Table 16-3: Factors influencing the traffic threshold for upgrading

Parameter	Impact
Use of more appropriate pavement designs	Reduced costs
Use of more appropriate geometric design	Reduced costs
Increased use of natural/unprocessed gravels	Reduced costs
Quantified impacts of depleted gravel resources	Reduced costs
Benefits from non-motorised transport	Increased benefits
Quantified adverse impacts of traffic on gravel roads	Increased benefits
Reduced environmental damage	Increased benefits
Quantified assessments of social benefits	Increased benefits

The impact of these factors is illustrated conceptually in Figure 16-10 which reflects the outcome of recent research carried out in the southern African region and which indicates that, in principle, in some circumstances bitumen sealing of gravel roads may be economically justified at traffic levels of less than 100 vpd. This is in contrast to the previously accepted figures for sub-Saharan Africa, which indicated a first generation bitumen surface at traffic of over 200 vpd.

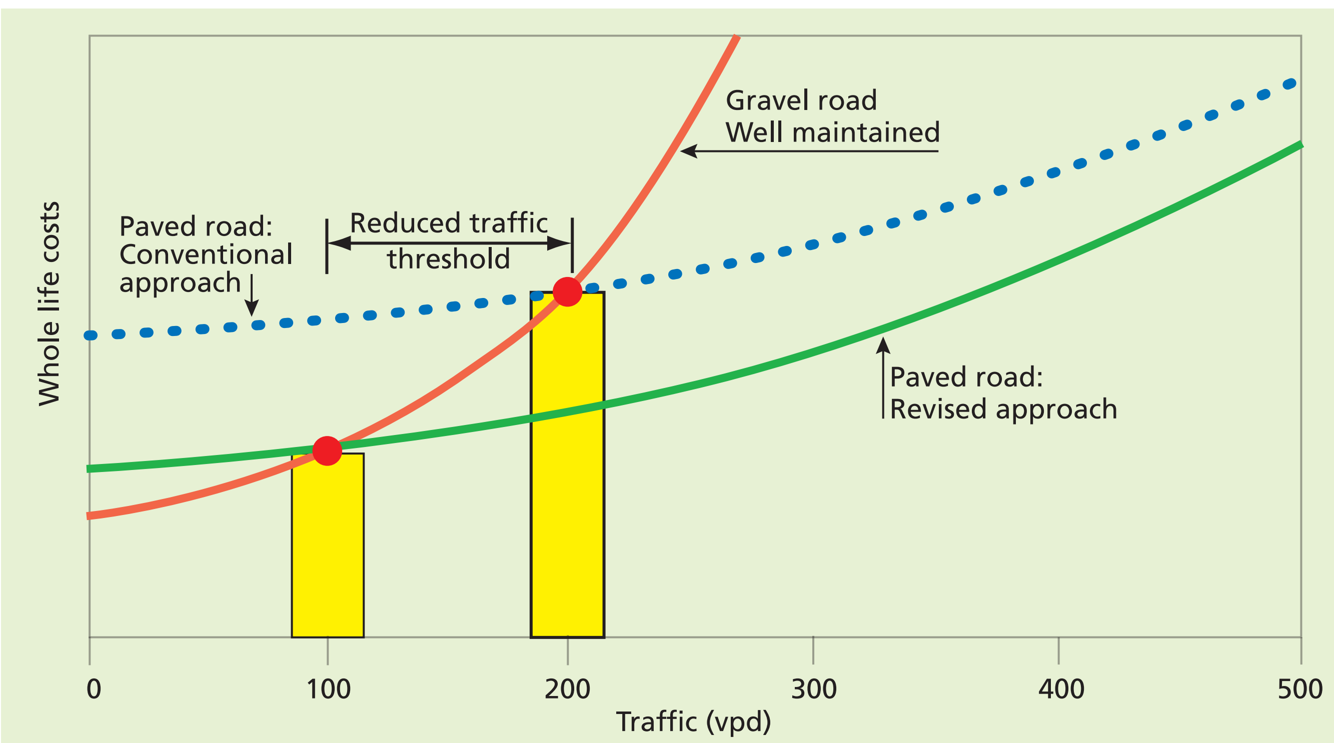

Figure 16-10: Break-even traffic levels for paving a gravel road: traditional versus revised approaches

16.3.3 Sensitivity Analysis

In view of the considerable uncertainty on future costs, e.g. hauling distances for gravel, aggregates, bitumen prices etc., there would be merit in undertaking a sensitivity analysis of the main parameters in the LCC equation.

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Part E: Construction

Low Volume Roads Manual

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  - 1. General Introduction
  - 2. Low Volume Roads in Perspective
  - 3. Physical Environment
- **PART B: Planning**
  - 4. Rural Accessibility Planning
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17.1 INTRODUCTION

17.1.1 Background

The construction of a low volume road (LVR) is a practical manifestation of the previous planning, investigation and design phases of the project cycle. In this phase, the constructor faces the challenge of adopting a construction strategy that is appropriate to the requirements of the project, as well as to the prevailing social, economic and technical environment within which the project is being undertaken. Such a strategy, for example, may be aimed at optimising the use of local resources by complying with policy directives that may require the provision of income generating opportunities to local communities through the adoption of labour-based rather than equipment-based methods of construction.

Whatever construction strategy is adopted, the ultimate goal of all parties to the contract is to make optimal use of the available resources to meet the prescribed standards in the most efficient and effective manner. Moreover, the quality of the construction process is critical as it can impact significantly on the performance and subsequent costs of maintaining the road. This is particularly the case for LVRs where naturally occurring, inherently variable materials are being used which are sensitive to the construction processes adopted. Thus, a system of quality control (QC) is required to reduce the possibility of errors occurring throughout the construction process and this is usually embodied in 'quality assurance' (QA) plans.

17.1.2 Purpose and Scope

The chapter deals with the typical range of issues that the contractor and supervising engineer will face during the construction of a LVR. These include the adoption of an appropriate construction strategy, including a judicious choice of construction plant and equipment, and the adoption of appropriate techniques for undertaking earthworks, drainage structures and pavement construction operations. The precautions that should be followed in undertaking shoulder construction and surfacing of LVRs are also addressed.

The chapter also sets out the general approach to undertaking QA/QC activities to achieve an acceptable end product in an environment where resources are likely to be limited. Examples of a contractor's typical Quality Plan are also included in a number of appendices.

17.2 CONSTRUCTION STRATEGY

17.2.1 General

Low volume roads can be constructed using a variety of work methods, plant and equipment which range from relatively inexpensive, simple hand tools to relatively expensive and sophisticated plant. This makes it possible for such roads to be constructed using either labour- or equipment-based methods of construction. Both methods offer advantages and disadvantages, depending on a wide range of factors. Further, the choice of method may be open to the contractor or may be dictated by the policy objectives of the client. Whatever the case, the contractor must devise an appropriate construction strategy to comply with the requirements of the project in the most efficient and cost effective manner.

17.2.2. Labour-Based Technology

Labour-based technology can be defined as the construction technology which, while maintaining cost competitiveness and engineering quality standards, maximises opportunities for the employment of labour (skilled and unskilled) together with the support of light equipment and with the utilisation of locally available materials and other resources. This implies that labour-based methods do not exclude the use of machines. It is acknowledged that some work activities require inputs of conventional equipment. When applied in road construction, certain activities such as gravel transport and compaction still require trucks and compaction equipment. Nonetheless, there is a significant amount of work that can be carried out using labour.

The utilisation of labour-based and intermediate equipment technology are of particular interest in the construction of LVRs roads where employment creation is often an important goal. The objective of this approach is to maximise the number of job opportunities per unit of expenditure. However, despite the substantial potential benefits offered by labour-based construction, a number of myths and problems still prevail in the minds of many people concerning this technology. These need to be fully appreciated if the labour-based approach is to be successfully deployed on LVR projects.

Common myths:

- Standards should be lowered to allow for labour-based methods.
- Labour-based construction is out-of-date and incompatible with the modern world.
- Labour-based methods can be used for any construction activity.
- Labour-based construction is only for welfare relief schemes.
- Ill-educated contractors will never understand tender procedures.
- Voluntary labour can be used to keep costs down.

The above myths are ill-founded and should not prejudice consideration of labour-based construction where appropriate. Guidance on undertaking labour-based works is provided in the Labour-Based Road Works Technical Manual, Vols. I, II III and IV (MOW, 1997).

Suitability of Construction Activities for Labour-Based Works

A number of activities are well suited to labour-based methods such as site clearance/bush clearing (Figure 17-1), ditch excavation and screening of surfacing aggregate (Figure 17-2). However, other activities, such as compaction of pavement layers or haulage of materials over long distances (typically > 5 km) are not. Moreover, construction activities such as manipulating heavy precast sections, are not possible without the use of the appropriate kind of machinery. This chapter provides examples of those activities than can be effectively undertaken by labour-based methods, including the choice of appropriate plant and equipment.

Figure 17-1: De-stumping of trees using labour-based methods

Figure 17-2: Screening of aggregate for road surfacing using labour

To facilitate the increasing use of labour-based methods, emphasis should be placed on developing designs to increase labour tasks that also develop marketable skills. Examples include:

- Stone pitched rather than concrete drains.
- Cast in-situ rather than precast culverts.
- Stone rather than concrete retaining walls.
- Cast in-situ rather than precast kerbs.

It should be appreciated, however, that some construction operations cannot be undertaken by labour if standards are not to be compromised. For example:

- Compaction plant is required for road bases and subbases.
- A bitumen distributor (and possibly a chip-spreader) is essential for surface seals.
- A pneumatic-tyred roller is required for chip and sprayed seals.
- Sheep's-foot and pad-foot rollers are essential for compacting clay.
- A grid roller is usually required for in situ break-down of oversize material.
- Pre-collapse of collapsible soils normally requires heavy impact or heavy vibratory rollers.

Labour-based projects usually employ a relatively large number of labourers. In such a situation, the site management staff require to be particularly good "people-managers" with a strong managerial as well as technical background. They need to be familiar with local traditions and social structures in order to avoid disputes on site that could threaten the progress of construction and the sustainability of the project.

17.2.3 Equipment-Based Technology

Some projects, especially large ones, may require heavy plant and equipment for various reasons:

- Large volumes of earthworks may need to be moved.
- Haul distances are long and large quantities of fill and pavement materials may be required.
- Large volumes of materials are required from borrow-pits or quarries which have to be excavated and adequately rehabilitated after completion.
- Heavy watering and compaction may be required to achieve specified in-situ densities.
- Crushing of pavement and surfacing materials, where specified, may be required.
- Large quantities of concrete or asphalt may be required.

Generally, the overall size of the project and the amount of materials to be moved within a fixed construction period, are the governing factors when determining whether labour-based or plant-intensive methods are to be used. However, even the largest plant-intensive projects can accommodate many labour-based tasks within the works, and the designer should always try to incorporate these into the contract documents, where required, to assist with the government's aim of job creation and poverty reduction.

17.3 CONSTRUCTION EQUIPMENT

17.3.1 General

The most appropriate type of equipment for a particular project is normally dependent on the following factors:

- Site conditions.
- Type of operations.
- Size of the project.
- Soil conditions and material types being used.
- The degree to which manual labour is used in the operation.

Plant and equipment typically used for the construction of roads varies from heavy items for major highways to the light items for LVRs constructed by labour-based methods. It is often not cost effective to use high-capacity, heavy plant and equipment on LVR sites due to smaller quantities of materials and dimensions of the works. Use of manual labour for major construction operations requires flexible solutions with many smaller units of plant equipment.

17.3.2 Equipment Used with Labour-Based Methods

Labour-based methods involve the use of hand tools for excavation and spreading of material and equipment such as wheel barrows and animal drawn carts for transport. In addition, hand-operated compactors may be used for compaction. These compactors require the use of specific methods to be effective, such as the construction of maximum layer thickness of about 75 mm. They are unlikely to be effective in operations where pavement materials require compaction on a large scale. However, heavier compaction equipment may be required for the compaction of pavement layers for sealed roads. Penetration macadam, emulsion treated base and thin reinforced concrete pavement can all be constructed entirely by labour-based methods.

Labour based operations used in borrow pits for loading are described in detail in *Chapter 18 – Borrow Pit Management.*

Labour-adapted equipment - tractor Units

Construction units that use agricultural tractors as a power unit provide flexibility in the use of equipment in small units. This approach suits operations where manual labour is a major part of the resource input.

Figure 17-3: A typical tractor unit used in labour-based construction

The uses of agricultural tractors in key operations include:

- **Loading/transport:** A few tractors can operate many small trailers intermittently, thereby giving labourers sufficient time to load the trailers and maximising the utilisation of the mechanical units. Such trailers usually have a practical height for manual loading. Otherwise, it may be necessary to use the bench method for loading by hand *(refer to Chapter – 18 Borrow Pit Management).*
- **Spreading/shaping:** Towed graders are available in several sizes to carry out these operations, although spreading and shaping can also be done by hand.
- **Mixing on the road:** Towed agricultural disc harrows drawn by a large tractor are very effective.
- **Compaction:** Towed vibrating, grid or tamping rollers. Rollers on labour-based works are often hand controlled.
- **Surface reparation:** Towed mechanical brooms.
- **Bitumen operations:** Towed bitumen sprayers can be used for priming and binder application in conjunction with suitable heating and pumping plant. Emulsions are generally preferred to hot binders on labour-based sites to avoid the need for heating to high temperatures, and to ensure the safety if the workforce.
- **Surfacing aggregate:** Spreading aggregate by hand from towed trailers; tractors may be used for towing chip spreader units.

Figure 17-4: Tractor towed grader

Figure 17-5: Tractor towed roller

Advantages of using tractor units

Tractor based units (Figure 17-3) provide the following advantages for use by emerging contractors and for operations in remote areas:

- **Plant operation:** fewer mechanical items are in use and units are simple to maintain with local mechanical skills; easy access to spare parts compared to heavy construction machinery.
- **Plant availability:** often relatively easy to find locally available tractors outside the ploughing season, thereby offering flexibility in fleet management.
- Better utilisation rates of agricultural tractors than heavy plant.
- Income to the community outside of the ploughing season.

Figure 17-6: The use of small tractor-drawn trailers in labour-based construction

17.3.3 Heavy Equipment Units

The use of construction units based on conventional equipment, as opposed to tractor based units, is also an option for use in the construction of LVRs. Units of this kind typically have the following features in the context of the construction of LVRs in remote areas.

- **Bulldozers for stockpiling:** Have generally been replaced with more economical excavators. Caterpillar D8 or larger bulldozers are difficult to utilise economically where material sources are small, scattered and of variable quality within each borrow pit. In this regard, Caterpillar D7 or smaller models are normally better suited for this purpose. Bulldozers require regular preventive maintenance, typically every 250 hours.
- **Front-end loaders:** Are available in a variety of sizes. Those mostly used for loading gravel for layer works are the Caterpillar 936/950/966 Loaders or similar. This depends on the size of the tipper trucks available. For labour-based construction, a Tractor Loader Backhoe is suitable and can load a 6 cubic metre truck in about 5 minutes.
- **Scraper-operations:** Are effective where earthworks quantities are large and where material quality is not critical. The control of materials quality is very difficult when using scrapers. The advantage of scrapers is that they can be used for cutting the road way, excavation of drains, filling, spreading and to some degree compaction with a single machine. However, motor scrapers typically incur very high investment and operational costs, require skilled mechanics for their maintenance and are expensive to operate on relatively small projects.
- **Motor-graders** (Figure 17-7)**:** Are versatile and are typically used to level tipped heaps, spread gravel, break down oversize material, mix in water, place gravel layers for compaction, cut levels, shape the road prism, shape cut-off berms and cut mitre drains. Most operations carried out by motor graders can be undertaken by labour-based methods. However, on higher trafficked roads, it may be preferable for good riding quality to cut the final levels with a motor grader. This can be carried out as a one-off operation whenever a sufficient length (say 20 km) of base has been placed by hand.

Figure 17-7: Material processing using motor graders

- **Excavators:** Large excavators can carry out earthmoving operations of both a bulldozer and a front end loader in the road way and in the borrow pits. This is often an economical option. Selection of material quality is difficult using excavators and such operations can therefore only be used where material quality in the borrow pit is uniform, or the material can be mixed (e.g. for bulk earthworks).
- **Articulated dump trucks:** These incur high investment and operational costs with stringent requirements for mechanical skills in their maintenance. They can be efficient in high capacity operations and provide both an off-road and an on-road driving capability where the units can legally use public roads. Loading of dump trucks normally requires the use of mechanised plant.
- **Tipper trucks:** Ordinary tipper trucks are often favoured by emerging contractors because they can be used for other transport purposes and are readily available on the second hand market, generally with readily available spare parts. The skills required for their mechanical maintenance are moderate.

17.3.4 Compaction Equipment

Types of plant

In addition to conventional rollers for compaction there are examples of equipment that offer particular benefits in the construction of earthworks and pavement layers for LVRs. Some of these examples include:

Grid roller: This is a static roller towed at a relatively high speed of 15 km/hour for breaking down oversize and 8 km/hour for compaction. In this manner the material is better utilised and problems due to oversize particles are avoided. Good results are generally obtained with the use of this plant for compaction of pavements constructed with natural gravel and of fill layers with lower quality materials which can sometimes be difficult to compact to the full layer depth.

The grid roller allows compaction of the layer to take place in several smaller lifts at the same time as the graders spread the material. The pattern of the surface of the roller ensures that compaction is achieved without forming laminations and shear planes within the layer.

Very heavy towed pneumatic rollers: This type of roller (Figure 17-8): can be up to 50 tonnes mass on one axle and has been used successfully for compaction and proof rolling of the roadbed, especially in thick single-sized graded sand. Its advantage is in the provision of a uniform and sound foundation for the pavement, achieved by collapsing and densifying any soft areas.

Figure 17-8: Towed pneumatic tyred roller

Selection of Compaction Plant

Figure 17-9 provides a broad guide to the selection of compaction equipment. Each roller has been positioned in its economic zone of application. However, it is not uncommon to find them working out of their zones. Moreover, the exact positioning of the zones can vary with differing material conditions.

