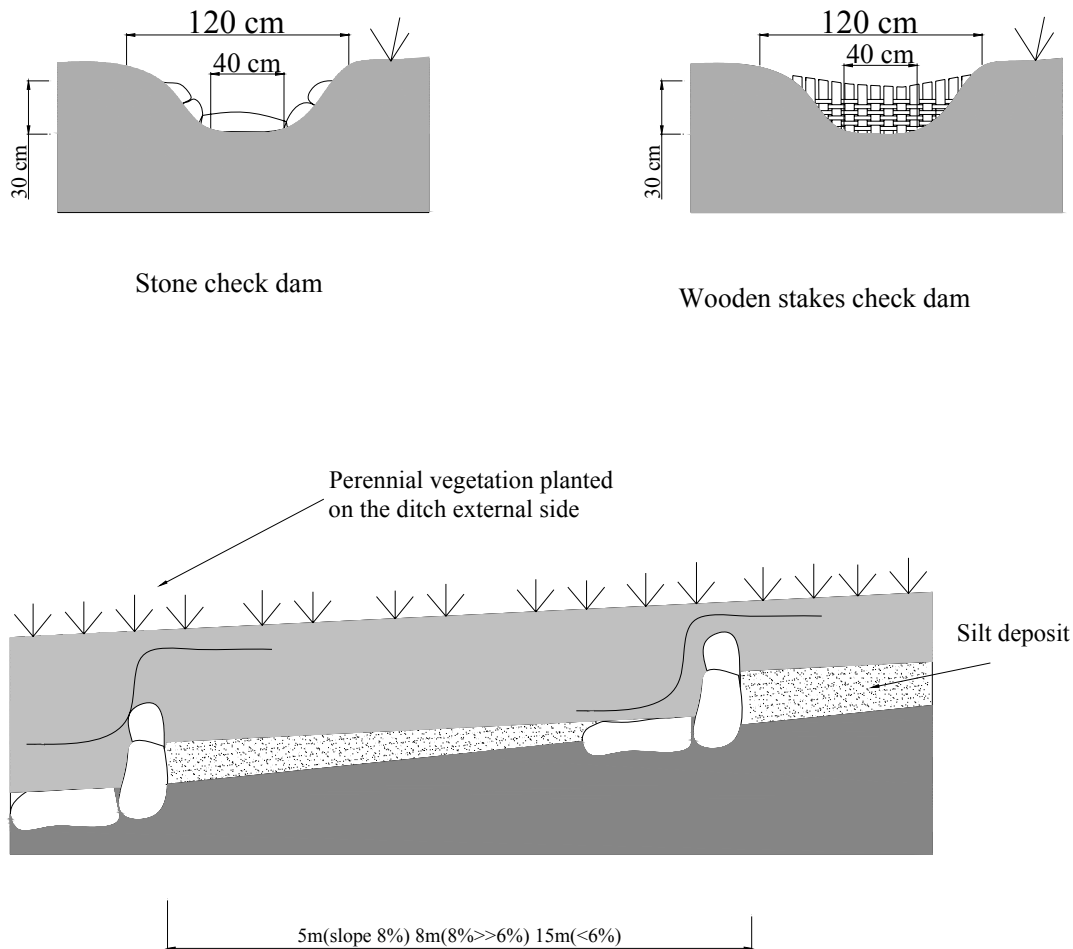


Figure 5.3.B : Check dam in longitudinal drain

Spacing of check dams depends upon the slope of the ditch – the following is a guide:

Table 5.3.A – Spacing of Check Dams	
Slope	Minimum spacing of check dams
Less than 6%	15 metres
6% to 8%	8 metres
Greater than 8%	5 metres

In the best case, ditches will outfall to existing stream beds, which will generally coincide with culvert locations to allow water to discharge from the upslope side of the road. Where this is not the case, ditches should be constructed with “turn-outs”. These allow water out of the ditch at intervals, preventing the ditch from overflowing.

