LABOUR-BASED TECHNOLOGIES AND METHODS FOR EMPLOYMENT INTENSIVE CONSTRUCTION WORKS

BEST PRACTICE GUIDELINE 4-9

Labour-based methods for unsealed roads

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Note: Unsealed roads include all roads constructed without the use of bitumen, concrete, blocks or other durable surfacing interfacing with wheels of vehicles. They include earth tracks, earth roads, gravel roads and roads treated with a dust palliative or chemical stabilizer. The term unsealed roads is generally used internationally as a replacement for the older terms, "dirt" or "gravel" roads. In order to provide the expected level of service, unsealed roads must be constructed from suitable materials, must be constructed to the specified quality and must be maintained to an appropriate standard. As the majority of roads in rural and developing areas are unsealed, are not stabilised and carry relatively light traffic, these roads provide excellent opportunities for the use of labour-based construction and maintenance methods.

1. Introduction

1.1 Background

Unsealed roads were the first roads constructed by man when the operators of the earliest wagons and carts encountered difficulties traversing poor materials. Localised troublesome areas would have been made passable by the addition of local materials that provided improved bearing capacity and trafficability. As the use of wheeled vehicles increased, it became more important to provide acceptable passability over the entire length of road and appropriate materials were selected and placed with some "engineering" input. These roads would probably have been constructed using entirely labour-based methods. As time progressed, more automation was used until the present, when most unsealed roads are constructed using predominantly heavy plant.

Unsealed roads are still the principal type of road making up more than 90 per cent of the road network in many developing countries and over 50 per cent in some of the worlds most developed countries. These are generally the least expensive roads to construct, but unlike sealed roads, the surface is not protected from environmental or traffic stresses and deteriorates rapidly. Ongoing maintenance is thus an essential and costly necessity for unsealed roads. This of course does provide an excellent opportunity for sustained local employment using labour-based construction and maintenance technologies.

1.2 Definition

Unsealed roads include all roads with no waterproof or structural surfacing, ie, bitumen, concrete, interlocking blocks, etc. In their simplest form, unsealed roads usually consist of two tracks resulting from the compaction of the in situ material and destruction of vegetation following the passage of a few vehicles or carts along the same alignment. Once the traffic increases to a certain point (this will vary depending on the in situ material and nature of the traffic), the wheel tracks become wider and eventually the full width of a road is cleared, usually by grader or bulldozer. Traffic still rides on the in situ materials and the road is classified as an earth road. This type of road obviously has shortcomings in that the material properties are dictated by the local material and may or may not be suitable for sustained use as a wearing course. In addition, wear of the road results in general lowering with respect to the surrounding natural ground level, resulting in poor drainage and an eventual need for importing material to provide some type of formation and shape to the road.

When a selected material is imported and the road is shaped, it then becomes a gravel road.

2. Materials and specification

2.1 Aggregate specification

The properties of the materials used as gravel road wearing courses have a significant impact on both the performance and maintenance needs of the road, far more so than in sealed roads. Gravel wearing course materials require:

- Adequate cohesion to avoid ravelling and corrugation of the surface under traffic
- A grading that produces a tightly bound, interlocked layer with sufficient strength to avoid erosion and shear failure
- A limited plasticity such that the road does not become excessively slippery when wet
- Sufficient gravel to provide a skeleton for the fine material and adequate skid resistance, but not enough to cause excessive tyre wear or large particles that will affect riding quality

Research and experience have shown that materials complying with the following requirements (Table 1) are generally adequate (TRH 20, 1990).

Table 1: Recommended material specification for unsealed roads

Property	Specification limit
Maximum size (mm)	37.5
Maximum Oversize Index (I_o) (%)[a]	5
Shrinkage Product (S_p)[b]	100 – 365 (max of 240 preferable)
Grading Coefficient (G_c)[c]	16 – 34
Minimum CBR (%)[d]	15 at 95 per cent Mod AASHTO
Treton Impact Value (%)	20 – 65

[a] – I_o = Percent retained on 37.5 mm sieve
[b] – S_p = Linear shrinkage x percent passing 0.425 mm sieve
[c] – G_c = Percent passing 26.5 mm sieve-per cent passing 2 mm sieve) x per cent passing 4.75 mm sieve
[d] – Conventional soaked CBR unlike the unsoaked CBR originally specified in TRH 20

The grading and plasticity components of these specifications can be plotted as shown in Figure 1 as an aid to predict the likely performance of materials not complying with the requirements of Table 1.

Materials falling into Zone E will provide the best performance, provided the oversize content and strength are correct. Materials falling into Zones A, B, C and D can be expected to be erodible, to corrugate and ravel, to ravel or to become slippery, respectively. The degree of the expected defect will generally increase as the material plots further away from Zone E.

Materials must be located and tested prior to initiation of construction. Initial testing and material acceptance needs to be carried out in a conventional soil testing laboratory, but quality control on site can use simplified techniques (Paige-Green, 1998).

The use of geological, engineering geological or engineering material classification systems is generally unsuitable for the identification of suitable wearing course materials: only the individual material properties can be effectively used. Dolerites for example could be excessively stony, highly plastic or very granular with a low plasticity, none of which would perform satisfactorily. Depending, however, on their stages of weathering and the prevailing environmental conditions, other dolerites could perform very well. It is thus essential to determine the actual properties of every potential material source.

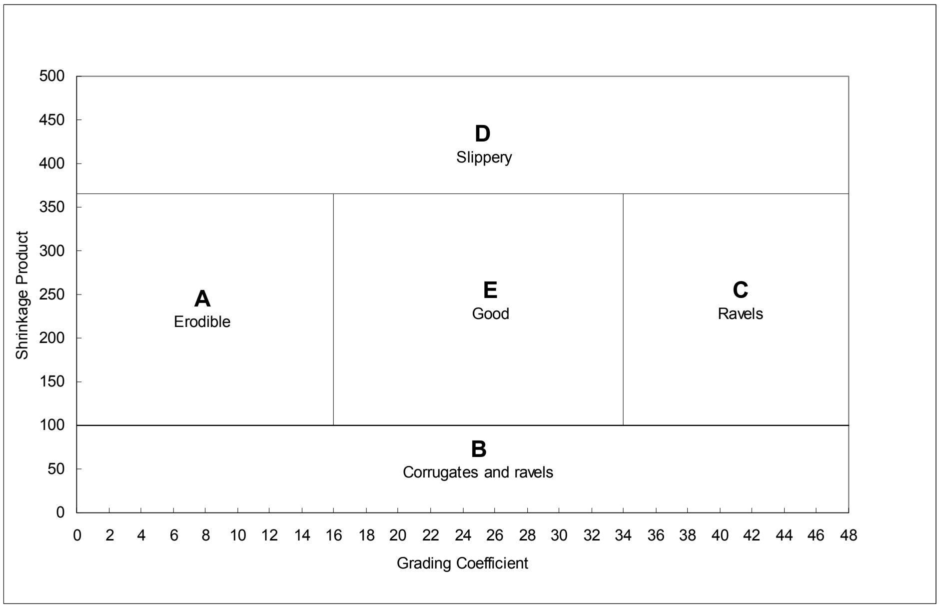


Figure 1: Gravel road specification and performance

Provided certain conditions are accepted, it is possible to make use of materials not complying fully with the requirements of Table 1. For example, a material with a very low shrinkage product could perform satisfactorily in a moist area with low traffic as moisture will provide an effective cohesion for long periods reducing the tendency for the material to corrugate (which will take longer under low traffic). Such material may be used provided that the periodic need to provide increased maintenance (light grading or dragging to remove corrugations) is accepted. In a dry area with relatively high traffic, the maintenance needs on this type of material will be very high resulting in high costs and significant disruption of traffic flow, making the use of the material impractical.