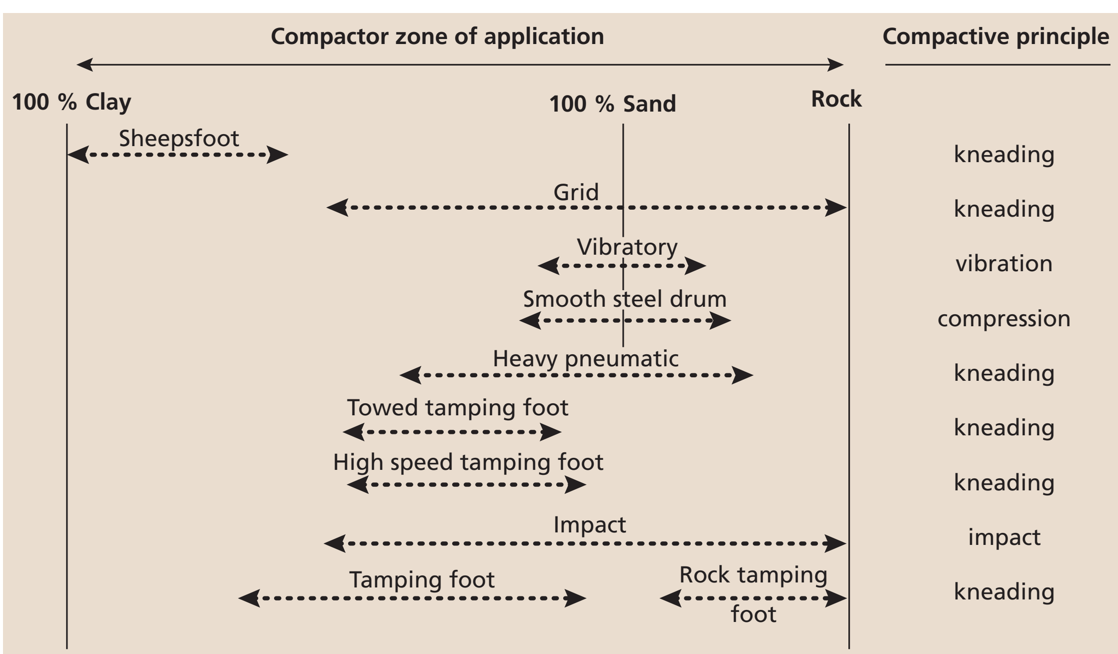

Figure 17-9: Compaction plant guide

17.4 CONSTRUCTION ISSUES

17.4.1 General

There are a number of issues that must be dealt with before construction starts. These are varied in nature and include:

- Land acquisition and utilities.
    - Environmental studies of various types.
    - Temporary environmental issues caused by the construction process itself.
    - Overall environmental issues potentially caused by the longer term existence of the new road.
    - Environmental Impact Studies leading to an Environmental Impact Mitigation Plan and an Environmental Improvement Plan.
- Traffic logistics and control during construction.
- Social issues.

In view of the above, the contractor should acquaint himself with the following documents immediately after award of the contract:

- The Environmental Code of Practice for Road Works (2009).
- Road Sector Compensation, Resettlement Guide (2009).
- Section 3400 of Standard Specification for Road Works (2000).
- Mining Act of 1998 and its Regulations of 1999.

17.4.2 Utilising Natural Gravels and Soils

General

In areas where natural gravel and soils are available for road building purposes, these materials constitute the most valuable resource in the construction of LVRs. Hence, every effort must be made to use them in a creative manner. However, particular attention must be paid to the manner of their utilisation and to the construction techniques adopted to ensure that optimal use is made of them in the construction of the LVR.

Materials Issues on Site

A good appreciation of the properties of natural gravels is required if they are to be used successfully in the construction of LVRs. For example, some of these materials often include weak, larger particles. When such materials are compacted, these larger particles may break down, hence changing the properties of the material as a whole. An assessment of the consequences of this is required in order to establish whether or not the material still meets the specifications following construction.

As is the case with all materials used in LVR pavements, the level of performance is directly related to successful construction methods and workmanship. Aspects of materials utilisation that require particular attention are discussed below.

Materials Management: Proper management of the material sources is essential to ensure that those of best quality are used in the top layers of the pavement structure. Efforts made in locating the best quality, locally available, and often scarce, materials for road base are of no avail if this material ends up in earthworks layers due to poor management of the resources. This is far more critical for the construction of LVRs compared with the construction of more highly trafficked roads, where high quality processed material is typically used.

Many naturally occurring materials are found in thin seams and utmost care is required not to indiscriminately mix different quality materials during their exploitation. This issue is discussed in more detail in *Chapter 18 – Borrow Pit Management.*

Dealing with variability: Natural gravels are inherently variable. The mixing of two different materials to achieve a quality that exceeds that of the two individual sources is the most common, and probably one of the best methods of improving the engineering properties of natural gravels. For example, mixing fine graded materials with sources that lack fines, such as some volcanic tuffs, can create a material with less potential for breaking down under compaction. The resulting material may have a higher density after compaction due to improved grading, and improved stability and workability.

Stockpiling: This forms an important part of materials management by promoting appropriate selection of materials, and providing the opportunity to perform testing before transportation of the materials to the road. The biggest threat to good materials management is when borrow pit operations are not kept sufficiently ahead of the construction.

The following sequence of procedures ensures good management of the material resources:

1. Initial investigation of material sources by trial holes.
2. Stockpiles to be clearly marked.
3. Allocation of materials for specific layers on specific sections of the road after stockpiles are completed. Laboratory testing should be conducted if possible.
4. Loading from stockpiles according to allocation for transportation to site.
5. Re-testing for suitability of material after breaking down and compaction.

The procedure outlined above ensures that acceptance or rejection of materials is carried out at the source, before the material has been transported to the road. However, this requires sufficient plant for opening of borrow pits to avoid the construction demand exceeding material supply from the borrow pits. In cases where opening of borrow pits cannot keep ahead of construction, there is a considerable risk that materials selected for base-course, for example, will end up in the lower layers of the pavement. This exerts pressure on material supply when base course materials are needed at a later time.

Mixing technique on the road: Motor graders should be used for mixing two types of material on the road. Graders may be used in combination with disc harrows to achieve a homogeneous mix. As illustrated in Figure 17-10, the method should typically be as follows:

- Dump gravel (A) on the road in the required quantity then flatten the heaps and spread the gravel over half the width of the layer.
- Dump gravel (B) on top of the spread material and then spread also over the same half width.
- Mixing should proceed as normal with the blading of both materials.

Figure 17-10: Mixing material on road with a motor grader

17.4.3 Roadbed preparation

Clearing, Grubbing and Top Soil Removal

It is particularly important to take account of environmental issues at the early stages of construction so that sensitive operations, such as clearing and grubbing, are conducted as carefully as possible. It is important that damage to the vegetation cover is minimised, shifting of soil and associated damage due to erosion is avoided and that any mitigation measures set out in the Environmental Impact Mitigation Plan are observed.

All topsoil that is stripped should be stockpiled for use in areas that are being reinstated for farming purposes or to promote re-vegetation. Any tree limbs or stumps being removed should be handled and stockpiled in such a manner that the wood can be of benefit to the local community, e.g. as firewood.

Suitability for labour-based operations: Clearing and grubbing is suitable for labour-based operations where the required speed of construction and availability of labour makes it possible. Labourers may experience problems in achieving the required result as described in specifications due to the need for ripping, depth of grubbing, size of roots, etc. In such cases it is advisable to review the specifications in the light of the requirements of a LVR and to ascertain whether there is a realistic risk of damage to the pavement due to reduced standards of grubbing.

Roadbed operations

After clearing and grubbing, any unsuitable materials should be removed to appropriate depths (clays, black cotton soils, dispersive soils, etc.) and the roadbed graded.

The roadbed should then be compacted, either to a specified percentage density or by using a method specification. A method specification usually consists of watering the roadbed and applying a specified number of roller-passes to the roadbed at the in situ natural moisture content. A trial-section should be prepared and the in-situ compaction measured after each pass of the roller. This can be done by density tests or by using DCP measurements.

Once the required compaction has been achieved, then the number of passes should be used thereafter for the rest of the roadbed compaction where soil conditions are homogeneous. Method specifications are very practical and time-saving and their use should be encouraged where appropriate

If collapsible soils are found beneath the roadbed, it is necessary to pre-collapse them before commencing the earthworks. There are a number of ways of achieving pre-collapse, but the recommended methods are those that minimise the amount of water required by using Heavy Impact Rollers or Heavy Vibrating Rollers.

Existence of hard stratum

The existence of a hard stratum below the roadbed can present drainage problems, particularly in cut areas. The solution for dealing with this depends on a number of factors including the proximity of the rock stratum to the finished road level, the thickness/hardness of the rock stratum, and whether the road is in cut or fill. Remedial measures for dealing with the hard stratum are:

- Relatively thin (< 1 m) stratum. Breaking up the rock layer using jack hammers or by blasting in order to provide a vertical drainage path to an underlying pervious stratum. Providing lined drains to minimise seepage of water under the road pavement.
- Relatively thick (> 1 m) stratum: Raising the road embankment and/or providing lined drains to minimise seepage of water under the road pavement.

17.4.4 Subgrade Construction

The best techniques and methods for undertaking earthworks and subgrade operations are dependent on available plant in addition to the operational skills and experience of the field staff.

When compacting earthworks and subgrades it may be difficult to adjust the in situ moisture content before compaction, especially when using clayey material where a good distribution of water in the material is difficult to achieve. To mix water into such materials requires much effort and is not very effective.

Adjusting moisture contents of earthworks is also particularly difficult in wet climatic regions whereas, in drier areas, it is possible to dry out materials that are too wet. Careful timing of earthworks, where possible, can alleviate these problems.

The use of labour-based methods in earthworks operations is appropriate where there is a large source of labour available for the work of the quantities are relatively small.

17.4.5 Pavement Layer construction

Aspects of construction that require particular attention are as follows:

- Natural gravels with high contents of fines or clay particles gain their strength as a result of suction following drying back, rather than from friction between particles. This means that the in-service moisture regime of the pavement, achieved through appropriate internal drainage measures, is of vital importance for the performance of the layer.
- Correct moisture content (ranging between 1% above and 2% below optimum moisture) and achievement of the specified density for the different layers, is essential.
- Depending on the construction plant used, a good surface finish is sometimes difficult to attain. It is critical that the base course has a smooth finish before sealing. Correct after-care following construction is important for a good bond between the base course and the bituminous seal and subsequent performance of the pavement.
- Natural materials often consist of soft particles and placing, mixing and compaction may result in a change in the material properties. An assessment of the consequences of this processing action is required in order to establish whether the material meets the specification requirements following construction.

17.4.6 Surfacing Construction

General

There are a number of different types of surfacings, both bituminous and non-bituminous, that may be used for LVRs (refer to *Chapter 15 – Surfacing)*. Each type has its particular construction requirements in terms of materials quality, labour skills and complexity of equipment. Some are much more ‘construction friendly’ than others and are easier to construct but they also differ considerably in their expected service lives. Their service lives are extremely dependent upon the quality of their construction and this, in turn, affects the performance of the entire pavement.

The commonly used sprayed surfacings, such as surface dressings, Otta Seals and sand seals, follow a similar construction procedure, as follows:

1. Priming of the base (sometimes may be omitted as for a double Otta seal and Penetration Macadam).
2. Base repair of primed base (chip & spray by hand using emulsion) to even out the occasional rut caused by a stone under the motor grader blade.
3. Spraying of bituminous binder.
4. Spreading of aggregate (Chip spreading requires uniform aggregate cover and a drag broom can assist this process on large areas).
5. Rolling, preferably carried out with pneumatic rollers but can also be done by trafficking.
6. f applying a double layer, repeat 2 to 6.
7. An emulsion “fog spray” is sometimes applied to chip seals.

In slurry seals, crusher dust, bitumen emulsion, water and cement filler are premixed with either a specialised “mix and spread” machine or in a concrete mixer for spreading by hand with squeegees. Mixing by hand may be used but is not encouraged.

Need for Good Construction Practice

There are a number of potential problems associated with the construction of surface treatments, particularly sprayed seals such as surface dressings and Otta Seals. The majority of instances of poor performance are related to the following:

- Poor transverse distribution of binder as illustrated in Figure 17-11.
- Poor joint construction as illustrated in Figure 17-12.
- Over or under spray.

Figure 17-11: Example of poor transverse distribution of binder

Figure 17-12: Example of poor transverse joint construction

Non-bituminous surfacings (e.g. cobble stone) offer potentially less construction problems than bituminous seals because they avoid the use of imported bitumen and relatively expensive construction equipment as shown in Figure 17-11. In addition, they offer the advantage of promoting and utilising local industry in areas where stone such as granite or limestone may be won and shaped easily by local entrepreneurs, predominantly with hand tools. Thus, in a small-scale contractor environment, and in appropriate circumstances, they may offer an attractive option to bituminous surfacings.

Figure 17-13: Construction of cobble stone paving

Figure 17-14: Constructed cobble stone paving

Because of the wide variety of both bituminous and non-bituminous surfacings, a full description of the construction of these different types of surfacings is outside the scope of this manual. Such a description may be found in the AFCAP Guideline *Low Volume Rural Road Surfacing and Pavements: A Guide to Good Practice* (2013).

Suitability for Labour-Based methods

The various types of surfacing provide varying scope for use with labour-based works in a practical, and economic manner. Table 17-1 provides an assessment of the suitability of each surfacing type for the use of manual labour in production of aggregate and construction respectively.

Table 17-1: Labour friendliness of various surfacing types

		'Friendliness' for labour-based methods (Good – Moderate – Poor)				
		Surface dressing[1]	Otta seal[2]	Sand seal	Slurry[3]	AC[4]
Production of aggregate	Quality	Poor	Good	Good	Good	Poor
	Output	Poor	Good	Good	Poor	Poor
Construction of surfacing	Quality	Moderate	Good	Good	Good	Poor
	Output	Good	Good	Good	Moderate	Poor

1) Hand-crushing of aggregate for surface dressing tends to produce flaky chippings with some rock types.
2) Oversize and fines can be removed by hand screening of natural gravel aggregate for use with Otta seals.
3) Output of aggregate production for slurry (crusher dust) depends entirely on availability on the commercial market.
4) Although included for comparison with other seal types, AC would not normally be used on a LVR.

As indicated in Table 17-1, all seal types offer varying scope for labour-based operations, both as regards production of aggregate as well as construction on site. However, the uniform binder spray rates required for surface dressing are more difficult to achieve with labour-based methods. Thus, where labour-based methods are being considered, seal types that are most suited for this type of construction should be given priority. It should also be noted that all seals, except the slurry seal, need rolling, and therefore require some form of machine-based equipment for this purpose. Where traffic volumes are sufficiently high, it may be possible to rely on it for rolling, but at the risk of an inferior result.

Examples of surfacing operations that can be adequately undertaken by labour-based methods are illustrated in Figures 17-15 and 17-16.

Figure 17-15: Screening of aggregate using labour-based methods

Figure 17-16: Spreading gravel using labour-based methods for an Otta seal

17.4.7 Shoulder Construction

Construction difficulties and subsequent delays can easily occur if materials that differ from those used in the main carriageway are specified for the shoulders. When the surface is to be sealed, shoulders should always be constructed using the same material and specification as for the main carriageway. However, when the shoulders are unsealed, the surface needs to be durable when exposed and this places particular demands on the type of gravel materials that should be used. This type of design may require separate construction of shoulders and carriageway.

The seal used for the main carriageway should also be specified for the shoulders, i.e. the same seal for the full width of the surfaced area. Construction difficulties and delays are likely if the shoulder seal differs from the main carriageway seal.

17.4.8 Concrete

There are a number of elements of LVR construction that require the manufacture of concrete. They include concrete strip and slab surfacings as well as various types of drainage elements, such as head and wing walls, box culverts, etc. The integrity of these elements will depend on the quality of concrete used. Appropriate measures must be observed to ensure that the strength of the concrete complies with the specified requirements.

7.5 COMPACTION

17.5.1 General

Compaction is a vital aspect of LVR construction. Good compaction results in all-round improvements of soil properties and in their performance as a pavement supporting layer. A well-compacted subgrade possesses enhanced strength, stiffness and bearing capacity, is more resistant to moisture penetration and less susceptible to differential settlement.

17.5.2 Compaction to Refusal

One of the critical aspects of using natural gravels is to maximise their strength and increase their stiffness and bearing capacity through effective compaction. This can be achieved, not necessarily by compacting to a pre-determined relative compaction level, as is traditionally done, but by compacting to the highest uniform level of density possible without significant degradation of the particles. This compaction to refusal is illustrated in Figure 17-17. It results in a significant gain in density, strength and stiffness, the benefits of which generally outweigh the costs of the additional passes of the roller.