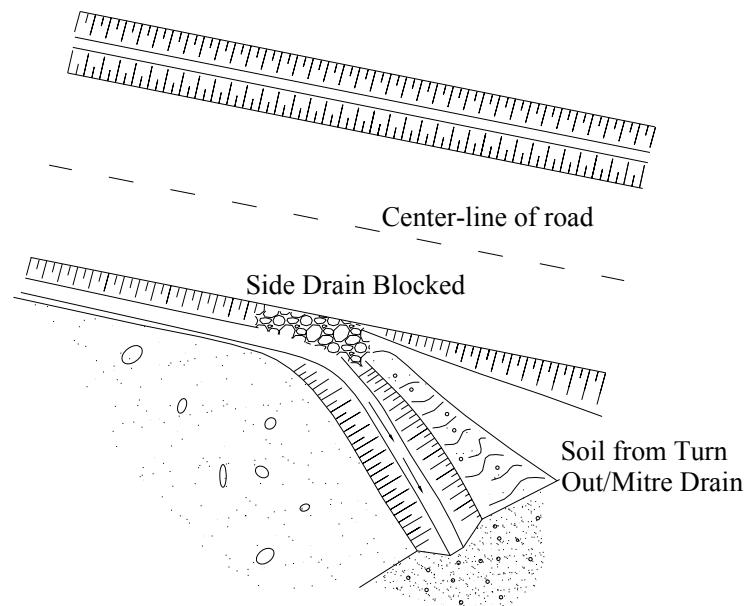


Figure 5.3.C: Turnouts

The turn out area may need to be stabilised to prevent erosion – there are several methods of doing this:

- Turn out discharges to a relatively flat area with a gentle slope, covered in grass. The flow from the ditch spreads out and slows, reducing the potential for erosion.
- The discharge area can be reinforced with a geotextile mesh. This is a plastic material which helps to retain topsoil and vegetation and stop it being washed away. Vegetation is allowed to grow through the mesh.
- Water from the turn out is discharged onto a bed of loose stones or rocks spread across the ground. This again slows the flow of the water. The stones must be big enough to prevent them being washed away. This is a **splash apron** described in section 5.6.

In all cases, the end of the turnout is constructed in a fan shape, to aid in slowing and dispersing the flow. Increased protection will be required where a turnout is used to distribute water from a culvert transferring water from the upslope ditch.

The spacing of turnouts will vary with the steepness of the ditch and with the levels of rainfall. In general, closely spaced turnouts are better, as discharge flows are less likely to cause erosion. A spacing of 20 metres is suggested for ditch slopes greater than 5%, although the spacing may be increased in flatter areas.

Ditches may also be constructed at the top of cuttings, to divert water away from the face of the cutting and prevent erosion (see section 6.3).

When digging ditches, the excavated material should be stored well clear of the ditch, to prevent it being washed back in.



Photo 5.2

**Material excavated from ditch may wash back in**

## 5.4 CROSS DRAINAGE

Cross drainage structures are used where the road intersects a watercourse. They include:

- Fords
- Drifts
- Culverts
- Bridges

Fords are the simplest crossings. The road crosses through the water course on the existing river bed. This is only possible when the channel is shallow and slow moving, and not prone to flooding.

The next step up is to place a concrete slab in the bed of the river. This is a drift. Care must be taken to protect the downstream side of the slab against scour by putting in place a masonry apron.

The most common type of cross drainage used for rural roads are culverts. These are corrugated metal or concrete pipes which carry the watercourse beneath the road. They are discussed in more detail in the following section 5.3.

Bridges are required for crossing larger streams and rivers. They require specialist design by a qualified engineer. National Romanian standards are applicable for bridges and a county engineer should be consulted as to the proper procedures when a bridge is being considered.