Similar constraints are found when labour-based construction and maintenance techniques are employed. The degree of compaction attained may not be as high as that from conventional plant, resulting in poorer performance of low plasticity material or highly plastic material. These aspects must be considered when using materials not complying with the requirements of Table 1.

3. Practical aspects

3.1 Impact on performance

The specifications described above were developed over a wide range of materials, climate and traffic conditions and can be applied generally. It has, however, been found that they can be fine-tuned for local conditions but this can only be done with experience in certain areas. It is more important to ensure that certain aspects such as material homogeneity, stoniness, compaction and drainage are carefully controlled and supervised, during both construction and maintenance.

3.2 Material homogeneity

The use of variable or heterogeneous materials on unsealed roads results in localised problems, particularly in relation to passability and drainage. It is thus essential that the material is as homogeneous as a natural material can be and this is best achieved by stockpiling the materials for use on the road. The actions of excavation, loading, haulage, stockpiling, reloading, haulage and dumping, although involving double handling, creates a significant degree of mixing and homogenisation of the material. More detail in this regard is provided in Section 1.3.5.2 of Part 2 (Labour-based Construction Methods for Earthworks)

3.3 Stoniness

One of the major contributors to poor performance of gravel roads is the presence of excessive oversize material. The presence of large stones in the wearing course results in extreme roughness and severe difficulties in maintaining the road.

Material containing significant oversize particles should be processed at source, especially in labour-based projects, where the haulage of unwanted material can have a major impact on productivity. Processing of the material through a series of small grizzlies or mesh screens should form a part of the excavation to stockpile process.

Removal of oversize material from the road during mixing and compaction is seldom successful, and results in wastage and unnecessary haulage. Manual breaking of oversize material can be carried out using large hammers, but this needs very close supervision, as hammers tend to bury the problem rather than break the cobbles and boulders, with the result that they are exposed some time later in the service-life of the road. If this is carried out, it is important that the fractured particles are separated from each other so that they do not behave as an integral particle. This requires careful mixing in the area of the broken particles.

3.4 Compaction

The act of compacting soils and gravels improves their quality/performance by improving particle interlock and thus shear strength and reducing permeability. These aspects are all necessary to ensure a road that fulfils its social and economic needs.

To achieve any reasonable degree of compaction, the material should be at a specific moisture content related to the compaction effort available on site. Material that is too wet will become spongy and will not compact, whereas material that is too dry requires an excessive effort to overcome the friction between the particles and achieve any reasonable density. Some sandy materials can be compacted successfully when dry, but they do not achieve the same strength as when wet compacted as the suction forces created between the particles on drying out do not develop.

Traditionally, construction specifications require materials to be compacted to a specific (although arbitrary) density, which may or may not be achievable with the available plant or be necessary for that material and the prevailing conditions. The control of compaction is difficult, relying on either sophisticated nuclear equipment or time consuming labour-based methods, which are carried out at very few points on the road. A method specification, based on proof rolling trials allows for much better control and the results can be assessed at many more points on the road using simple equipment as discussed in 4.

3.5 Drainage

3.5.1 General

The uncontrolled passage of water on and adjacent to unsealed roads can cause significant damage to the road and seriously affect the movement and safety of traffic using the road. Rain falling on the road must be removed from the road surface as rapidly as possible whilst that falling adjacent to the road must not be allowed to accumulate on or close to the road structure.

3.5.2 Road surface drainage

In order to ensure that precipitation does not remain on the road surface, a good shape needs to be maintained. This requires a central crown and a camber, preferably of about 4 per cent, towards each side of the road. Cambers greater than 5 per cent result in erosion and unsafe driving conditions, whilst those less than about 2.5 per cent allow the water to permeate into the road and usually result in ponding on the road. This camber must be carefully maintained during routine maintenance activities. On mono-camber sections of road, the cross-fall/superelevation should not exceed 4 per cent to avoid excessive erosion and to facilitate maintenance.

It is important that windrows, which will disrupt the flow of water from the road surface, do not remain along the road after maintenance. Any material retained for maintenance activities should be off the road shoulder and must not block the entrance to side or mitre drains.

Potholes and depressions in the road will hold water and gradually increase in size and severity under traffic. These should be repaired manually on a regular basis.

3.5.3 Side drains

Water drained form the road surface will inevitably be collected in side drains adjacent to the road shoulder. These must be well-maintained and effective at all times, and provide unhindered paths for the removal of the water into adjacent fields (by way of properly designed mitre drains or across the road through effective culverts). For this to be effective in flat terrain, it is essential that the road is constructed on an adequate formation. The spacing of mitre-drains (particularly on steeper grades) should be such that high water velocities are not achieved and scouring is minimised.

Side drains should be wide and deep enough to handle the expected water without flooding the road, but also to facilitate maintenance. Maintenance using labour allows much narrower and deeper drains than that using motor graders.

4. Structural design

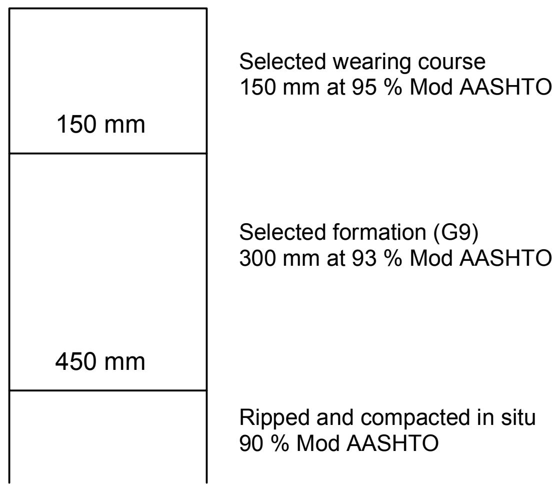
The pavement structure of sealed roads is designed to carry a finite number of vehicles over a specific period under the prevailing environmental conditions. This is achieved by providing a series of pavement layers each distributing applied stresses so that no part of the pavement is overstressed, but the cumulative infinitesimal damage that occurs under each vehicle pass reaches a defined terminal condition at the end of the design life. Any premature damage due to overstressing or inadequate layers results in localized damage requiring unscheduled maintenance (e.g., crack filling, pothole patching, rut filling) or possibly even rehabilitation/reconstruction.

Although similar forces (in addition to environmental stresses) affect unsealed roads, most damage that occurs is usually corrected during scheduled routine maintenance, i.e. potholes or ruts are filled during grader blading or spot regravelling. In comparison with equivalent damage to sealed roads, any other maintenance that may be needed is relatively inexpensive and less disruptive to traffic. For this reason, the structural design of unsealed roads requires significantly less input.

Unlike sealed roads, structural design decisions for unsealed roads are generally more labour-friendly. All unsealed road materials are usually natural, so labour-unfriendly decisions, e.g., to stabilize the materials, as would be the case for many sealed roads, do not affect the outcome.

One of the main components of the structural design is to ensure that a formation with appropriate dimensions is designed with a suitable specified material and compaction. The subgrade must be cleared and grubbed and then rolled to refusal with the available equipment in preparation for placement of the formation. At least 300 mm of material with a minimum soaked CBR of 7 per cent (G9) should be placed as formation in order to raise the road prior to placement of the wearing course. This should be compacted to refusal ensuring that a minimum density of 93 per cent Mod AASHTO is achieved. Typically, 150 mm of material complying with the specification described in Section 2 and compacted to refusal for the available equipment or plant (but not less than 95 per cent Mod AASHTO) should be placed as the wearing course.