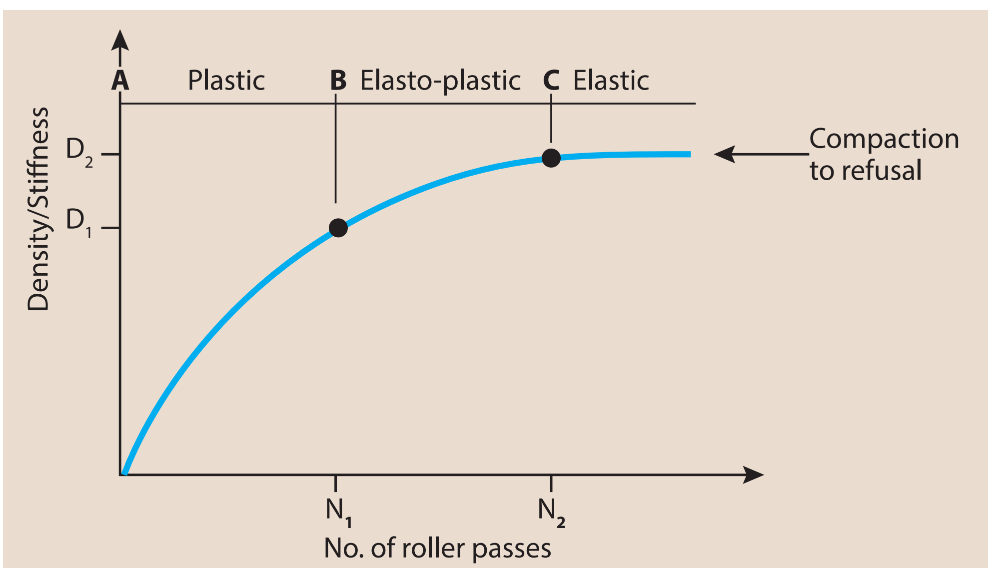

Figure 17-17: Illustration of concept of compaction to refusal

A maximum allowable moisture content during construction should be specified and proper precautions for surface and sub-surface drainage (where required) should be taken on all roadbuilding projects to ensure optimal performance from the road.

In general, the effectiveness of the compaction process depends on three important, inter-related factors, namely:

- Soil moisture content during compaction.
- Soil type, and
- Type and level of compactive effort.

Different types of soils respond to compactive effort in different ways. Thus, it is important to ensure that the compaction plant being used is appropriate for the type of soil being compacted and the purpose intended. For example, sand or sandy soils are most efficiently compacted with high frequency vibrating rollers whereas cohesive soils are most efficiently compacted by static pressure, high amplitude compaction plant. Furthermore, if the requirement is to compact and produce a good riding quality of base course, this is unlikely to be achieved with a very heavy roller that compacts to a great depth and, in the process, disturbs the surface.

17.5.3 Subgrade Compaction

Effective subgrade compaction is one of the most cost-effective means of improving the structural capacity of pavements. A well compacted subgrade possesses enhanced strength, stiffness and bearing capacity; is more resistant to moisture penetration; and less susceptible to differential settlement. The higher the density, the stronger the subgrade support, the lesser the thickness of the overlying pavement layers and the more economical the pavement structure. Thus, there is every benefit to achieving as high a density and related strength as economically possible in the subgrade.

17.5.4 Pavement Layers Compaction

Compaction of the pavement layers (and the subgrade) is specified as a percentage of the maximum dry density (MDD). Such a requirement should desirably be that obtained at “refusal” density, for the reasons discussed above. To achieve a well-balanced pavement, the compactive effort is increased in each layer as the pavement prism is built, and the quality and therefore the physical strength of material is greater in each ascending layer, thereby making the pavement stiffer at the top than at the bottom. Whatever level of compaction is specified it is important to achieve it on site for each layer by ensuring that the material is appropriately watered and mixed before starting the compaction of each layer. The higher the density in the underlying layer, the stiffer and more deeply balanced the pavement structure will be.

The minimum compaction requirements for the pavement layers and subgrade are specified in *Chapter 7 – Construction Materials,* Table 7-10. Where higher densities can be realistically attained in the field (compaction to refusal) from field measurements on similar materials or other established information, they should be specified by the Engineer.

17.5.5 Moisture for compaction

Thorough mixing of water with soil over the full width and depth of the layer and at the optimum moisture content of the admixture is essential for achieving the required density and an even surface finish. The optimum moisture content determined in the laboratory is a good guide to the amount of water required in the field compaction process, bearing in mind that modern compaction plant normally requires a lower moisture content than the optimum indicated from laboratory compaction methods.

Natural gravels used in LVR pavements often have a high fines content and therefore require much larger amounts of water for compaction than crushed or coarser, well-graded, materials. Effective mixing is therefore of particular importance when utilising these materials. Mixing equipment such as ploughs or large disc harrows (Figure 17-18) greatly reduces the required time for mixing water into the material compared to blade mixing with grader, but blade mixing is more effective.

Figure 17-18: Use of grader tines for effective mixing of water in material

Drying-out of layers

Natural gravels may need to be brought near to saturation moisture content for efficient compaction on hot days, but it is also good practice to allow a significant amount of drying back to occur before sealing takes place. This is particularly beneficial for fine-grained materials that rely on suction and cohesion as their predominant source of shear strength.

17.5.6 Water Usage, Evaporation and Temperature Variations

Before deciding the required moisture content, the in-situ moisture content must be determined. If evaporation is taken into account, then the water investigations should aim to provide at least 50% more water than the amount required to compact all materials at OMC, particularly in dry areas.

Some areas of Tanzania have high daily temperature and evaporation rates, particularly at altitudes between 1500 and 3000 m above sea level. The northern part of the country (Moshi-Arusha and Serengeti areas) for example, can reach high temperatures in excess of 30°C during the day, dropping to about 10°C or lower during the night, as is the case for the southern and western parts of the country (Mbeya and Subawanga).

High daytime temperatures can result in an extremely high evaporation rates leading to excessive loss of water. Hence, it is prudent to programme watering and mixing activities very early in the morning or late in the afternoon to prevent such losses. For LVRs the cost of transporting water may constitute a substantial part of the total cost and any means of reducing this cost should be considered.

Generally, the lower temperatures do not affect pavement layers unless freezing of free water in a layer causes expansion and de-densification. This can be easily checked by re-testing the following day and re-processing the layer. However, extremely high temperatures cause high evaporation during processing and care must be taken not to compact the layer when it is too dry of OMC because it will be impossible to achieve the specified density. Compaction at too low a moisture content may also impose a high risk of lamination at the top of the layer. Thus, during extremely hot days, it may be necessary to add water frequently during processing to arrive at the correct moisture content immediately prior to compacting.

17.5.7 Quality Attainment

LVR design procedures assume that both the material properties and levels of density specified are achieved in the field. However, in order to attain the specified densities, it is essential to ensure, as far as practicable, the uniform application of water, the uniformity of mixing and uniformity of compaction at or near OMC.

It is also important to note that layers below the one being compacted should be of sufficient density and strength to facilitate effective compaction of the upper layer(s). Adherence to the compaction recommendations given in *Chapter 7 – Construction Materials* (Table 7-10) should ensure this.

Granular materials which are well graded are easier to compact than poorly graded ones. It may therefore be more economical to get the gradation right (e.g. by mechanical stabilisation) before wasting time and energy with excessive rolling. Improved grading is also likely to improve the material strength to an extent where a subbase quality material could become eminently suitable for road base.

Whilst it is necessary for natural gravels to be brought to OMC for efficient compaction, it is also necessary to ensure that premature sealing does not lock in construction moisture. This can be achieved by allowing a significant amount of drying out to occur before sealing takes place, particularly for materials that rely on soil suction forces for strength gain and improved stability.

The variability of natural gravels is a significant factor in the reliability of performance of the pavement. However, various measures can be taken during construction to reduce such variability. These include:

- Careful selection during the winning process (refer to *Chapter 18 – Borrow Pit Management*).
- Processing of stockpiled material: (refer to *Chapter 18 – Borrow Pit Management)*.
- Quality control and assurance: (refer to Section 17.6).

17.5.8 Single and Multi-layer Construction

Single layer construction is usually specified for pavement layers from 75 mm to 200 mm thick. The most common layer thickness is 150 mm. However, when a pavement layer is specified at a thickness greater than 200 mm it will be necessary to compact it in more than one layer of the same thickness in order to achieve uniform specified density throughout the layer. The maximum allowable size of any layer should not exceed 2/3 of the layer thickness.

17.5.9 Finishing of Base Course

If the operation of mixing, spreading and compaction is not completed before drying out of the surface takes place, then a loose upper layer (biscuit layer) will result. If this happens, the bituminous surfacing will not have a hard surface on which to bond resulting in base course failures due to shearing from wheel loads. Such failures may appear to be the result of insufficient material strength, but studies of construction records, and evidence of good performance under similar conditions in base course layers of poorer material qualities, indicate that premature failure of the uppermost layer of the base course can often be linked to poor finishing of this layer. Careful finishing of the base course layer is vital and decisive for good performance of LVRs.

Figure 17-12 illustrates a recommended procedure for finishing off base courses made of natural gravel. The advantage of this method is the speeding up of the processing of the base course to prevent drying out of the surface, whilst ensuring that full attention is given to surface finish instead of minor irregularities of geometric levels. Trimming of the surface should be confined to the action only of cutting off gravel to side spoil or off loaded for use in subsequent sections. Attempts to spread loose material over the surface in a thin layer is unacceptable. This is likely to prevent a firm finish of the layer and inhibit the bond with the bituminous surfacing.

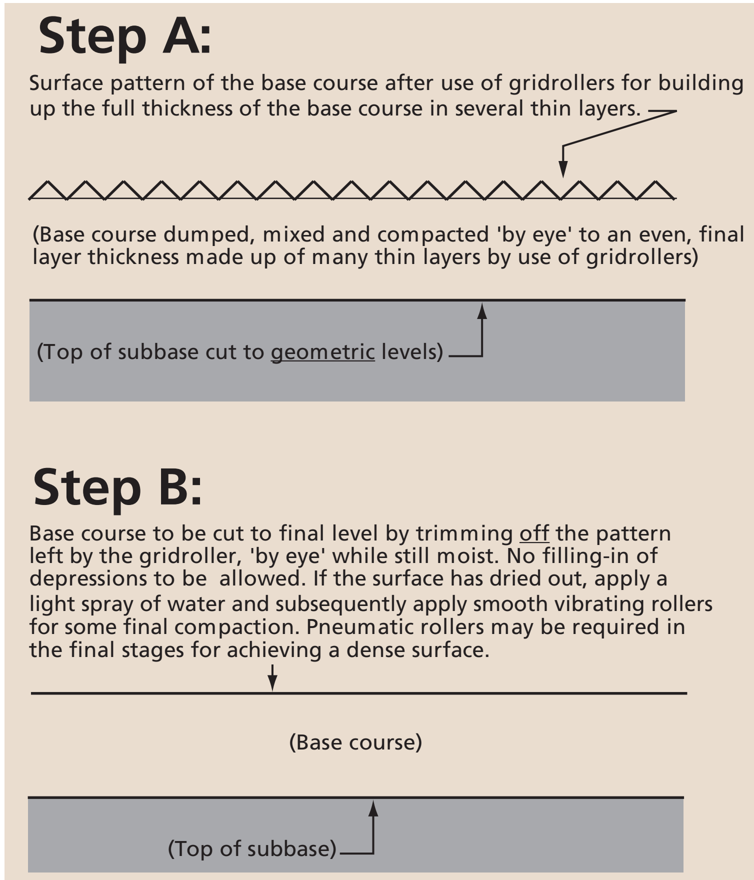

Figure 17-19: Illustration of procedure to finish off base course constructed from natural gravel

17.6 QUALITY ASSURANCE AND CONTROL

17.6.1 General

Good quality control/quality assurance (QC/QA) practices are essential to obtain satisfactory results on any road project. This is particularly the case for LVRs where naturally occurring, inherently variable materials are being used and it is essential that the underlying design assumptions are achieved on site. This includes critical factors such as use of materials of acceptable quality and attainment of the minimum compaction requirements and pavement layer thicknesses specified. Unless these, and other specified requirements are met, such as an adequate quality surfacing to waterproof the pavement structure, and effective internal and external drainage, then premature failure of the LVR is likely.

In developing a QC/QA system, it should be borne in mind that LVR projects in Tanzania are often relatively small in size and widely scattered in remote areas with limited facilities. Moreover, the speed of construction is relatively slow and the available resources as well as skills with small contractors are at a relatively low level. It is therefore necessary that while developing a suitable QC/QA system for construction, such constraints are borne in mind. Thus, the types of quality control and their frequency must be judiciously selected so as to be achievable under the prevailing conditions.

17.6.2 General Approach

There are various means of ensuring that an acceptable quality of the final LVR is achieved. Each is separate and each has an important role to play. Together they consist of a suite of procedures that work together to ensure good quality. A clear distinction should be drawn between the following:

- Quality Plan (QP).
- Quality Assurance (QA).
- Quality Control (QC).
- Production Control (PC).
- Acceptance Control (AC).

The differences and functions of each component of the Total Quality Management System (TQMS) are explained below.

17.6.3 Components of a TQMS

Quality Plan (QP)

This refers to a written plan submitted by the contractor, which is reviewed and approved by the client/ supervising engineer. This document clearly demonstrates how the contractor will control the processes used during construction in order to meet the requirements set out in the technical specifications. The QP will typically include the sequence of tests (QC tests) to be performed on the materials intended for use at a prescribed frequency, with the objective of demonstrating that the intent of the specification is being satisfied.

The tender documents should include the requirement that the contractor must present his project Quality Plan that he/she intends to follow during the working process. An example of such a plan is presented in Appendices A to E.

Quality Assurance (QA)

QA is the documentation required to show that the contractor is following the Quality Plan. It incorporates standard procedures and methodologies and applies to all site activities aimed at significantly reducing or eliminating, non-conformance before it occurs. The QA Plan should be followed by everyone on site and checked by both the supervising engineer and the contractor. QA activities are determined before construction work begins and are performed throughout construction. Components of a QA system typically include process checklists and construction methodology (contractor's work plan).

Quality Control (QC)

This refers to measured quality-related attributes associated with the construction of various aspects of the project. QC is generally concerned with measuring properties and checking that specifications have been met consistently throughout the project. It does not in itself create higher quality. Examples of quality control activities include site inspections, field and laboratory testing. Such activities are performed after the work has been completed. A good practice for QC is the development and use of a checklist for monitoring and inspecting the construction of the pavement system.

Production control

This is carried out by the contractor for the purpose of satisfying himself that chosen methods and materials meet the specified standards. Production control serves as an early warning for the contractor and helps reduce his risk of failure and associated additional cost to himself of remedial work. The contractor may be obliged to submit results from the production control to the supervising engineer and may in some cases these may be taken as part of the acceptance control.

Acceptance control

This is carried out by the supervising engineer to check compliance with the specified standards and to enable payments to be made. Acceptance control makes use of confirmed QA and QC testing. Results from acceptance control will normally form part of the as-built data which provides the basis of the road inventory kept by the responsible road agency.

Quality control supervision therefore comprises two principal elements namely site inspection and laboratory and in-situ testing. A large component of the latter is compaction control and testing.

Site Inspection

The works are inspected visually to detect any deviation from the specified requirements. Visual assessment is an essential element of pavement layer approval, particularly in the identification of oversize material in lower pavement layers or in a gravel wearing course. Physical measurements of thickness, widths and crossfall are an essential element of this assessment. This activity is supplemented by simple in-situ checking of specified procedures; for example, temperature of bitumen and spray rates, concrete slump, etc.

Laboratory and in situ testing

Materials as well as the finished product are subject to laboratory testing for such characteristics as density and strength. On larger projects it may be possible for the contractor to set up and maintain a basic field laboratory for routine tests for quality control testing required on a day to day basis. The field laboratory will normally have test equipment that does not require an electric power supply and is relevant to the project specifications. There are also portable field test kits, such as the Gravel Test Kit supplied by CSIR of South Africa, which includes simple equipment for basic control tests.

Field compaction control

One of the most critical quality control activities is the field density compaction tests, the outcome of which could have a significant bearing on the performance of the road. The Sand Replacement Test, sometimes used in conjunction with Nuclear Density testing, is commonly used for compaction control on LVR projects. However, on a practical level, these tests are time consuming. They may be replaced for quality control purpose by the easier-to-perform DCP test, initially in conjunction with in situ density testing and moisture content testing for correlation purposes.

Compaction control is typically based on absolute requirements and spot tests. However, the number of such tests is often too low for a high level of statistical reliability and therefore does not necessarily ensure a well-defined quality of the product. It is for this reason that a statistical approach to quality control should be adopted, particularly for the larger LVR projects. Works and materials are accepted or rejected based on the requirements given in the MOW Standard Specification Road Works (2000).

17.6.4 Quality Assurance/Quality Control in Practice

The construction specification establishes the framework for QC/QA. With a method specification, the individual responsible for QC would document the equipment utilised and continuously monitor its activities during operation. The QA may be by certification of QC tests and reports with intermittent inspection.

With an end-result specification, the individual responsible for QC would perform frequent testing at the start of the process, testing for changed conditions, and some testing for verification. The QA would typically be a prescribed number of tests for a specific quantity of materials at random locations.

Statistical processing of the test data may be used to determine the acceptance of the results and are addressed in Section 7200 of the MOW Standard Specification for Road Works (2000). Statistical methods of QC offer the following advantages:

- Both the quality level and the variability of the product are taken into account in the assessment, thus providing greater production flexibility and potentially more economic gain.
- The need for engineering judgment is reduced, since no such judgment is required to assess the material against the acceptable control limits determined.
- The introduction of a conditional acceptance range below the previous coincident acceptance/ rejection limit will result in greater procedural flexibility and reduced numbers of disputes in the case of products of marginal quality.

17.6.5 Quality Control with Limited Resources

The resources available for quality control in construction of LVRs are sometimes limited, depending upon the size of the contract. Use is also made of new and emerging contractors with little experience. It is therefore important to utilise whatever means are available as efficiently as possible and to combine conventional control methods with other practical procedures as described below.

Quality control procedures where control systems are applied at reduced levels include the following:

- **Stockpiling** as a means of selecting qualities and ensuring known quality of the materials being used (stockpiling carried out preferably in the borrow pit rather than on the road).
- **Good management procedures** to ensure that materials are used to their full potential and to prevent rejection of material after transportation to the road.
- **Control by observation** of construction procedures by an experienced practitioner.
- **Proof rolling** (e.g. with loaded trucks) to test the stability of layers before proceeding with further construction.
- Use of methods for **direct strength measurements** by correlation with known parameters (e.g. probing methods such as DCP and others).
- Laboratory testing for **'calibration'** of method specifications.
- Laboratory testing of typical material sources for **'calibration'** of visual observations.