In all cases, it is good practice to try and ensure that any stream crossing is located:

- On a straight length of stream, away from bends
- Away from places where two channels join
- In an area with a well defined channel
- At a site where the road can cross at right angles

## 5.5 CULVERTS

Culverts are used to carry streams and other water courses beneath roads. They may also be used in to transfer water from long lengths of longitudinal side drains on the upslope side of a road – in this case, they will discharge into turn out drains (see section 5.3)



Photo 5.3

### **Culvert at watercourse**

Culverts for streams should be large enough to match the capacity of the channel. The depth of cover between the top of the culvert and the underside of the road pavement (ie the bottom of the gravel layer) should be equivalent to at least half the diameter of the culvert. More is better. In order to achieve these two requirements, two or more smaller diameter culverts may need to be placed in parallel.



Photo 5.4

### **Two smaller diameter culverts used to provide capacity required, Arges County**

The minimum recommended culvert size is 600 mm – less than this, and the culverts tend to become blocked and are difficult to clean and maintain

The culvert should be aligned with the existing stream channel as far as possible. Where this cannot be achieved, the culvert must be aligned with the center of the channel immediately downstream of the outlet. If channel excavation is required to help align the culvert, it is better to excavate the upstream channel to fit the culvert entrance and then align the outlet with the existing natural channel. Minimal disturbance of the channel at the culvert outlet should be the priority consideration.

The grade of the culvert should follow the grade of the existing channel, but with a minimum of slope of 2%. Additional protection at the outlet will be required (see section 5.6). The outlet should be at the same level as the bottom of the existing channel.

Culverts used to transfer water from an upslope side drain should be spaced every 150 metres or so. On steep slopes, greater than 5%, the spacing may need to be reduced. They should discharge to a turnout drain. The discharge point of the culvert and the discharge from the turn out drain must both be protected against erosion.

Culverts should also be used to carry water in ditches beneath side roads and under private accesses.

Culverts should be constructed from the outlet end towards the inlet end. Existing stream flows should be diverted to one side or pumped around the excavation. The trench for the culvert should be twice as wide as the culvert. Soil around the culvert should be compacted by hand in layers no thicker than 15 cm.

At the inlet and outlet of the culvert, the edges of the pipe shall be protected by headwalls. These can be constructed from a variety of materials such as:

- Mass concrete
- Stone pitching
- Hessian sacks filled with dry concrete mix
- Concrete blocks

The standard details are included in Standard Details for Low Cost Rural Roads (see section 1.1). The headwall must extend below the channel bed to protect against scour.

The headwalls may be constructed with wings at the inlet and outlet to direct flow through the culvert.

## 5.6 EROSION AND SCOUR PROTECTION

Measures to protect against scour in ditches and at outfalls are extremely important. They work by reducing the velocity of water and making sure it is discharged in a controlled manner. The different structures described below should be used wherever there is concentrated, turbulent, or high velocity flow.

The need for scour protection cannot always be predicted, and it is recommended that the drainage system be examined after the first heavy rain. Additional protective works can be installed where necessary. It is often instructive for the engineer to inspect the system during the rain, when the behaviour of the water in the drainage system can be observed directly.

Heavy loose stones are often used in preference to concrete for lining and protection. Concrete linings are very rigid, and tend to crack easily with even slight ground movement. In contrast, stone pitching can deform with the ground, and is easier to maintain or replace.

Outlets from culverts carrying watercourses will be level with the existing stream bed where possible. In other cases, outlets from turnout drains and culverts should spread water over a vegetated area with a gentle slope whenever possible. This allows pollutants and sediment from the runoff to be dispersed before the water drains to a watercourse.

**Plunge basins** are pits that become filled with water. They are located where there is a sudden drop in level. This may be beneath cantilevered pipes where the natural channel bed is too steep to lay a culvert at grade, or at the end of steep chutes or flumes carrying water vertically down a steep slope such as a cutting face.

Basins are usually constructed as a depression below the outlet channel as shown in Figure 5.6.A, but can be constructed with the basin bottom at the outlet channel elevation and the basin formed by constructing a weir (riprap, gabion, etc.) across the outlet channel as shown in Figure 5.6.B. The basin is usually wider than the outlet channel by design and tapers to fit the existing channel at the basin exit point. The basins must always be lined with a non-erosive lining such as riprap, concrete mats, gabions, etc. underlain with filter fabric or a graded aggregate filter.