This pavement structure is illustrated in Figure 2.



This structure has been found to be appropriate for most gravel roads. In drier areas, the height of the formation can be reduced although the side drains must be at least 300 mm beneath the road crown. The placement of pipe culverts requires adequate formation and cover and often dictates the formation thickness. Care must be taken to ensure that culverts and pipes do not result in “speed humps” along the road.

5. Plant and equipment

Typical tools that are needed for labour based gravel road projects are:

- Axe, panga, machete, etc for removal of vegetation
- Shovel
- Pick
- Wheelbarrow: Typically 50 to 70 litres
- Donkey Cart
- Setting out profiles and/or templates
- String, dip sticks, stakes, pegs, etc
- Water tanks and spraying equipment
- Rake
- Levelling beam
- Hand stampers

Mechanical compaction equipment may also be required to complement manual activities. Where necessary mechanical hauling equipment (tractors and trailers) should be available.

Apparatus for carrying out a Dynamic Cone Penetrometer (DCP) test and quality control testing should also be available.

6. Construction

6.1 Earthworks

New unsealed roads will result either from the upgrading of an existing earth track or less commonly on a totally new alignment. In either case, the centre-line of the proposed road should be staked out (stakes at 20 to 50 m intervals, depending on topography and vegetation) and the proposed vertical alignment/ final road levels marked on these stakes. This is most easily done using ranging roads and an Abney Level, but where steep grades prevail, more sophisticated levelling surveys may be necessary. (See Annexure A)

The crown height, layer thicknesses and crossfalls are then transferred to offset stakes or pegs adjacent to the edge of the road and side drain, prior to clearing and grubbing, which will usually result in loss of the centre-line stakes. This should be done using string, tape measures, calibrated dip sticks and levelling beams.

Clearing and grubbing can then commence. Traditionally this is done with a bulldozer or grader, but labour-based methods can be equally effective. Labourers should initially remove all vegetation above ground level using the appropriate equipment. Trees should be cut down, bushes hacked back and grass cut as described in Section 1.2 of Part 2 (Labour-based Methods for Earthworks). The root and organic rich topsoil must then be removed and disposed of as instructed. Grubbing should be done using shovels and picks where necessary, ensuring that the absolute minimum soil material is removed. Where isolated rock outcrops or large boulders occur, dry wood removed during the bush and tree clearing should be collected and retained for use in fires to break the rock as described in Part 2 (Labour-based Methods for Earthworks).

The cleared and grubbed roadbed must then be levelled and compacted to as high a density as practically possible using available plant. On small projects, use can be made of hand tampers but generally, small pedestrian or sit-on rollers are necessary. The addition of water to the roadbed material will usually be necessary to assist compaction, unless this is carried out in the wet season. On certain materials, it may be necessary to loosen the roadbed material with forks prior to compaction in order to break up loosely cemented particles and possible collapsible soil structures. It is also recommended that, where possible, a camber towards the side-drains is applied to the top of the subgrade to assist with drainage of water that may seep through the pavement structure.

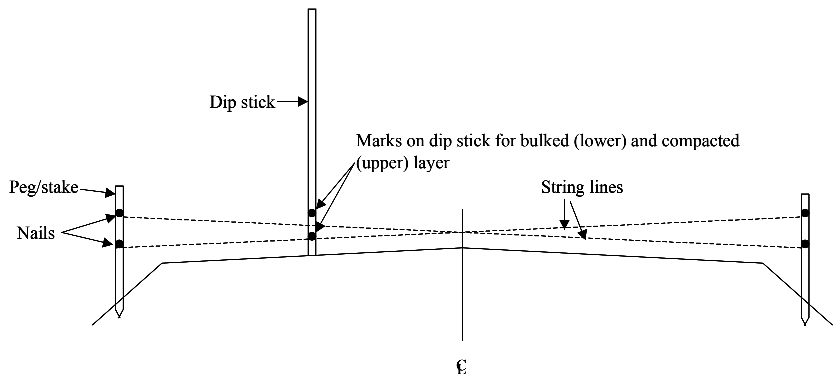
6.2 Formation

The formation should be constructed of selected material that is excavated, loaded, hauled, unloaded and spread as described in Part 2 (Labour-based Methods for Earthworks). Suitable material should be obtained from the relevant stockpiles and dumped and spread according to Part 2 (Labour-based Methods for Earthworks). Dip sticking of string lines, which allow for the bulking of the material, should be carried out during spreading to ensure an even distribution of material. It is also possible to use pegs or pins marking the top of the layer for spreading, but these should be removed prior to compaction. (See Figure 3)

The top of the formation should be constructed to the same shape as the proposed wearing course to maintain a constant wearing course thickness and to assist in internal drainage of the layers. As the formation is typically 300 mm thick (compacted), it is impracticable to compact this material with light equipment in one layer. Compaction should thus be carried out in three 100 mm layers.

It is useful to determine the typical bulking factor of the material and to place marks for both this and the compacted layer on the dip stick. This provides additional control for spreading and compaction. It is also usual to require stakes or pegs more frequently than one every 20 m during actual labour-based construction.

For very light pavement structures, it is possible to use only very light compaction and not to be too concerned with the actual compaction. The result of this will typically be significant rutting during early trafficking (as a result of traffic compaction), which can be corrected during surface maintenance. The implication of this is that additional wearing course material will be required earlier in the life of the road. This is not recommended if heavy trucks are expected to use the road as early potholing and shear failures in the uncompacted formation are likely.



6.3 Wearing course

The gravel wearing course will be constructed of selected material that is excavated, stockpiled, loaded, hauled, unloaded and spread as described in Part 2 (Labour-based Methods for Earthworks). The material for the wearing course should preferably be moistened to just above optimum moisture content at the stockpile prior to hauling so that segregation is minimised and the loading, hauling, unloading and spreading process homogenises the material as far as possible. Traditionally, the gravel is tipped along the side of the road and then spread by grader (with simultaneous watering and mixing) across the road. On labour-based projects, however, the material will typically be spread with forks and/or rakes and should thus be dumped on the road to accelerate the spreading procedure. During spreading, all oversize material that may have been "accidentally" incorporated into the wearing course gravel must be removed. It is important that oversize particles are not just buried in the layer, as they will appear over time as the gravel is worn away by traffic and environmental effects.

As it is very difficult to trim the final levels using only labour, it is important that the surface is as even and as well shaped as possible prior to compaction. The use of string lines and dipsticks is the most practical method of ensuring this on labour-based projects, although it is useful for each labourer to have a suitable camber board (planks with a spirit level on the upper surface and a 4 per cent slope on the lower surface – Figure 4) for checking his individual work. (Levels can also be estimated using a calibrated probe as described in Paige-Green, 1998.) This process should be carried out as rapidly as possible to avoid excessive loss of moisture from the material and compaction must commence as soon as possible. (The use of pins in the road carriageway to mark the top of the layer should never be considered for the wearing course as any that may be inadvertently left in the layer can cause potentially unsafe conditions as they become exposed to vehicle tyres.)