17.6.6 Priority in Quality Control

General

Compaction is a crucially important aspect of road construction as it substantially influences the long-term durability and performance of the pavement structure and, hence, the whole-life cost of the road. Thus, this aspect of the construction process must be carefully controlled on site to ensure that the specified densities are met in a consistent manner. The main aspects that need to be considered, other than routine material control testing, are the field density attained, the layer thickness and surface finish of the pavement layer being compacted.

Compaction control

The pavement layers (or gravel wearing course) should be compacted preferably to refusal or to the minimum specified density assumed in the pavement design. This requires that the materials be processed at or about Optimum Moisture Content and rollers of adequate mass are used. Trial sections should be constructed using the materials and plant that will be used on site, and density increase monitored for each pass of the roller. Compaction control can make use of any density determination method (nuclear, sand replacement, etc.) but the most practical method is to use a DCP which is quick and easy to carry out and which will provide adequate assurance that satisfactory compaction has been achieved.

Compaction trial using the DCP: Provided the material is tested at or close to OMC, a reliable Target DCP DN value can be obtained from the compaction trial for the subsequent compaction control of the road works. This Target DN value can be determined as follows:

1. Following completion of the first 3 roller passes, undertake 3 No. DCP measurements after every successive pass of the roller up to about 8 passes.
2. Calculate the average DN value after each successive pass of the roller.
3. Plot the average DN values against the number of roller passes as shown in Figure 17-20.

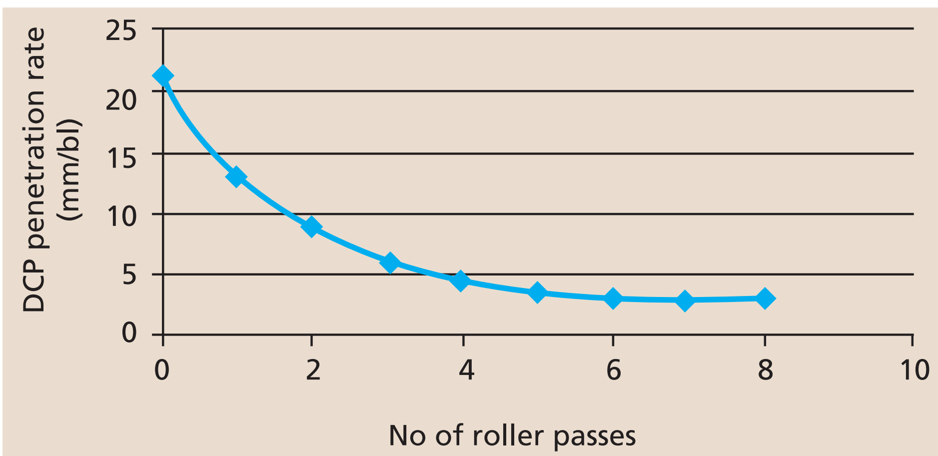

Figure 17-20: Typical results obtained from compaction trials

The average DN value will normally decrease with an increase in the number of roller passes until the curves flattens out to a point where the decrease in DN value becomes negligible, in this illustrative example after 6 passes. This DN value becomes the Target DN for compaction control, as described below. It is also necessary to correlate the Target DN value with the density obtained using the traditional density determination method (Sand Replacement or nuclear gauge) to ascertain whether the specified density has been achieved in the field. Both methods can provide quick results if the in situ moisture content can be rapidly determined on site through the use of an appropriate scale and calibrated sand to be used in the Sand Replacement test.

Compaction control procedure using the DCP: The procedure is described below and illustrated in Figure 17-21.

1. Determine from a compaction trial the optimum number of roller passes and Target DN value (which is deemed to be at “compaction to refusal” at or close to OMC (+1%/-2%) as described above.
2. For each lot do a minimum of 10 DCP tests in a staggered pattern illustrated as illustrated in Figure 17-21 with 3 tests on each side and 4 tests along the centre line.

The offset from CL for the LHS/RHS tests shall be varied and no tests shall be done closer to the start/end and to the outer edge of the lot than 0.2 m.

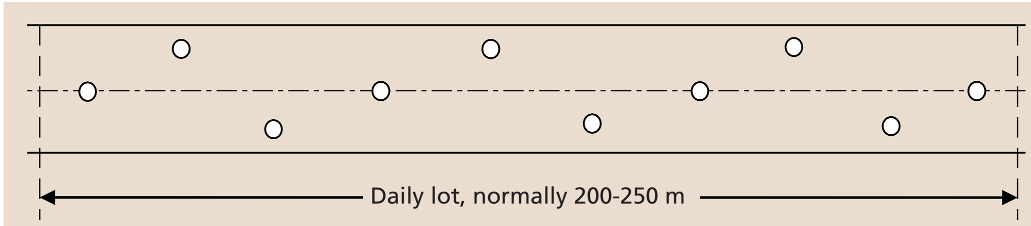

Figure 17-21: Pattern for DCP Compaction Control tests

Evaluation procedure: This entails a statistical calculation to determine the mean or average DN value and standard deviation of a minimum of 10 results obtained from the DCP measurements undertaken in the daily Lot. Figure 17-22 illustrates the evaluation procedure and criteria for compaction quality control using the DCP. Further details may be obtained from the AFCAP Guideline for Compaction Quality Control on Low Volume Roads Using the DCP (2015).

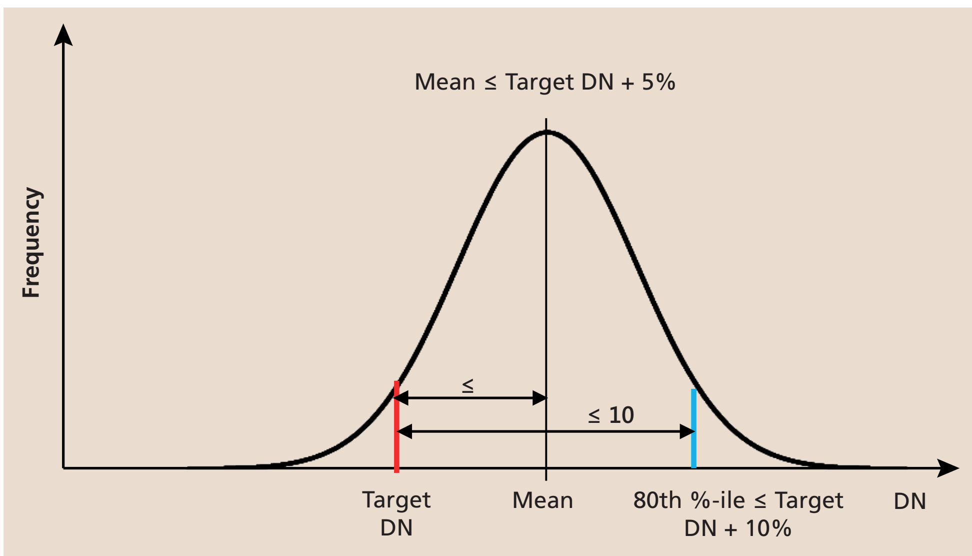

Figure 17-22: Evaluation of DCP quality control results

Thickness control

It is essential that the required thicknesses of material are placed. Layers that are too thin will require premature regravelling and those that are too thick will lead to an increased cost and possibly a lack of compaction in the lower part of the layer. Layer thickness can be easily controlled using a simple tool as shown in Figure 17-23. This can be easily made and is pushed into the ground until an obvious change in resistance is felt (the underlying, usually dried out layer). The thickness of the layer is then read off the scale. The tool can also be used to assess the uncompacted thickness before rolling which, together with knowledge of the bulking factor can indicate whether the loose material is adequately thick. The layer should be slightly thicker than required as some thickness will be lost during final trimming and shaping, particularly as regards developing the camber as discussed below.

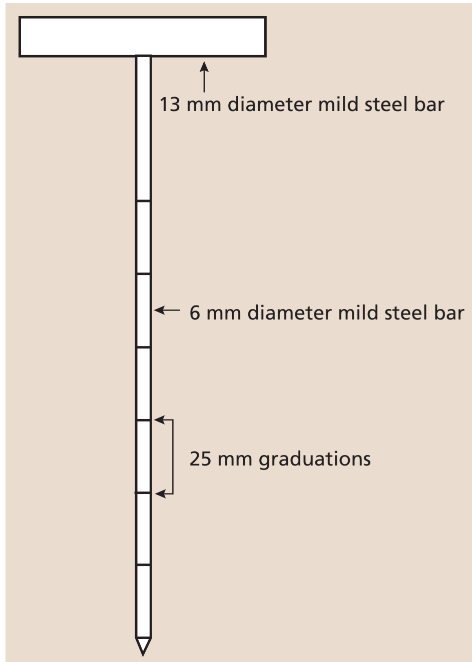

Figure 17-23: Probe for assessing gravel layer thickness

Final finish

The final finish is critical as this will affect the riding quality (and thus the vehicle operating costs) as well as the drainage from the road surface. Good shape of the road is also essential with a central crown and a crossfall of between 4 and 5%. In order to ensure this, proper control using stakes and string-lines must be carried out during construction.

In addition, it is essential to ensure that all oversize material has been removed. Any oversize material near the surface will be plucked during the final trimming and dragged along the surface leaving grooves. An excess of these indicates that the oversize material has not been removed properly and the layer should be reconstructed after removing these large particles. Failure to remove them will result in excessive roughness, difficult, expensive and ineffective maintenance and excessive vehicle operating costs.

Appendix A - Example Project Control Quality Plan*

Submitted by:

CONTRACTOR X

Date	Issued for	Changes	Rev No.

Prepared by:	Name:		**Approved by:**	Name:
	Signature:			Signature:
	Date:			Date:

Note: The example presented in this appendix is of a generic nature. It can be adapted and simplified, as necessary, to suit projects of varying complexity.

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1. Purpose

The purpose of this Project Quality Plan (PQP) is to confirm the following;

- Outline the Project quality objectives.
- Define the Project Quality System and Procedures.
- Outline the approach for implementing Quality.
- Project Procedures.
- Quality roles and responsibilities.
- The QA/QC monitoring programme.
- Auditing plan.

2. Scope

The scope of this Quality Management Plan includes all quality related functions and activities for the project management and construction.

The Quality Management Plan is applicable to all work undertaken by CONTRACTOR X– Projects, Home Office, Site, off-site manufacturing/fabrication facilities and any other temporary project offices.

This Plan describes Quality Assurance and Quality Control functions and activities to be implemented and includes or refers to established Quality Control plans, Method Statements and standard forms.

3. Reference

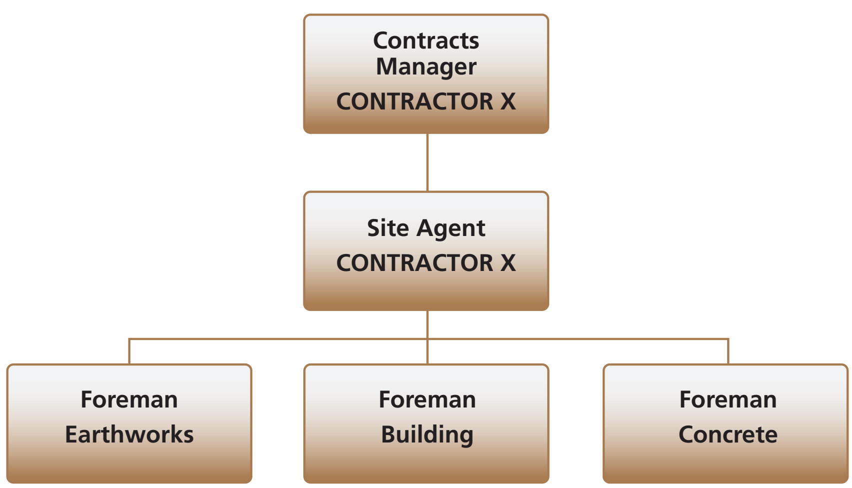
ISO 9001 – Quality Management Systems as best practice

Standard Specifications for Road and Bridge Works (1999). Ministry of Works.

Laboratory Testing Manual (2000). Ministry of Works.

4. Communication

- The language used on this contract will be English. The formal communication lines for the contract will be between the **CONTRACTOR X** Contracts Manager and the Client's representative knows on this contract as the Engineer.
- For day to day running of the works the Engineer can communicate with the Site Agent/ Manager and any formal communication that may arise from that will be done as prescribed above.
- The following Organogram will be the Contractor's team on site



5. Quality Management System

CONTRACTOR X is currently establishing, implementing and will maintain on an ongoing basis an effective Quality Management System (QMS) for all its projects. Internal audits on a regular basis of its processes will be conducted to ensure that the company aligns itself with ISO 9001-2000 as best practices.

The suitability, adequacy and effectiveness of the QMS will be monitored throughout the Project through the measures described in this Quality Plan.

5.1 CONTRACTOR X's Quality Policy and Management commitment:

CONTRACTOR X's objective is to establish, implement and maintain an effective Quality Management System for this project, which meets the requirements of the project as well as contractor X's own organizational goals.

CONTRACTOR X's commitment to quality, and to continuous improvement in performance, begins at the top management level as endorsed by our quality policy. The objectives are communicated and committed to by all members of the project team.

6. Quality Management Plan

This section describes the quality management system that will be used throughout the entire implementation of the project.

6.1. Definitions

Standard terminology, based on ISO 9000-2000 - Fundamentals and Vocabulary (in Quality Assurance). The following definitions define the terms used in this Quality Management.

- ***Corrective Action:***
  Action taken to eliminate the causes of an existing non-conformity, defect or undesirable situation to prevent recurrence.
- ***Evaluation:***
  An appraisal to determine whether or not design, manufacturing, manufacturing facilities, construction processes and quality programs are capable of producing a quality item or service and of generating evidence that support decisions on acceptability.
- ***Guideline:***
  The document that describes the preferred method for suppliers or contractors to carry out a task.
- ***Inspection:***
  A phase of Quality Control, which by means of examination, observation or measurement, determines the conformance of materials, supplies, components, processes or structures to, predetermined quality requirements.
- ***Procedure:***
  The internal document that describes the preferred method of carrying out a task.
- ***Quality Assurance (QA):***
  All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.
- ***Quality Audit:***
  A documented activity conducted for the purpose of verifying by examination and evaluation that the applicable elements of the Quality Assurance Program have been established, documented and effectively implemented.
- ***Quality Control (QC):***
  The operational techniques and activities that are used to fulfil requirements of quality.
- ***Quality Manual:***
  A document setting out the quality policy, organization, procedures and practices.
- ***Quality Plan:***
  A document setting out the specific quality practices, resources and sequence of activities relevant to a particular product, service, contract or project.

- ***Quality Systems:***
  The organizational structure, responsibilities, procedures, processes and resources for implementing quality management.
- ***Specification:***
  The document that prescribes the requirements with which the product or service has to conform.
- ***Traceability:***
  The ability to trace the history, application or location of an item or activity, or similar items or activities, by means of recorded identification.

Other terms may be defined in the project specifications Supplier/Contractor Quality Assurance Manuals in their specific areas of application.

6.2. Abbreviations

ITP	Inspection and Test Plan.
PQCP	Project Quality Control Plan.
NCR	Non-Conformance Report.
QIR	Quality Incidence Report.
QMS	Quality Management System.

6.3. Method Statements

Method Statements will be submitted prior to any section of work commence for the Engineer's approval and will be for the critical works and will be as follows:

- Accommodation of traffic.
- Clear and grub.
- Mass Earthworks and pavement layers.
- Asphalt pavements and surfacing seals.

6.4. Quality Management and Philosophy

6.4.1. Project Quality Management

Project quality management ensures that the project satisfies the needs for which it is undertaken. It includes all activities that determine the quality policy, objectives and responsibilities and implements them by means such as quality planning, quality control, quality assurance and quality improvements within the quality system. Project quality management addresses both the management of the project quality and the project's end product.

6.4.2. Quality Management Process

Quality management consists of the following processes:

- Quality planning is the identification of the relevant quality standards and the determination of how to satisfy them. The output from quality planning is a quality management plan that documents how the project management team will implement its quality policy. It addresses quality control, quality assurance and quality improvement for the project. In addition, it includes operational definitions or metrics (explicit descriptions of what something is and how it will be measured) and checklists (to verify that a set of required steps has been performed or that a set of required features have been included).

- Quality assurance evaluates overall project performance on a regular basis to provide confidence that the project will satisfy the relevant quality standards. Quality audits (structured reviews of other quality management activities) play a key role in quality assurance. Quality assurance results in quality improvements.
- Quality control on this project will done in accordance to SATCC 8100 and 8300. It will also be in line with this Project Quality Plan and Project Quality Control Plans which will be approved by the Engineer.

6.4.3. Responsibilities

The Contracts Manager in conjunction with the Project Quality Coordinator will be responsible for and have ultimate authority for overall quality management.

Project Quality Coordinator:

- Has the responsibility for management of the Quality Plan.
- Quality Assurance checks to ensure that the Project meets the required quality standard in all its activities and functions.
- Establishing, implementing and coordinating all Quality Assurance Procedures.
- Guides, Specifications and activities, including those functions established by other Project management functions.
- Communicating Quality Assurance Responsibilities to the Site Team members.
- Communication of Quality Control requirements to Vendors, and Quality Assurance confirmation that Inspection and Test Plans are complied with.
- Overall Coordination of Quality Assurance efforts, including QA by Consultant, QA by Project team on site, Testing Consultants, Inspection Companies, Regulatory Inspection Services.
- Management of Project Audits.
- Manage and supervise Audits at Vendors facilities.
- Management of Quality Documents.
- Assessing the effectiveness of the Quality Management Plan, and managing required changes.
- Interfacing with Engineer.
- Maintenance of all Quality Control Records.

The Contracts Manager’s Quality Assurance responsibilities include:

- ○ Developing and maintaining appropriate document control procedures for ensuring that construction materials and workmanship for the project are in accordance with approved Project Procedures.

- Ensuring QA/QC requirements for site construction are being performed in accordance with the Quality Assurance Execution Plan for Contracts.
- Support the site Quality Manager with Field Engineers to perform assigned verification, and witness inspection activities in conformance with the Quality Management Plan and relevant Project Specifications and Codes and in accordance with Contract and construction discipline requirements.
- Communicating significant quality problems to the Quality Manager and the Engineering or Procurement Managers.