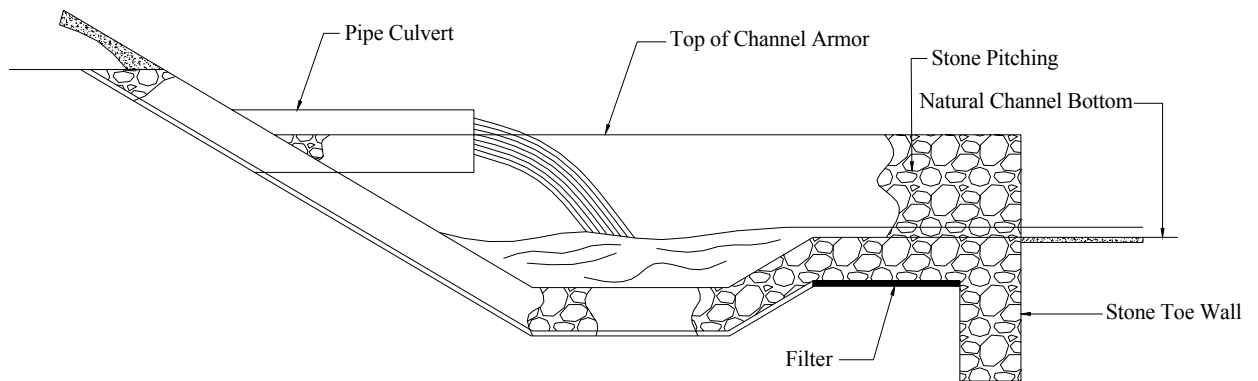


Figure 5.6.A: **Plunge Basin**

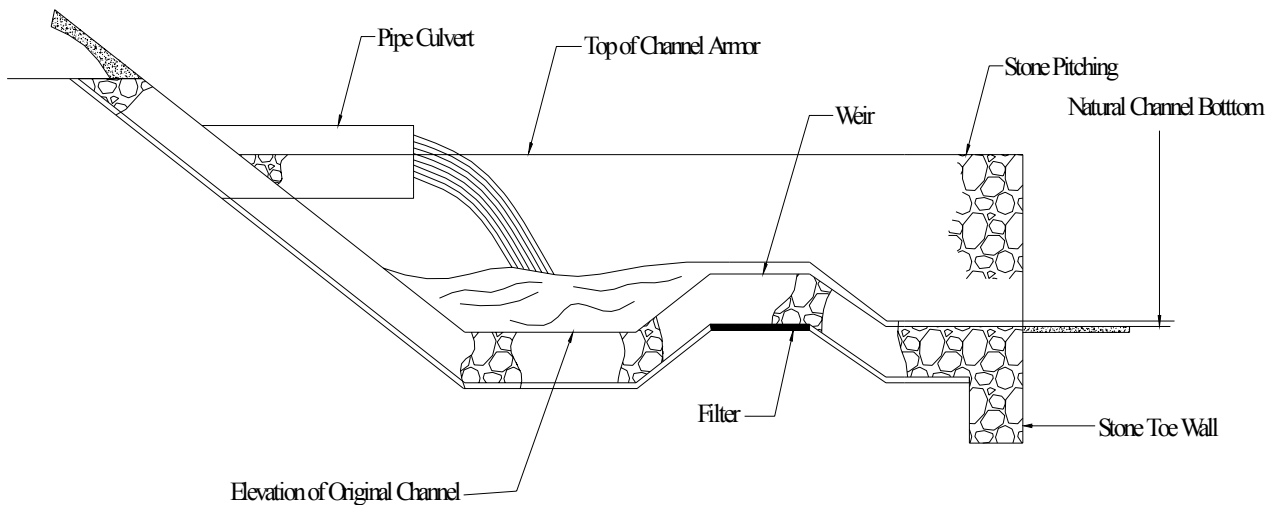


Figure 5.6.B :**Plunge Basin with Stone Weir**

A **splash apron** is commonly used at the end of turn out drains, but may also be used downstream of culverts, plunge basins and other structures. It is a wide, flat area covered with large heavy stones or other material that will not erode. As shown in Figure 5.6.C, the dimensions taper from a narrow width at the entry point to a wider dimension at the

outlet some distance downslope. This spreads the water in a fanning action over the rough, armored surface. The armor blends into the existing slope to prevent scour and undermining at the discharge point. Toe walls may also be necessary where the structure outlets onto earthen surfaces.