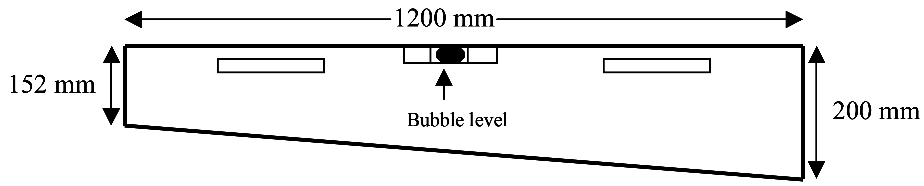


Figure 4: Four per cent camber board

Compaction will normally be done using a small pedestrian or sit-on roller. Density testing is notoriously difficult and poorly repeatable on this type of project and other techniques should be used to control the construction. It is recommended that the use of controlled dip sticking using the bulking/compacted relationship determined in a laboratory (usually during the initial material characterisation and evaluation process) should be the first check on compaction. The use of a method specification based on proof rolling as discussed in Section 7 should always be considered. This provides a target DCP penetration rate as well as permitting a much larger number of tests to be carried out and enhancing overall quality. The testing must be done immediately after compaction (i.e. at OMC) and where the DCP penetration rate is unsatisfactory, additional compaction must be applied as soon as practically possible. A calibrated probe can also indicate whether compaction has been achieved, provided the layer thickness before compaction is correct (Paige-Green, 1998).

On small projects, the use of hand stampers for compaction can be considered but it is difficult to obtain a consistent density and uniform surface. If this technique is used, the optimum number of blows should be determined by trial and error and this number used consistently over the layer, ensuring that all parts of the layer are compacted.

6.4 Drainage

Sidedrains will be excavated manually to a defined profile. An appropriate cross section should be identified during the design phase (sideslopes usually about 1 vertical : 1.5 horizontal with the ditch bottom at least 0.5 metres below subgrade level) and templates manufactured (typically from wooden planks). These should be used on an ongoing basis to ensure that the drainage shape is correct. Cross sections of typical side drains are shown in Figure 5.The longitudinal slope of the drain should compromise between effective water removal without silting and avoidance of scouring and erosion. Where erosion is likely, check dams (Figure 6) or other erosion protection measures should be implemented. It is equally important that the mitre drains are properly graded to ensure that water carried into them is effectively removed from the road area (Figure 7). They must also remain effective under the silt that will build up between maintenance activities.

The geometry of the drains must be consistent with labour-based maintenance. Mitre drains and flat bottomed side drains are frequently cleaned and maintained by grader and are designed for this. Labour-based drainage maintenance will be facilitated by a much smaller invert width or a V-drain.

Culverts and pipedrains must fit within the formation to avoid humps in the road. Where this is not possible, the thickness of the formation must be increased to accommodate the drainage structures. Care must also be taken to ensure that the pipe inverts are not below the natural drainage level, so as to become ineffective.