6.5. Measurement analysis and Improvement

6.5.1. Internal Quality Audits

Quality audits are a quality assurance activity to evaluate project performance on a regular basis and provide confidence that the project will satisfy the relevant quality standards.

An initial quality audit will occur once quality management activities have started. The results of the initial audit will determine the frequency of subsequent audits and a schedule will be circulated to the engineer for commence and approval. The Quality Coordinator is responsible for performing the audits and will involve technical specialists as and when the need arises.

6.6. Procurement Quality Management

6.6.1. Overview

The overall approach to quality management for the procurement of goods and services consists of:

- Selecting competent Suppliers/contractors in conjunction with Engineer's specification.
- Ensuring that they have a plan for controlling their work processes.
- Monitoring their compliance with the plan.

In summary, the Suppliers will be responsible for the quality of their work while the project team will be responsible for verifying that the Suppliers/contractors are fulfilling their responsibilities.

Quality management as it relates to the process of procuring goods and services consists of:

- Defining quantitative bid evaluation criteria for use on all equipment purchase packages (bid analysis, evaluation, and recommendation).
- Ensuring that all of the technical and commercial requirements are adequately defined in the bid documents.
- Selecting Suppliers that best meet the evaluation criteria.
- Verifying that each Supplier is in conformance with his quality plan as defined in the purchase order.
- Verifying the performance of each Supplier against the specification and Quality Plan during the delivery of the goods or services as called for in the purchase order / contract.

In their quotation, all bidders will be required to describe their quality management system and the quality management system used by their sub-suppliers/subcontractors. In addition, they will provide a copy of their corporate quality manual (if available).

Prior to purchase order/contract award, the Suppliers will submit for review a quality management plan (including an inspection and testing plan) for the specific scope of work. The purchase order will be awarded once the quality plan has been finalized. Then the project team can start performing the necessary reviews, inspections or audits required to assure that the Supplier is in conformance with the plan and that the work conforms to the requirements of the purchase order/contract documents.

Responsibility for managing Supplier quality is shared between Engineering, Procurement, and the Quality Co-ordinator. Engineering is responsible for defining the specific quality requirements applicable to pre-purchased equipment packages and for determining the technical acceptability of bidders.

6.6.2. Quality Assurance activities

A Quality Surveillance program will be developed by the Quality Co-ordinator, to monitorand evaluate suppliers and Vendors procedures (including ITPs), methods, products and records (including MDRs) to ensure conformance to specified requirements. This program will be administered by the Quality Coordinator, directing discipline specialists, field representatives and the Quality Control Inspection Agency for verification and witness inspection activities.

The Quality Surveillance Program will commence upon award of Purchase Order and/or Contract and will include but not limited to the following activities:

- Evaluating Suppliers' and Vendors' Quality Assurance and Quality Control Programs.
- Monitor the Preparation of Suppliers' and Vendors' Inspection and Test Plans (ITPs).
- Monitor Preparation of by Suppliers' and Vendors' Manufacturers Data Reports (MDRs).
- Monitor and review material certification, traceability and documentation by Suppliers and Vendors.
- Supplier and Vendor Quality Surveillance.
- Review and acceptance of ITPs.
- Non-conformance Applications, which are in effect changes to Specification requirements.

6.7. Construction

Project Quality Control Plans will be prepared by the Construction team for this project. They will be managed functionally by the Quality Coordinator and administered by the Site Agent and typically include the following activities:

- Minor concrete works including lined drains.
- Major concrete works.
- Mass earthworks.
- Pavement layers.
- Asphalt pavements.
- Road marking.

Where surveillance or witness inspection by the project team is required, only appropriately qualified and experienced inspection staff will be used to carry out these inspection activities.

The level of inspection surveillance to be carried out by the project team will be appropriate to the type, criticality and complexity of construction or equipment being installed, and the degree of confidence in the Vendor, based on an assessment of their Quality Plan and Procedures, personnel, facilities, demonstrated performance, and audit findings.

The specific verification, witness inspection, quality surveillance and reporting requirements for Contracts will be developed as part of the Enquiry document for these services, and an acceptable agency selected and appointed to carry out this function.

QC verification, witness inspection and quality surveillance activities will be carried out in conformance with this Project Quality Plan and relevant Project Specifications and Codes and in accordance with Contract requirements, as follows:

- Carry out assigned inspections and verifications as necessary to ensure that the equipment and material installed or fabricated on site, has been fabricated, installed, tested and accepted in accordance with the requirements of the Contract and discipline, and is ready for pre-commissioning activities.
- Complete all recording and reporting requirements for each Contract.
- Maintain contact, with the Vendor, from placement of the Contract throughout fabrication and/or installation, until Practical Completion.
- Follow-up Pre-Inspection Meeting action items as required.
- Issue timely inspection reports of acceptable quality, indicating inspection results in accordance with contract requirements.
- Report Non-conformances on a priority basis.
- Conduct regular review of Vendor's Quality Control Documentation for progressive compilation.

For work that requires release inspections, the Quality Coordinator will issue Final Release Certificates after all required inspection, test activities and MDR documentation required by the Contract, have been satisfactorily completed.

Non-Conformance Reports will be treated with the highest priority until the details are established submitted to Company for comment and or approval and corrective action implemented to resolve the problem.

Quality Control records will be maintained as follows:

- Non-Conformance Reports (NCR).
- Non-Conformance Report Register.
- As-Built" Drawings.
- Contract Inspection Records, including all related documents.

6.8. Non-Conforming Product

All Non-Conformances that occur during the course of supply, fabrication or construction, will be processed by the Supplier/Vendor such that Specification compliance is achieved. A copy of all Supplier/Vendor or Contractor Non-Conformance Reports, with proposed corrective action/ disposition will be reviewed and approved as required by:

- The Project Quality Coordinator.
- The Contracts Manager.
- Client's Representative – Engineer.

The parties will evaluate the potential for adverse impact on the project. The NCR's will be regularly reviewed at Suppliers/Vendors premises as part of the Quality Surveillance and Audit Programs, to verify effective control and close out.

Non-Conformances that occur as a result of audit, will be recorded on Non- Conformance Report (NCR) by the audit team, and will be managed from Corrective Action and Preventative Action, to close out, by the Supplier or Vendor, or the Contractor. These Non-Conformance Reports will be regularly reviewed at Suppliers/Vendors premises as part of the Quality Surveillance and Audit Programs, to verify effective control and close out or at the construction site.

Supplier/Vendor or the Contractor requested disposition of non-conformances which would result in a specification deviation will be notified in writing to the Quality Manager, or the site representative, by returning the Non-Conformance Report, with requested deviation as an action item. The Project Quality Coordinator will coordinate an appropriate review, which includes the technical, regulatory, health and safety, and environment with the Contracts Manager.

6.9. Handover

The handover process will be verified by the Contractor X, Contracts Manager and the Engineer. The Data books index will be agreed upon at the start of the project and will be constantly monitored during the contract through inspection and internal audits. This will ensure that the Data book is built up progressively as the works progress.

6.10. Deliverables

Deliverables will be identified when the contract is formalized but are typically those referenced in the attached Project Quality Control Plan.

APPENDICES

Appendices B – E show examples of a typical Production Quality Control Plan (PQCP) which should be included in the tender documents. This should ensure that the Contractor will adhere to the requirements of the PQCP requirements during construction.

Appendix B: PQCP – Major Concrete Works.

Appendix C: PQCP – Mass Earthworks.

Appendix D: PQCP – Minor Concrete Works

Appendix E: PQCP – Pavement Surfacing.

Appendix B: PQCP - Major Concrete Works

Contract: XXX PQCP: Major concrete works

No	Activity	Conformance Criteria, Specifications and Standard References	Record Type	Intervention Levels		
				Contractor	Laboratory	Engineer
1	Obtain approved drawings	Drawings signed by Consulting Engineers	Drawings signed by Consulting Engineers	A/H		H
2	Establish survey points	Instruction from Engineer	Engineer's instruction	A/H		H
3	Submit certificates for concrete material	SSRBW & Lab. Testing Manual	Material certificates	A/H		H
4	Obtain mix design approval	SSRBW & Lab. Testing Manual	Engineer's instruction	A/H		H
5	Survey setting out	SSRBW & Lab. Testing Manual	Survey data sheet	A/H		S
6	Formwork erection	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
7	Pre- concrete inspection	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
7.1	Check reinforcing to drawing and bending schedule	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
7.2	Check concrete mix specified	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
7.3	Check verticality of shutter	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
7.4	Check for soundness of stop-ends	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
7.5	Cast-in items (if and when applicable)	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
8	Casting concrete and testing	SSRBW & Lab. Testing Manual	Delivery/ dispatch notes	A	T	S
8.1	Slump testing	SSRBW & Lab. Testing Manual	Slump test sheet	A/H	T	S
8.2	Concrete cube sample testing	SSRBW & Lab. Testing Manual	Concrete cube sheet	A/H	T	S
9	Post concrete inspection	SSRBW & Lab. Testing Manual	Post concrete inspection	A/H		S
9.1	Dimensional check	SSRBW & Lab. Testing Manual	Post concrete inspection	A/H		S
9.2	Honeycomb check	SSRBW & Lab. Testing Manual	Post concrete inspection	A/H		S
10	Punch list items (if necessary)	SSRBW & Lab. Testing Manual	Punch list	A/H		S
11	Data book finalisation (built progressively)	PQP	Data book	A/H		H
12	Handover	Data Books Index & contents	Hand over certificate	A/H		H

Prepared by:	Approved by:	H = Hold		
Name:	Name:	A = Action		
Signature:	Signature:	S = Surveillance		
Date:	Date:	T = Test		

SSRBW (1999) & Lab. Testing Manual (2000) MoW

Appendix C: PQCP - Mass Earthworks

Contract: XXX PQCP: Mass earthworks

No	Activity	Conformance Criteria, Specifications and Standard References	Record Type	Intervention Levels		
				Contractor	Laboratory	Engineer
1	Obtain approved drawings	Drawings signed by Consulting Engineers	Drawings signed by Consulting Engineers	A/H		H
2	Establish survey points	Instruction from Engineer	Engineer's instruction	A/H		H
3	Permission form Engineer to use material (cut to fill)	Instruction from Engineer	Engineer's instruction	A/H		H
4	Check moisture content and adjust if required	SSRBW, 1999 MoW	Engineer's instruction	A/H	T	H
5	Level and compact	SSRBW, 1999 MoW	Layerworks and density sheet	A/H	T	S
6	Place approved material - layer	SSRBW, 1999 MoW	Layerworks sheet	A/H		S
7	Check water content	SSRBW, 1999 MoW	Moisture content lab sheet	A/H	T	H
8	Level and compact	SSRBW, 1999 MoW	Layerworks and density sheet	A/H	T	H
9	Place approved material - layer	SSRBW, 1999 MoW	Pre concrete inspection	A/H		H
10	Check water content	SSRBW, 1999 MoW	Moisture content lab sheet	A/H	T	H
11	Level and compact	SSRBW, 1999 MoW	Layerworks and density sheet	A/H		H
12	Check height in accordance to drawing	SSRBW, 1999 MoW	Survey sheet	A/H		H
13	Data book finalisation (built progressively)	PQP	Data book	A/H		H
14	Handover to the next operation - Layerworks	Data Books Index & contents	Hand over certificate	A/H		H

Prepared by:	Approved by:	H = Hold		
Name:	Name:	A = Action		
Signature:	Signature:	S = Surveillance		
Date:	Date:	T = Test		

Appendix D: PQCP - Minor Concrete Works

Contract: XXX PQCP: Minor concrete works – lined concrete drain

No	Activity	Conformance Criteria, Specifications and Standard References	Record Type	Intervention Levels		
				Contractor	Laboratory	Engineer
1	Obtain approved drawings	Drawings signed by Consulting Engineers	Drawings signed by Consulting Engineers	A/H		H
2	Establish survey points	Instruction from Engineer	Engineer's instruction	A/H		H
3	Submit certificates for concrete material	SSRBW & Lab. Testing Manual	Material certificates	A/H		H
4	Obtain mix design approval	SSRBW & Lab. Testing Manual	Engineer's instruction	A/H		H
5	Survey setting out	SSRBW & Lab. Testing Manual	Survey data sheet	A/H		S
6	Trimming of excavation for lined concrete drain	SSRBW & Lab. Testing Manual	Excavation sheet	A/H		S
7	Compaction of excavation to specified compaction	SSRBW & Lab. Testing Manual	Density sheet	A/H	T	H
8	Formwork erection	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
9	Pre- concrete inspection	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
9.1	Check reinforcing to drawing and bending schedule	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
9.2	Check concrete mix specified	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
9.3	Check verticality of shutter	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
9.4	Check stop-ends and prepare for joints	SSRBW & Lab. Testing Manual	Pre concrete inspection	A/H		H
10	Casting concrete and testing	SSRBW & Lab. Testing Manual	Delivery/ dispatch notes	A	T	S
10.1	Slump testing	SSRBW & Lab. Testing Manual	Slump test sheet	A/H	T	S
10.2	Concrete cube sample testing	SSRBW & Lab. Testing Manual	Concrete cube sheet	A/H	T	S
11	Post concrete inspection	SSRBW & Lab. Testing Manual	Post concrete inspection	A/H		S
11.1	Dimensional check	SSRBW & Lab. Testing Manual	Post concrete inspection	A/H		S
12	Punch list items (if necessary)		Punch list	A/H		S
13	Data book finalisation (built progressively)	PQP	Data book	A/H		H
14	Handover	Data Books Index & contents	Hand over certificate	A/H		H

Prepared by:	Approved by:	H = Hold		
Name:	Name:	A = Action		
Signature:	Signature:	S = Surveillance		
Date:	Date:	T = Test		

SSRBW (1999) & Lab. Testing Manual (2000) MoW

Appendix E: PQCP - Pavement Surfacing

CONTRACTOR X

PROJECT PROJECT CONTROL PLAN

CONTRACT NO.:

Ref :

CONTRACT NAME:

Section: All — Also refer Project Specification : — Date :

Pavement Surfacing

Key:
IRB - Inspection Request Book — **H -** Hold (not to proceed without necessary approval)
E - Engineer — **R -** Request Inspection
C - Contractor — **S -** Surveillance
L - Laboraroty — **T -** Test
SR - Submit Results

Note : **Surveillance (S), Test (T) and Hold (H) Points as indicated on Inspection and Test plans are to be recorded in the Inspection and Test Request Book**

Item No	Activity	Drawing No.	Conformance Criteria, Specification and Standard References	Frequency	Record Type	Intervention levels C	Intervention levels L	Intervention levels E	Remarks
1	**Base**								
1.1	Obtain Approved Drawings		Approved Drawings	Initial		R/H		H	
1.2	Survey/Setting out		SSRBW 1999, MoW	Each Section	Survey Report	R/H		H	Submit Report
1.3	Inspect Base		SSRBW 1999, MoW	Each Section	Layerworks Sheet	R/H		S/H	Levels, Density,CBR
1.4	Repair Base where required		SSRBW 1999, MoW	Each Section	Layerworks Sheet	R/H	T	S/H	Levels, Density,CBR
2	**Prime**		SSRBW 1999, MoW						
2.1	Survey/Setting out		SSRBW 1999, MoW	Each Seaction	Survey Report	R/H		H	Submit Report
2,2	Approve Materials		SSRBW 1999, MoW	Routine	QC Report	R/H	T	H	Submit Results
2,3	Prepare Layer		SSRBW 1999, MoW	Each Seaction	QC Report	R/H		S/H	
2,4	Pretreatment for Existing Surfacing		SSRBW 1999, MoW	Each Seaction	Layerworks Sheet	R/H		S/H	
2,5	Check Weather		SSRBW 1999, MoW	Each Seaction	Layerworks Sheet	R/H	T	S	
2,6	Apply Prime		SSRBW 1999, MoW	Each Seaction	Layerworks Sheet	R/H		S/H	Submit Report
2,7	Testing		SSRBW 1999, MoW	Each Seaction	Test Sheet	R/H	T	S/H	
3	**Single Seal**		SSRBW 1999, MoW						
3.1	Survey/Setting out		SSRBW 1999, MoW	Each Seaction	Survey Report	R/H		H	Submit Report
3.2	Approve Materials		SSRBW 1999, MoW	Routine	QC Report	R/H	T	H	Submit Results
3.3	Precoating		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	
3.4	Inspect Prime		SSRBW 1999, MoW	Each Seaction	QC Report	R/H		S/H	
3.5	Apply Bitumen and Aggregates		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	Submit Report
3.6	Roll Aggregates		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S	
3.7	Fog/Mist Spray		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	Submit Report
3.8	Handover		SSRBW 1999, MoW	Each Seaction	QC Report	R/H		H	
4	**Double Seal**		SSRBW 1999, MoW						
4.1	Survey/Setting out		SSRBW 1999, MoW	Each Seaction	Survey Report	R/H		H	
4.2	Approve Materials		SSRBW 1999, MoW	Routine	QC Report	R/H	T	H	Submit Results
4.3	Precoating		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	
4.4	Inspect Prime		SSRBW 1999, MoW	Each Seaction	QC Report	R/H		S/H	
4.5	Apply Bitumen and Aggregates 1st Seal		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	Submit Report
4.6	Roll Aggregates		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S	
4.7	Apply Bitumen and Aggregates 2nd Seal		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	Submit Report
4.8	Roll Aggregates		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S	
4.9	Fog/Mist Spray		SSRBW 1999, MoW	Each Seaction	Surfacing Sheet	R/H		S/H	Submit Report
4.10	Handover		Data Books	Each Seaction	QC Report	R/H		H	
8	**Final Inspection of each section completed**		SSRBW 1999, MoW	Each Seaction	Hand Over Certificate	R/H		H	Snag