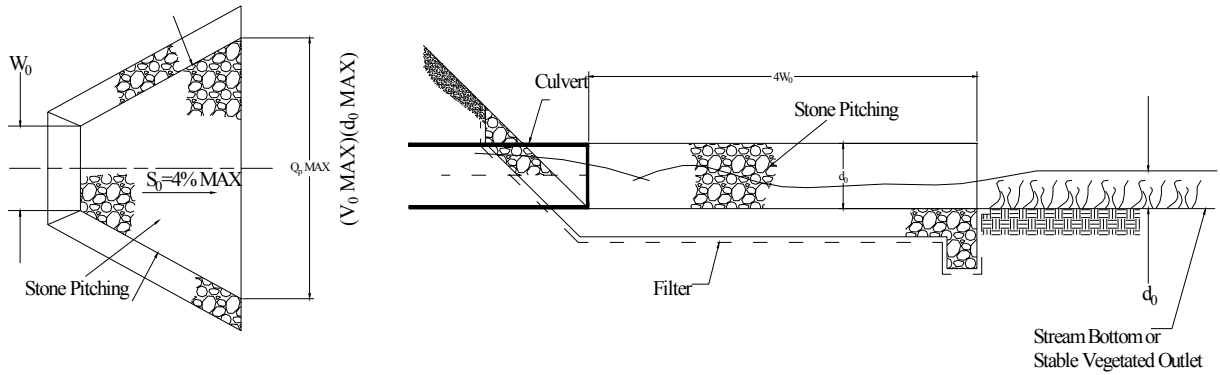


Figure 5.6.C: **Splash Apron**

A **drop inlet** is similar to a plunge basin but is used at the inlet of culverts. It is constructed from reinforced concrete, concrete blocks, bricks or other sound structural material. Water from a ditch, chute or flume drops vertically into a box - see Figure 5.6.D. A drop inlet works well where there is a severe cross-slope from one side of the road to the other, or where there is a need to suddenly reduce road ditch and flume elevation where erosion has progressed upstream.

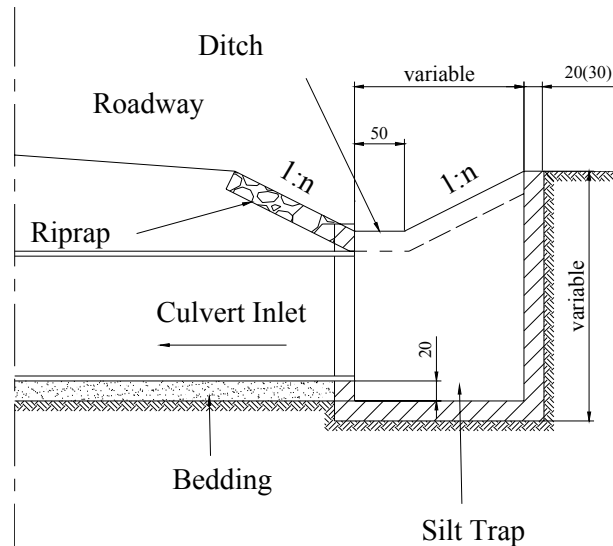


Figure 5.6.D: **Concrete Drop Inlet**

## **6. EARTHWORKS DESIGN**

### **6.1 GENERAL**

Earthworks involve removing and placing natural material to construct a base for the road pavement. Earthworks include the formation of cuttings and embankments.

### **6.2 DESIGN PRINCIPLES**

The design of earthworks is an extensive subject. This manual provides some basic guidance but additional professional advice should be obtained for major fills and cuttings.

For low cost rural roads, earthworks should be kept to a minimum, and it would be rare to find embankments higher than 3.0 metres or cuttings deeper than 6.0 metres.