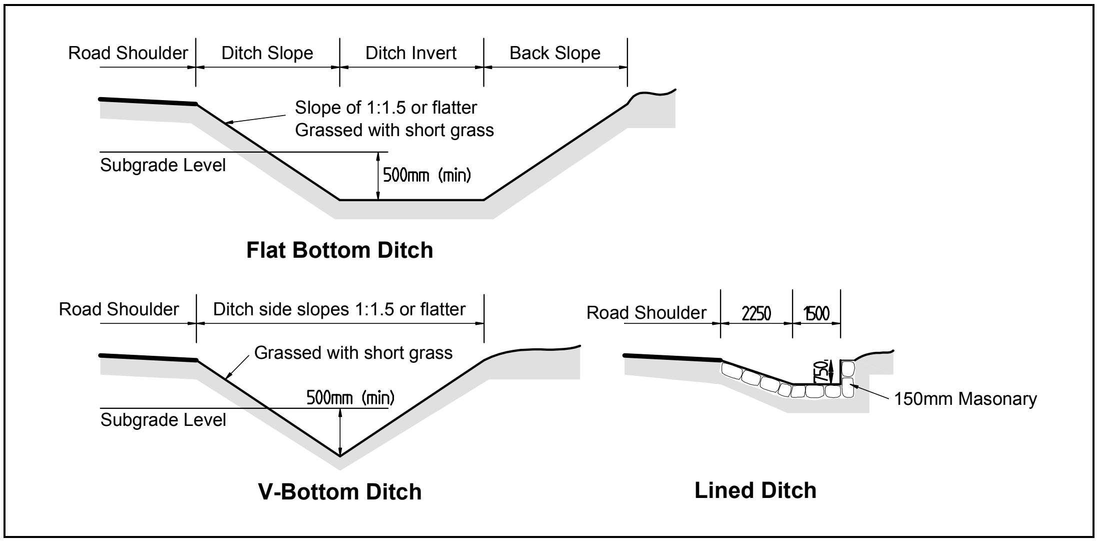


Figure 5: Cross sections of typical drains

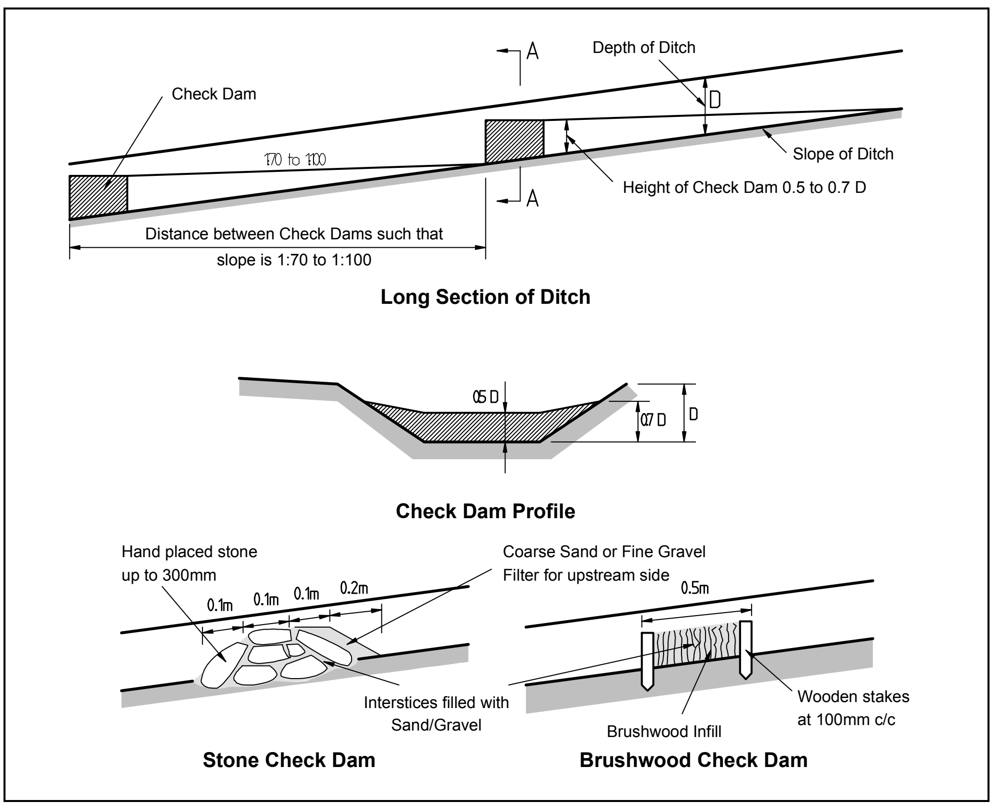


Figure 6: Erosion control measures and check dams

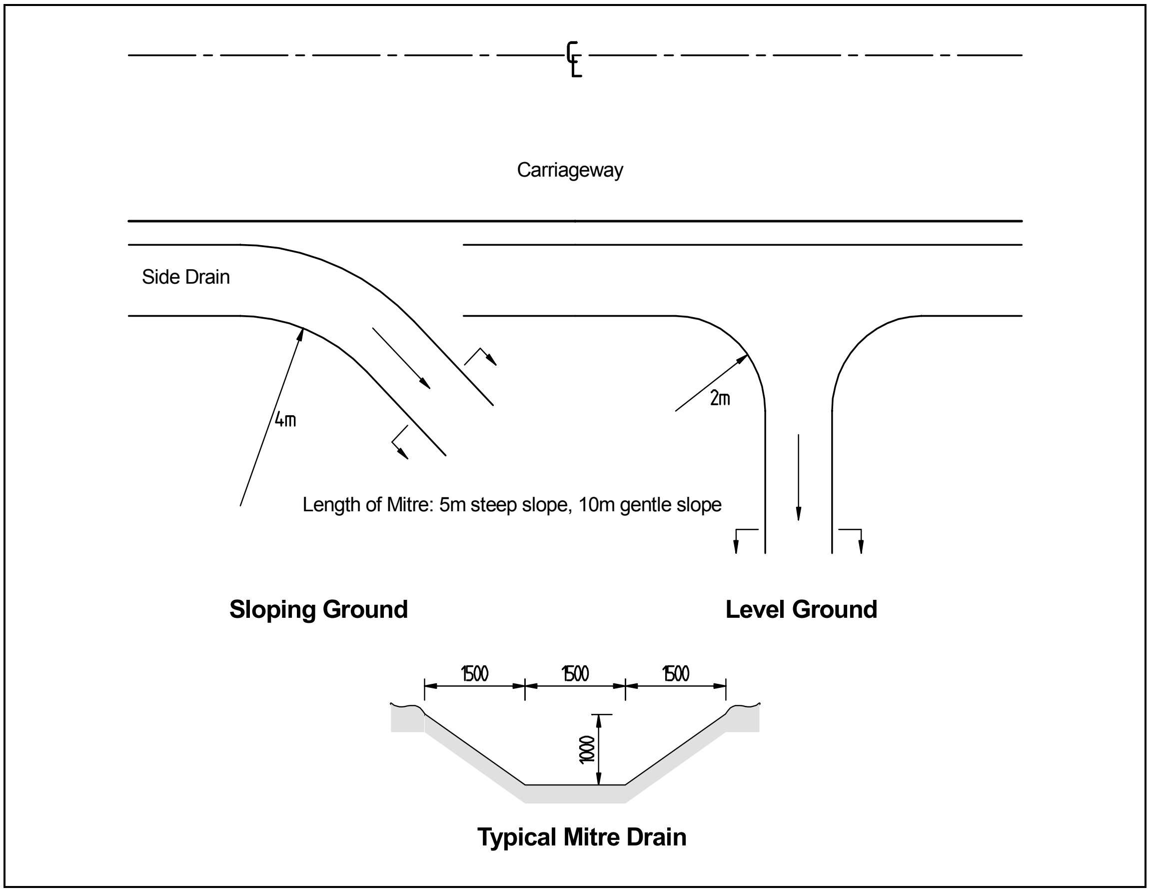


Figure 7: Typical mitre drain layout and cross section

7 Quality control

7.1 General

It is essential that the quality of construction is controlled fully. (See Paige-Green, 1998).

7.2 Road shape

Obtaining the correct shape of the road surface during labour-based construction is imperative, as it is difficult to correct any significant problems after construction using manual techniques. The provision and use of an adequate number of camber boards or carefully set out string lines is essential.

These camber boards should be used regularly and frequently during the spreading and compaction of the wearing course.

7.3 Material thickness

Control of the material thickness must start during the unloading phase of the project. It is imperative that the material is dumped at the required spacing and frequency, so that it can be evenly spread out at a consistent density. A simple hand probe similar to that illustrated in Figure 8 can be used to judge the thickness of both the spread (uncompacted) and compacted layer. By simply pressing the probe into the layer, the thickness can be observed from the exposed calibration marks. Typically, the underlying layer will have dried out since compaction and a greater resistance to penetration will be easily felt as the probe is pressed into the layer.

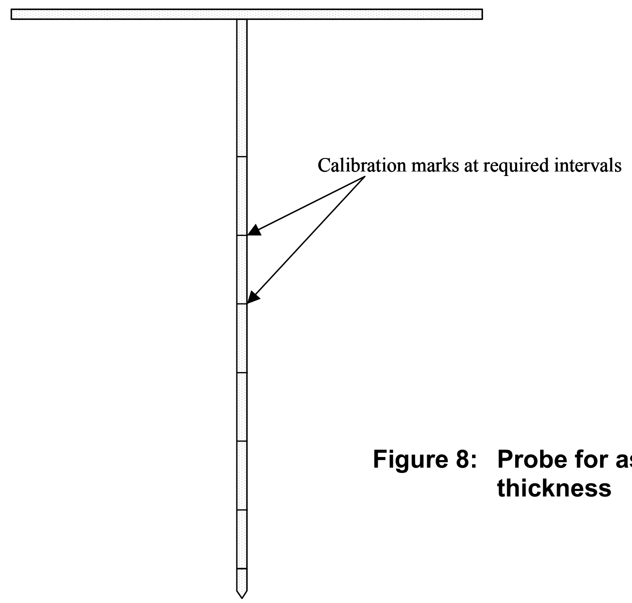


Figure 8: Probe for assessing layer thickness

7.4 Compaction

Compaction of road pavement layers is traditionally controlled by density measurement. This requires a knowledge of the density of the material at a specified compaction effort (usually 95 per cent of mod AASHTO for a gravel wearing course). The density is usually controlled using an in situ replacement method (sand replacement) or a nuclear measuring device. Both of these techniques have inherent problems and are considered inefficient for labour-based projects.

The simplest method for checking compaction of labour-based projects is by measuring the height of the material before and after compaction. This can be done using a number of techniques as discussed (dip stick, string lines, calibrated probe, etc). Although not entirely accurate, a good indication of the overall quality of compaction can be obtained.

It is suggested, however, that a method specification, based on proof rolling, be implemented and controlled using a DCP or Rapid Compaction Control Device (RCCD) apparatus. The suggested process for this is as follows:

After the material has been spread and is ready for compaction, a short section of road should be given one “pass” with the available compaction plant, (i.e., forwards and backwards). A DCP test (or RCCD) is carried out to a depth of 150 mm (or the layer thickness if less), and further passes are applied with a DCP test being carried out after each pass. The DCP penetration rate is plotted against the number of passes (Figure 9) and the number of passes after which no beneficial compaction occurs is identified (point X or 3 passes in Figure 9). The DCP tests should be carried out in close enough proximity to allow direct comparison of the results but not so close that the result is affected by previous tests. The minimum DCP penetration rate obtained (at compaction moisture content) is also the target rate for quality control of the layer after compaction. A statistical judgement scheme (example COLTO, 1996 or TRH5, 1977) or some simplified version of this (eg, Annexure B) can be applied for acceptance testing.

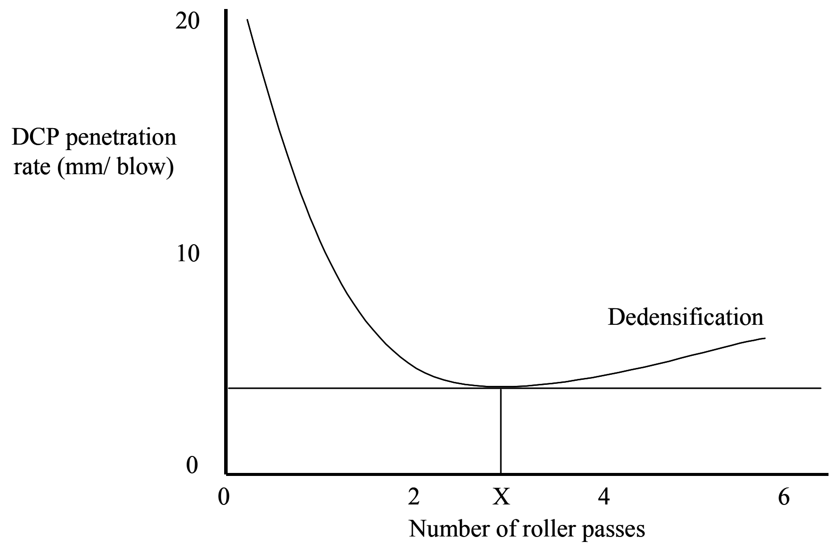


Figure 9: Proof rolling example

8 Maintenance

8.1 Surface maintenance

Road surface maintenance using conventional plant includes light grading, heavy grading and occasionally ripping and recompaction. Where only labour is used for maintenance, only the light grading activity can be effectively simulated. Heavy grading and ripping and recompaction require a grader at least and the relevant techniques are described in LICT 4 (1997). The process of light grading can be substituted by labour-based techniques on small projects but is usually not cost effective on projects more than between three and five kilometres long.