QCP Approval

1. QCP Prepared by : — Position: — Signed: — Date:
2. QCP Approved by — Position: — Signed: — Date:

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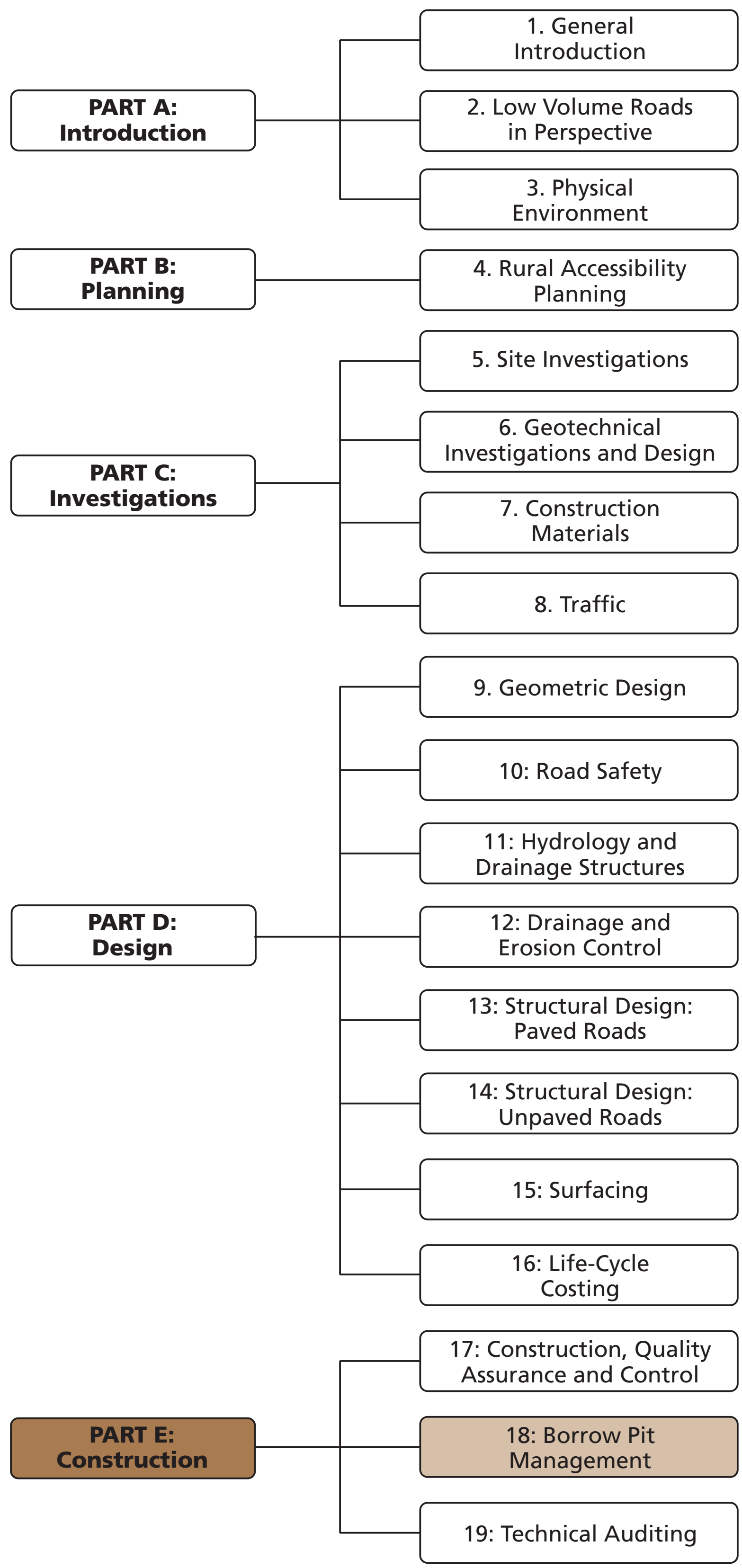

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18.1 INTRODUCTION

18.1.1 Background

The identification and development of good sources of pavement construction material at regular intervals along the length of a LVR is essential for achieving cost effective construction and ongoing maintenance operations.

Approximately 70% of the construction cost of a typical LVR may relate to pavement materials production and supply. Also, aggregate replacement costs are often as high as 60% of the maintenance costs of an unpaved road. There are therefore significant cost-benefits that can be achieved by implementing improved borrow pit management procedures and material supply strategies.

Proper management of material sources is essential to ensure that the best quality available materials are used in the top layers of the pavement structure. The efforts made to locate these often scarce materials for road base are of little use if this material is wastefully used in earthworks layers. Too often (and in particular for borrow pits located for low volume roads) borrow pit excavation is carried out with only the plant operator present and no correct supervision. In many cases this results in good quality gravel getting contaminated and having to be spoiled. Good management of materials (including skilful supervision during all operations in the borrow pit) is therefore a critical operation in LVR construction.

An awareness of the potentially damaging effects (negative impacts) that borrow pits and quarries may have on the local environment is also required so that mitigating measures may be incorporated in the tender documents for enforcement during the construction operations.

18.1.2 Purpose and Scope

The main purpose of the chapter is to provide the basic principles of good borrow pit development, including the application of appropriate management strategies with the objective of encouraging cost effective selection and development of natural resources for LVR construction. In so doing, the chapter:

- Encourages improved record keeping relating to material resources and their utilisation. In particular, it provides guidelines on the establishment of material resource inventories and databases and promotes the benefits that may result from the use of such databases to improve materials management and design of material supply strategies.
- Highlights environmental and social issues associated with road material source development.
- Reviews possible negative impacts and provides guidelines in terms of gravel sources that may be implemented to prevent or reduce adverse effects on local populations and the environment.

The chapter provides a concise overview of the importance of materials and borrow pit management with a focus on borrow pit planning and preparation, material extraction (both by the use of labour based methods and plant), stockpiling, processing and control. Record keeping and materials data management are also briefly addressed. The chapter does not deal with the investigations required prior to the establishment of a borrow pit, such as prospecting, resource quantity estimation and borrow pit evaluation. Record keeping and materials data management are also discussed.

18.2 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

18.2.1 General

The development of borrow pits and quarries to supply road construction material may impose significant negative impacts on the local environment and its inhabitants. Therefore appropriate precautions must be taken in the planning, development and operation of all borrow pits.

In relation to low volume road construction and maintenance, financial considerations are a major factor in all engineering decisions. As a result, the costs associated with minimising the environmental impact need to be in proportion to the funds available.

The following documents should be consulted prior to opening a quarry or borrow pit:

- Environmental Code of Practice for Road Works, February 2009. Tanzania.
- Road Sector Compensations, Resettlement Guideline, 2009. Tanzania.
- The Mining Act of 1998 and its regulations of 1999. Tanzania.
- Mineral Sector Environmental Impact Assessment (EIA) Guidelines of October 2014. Tanzania.

18.2.2 Types of Material Source and Environmental Impact

There is a need to be aware of both the potential negative and positive aspects that may be associated with different types of borrow pit or quarry development. This is particularly relevant when there may be a choice of developing one or other type of resource.

Environmental impacts may be associated with extraction of the following main types of road building materials:

- River bed gravels.
- Near-surface natural gravels (duricrusts, residual and transported soil).
- Alluvial terrace deposits.
- Hill-slope material (weathered and/or closely fractured rocks).
- Hard rock.

River bed gravel borrow pits: The development of river bed gravel sources is a sensitive environmental issue. Negative impacts are typically associated with over-exploitation and careless extraction. The intermittent extraction of small quantities of sand and gravel from a large dry river bed is probably the least damaging form of material supply. This is because no productive land is lost and the deposits will be replaced during future high water flows. Problems arise when the quantities of material extracted greatly exceed nature's ability to compensate for the loss. If there is any doubt about acceptable excavation volumes, then expert advice should be obtained.

One serious consequence of over-extraction close to bridges is loss of gravel around abutments and piers leading to scour damage. Gravel should always be extracted at a minimum distance of 300 m downstream of bridges. If excavation is to be carried out in the river, then care must be taken to limit impacts on the water quality by fine sediment or, for example, by fuel pollution. There will typically be communities downstream who use the river water or perhaps obtain food from the river.

Beach gravel borrow pits: Beach deposits within the tidal zone usually undergo rapid natural replacement (recharge). However, this may be associated with long shore drift (regional movement of deposits along a shoreline), in which case excessive extraction of these deposits may lead to serious depletion of beach materials at other locations along the shore. As a rule, extraction from the tidal zone should be restricted to stockpiling of small quantities of materials at intervals throughout the year with monitoring to ensure that this activity does not adversely affect other beaches. If larger scale extraction is required then expert advice should be sought, particularly if excessive extraction could have any adverse effects on local communities relying on tourism or other coastal activities. Excavation of beach deposits from above the high water level may have a long term effect on the coastal environment, particularly if the pit becomes flooded and swampy. In such a case it may become a health hazard for the local population (e.g. breeding ground for malarial mosquitos).

Near-surface natural gravel borrow pits: LVR construction may rely heavily on winning construction materials from relatively thin and discontinuous, near-surface gravel deposits. These deposits include calcrete, as shown in Figure 18-1, residual quartz gravels and alluvial gravels.

Figure 18-1: Near surface natural gravel borrow pit containing calcrete (Pemba island)

Easily extracted deposits close to existing unpaved roads are becoming exhausted in many areas. This is now resulting in pressure to exploit marginal quality deposits in poor locations.

The working of deposits less than 2 m thick should be subject to an environmental impact review.

Working thin deposits involves a poor ratio between land take and resource size. This may become environmentally unacceptable in the following situations:

- In populated and cultivated areas, where pit development may result in permanent loss or down grading of productive land.
- In areas of natural beauty and or habitats justifying a high level of conservation.
- In areas where topsoil is thin and cannot be salvaged to enable adequate pit reinstatement and prevention of soil erosion.

In such circumstances consideration must be given not only to initial economics of extraction, but also to long term economic and environmental consequences. Hauling material longer distances from pits with less adverse environmental impacts could to be considered.

Hill-slope borrow pits: The development of borrow pits in mountainous and hilly terrain can have significant damaging effects on the local environment, if they are not carefully located and operated in an environmentally sensitive way.

Most hillside borrow pits exploit weathered and fractured rock materials. Topsoil is usually thin and stony and as a result difficult to salvage and replace.

Excavation of natural gravel from steep slopes can cause serious slope stability hazards that may endanger the workforce, road users and people living downslope. Slope failures on valley sides can result in heavy sediment pollution of rivers. Carefully constructed benched excavations are usually required.

On some hill roads there is a desire to open a large number of small pits (less than 3,000 cu.m) at regular intervals. This can be very destructive in the short and long term. It is better to identify a few well located borrow sites with relatively large potential resource sizes at longer intervals. Thus, short haulage should not be a factor that overrides environmental considerations in hilly terrain.

If borrow pit development must be adjacent to the road, efforts should be made to locate sites where extraction will improve the road alignment.

Short haulage should not be a factor that overrides environmental considerations in hilly terrain.

Hard rock quarries: Environmental considerations are particularly important at the planning stage when construction materials need to be obtained from hard rock quarry sources. The following guidelines apply to quarry planning:

- Hard rock deposits rarely occur in isolation, therefore it is necessary to check the geological maps and consider environmental effects when looking for the best site for development.
- Quarry sites should be located as far away from settlements as possible. Quarry operations will produce noise, vibrations and dust that could impact on nearby residents even if controls are imposed. Steep quarry faces are a hazard to people and livestock, therefore fencing and site security measures are essential.
- The arrangement of the quarry operations should be designed to cause least visual impact on the landscape and to allow for future reinstatement. Natural vegetation (trees and bushes) should be preserved around the quarry.
- Quarry site development costs are high and negative environmental impacts significant. Therefore, quarry sites should be fairly widely spaced and located so that there is the potential to supply large quantities of material over a long period of time to various sites. Haulage of aggregates, between hard rock quarries, for distances of greater than 20 km is usually economically and environmentally justified (when natural gravel deposits are not available).
- Crushing and screening plant and stockpile areas need not be located directly adjacent to the actual quarry excavations. Visual intrusion may be significantly limited, at no great additional cost, by processing aggregates at a concealed location a short distance from the outcrop.

18.2.3 Borrow Pit Planning

Borrow pit location: Borrow pits and quarries should be located in such a way that they cause a minimum of environmental damage and impact on the local environment.

Typically, the following guidelines apply, subject to the over-riding requirements of the various proclamations dealing with environmental and social impact assessment issues:

- Borrow pits should not be within 500 m of a watercourse or human habitation.
- If possible, pits should be on land that is not suitable or currently used for cultivation and is not wooded.
- Areas of local historical or cultural interest, cemeteries or grave sites, classified forests, public or private buildings, trunk or regional roads, railroads, water pipelines should be avoided. If established, borrow pits and quarries should be at least 500 m of from the elements described.
- Wherever possible, borrow pits should not be visible from the road. Development should be designed to minimise visible damage to the landscape.
- There should only be one agreed access road to each borrow pit site.
- Borrow areas should not be on steeply sloping ground if it can be avoided.

Land take: Land used for material sources should always be minimised as far as possible and fair compensation should be paid to the owner according to the regulatory framework. This applies equally to both permanent and temporary land take. No land should ever be used without formal authorisation.

Pit working plan: Borrow pits should never be opened in an uncontrolled manner – i.e. a proper working plan must be in place before any excavation begins. The plan must include:

- Arrangements for consultation with affected parties.
- A compensation agreement signed with the land user/owner, including agreed borrow pit access arrangements.
- The extent of each borrow pit/quarry, and possible future extension, clearly demarcated on the ground.
- An outline of the direction, timing and depth of working area, including suitable locations for stockpiling the topsoil and overburden materials.
- Provision for adequate drainage and implementation measures for sediment control, re-soiling and re-vegetation.
- Provisions for safety of workers at the borrow pit and the neighbouring community.
- A reinstatement plan which gives details of the final shape of the borrow pit and the method of achieving it, including possible Complementary Intervention plans for the affected community.

18.2.4 Borrow Pit Development

Borrow pit location: The first borrow pit development activity is the clearing of vegetation and the stockpiling of topsoil for re-instatement. Topsoil is the organic soil typically occurring as a surface layer, normally 150 mm to 200 mm thick.

The future productivity of the restored land is totally dependent on careful replacement of the topsoil layer. Failure to adequately return topsoil materials will have a long term damaging effect on the environment and on the future ability of the land user/owner to earn a living from his/her land.

Any overburden soil (soil that rests on the gravel deposit and under the topsoil), which is important for reinstatement of borrow pits, should be stockpiled separately and overburden stockpiles should be located where they will not interfere with future pit extensions. They should be shaped in order to best resist the erosive actions of rainfall.

Borrow pit layout: Restoration of land used for borrow pits and quarries should be considered from the start of excavation. The borrow pit layout should be designed to enable easy reinstatement.

Unnecessarily high and steep slope faces should be avoided both to avoid reinstatement problems and to minimise danger to people and livestock.

Reduction in visibility of an excavation can often be achieved by identifying the best orientation of the working faces. However, despite the environmental desirability of a particular direction of working, the geological structure may determine the safest and most effective method of excavation and this will sometimes be the more important factor.

Borrow pit operation: The actual extraction and processing of pit or quarry materials can have several adverse effects on the local environment. The most significant of these is the creation of noise, air borne dust and the pollution of water courses.

- **Noise** may be generated by the excavation process. It is important to limit noise as far as possible both for the local residents and the workforce who should be provided with ear protectors and dust filters.
- **Dust** generated during the extraction of materials can be a health hazard causing respiratory diseases, it can cause of accidents in the pit and can inhibit the growth of plants. Care should therefore be taken to minimise dust emissions. The workforce should be provided with dust filter masks. The main sources of dust and appropriate methods of reducing emissions are listed below:
  - Drilling. Dust suppressers can be fitted to drilling rigs.
  - Movement of traffic. Dusty access/haul roads should be watered regularly during dry weather using water bowsers (trucks or towed by tractors). Dumping of dryaggregates in stockpiles. Material processing plants should be fitted with water sprays when stockpiling: this will not only suppress dust but also prevent aggregate segregation.
- **Water course pollution** may be associated with sediment entering streams from the borrow pit excavation. This can be prevented by constructing bunds to divert surface water away from the excavation and by ensuring that any water leaving the excavation passes through a settlement pond. Any re-fuelling or other plant maintenance activities carried out in the borrow pit should be controlled to avoid spills and water contamination. Any accidental spills should be cleared up immediately and disposed of safely.
- **Safety** aspects such as access to borrow pits and quarries with steep and potentially dangerous working faces must be controlled to avoid accidents involving local people and livestock. This may require construction of fences with warning notices and the posting of guards.

For the safety of the work force, dangerous loose faces should be made stable. Workmen and plant operators should receive suitable training that covers safe working practices in borrow pits and quarries.

Appropriate safety clothing should be provided and may include hard hats, protective boots and road safety vests.

Special care must be taken when blasting takes place in quarries. Quarries should not be located close to settlements. Only suitably trained and qualified staff should handle explosives. Storage of explosives must comply with internationally recognised standards of practice in terms of security and safety. More specific guidance is given in the Environmental Code of Practice for Road Works (MOID, 2009).

18.2.5 Borrow pit / quarry reinstatement

During the planning phase (before appointment of a contractor), the possible use of the borrow pit/ quarry after the construction phase should be discussed with the local community. For instance, many communities like to use the borrow pit/quarry as a collector of water for both human and animal consumption. Whether the borrow pit/quarry area should be fenced or not needs to be discussed and agreed, as the stored water can be hazardous for children (drowning). Ponded water also increases the potential for mosquito-borne diseases (Figure 18-2).

Before any use by the community, the borrow pit must be cleaned up properly and shaped according to its use.

The work required must be adequately described in the tender documents so that the contractor can price the work accordingly.

Figure 18-2: Children exposed to risk of drowning and water-borne disease

Before fully reinstating a borrow pit/quarry, the need for materials in future road maintenance should be assessed and appropriate quantities of gravel stockpiled for this purpose.