When designing earthworks, it is economic to try and balance the amount of material excavated from cuttings against the requirements for embankments, to reduce the need to obtain or dispose of additional material.

### **6.3 CUTTINGS**

Cuttings are required where the natural ground level lies above the proposed alignment of the road.

Cuttings in sound rock can often be vertical, but in weathered rocks and soils it is necessary to use shallower slopes.

One of the simplest ways to decide upon a suitable cutting slope is to survey existing cuttings in similar materials along the proposed route. New cuttings can be formed at the same slope as stable existing cuttings if they are in the same material.

The stability of cuttings depends not only on the material but also on the height of the cutting and on the water table conditions. In the absence of any other information, the following table gives preliminary advice on suitable cutting slopes, although the slope may need to be adjusted for local conditions. It must be stressed that for higher slopes and for problem soils such as loose or soft soils and material with a high organic content, further professional advice must be obtained.

<b>Table 6.3.A – Preliminary advice for cutting slopes</b>			
<b>Soil Type</b>	<b>Water Table</b>	<b>Cut Height 0-3 metres</b>	<b>Cut Height 3-6 metres</b>
Gravels, sands	Low	1 V:1.5 H	1 V:1.5 H
	Moderate	1 V:1.5 H	1 V:1.5 H
	High	1 V:1.5 H	1 V:1.5 H
Clayey gravels, sands	Low	1 V:1 H	1 V:1 H
	Moderate	1 V:1 H	1 V:1 H
	High	1 V:1 H	1 V:1.5 H
Stiff Clays	Low	1 V:1.1 H	1 V:1.1 H
	Moderate	1 V:1.1 H	1 V:1.1 H
	High	1 V:1.1 H	1 V:1.5 H
Soft clays		Obtain specialist advice	Obtain specialist advice
Organic soils		Obtain specialist advice	Obtain specialist advice

One of the main causes of failure of cutting slopes is the presence of water. It is critical to ensure that surface water is moved away quickly from the area of the cutting. If there is a problem with erosion on the face of the slope, cut-off drains may be used. These are longitudinal drains running along the top of a cutting, which intercept surface water before it reaches the face of the slope. It is important to regularly clear these ditches of debris to ensure they do not become blocked, as this may cause water to become trapped possibly leading to failure of the slope. Longitudinal ditches should also be used at the base of the cutting, alongside the road. A generalised cutting section is shown in **Figure 6.3.A.**