The frequency of maintenance will depend primarily on the traffic and the precipitation and should be such that the state of the road does not deteriorate significantly. It is practically impossible without heavy grading to restore a reasonable riding quality to a badly deteriorated road. Similarly, the presence of excessive oversize material results in serious maintenance difficulties. Where a labour-based unit or local contractor is available and a routine maintenance contract can be awarded, the road surface can be maintained without a grader.

The process will usually involve a combination of pothole patching as described in section 8.2 and light scarification of surface irregularities, including protruding stones, corrugations and compacted windrows using rakes or forks. The loosened material will be spread to fill depressions and even out the surface, ensuring that the crown and camber of the road are retained. Any large stones must be removed from the road surface. This can often be combined with surface dragging using a small tyre or steel drag (LICT 4, 1997). These drags can be drawn by labourers, animals or small vehicles and assist in retaining the shape of the road. The shape of the road during dragging should be controlled using camber boards. The use of bush or tree drags is not recommended as these invariably result in dishing of the road with a severe effect on the surface drainage of the road.

It is important that during surface maintenance, windrows of material that will affect the drainage of water from the road surface are not left adjacent to the carriageway.

8.2 Patching

Early repair of potholes and depressions is essential as they can cause significant damage to vehicles and result in unsafe driving conditions. This may be defined as patching or spot regravelling. On materials that form a crust or “blad” (including many calcretes and ferricretes), conventional grading can cause extensive damage to the hard surface and patching is the most appropriate maintenance technique.

Potholes can vary in diameter from 100 mm to in excess of 1500 mm and when more than 50 or 75 mm deep, have the greatest impact on vehicles. They arise through a number of processes, including poor road shape and drainage, poor maintenance, corrugations, rutting, excessive stoniness, weak wearing course materials, formation or subgrades, poor compaction, etc. Potholes can seldom be repaired during normal grader maintenance and the following procedure is suggested.

Remove all unstable or weak material, preferably in a diamond shape as seen when driving along the road (Figure 10) and clean the hole by brooming. It is not necessary to produce a hole with smooth vertical sides for unsealed roads: a rough surface finish in fact results in better bonding of the patch material.

The sides and base of the hole should be watered to enhance the bond between the hole and the patch material. It is important, however, to avoid the addition of too much water, such that the material becomes soggy.

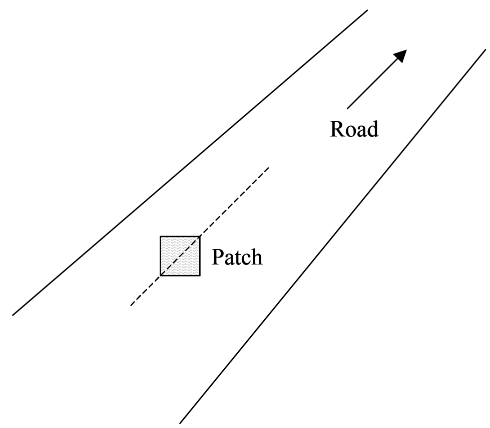


Figure 10: Pothole repair using diamond shaped patch

The patch material should come from the same source (and have similar properties) as the original wearing course material. (Under no circumstances should material from windrows on the carriageway be used for patching as these materials have generally lost the majority of their fines and thus lack adequate cohesion). It should be moistened until it can be squeezed in one hand into a tight “ball” without excess water being expelled. It must then be compacted, using a hand stamper or rammer, into the hole in layers about 60 to 75 mm thick, ensuring that the material adjacent to the edge of the hole is well compacted. This should continue until the material is about 15 mm proud of the road surface. Compaction in layers thinner than about 40 mm will result in lamination, which will often disintegrate under traffic on drying out.

A similar process is necessary to repair damage to the road caused by water flow and erosion, but it is not practical to excavate diamond shaped holes – the erosion channels must just be cleaned out and repaired as described above. It is important to identify, and attempt to rectify, the cause of such distress where possible.

8.3 Regravelling

Depending on the traffic the full thickness of the gravel wearing course will be lost over time. This can take from 4 or 5 years for heavily trafficked roads to in excess of 10 years for roads carrying only light traffic. It is recommended, however, that the road be regravelled before the entire wearing course is lost, in order to avoid deterioration of the formation. This material is neither designed nor constructed to support traffic and a minimum cover of 25 to 50 mm of wearing course gravel should be retained on the road to avoid excessive deformation of the surface prior to regravelling.

Regravelling will generally follow the construction procedure described earlier for construction of the wearing course, including the material location, ELHUS, compaction and quality control requirements outlined.

8.4 Spot Improvement

Spot improvement can be described as an activity somewhere between pothole patching on a large scale and regravelling on a small scale. This operation is usually necessary when:

- serious damage has been done by water (erosion on grades or adjacent to culverts);
- where deficiencies in gravel or construction quality occur, or
- on flat sections or in sag curves where drainage is impeded.

A successful spot improvement operation makes use of those principles described under patching and regravelling/wearing course construction.

8.5 Drainage maintenance

The regular maintenance of side drains and culverts is traditionally a labour-based activity. This involves the clearing of bush and cutting of grass as well as the desilting of culverts and other drainage structures. It is essential that this is carried out meticulously, all of the debris removed from the drains and structures being disposed of well away from the drainage systems. Silt from drains should never be used for filling depressions or potholes on the road surface.

6. Safety

The construction, maintenance and repair of unsealed roads using labour-based techniques, like any other road, require stringent safety measures. Labour on these projects often has little experience of conventional safety measures. As described in Section 1.4 of Part 2 (Labour-based construction Methods for Earthworks), safety should be an inherent component of any project. It is essential that adequate warning and control be provided for labour working both on and adjacent to the road. Extensive use of warning signs, demarcation cones and barriers and flagman following conventional practice is a prerequisite for a safe project.

Fortunately, the majority of unsealed road projects on which labour based techniques are used have light, and often slow-moving, traffic.

7. Specialist literature

1 The design, construction and maintenance of unpaved roads. 1990. Pretoria: Department of Transport. (Technical Recommendations for Highways: Draft TRH 20).

2 Paige-Green, P. 1998. Material selection and quality assurance for labour-based unsealed road projects. Nairobi, Kenya: ILO/ASIST (Technical Brief No 9).

3 Maintenance of unsurfaced roads/streets. 1997. Pretoria: South African National Roads Agency. (Labour Intensive Construction Techniques: LICT 4).

4 Statistical concepts of quality assurance and their application in road construction. 1977. Pretoria: Department of Transport. (Technical Recommendations for Highways: Draft TRH 5).

5 McCutcheon, RT and Marshall J. Labour-intensive construction and maintenance of rural roads: Guidelines for the training of road builders. Construction and Development Series, Number 14. Development Bank of Southern Africa. November, 1996.