The environmental damage caused by inappropriate extraction and rehabilitation practices can extend over a wide area and may only become apparent after project completion. Hence, the borrow pit/quarry. preparation work must be carried out carefully and in such a way that the topsoil is stockpiled separately from overburden soils and shaped in such a way as to minimise any loss by erosion, wind and rainwater.

Reinstatement should follow simple procedures which minimize the limitations the construction activity has placed on future use of the land and is described below:

- Shape mounds and steep banks to a slope that is found naturally in the landscape. (steepest 1V:3H).
- Spread the overburden and topsoil evenly back into the pit in order to promote growth of vegetation.
- Ensure that the area is self–draining.
- Re-vegetation and re-forestation if required.

18.3 BORROW PIT PREPARATION

18.3.1 General

The preparation and arrangements that are typically necessary prior to material excavation, including administrative/planning activities and physical site preparations are often neglected. This is often the case for borrow sites that are opened for low volume roads.

Borrow pits for the supply of low volume road materials are usually not in continuous use. In the case of gravel wearing course sources, 3 to 5 years will typically occur between regravelling operations and paved roads will usually only require rehabilitation after more than 10 years. This should be taken into account during planning. The area stripped should only be large enough to provide aggregate for the immediate needs, with some stockpiling of maintenance materials.

Site survey: In the case of small borrow pits in remote uncultivated areas, it may be sufficient to prepare pit sketches with important dimensions determined by tape measure or GPS coordinates using a hand-held GPS. When a borrow pit will affect cultivated land and local inhabitants then an accurate site survey should usually be made and a plan prepared at a scale of about 1:500 to 1:1000 depending on the size of the proposed borrow pit and nature of the site.

18.3.2 Borrow Pit Working Plan

Arrangements should have been made for consultation with affected parties and a compensation agreement reached with the users/owners. Access arrangements should also be agreed.

Borrow pits must be opened and operated in a controlled manner taking into account the considerations summarised under the working plan arrangements in Section 18.2.3. Other issues that must be considered include:

- Undertaking a survey for record purposes to define agreed limits of working area and time.
- Defining the direction, timing and depth of working.
- Ensuring that borrow pits are excavated to a regular width and shape. As far as possible, all existing trees, hedges, fences etc. should be preserved.

18.3.3 Access Roads

The following recommendations relate to the provision of access roads to borrow pits:

- Access roads should be designed to be strong enough to carry the expected haulage traffic without significant deformation or maintenance. Economies of construction may easily be outweighed by increased haulage costs.
- Adequate provision should be made for drainage in order to prevent soil erosion, sediment pollution or road closure due to flooding.
- Whenever possible, only one access per exploitation surface should be created.
- The width of the access road should not exceed 2.5 times that of the larges vehicle to be used for the transport of materials.
- Borrow pit access roads should be aligned in such a way that they cause minimum disturbance to the local population and the environment. They should be located at a safe distance from permanent dwellings and if necessary, fencing should be provided to protect local people and livestock. Figure 18-3 shows a sketch of an undesirable access route and desirable access road.

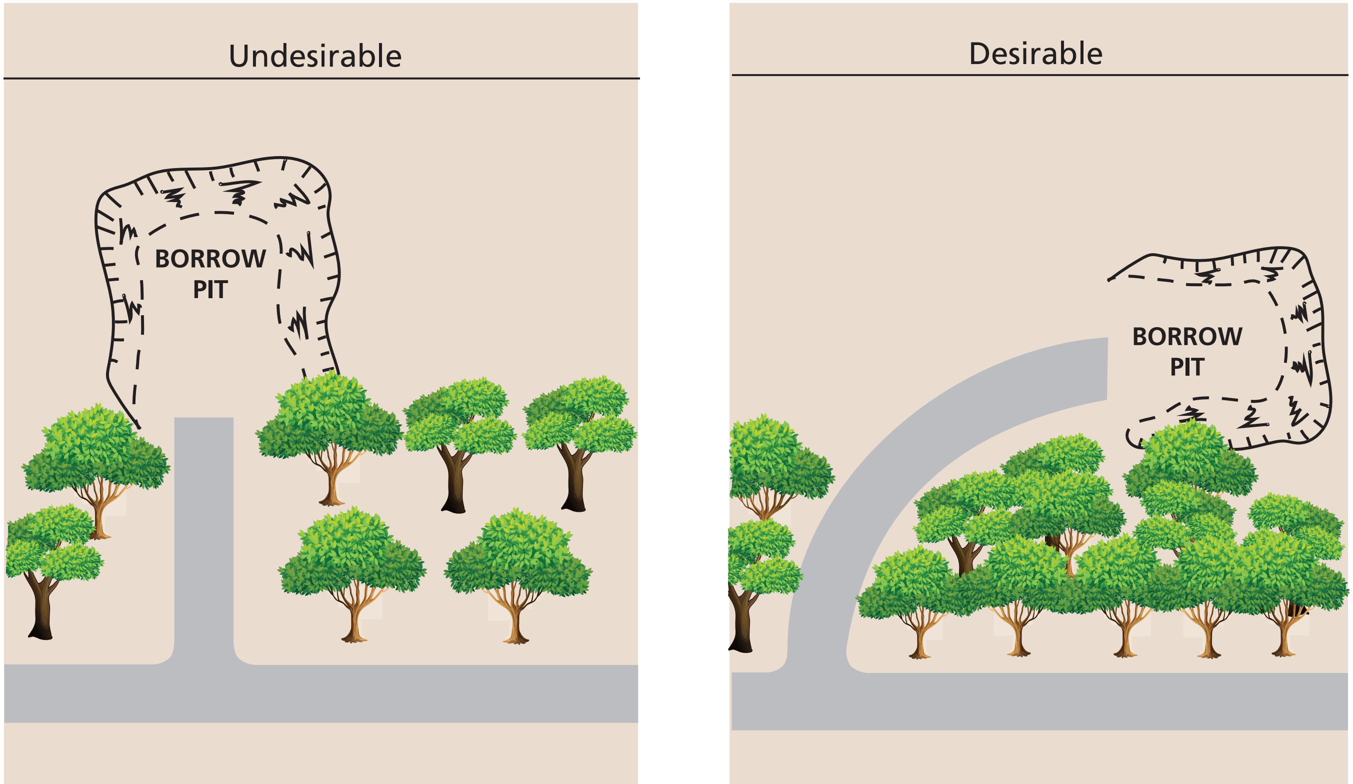

Figure 18-3: Undesirable and desirable access road locations

Source: Roughton International (2000).

18.3.4 Site Clearance

In flat to rolling terrain road construction materials often occur in thin gravel seams beneath a similar thickness of topsoil and subsoil (overburden). As a result, excavation of the gravel will require a relatively large area of site clearance to obtain a relatively small quantity of construction material.

In hilly to mountainous terrain exploitable deposits are often fractured rock materials occurring beneath very thin topsoil layer that rests on a variable depth of residual soil and highly weathered rock.

In both situations great care needs to be taken during the site clearance operations to expose the gravel bank or the rock materials, otherwise effective pit reinstatement may not be possible and significant environmental damage will result. Many current practices employed in respect of site clearance for borrow pits supplying materials are typically very poor. In particular, the following bad practice often occurs.

Bush clearing is often carried out by burning, prior to topsoil stripping. However, this practice removes organic matter and kills useful bacteria in the soil that assist in producing the required soil nutrients. If uncontrolled, extensive damage due to fire may affect the surrounding country side.

- The removal of topsoil and sub-soils is often carried out as one operation. This results in complete destruction of the fragile top soil.
- Heavy plant is frequently used to remove, stockpile and replace surface soils. This can cause soil compaction that will reduce future agricultural productivity.
- Site reinstatement often involves bulldozing the mixed surface soils back into the excavation. This practice can result in rocks and boulders being strewn across the surface. The overall effect is severe degradation of the agricultural potential of the land.

- In mountainous terrain disposal of overburden soils is sometimes carried out by side tipping downslope. This degrades the agricultural potential of the hill-slope and frequently leads to slope instability (landslides that may involve just the spoil, or the spoil and the underlying weak soils).

Removal of vegetation: Vegetation clearance is often carried out by bulldozer when site growth comprises bush and trees. This can cause densification of the surface soils and should be avoided if possible. Manual removal of vegetation is the least damaging form of site clearance and should be used when manpower resources are available.

During site clearance any shrubs that would be suitable for any later use should be identified and protected. Transplanting or taking cuttings of the shrubs will preserve them for future replanting.

Removal of top soil, sub-soil and other overburden: Guidelines on appropriate procedures for topsoil removal, overburden soil stripping and pit reinstatement have been prepared by TRL (1999). Figure 18-4 shows the recommended procedure diagrammatically. The process includes careful removal of topsoil and its stockpiling. This is followed by extraction of identified sub-soil layers separately into stockpiles followed by borrow pit extraction.

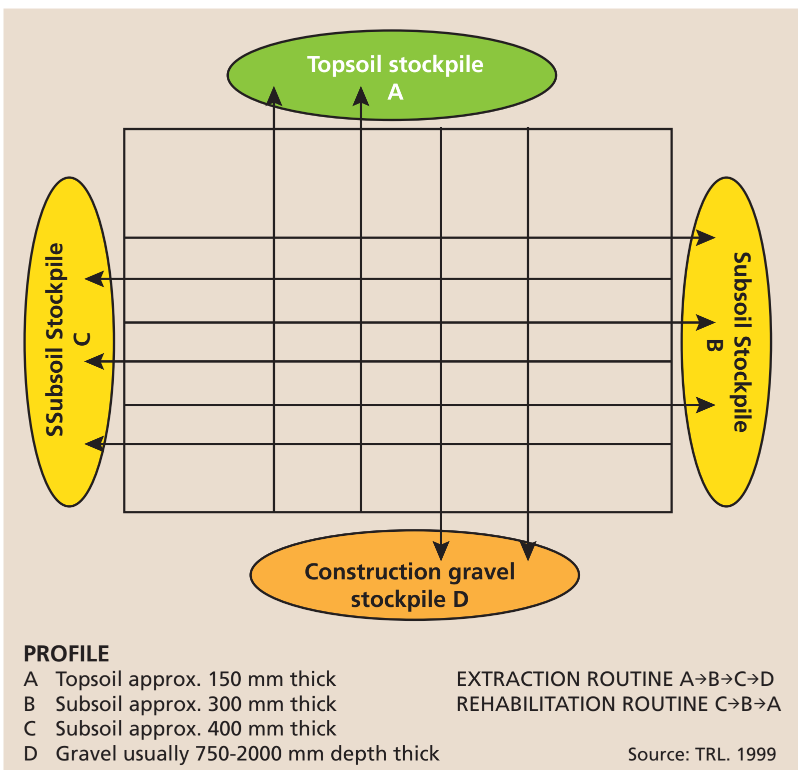

Figure 18-4: Recommended procedure for removal of overburden and stockpiling

Source: TRL (1999).

The following recommendation applies to sub-soil and overburden stripping:

- The average thickness of overburden soils should be accurately known from site investigations and must be shown in the borrow pit plans. The overburden should be stockpiled in such a way that it does not interfere with the drainage of the adjacent land area.
- In mountainous terrain where there is limited space for storage of overburden materials, the soil should be hauled to a suitable disposal site or to a stockpile area located in stable terrain.
- Side tipping of overburden soils on steep slopes besides the road should never be permitted.

18.3.5 Layout of Shallow Borrow Pit

The working of relatively thin near-surface deposits, whether the borrow pit is operated by labour-based methods or machine-based methods, involves a poor ratio between land take and resource size. Hence, these borrow pits have the potential to create significant adverse effects on the environment. Borrow pit layout and method of borrow pit operation can therefore help to reduce these negative impacts on the environment. Figure 18-5 shows a small quarry operation using labour-based methods where the aggregate is crushed by hand. In contrast, Figure 18-6 shows shallow borrow pit excavation using machine based methods.

Shallow gravel borrow pits using labour based methods.

The layout of a borrow pit exploiting near surface deposits will be strongly influenced by whether it is to be worked by labour-based methods or using mechanised plant.

The following considerations should be taken into account when planning borrow pit development using labour-based methods:

- The optimum height of a face to be worked with a pick is about 700 mm. The most efficient borrow pit layout should avoid multiple handling. When possible, excavation bays should be about 3.5 m wide so that trailers/trucks can be backed in for loading.
- Provide sufficient space to allow tractors and trailers or trucks to manoeuvre in and out of loading positions without difficulty. It may be desirable to have both access and exit routes into the working area.
- Ensure that the borrow pit layout will not be subject to the accumulation of water and the development of soil erosion problems.
- In hillside borrow pits, emphasis should be given to allow easy loading of the material and ensure the safety of the workers.

Figure 18-5: Aggregate crushed by LBM

Shallow gravel borrow pits using machine-based methods: When mechanised extraction methods are employed the main influences on the borrow pit layout may be somewhat different from using labour-based methods, as follows:

- The working face should be arranged in such a way that the excavation plant can operate efficiently. For example, bulldozers work best down a slightly inclined face, whilst backhoes usually operate most efficiently in a near vertical face several m high.
- The need for mixing or to avoid mixing of different deposits (strata), may influence both borrow pit layout and the selection of appropriate excavation plant.
- Some stockpiling of excavated materials is typically associated with plant based extraction. Therefore careful consideration needs to be given to the location of stockpile areas. They should not interfere with future development or extension of the pit and need to be arranged so that there is sufficient space for the efficient operation of loading plant and trucks.
- If processing of the excavated materials is required, careful consideration must be given to the area required for this as such operations will require considerable space i.e. blending two different stockpiles.
- Fencing is required to protect the local population and livestock when the borrow pit has hazardous steep faces. However, in shallow borrow pits fencing may not be required.

Figure 18-6: Shallow borrow pit excavation using machine based methods

18.4. BORROW PIT MATERIAL EXTRACTION USING LABOUR-BASED METHODS

18.4.1 General

The purchase and maintenance of equipment for materials extraction requires major foreign currency expenditure. Mechanised extraction can thus be relatively expensive: labour is usually readily available, inexpensive and can provide social benefits to the local community.

18.4.2 Geological Considerations

Geological conditions required for efficient labour-based material extraction and supply may only be viable when:

- Un-cemented gravel occurs beneath a relatively thin overburden cover.
- Exploitable deposits occur at frequent intervals close to the road. Typically, it is more efficient to haul materials by tipper truck when distances exceed 5-10km. This is due to the long travel time for tractor/trailer combinations and because it is difficult to load tipper trucks efficiently by hand labour.

Labour-based methods are most successful in areas where:

- There is a widespread occurrence of near-surface weakly cemented laterite or calcrete deposits.
- There are frequent exploitable river bed or river terrace gravel deposits.

18.4.3 Environmental Considerations

Labour based methods are sometimes used in mountainous terrain where there are roadside occurrences of suitably fractured residual rock. However, the development of frequent small borrow pits in terrain which is prone to soil erosion and slope instability is not good practice. In mountainous terrain it is better to open a limited number of carefully selected borrow pits in order to limit environmental damage. Large borrow pits and longer haulage distances then favour mechanised extraction and loading and tipper truck haulage.

18.4.4 Resources and Work Methods

A pit labour gang requires picks, crow bars, hoes, shovels and sledge hammers for effective excavation. In addition, they should be provided with drinking water, a first aid kit and head, hand and foot protection. Careful pit planning and preparation is particularly important in the case of material extraction using L-B methods. The plan should indicate some of the most important aspects of work to be considered when excavating and stockpiling in the pit. The minimum number of labourers will depend on the following:

- Size of the borrow pit site and quantity of overburden to be cleared. Large borrow pit operations may require between 40 and 60 labourers both for the site preparation and the subsequent excavation.
- Availability and capacity of the equipment used for hauling.
- Productivity rates, which will be influenced by the hardness of the in-situ material.

18.4.5 Gravel Excavation and Stockpiling

During gravel excavation and stockpiling activities, the following items should be considered in order to optimise the borrow pit operations:

- Gravel should be excavated, stockpiled and confirmed for use (QC testing) at least one day before it is required to be hauled.
- Gravel should be excavated and stockpiled alongside the loading bays to allow easy loading and avoid multiple handling.
- Where possible, loading bays should be constructed to allow trailers to be backed in for loading.
- Ramps into the loading bays must not be too steep for tractors hauling loaded trailers.

In hill-side borrow pits, material should be excavated such that loading is easy (lower instead of uphill) and to ensure that working conditions are safe. It is also important to ensure that the labourers have sufficient space to work comfortably and safely.

Figure 18-7 shows details of a borrow pit development on flat land while Figure 18-8 shows details of the development of a hill-side borrow pit.