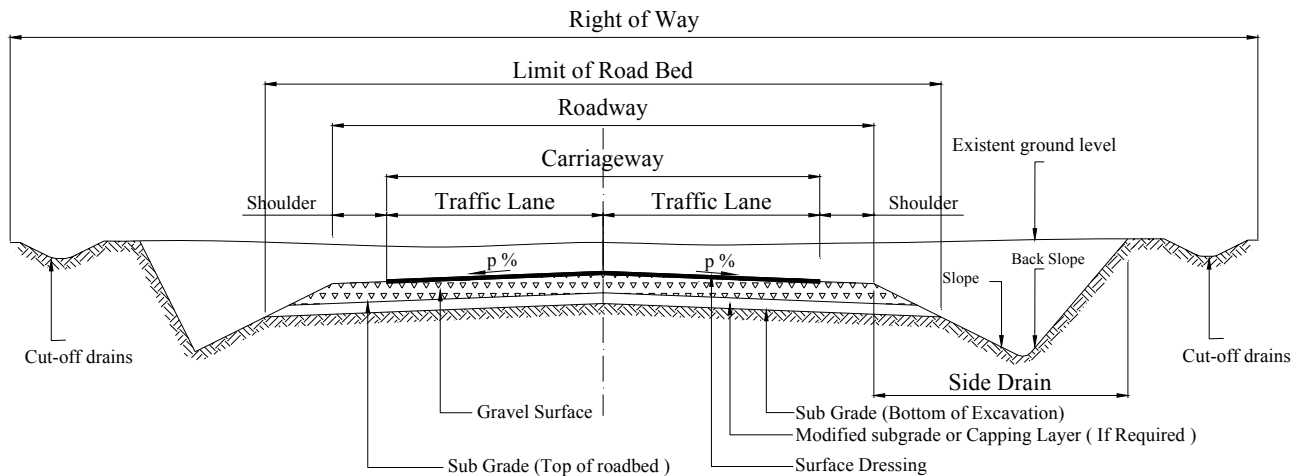


Figure 6.3.A: **Typical Cross Section in Cutting**

## 6.4 EMBANKMENTS

Embankments are required where the level of the road needs to be raised above the surrounding ground level. In very flat areas, the entire road may need to be constructed on a low embankment, and this is usually achieved by using material excavated from widened side ditches alongside of the road.

For the design of embankments, the following areas of concern should be addressed:

- Foundation conditions, with their associated potential problems of settlements and stability
- Embankment materials and methods of placing and compaction.
- Protection of the completed embankment slopes.

Most soils are suitable for embankment construction. The best materials should be reserved for the upper layers of the embankment, which will form the subgrade. Side slopes of low embankments up to 3.0 metres in height are dependant upon the quality of material used and are generally 2 Horizontal : 1 Vertical.

Some soils are however generally unsuitable for construction of embankments:

- Materials with more than 5% by weight of organic materials
- Materials with a swell of more than 3%

- Clays with a plasticity index over 45 or a liquid limit over 90

During construction, it is important that the thickness of embankment layers be monitored to ensure they are of appropriate thickness (20 to 30 cm is generally the upper limit for the thickness of individual layers), and material is compacted close to its optimum moisture content.

## 6.5 USE OF VEGETATION

The side slopes of embankments and cuttings can be protected against erosion by providing a cover of vegetation.

**Grass seeding** is the most efficient and cost effective method of protecting slopes. This method should always be considered first and used wherever possible. Grass will slow water movement and allow more infiltration. It will effectively hold soil particles in place, reducing sedimentation. On relatively shallow slopes of up to 3.0 metres in height and gradients steeper than 1 Horizontal :1Vertical, the slope can be covered in topsoil and seeded.

On higher and steeper slopes, it may be necessary to use other approaches such as **terracing**, where grass is sown on horizontal steps cut along the face of the slope.

**Trees and shrubs** can be planted to assist in stabilising slopes. Deep rooted species of trees and shrubs such as willows provide greater protection against soil slippage problems. Native plants must be used to ensure adaptability and reduce costs.

To improve long term slope stability, **live stakes** can be planted. These are cuttings of live branches neatly pruned of limbs, usually 1 cm to 3 cm in diameter, and 60 to 100 cm long. This technique is inexpensive and can be used when time and/or resources are very limited and the site is not complicated. See figure 6.5.A below. The end of the stake should be cut at an angle and pushed into the ground perpendicular to the slope, buds oriented upward, leaving only 2" to 3" of the stake above the ground. Stakes are planted in rows, with two to four stakes per square yard. Stakes should be cut during dormant seasons and installed the same day as cut, or temporarily stored (a few days) in a very moist, cool environment until use.