Annexure A: Setting out the road alignment and cross section

A1 Equipment

String line
Tape measure (3 and 50 m)
Line level
Ranging rods
Adjustable profile boards
Hammer
Steel spikes

A2 Centre line

On existing roads, the centre line and alignment will usually be followed. On new alignments it is necessary to set out the centre line and off set pegs marking the road edge and drainage.

The centre line is marked by placing ranging rods into the ground at 10 to 20 metre intervals (further apart on flatter more uniform alignments). In order to ensure straight sections of road, ranging rods are installed at 100 m frequencies and the intermediate rods are then installed at the appropriate points making sure that they are all directly in line and the same height to facilitate later setting out of cross section profiles (Figure A1). Each stake should be marked with the chainage/kilometre length from the start.

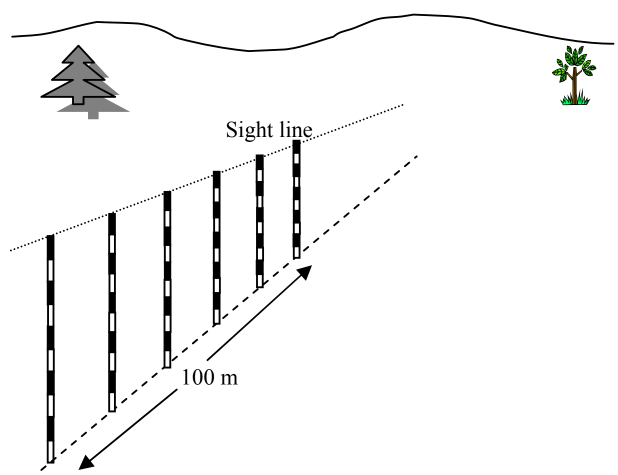


Figure A1: Setting out centre-line

Straight sections of road are easy to set out but horizontal curves require significantly more input. These should be smooth and large radius curves can be set out by eye with practice. Smaller radius curves are more difficult to set out by eye and string can be used to assist in this operation as indicated in Figure A2. At the point of curvature, the road is divided into two straight sections based on the approach and exit angles, meeting at point O. This can be done by using ranging rods. Points A and B are located on the basis of the minimum allowable radius of curvature. These are easiest located by measuring AO and BO as the specified minimum radius of curvature (Figure A2). AO and BO are then divided into four or five equal sections and string lines placed between the points on AO and the opposite points on BO, ie the point on AO closest to O is joined to the point on BO furthest from O. The outermost intersections of these lines provides the required horizontal curve.

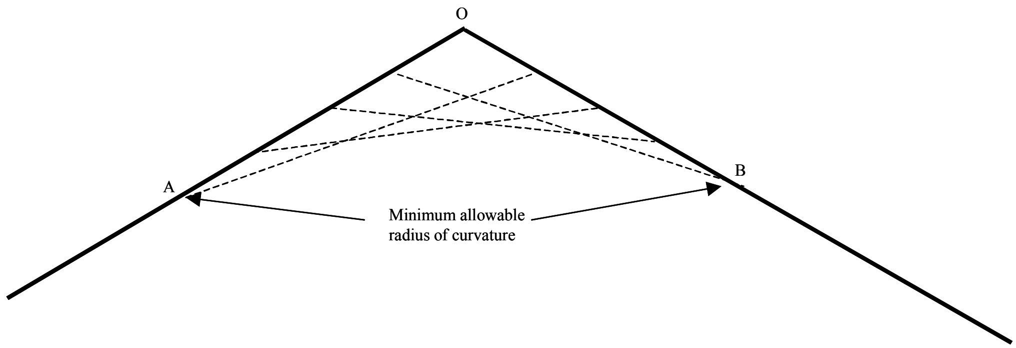


Figure A2: Setting out curves

Once the road centre-line has been set out, and the horizontal alignment fixed, the vertical alignment should be set. This will usually follow that of an existing road with minor smoothing out or require a full setting out. The aim is to provide a smooth surface and this can be achieved by ensuring that the ranging rods shown in Figure A1 are all at the same height along the sight line. They should thus be placed into the ground (or existing road) to ensure this. Ranging rods can usually be hammered into soft ground but in harder material or rocky terrain, a steel spike should be knocked into the ground first to avoid damage to the ranging rods. Where it is difficult to achieve the correct levels at the tops of the ranging rods, profile boards can be used. These are flat steel plates attached to a clampable sliding device such that they can be adjusted and clamped at the required heights using sight lines.

At this stage of the project, the centre-line of the proposed road should be marked out with ranging rods at regular intervals (or appropriately marked stakes replacing the ranging rods). The pavement/drain cross sections are then located at the site of each ranging rod/stake. These must be perpendicular to the centre line at the respective points. Ensuring that the profiles are perpendicular to the centre-line can be done using tape measures or marked strings and the 3-4-5 method as shown in Figure A3.

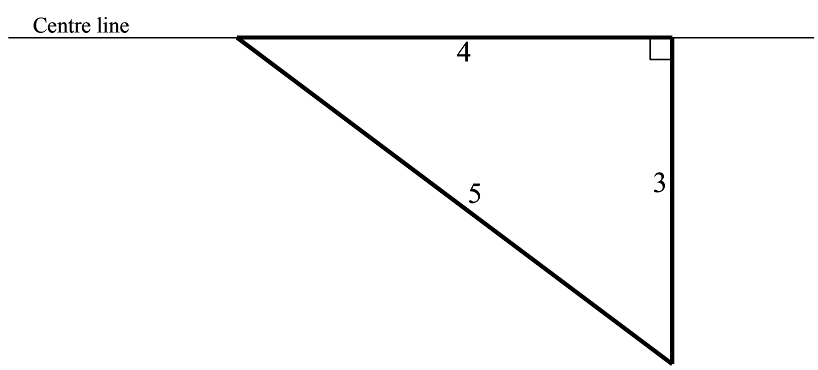


Figure A3: Setting out right angles

On these perpendiculars, the road profile should be pegged out using a tape measure and the pegs (or stakes) placed at the edge of the formation, and marking the drain break points on each side of the road. In order to ensure adequate drainage, however, the drains require a small grade and this should be ensured using ranging rods and profile boards. The grade of the drains can be determined from the spacing between ranging rods and their heights (assuming they have been correctly placed with a horizontal sight line or one with a known grade). Profile boards on these rods can then be used to establish stakes marked at the correct heights for construction control (Figure A-4).