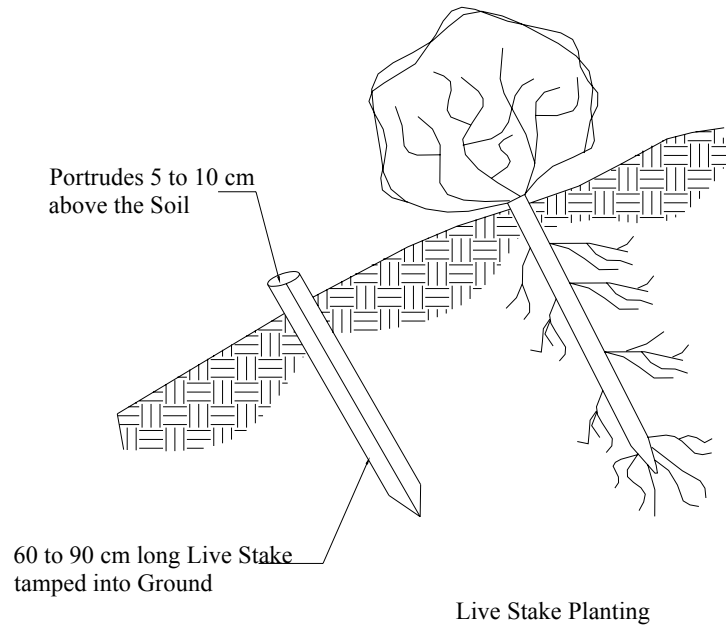


Figure 6.5.A L: **Live stakes**

For more immediate stabilisation, **fascines** can be used. These are long bundles, 1.5 to 9 m in length and 15 to 20 cm in diameter, of live branches tied together with growing tips oriented the same direction and tops evenly distributed throughout the length of the bundle. See Figure 6.5.B. The fascines are placed in a 30 to 40 cm deep trench dug along the contour of the slope, and secured in place with stakes. The bundles are then covered with a moist, compacted soil backfill. Fascines should be cut during dormant seasons and installed the same day as cut, or temporarily stored (a few days) in a very moist, cool environment until use. Installation begins at the toe of the slope and progresses up-slope.

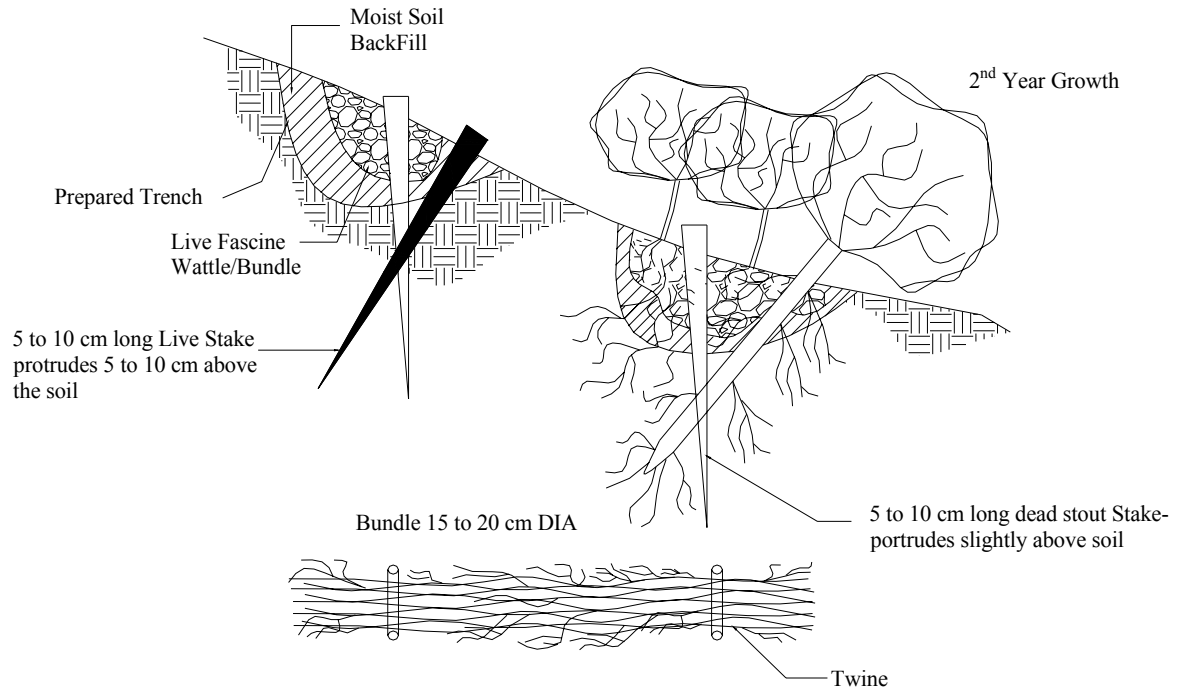


Figure 6.5.B: Fascines

## **7. REFERENCES**

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