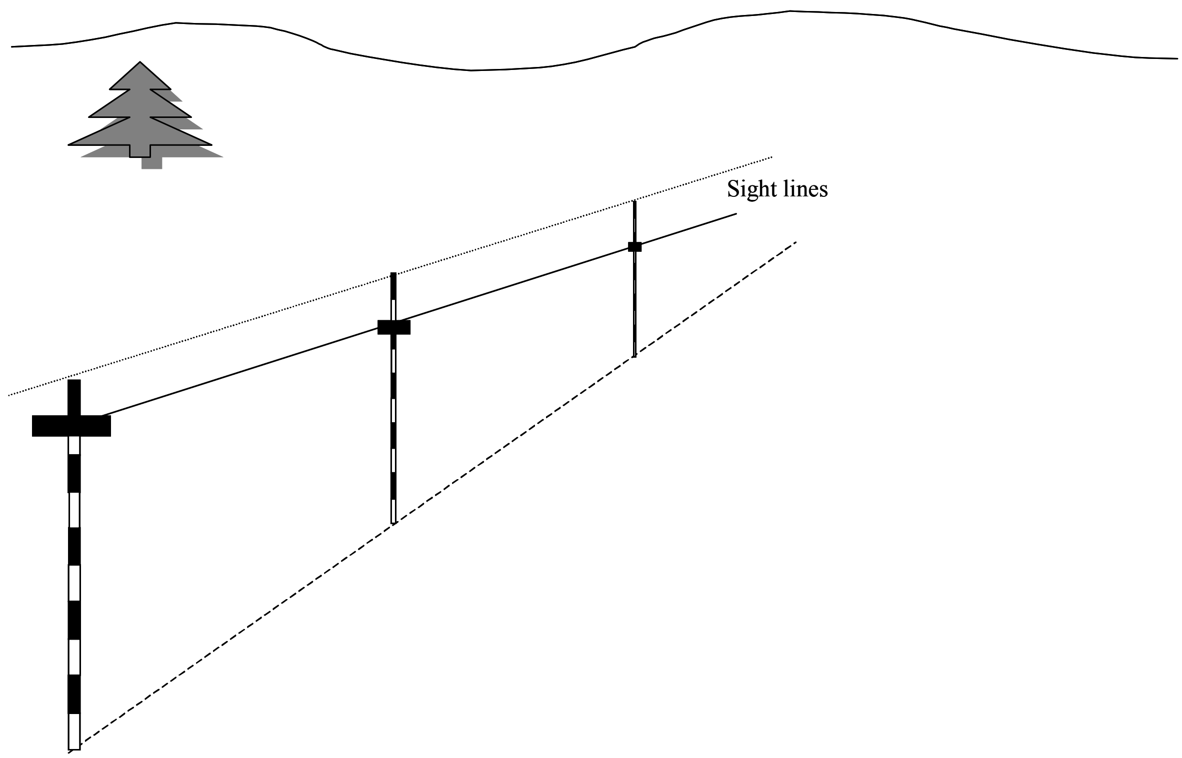


Figure A4: Using ranging rods and profile boards to set grades for drains

Annexure B: Simple statistical quality control technique

The testing of construction quality should be carried out at the end of every day for a lot (ie, one days production). This would usually comprise about 100 metres of new layer, depending on resources available. The properties to be tested would be compaction (or a proxy thereof) and layer thickness.

A minimum sample size of 6 is considered to be sufficient although a greater number of samples would be desirable. Sampling should be carried out in a random manner and a stratified random system as follows has been found to be effective:

The section to be evaluated must be defined by an area of width, W and length, L, separated by the centre-line as shown in Figure B1. Both the length and width are reduced by 400 mm compared with the actual construction.

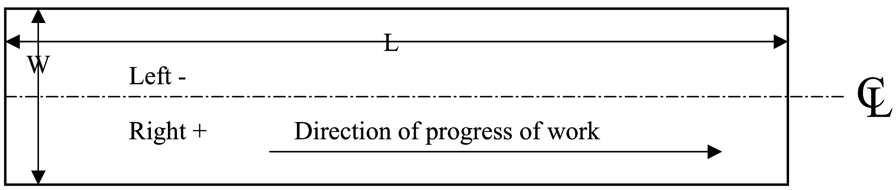


Figure B1: Definition of a surface lot

Random numbers for various sampling plans are provided in Table B1. A sampling plan is randomly selected – one way of doing this is by taking the minute reading on a watch at the time of the assessment:

Table B1: Random selection of sampling plan

Minutes past hour	Sampling plan
0-10	1
10-20	2
20-30	3
30-40	4
40-50	5
50-60	6

The coordinates of the sampling points are determined from Table B2 and transferred to the road by measurements along the road centre-line (f_1L) and offset from the centre-line (+ or – f_2W) as shown in the example below.

Table B2: Factors for determining coordinates of random sampling positions on a surface lot

	Sampling plan 1		Sampling plan 2		Sampling plan 3		Sampling plan 4		Sampling plan 5		Sampling plan 6	
n	f_1	f_2	f_1	f_2	f_1	f_2	f_1	f_2	f_1	f_2	f_1	f_2
1	0.075	0.225(-)	0.825	0.125(+)	0.275	0.225(-)	0.675	0.425(+)	0.375	0.125(-)	0.525	0.375(+)
2	0.925	0.275(-)	0.425	0.525(-)	0.925	0.375(+)	0.225	0.075(-)	0.925	0.425(+)	0.225	0.125(-)
3	0.275	0.375(+)	0.925	0.125(-)	0.175	0.425(+)	0.825	0.025(-)	0.275	0.475(+)	0.725	0.475(-)
4	0.575	0.325(-)	0.275	0.425(+)	0.975	0.275(-)	0.125	0.175(+)	0.925	0.225(-)	0.075	0.025(+)
5	0.075	0.475(-)	0.525	0.375(+)	0.175	0.175(-)	0.775	0.075(+)	0.025	0.025(-)	0.825	0.425(+)
6	0.525	0.275(+)	0.075	0.325(-)	0.975	0.275(+)	0.025	0.275(-)	0.575	0.275(+)	0.325	0.375(-)
7	0.325	0.275(+)	0.625	0.125(-)	0.475	0.075(+)	0.975	0.175(-)	0.325	0.375(+)	0.875	0.025(-)
8	0.775	0.025(-)	0.175	0.475(+)	0.625	0.025(-)	0.075	0.075(+)	0.675	0.075(-)	0.375	0.325(+)
9	0.175	0.425(-)	0.675	0.275(+)	0.375	0.475(-)	0.675	0.125(+)	0.425	0.125(-)	0.575	0.475(+)
10	0.975	0.075(+)	0.375	0.275(-)	0.975	0.075(+)	0.325	0.375(-)	0.775	0.275(+)	0.075	0.275(-)

The testing at each point will require a DCP penetration to 150 mm depth and a determination of the thickness (using the probe or excavating a small hole).

Example:

Sampling

A lot needs to be checked for compaction (DCP penetration rate) and thickness. Six samples are to be taken. The time is 16:25 (ie, sampling plan 3 is to be used).

The length of the lot is measured as 98 m and the width is 6.5 m.

The nett length, L of the lot = 98 - 0.4 = 97.6 m
The nett width, W of the lot = 6.5 – 0.4 = 6.1 m

The zero point for the longitudinal measurements is 200 mm from the start of the lot in the direction of progress and on the centre-line for the transverse measurements.

The nett coordinates of the sampling positions are as follows:

Sample	f_1	f_1L (m)	f_2	f_2W (m)
1	0.275	26.84	-0.225	-1.37
2	0.925	90.28	+0.375	+2.29
3	0.175	17.08	+0.425	+2.59
4	0.975	95.16	-0.275	-1.68
5	0.175	17.08	-0.175	-1.07
6	0.275	26.84	+0.275	+1.68

Thus, test 1 will be at 26.84 + 0.2 = 27.04 m from the start of the section and 1.37 m to the left of the centre-line, etc.

The tests will be interpreted as follows:

Compaction (DCP penetration):

The target value will be that obtained from the proof rolling usually in the range 6 to 12 mm penetration per blow. A maximum mean value and an absolute maximum value as shown will be required.

Target value (mm/blow)	Maximum mean	Maximum for single test
6	5.4	8
8	7.4	10
10	9.4	11.5
12	11.4	13

Where the maximum mean value is not achieved, additional rolling should be applied to the entire section, until the value is achieved. At areas with values higher than the target value and where the maximum for the single test is obtained, additional rolling should also be provided. The results should obviously be assessed in terms of the overall visual impression of the section.

Layer thickness

Typically, a layer thickness of 150 mm will be specified. The results of the random thickness testing will be assessed in terms of the following:

Target thickness (mm)	Minimum 90th percentile thickness	Minimum mean thickness
150	140	134