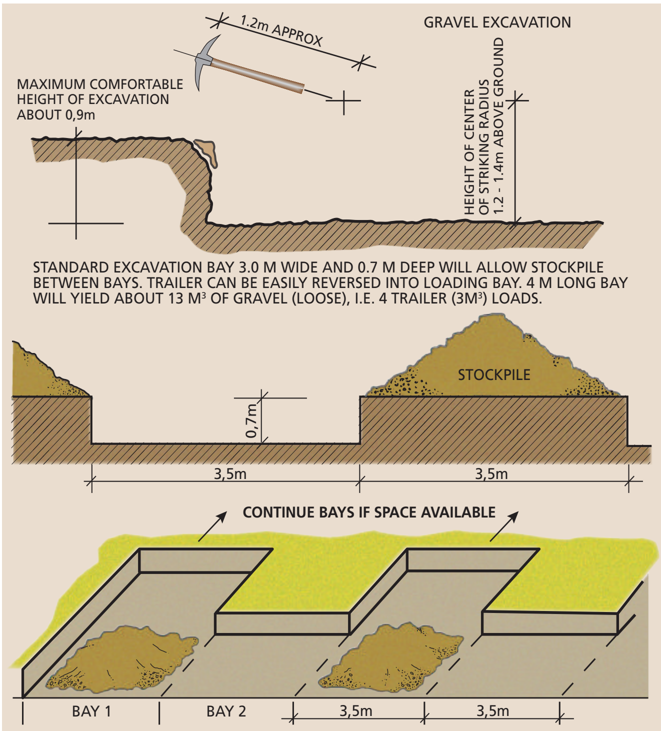

Figure 18-7: Sketch of a borrow development on flat land

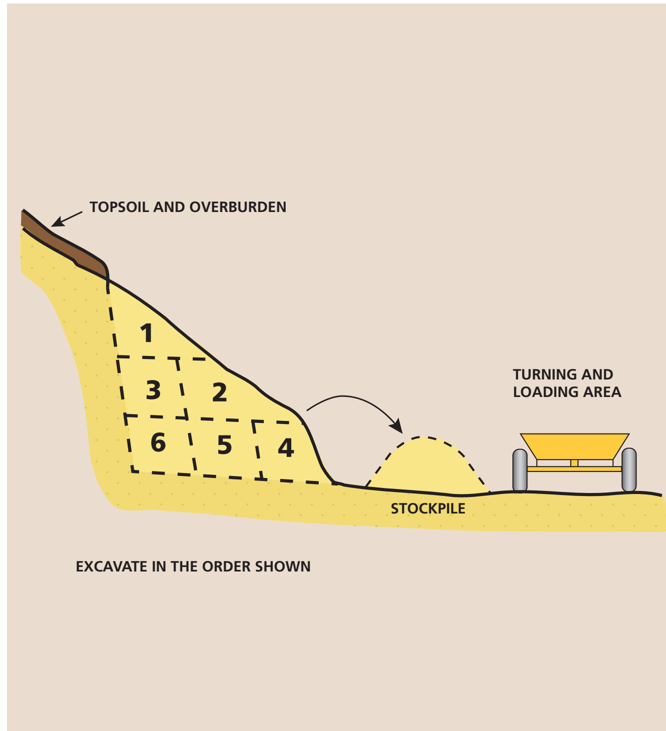

Figure 18-8: Sketch of a borrow pit development on land side land

Source: Roughton International (2000).

Loading: Where possible, trailers should be parked at the same height as, or preferably below, stockpiles for ease of loading. The loading gang should be divided into groups of 4 to 6 workers and these groups load the empty trailers in the same order as they arrive in the borrow pit. All of the trailers must be loaded to the correct load line (capacity) to facilitate uniform dumping of material.

Figure 18-9 shows details of the trailer loading height.

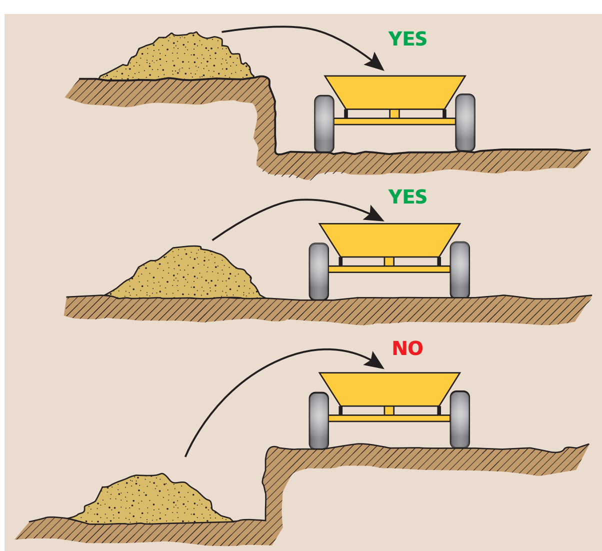

Figure 18-9: Sketch of trailer loading height

Source: Roughton International (2000).

Dumping and spreading of the material should commence from where the borrow pit access joins the road to be regravelled/constructed. Initially the road should be gravelled/constructed away from the borrow pit access in both directions simultaneously. With short hauls this reduces congestion at the loading sites. When hauls exceed about 1 km, gravelling/construction should continue only in one direction at a time. The advantages of this are:

- The tractors and trailers compact the material as they haul over the already laid material.
- Damage to un-gravelled road formation is minimised.
- Gravelling does not interfere with reshaping activities.
- Gravelling can recommence sooner after rainfall.
- Ideally one tractor works with two or three trailers to maximise the use of the tractors.

Figure 18-10 shows an ideal borrow pit arrangement using labour-based methods during trailer loading. However, ideally, if loading area allows for it, it may be beneficial to have both access and one exit route from the loading area.

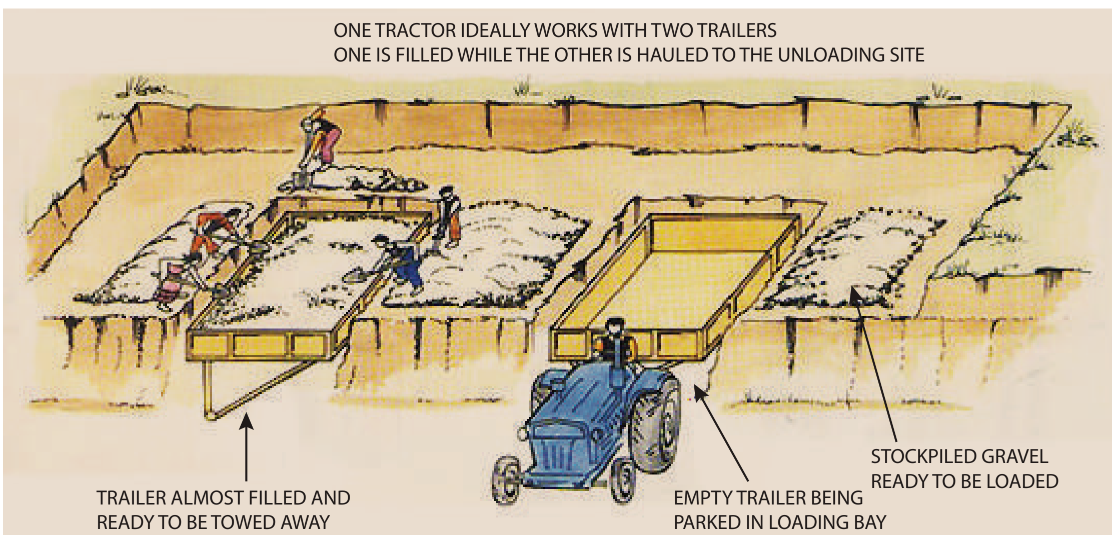

Figure 18-10: Ideal borrow pit arrangement for labour-based methods

Source: Roughton International (2000).

18.5. BORROW PIT MATERIAL EXTRACTION, MECHANISED PLANT METHODS

18.5.1 General

The economic extraction and production of borrow pit materials for construction purposes using plant depends on the correct selection of mechanised plant for the project and the careful programming of the works. Mechanised plant used for borrow pit excavation may only be suitable for larger projects or when the haul distance is long. The use of mechanised equipment has a production output much greater than when using LBM. However, the environmental impact may also be greater.

18.5.2 Excavation Planning and Plant Selection

The types of plant suitable for heavy, medium and light excavation work in gravel and rock are summarised in Table 18-1. Factors to consider when planning material excavation and use of mechanised plant include:

- Choose a method of extraction that produces the best quality “as dug” materials (i.e. does not generate a large proportion of oversize material that will be spoiled).
- If borrow pit materials are variable or inter-bedded, use plant and excavation methods that can produce a suitably mixed aggregate.
- Select plant that achieves an acceptable rate of material production; alternatively, programme stockpiling ahead of aggregate supply.
- When possible, use plant that can both excavate and load the aggregate.
- If aggregates are likely to deteriorate/segregate in the stockpile, try and combine excavation and supply activities.
- Carefully programme plant and borrow pit activities that require more than one type of plant (i.e. the dozer to strip overburden and the excavator to dig gravel for loading or stockpiling).
- Programme activities so that the plant does not stand idle in a borrow pit.

In order to ensure satisfactory plant utilisation/output in the borrow pit the following should be considered:

- All plant should be in a sound mechanical condition and well maintained.
- All operators should be adequately trained and experienced.
- All items of plant should be operated within the normal limits of their capacity. The plant on site should not be overworked.
- There must be adequate supervision in the borrow pits to ensure that appropriate extraction methods and procedures are being followed by all concerned.

Table 18-1: Suitability of plant for gravel/rock extraction.

Table 18-1: Suitability of plant for gravel/rock extraction

Method	Exavation			Comments
	Heavy	Medium	Light	
Drill and Blast	x			Pneumatic, top-hammer rotary percussive methods can be used for drilling small diameter blast holes.
Bulldozer ripping	x	x		Single tine used for very heavy ripping (poorly fractured rock) and multiple tines for medium ripping (fractured or weak rock). The corrected selection of tine, ripper arrangement and method of use will all affect the efficiency of excavation and the characteristics of the excavated material.
Bulldozer		x	x	Blade excavation of fractured rock may reduce oversize associated with ripping (when feasible). However, when ripping is not required, then use of plant that can excavate and load is desirable.
Grader			x	Typically not efficient for excavation, but may be required for mixing material in the pit or on the road.
Excavator		x	x	Versatile method of excavation and loading. Large selection of plant produced. Face excavation may allow effective mixing of beds.
Tractor backhoe			x	Rate of production may be limited, but might be adequate particularly if material is stockpiled.
Drag-line Excavator				May be required for excavating gravel from below the water table.
Wheel Loader			x	Ideal for excavating and loading loose gravel (after pit preparation).
Crawler			x	Usually not ideal due to lack of manoeuvrability on the tracks.
Scraper			x	Best suited for large scale earthworks operations, but will rarely be economical for low volume roads.

Source: Roughton International (2000).

18.5.3 Efficient use of Plant

The following gives a short description of the plant that is most commonly used for borrow pit extraction:

- Bulldozers.
- Excavators.
- Backhoes.
- Graders.
- Front end loaders.

Bulldozers: This is the most commonly used plant to extract gravel from borrow pits. However, it is not necessarily always the most suitable plant. With softer materials, the use of a dozer may be an “overkill’ as the material tends to get crushed under the tracks. Transport of dozers between the sites is slow and this may incur lost time and extra cost.

Crawler bulldozers are required when poorly fractured rock, weakly compacted rock or cemented gravels are to be extracted. Cutting and pushing downhill invariably improves the operating efficiency of bulldozer excavation, because the mass of the machine assists the process. Bulldozers may be used to push material up to about 150 m into a stockpile. However, their use is unlikely to be efficient for moving material over distances greater than about 150 m.

Bulldozers may be fitted with one or more ripper tines (shanks). The correct selection of tine, ripper arrangement and method of use affects the efficiency of excavation and the characteristics of the material being excavated. There are two basic types of ripper and several types of ripper tine (shank) and tip. They are:

- Radial ripper.
- Parallel ripper.

Refinements of the above two types of ripper are the adjustable radial and the adjustable parallelogram. These rippers have hydraulic controls to enable the operator to vary the tip angle while ripping. In very hard ground a single tine parallelogram ripper is usually the most effective arrangement.

Ripper tines and tips consist of two basic types, the straight and the curved. Straight tines provide the lifting action needed in tight, laminated materials plus the ripping ability in thick or slab type material. Curved tines work well in less dense material and require less ripping distance.

Efficient ripping for borrow pits: In order to maximise efficiency in ripping to produce road construction material, the following points should be considered as illustrated in Figure 18-11.

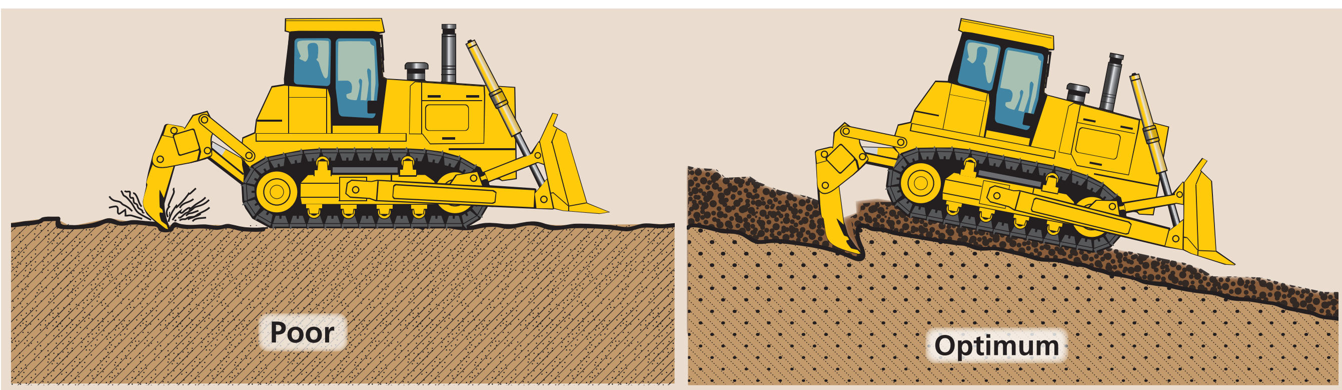

Figure 18-11: Poor and Optimum arrangement for effective ripping
Source: Roughton International (2000).

- Ripping should proceed downhill as far as possible to obtain the benefit from the weight of the machine.
- Care should be taken to arrange for ripping to make optimum use of natural fracture orientation in the material. Ripping will be most effective when carried out in the direction of inclined fracture planes (or bedding) as this tends to pull the tine into the ground.
- If the materials contain vertical laminations that run parallel to the cut, it is sometimes necessary to rip across the cut to obtain proper material break-up; ripping along the laminations may only produce deep channels in the material.
- Ripping as deep as possible will loosen the maximum amount of material, but ripping to partial depth may reduce the proportion of oversize material produced.
- Never remove all the ripped material before ripping deeper. Always leave a layer of at least 100 mm to 150 mm of ripped material to provide better traction. This also reduces track wear and minimises crushing of the surface materials.

Excavators: Excavators are versatile digging machines that are produced in a great variety of configurations. All excavators have boom-arm hydraulically operated digger buckets and are turntable-mounted on either a crawler track or with a wheeled chassis. The turntable can be horizontally rotated on the fixed chassis by a full circle. The reach of the boom arm for digging operations, either upwards or downwards, may be up to 6 m.

In order to maximise efficiency in excavator digging and loading operations the following guidelines apply:

- Greatest efficiency is achieved if borrow pit materials can be loaded for haulage as they are excavated. The excavator and trucks should be arranged so that the operating cycle is minimised. Ensure that there are sufficient trucks so that the excavator does not have to wait for loading. However, in highly variable materials this step often eliminates stockpiling, which can be a good homogenising process. It also removes the opportunity to test the material before placing it on the road.
- The size of the bucket should be appropriate for the particular conditions on site, such as the quantity and type of material to be loaded and the trucks used for haulage.
- The rake or angle of the bucket should be adjusted to suit the particular material. For easy digging and low cuts, maximum rake should be used. For harder digging and higher faces a smaller rake should be adopted.

Backhoes: A backhoe comprises a bucket or shovel mounted on a hydraulic boom and attached to the rear of a crawler or rubber-tyred tractor. Backhoes are well suited to excavating relatively loose material from above or below the level of its wheels into trucks. The reach for digging and loading is controlled by the length of the boom, but is usually up to 4 m.

Backhoes are easy to move between material sources and can also be useful for carrying out trial pit investigations during prospecting for borrow pit extension and or material prospecting.

Graders: In borrow pits graders will normally only be used for the following:

- Topsoil and loose overburden stripping.
- Mixing excavated materials (by windrowing).
- Maintenance of haulage and access roads.
- Reinstatement of topsoil.

For mixing purposes the blade is leaned forward at the top edge to enable the material to flow and rise freely.

Graders are frequently fitted with tines to allow hard road surfaces to be ripped to shallow depth, but graders are not generally efficient for borrow pit excavation work. Use of the ripping tines to aid extraction of borrow pit materials is liable to overwork the machine and also result in serious tyre wear.

Front end loaders: A front end loader is a bucket mounted on the front of a rubber-tyred or crawler tractor. Loaders are often used to excavate loose materials, such as river gravel. Tyres are likely to suffer excessive wear when excavating hard materials. Their main use in borrow pits is usually to load from the stockpiles into trucks.

Loaders may also be used to transport small quantities of material over short distances (up to 200 or 300 m). For instance, loaders may be used to transport ripped materials to the grizzly feed of a screen or crusher. For the efficient use of front end loaders, the following guidelines apply:

- Loaders are usually not efficient at winning material and loading at the same time. Loading from stockpiles is their normal use.
- Match the size and capacity of the loader to the trucks that they are working together with.
- Material should be stockpiled in such a way that a full bucket may be easily achieved.

18.6. STOCKPILING

18.6.1 General

It is often necessary to extract and store quantities of material either in the borrow pit or at a location close to the section of the road that is to be constructed or maintained.

Handling and stockpiling of aggregate needs to be undertaken with care to ensure that wastage of material is minimised and particle segregation does not occur. Segregation is the grouping together of similar sized particles that will result in pockets of coarse material with no fines in some places and pockets of fine material in others.

Sometimes there are different types of materials in the borrow pit and one may have the following options to utilise the material:

- Different stockpiles according to properties of the material.
- Mixing the two gravel seams in the borrow pit.
- Mixing the two material types on the road.

Stockpiling is an efficient way of reducing material variability because of the additional mixing that occurs during creation of the stockpiles and loading into the trucks for hauling.

18.6.2 Segregation

In order to avoid segregation in the borrow pit the following method is recommended (Figure 18-12).

During transportation of the materials, care should be taken to ensure that the loaded material does not segregate. On longer hauls, more segregation takes place and watering of the material is an option to avoid excessive segregation (and loss of dust during haulage).

18.6.3 Mixing

Mechanical blending involves the mixing of two different materials to achieve a quality that exceeds that of either of the two individual materials. It is often the most cost-effective option for increasing the quantity of an acceptable material quality or improving the quality of the final material. However, careful mixing of the various components being blended is essential. The commonly-used procedure shown in Figure 18-13 is seldom effective and is not recommended for a borrow pit.

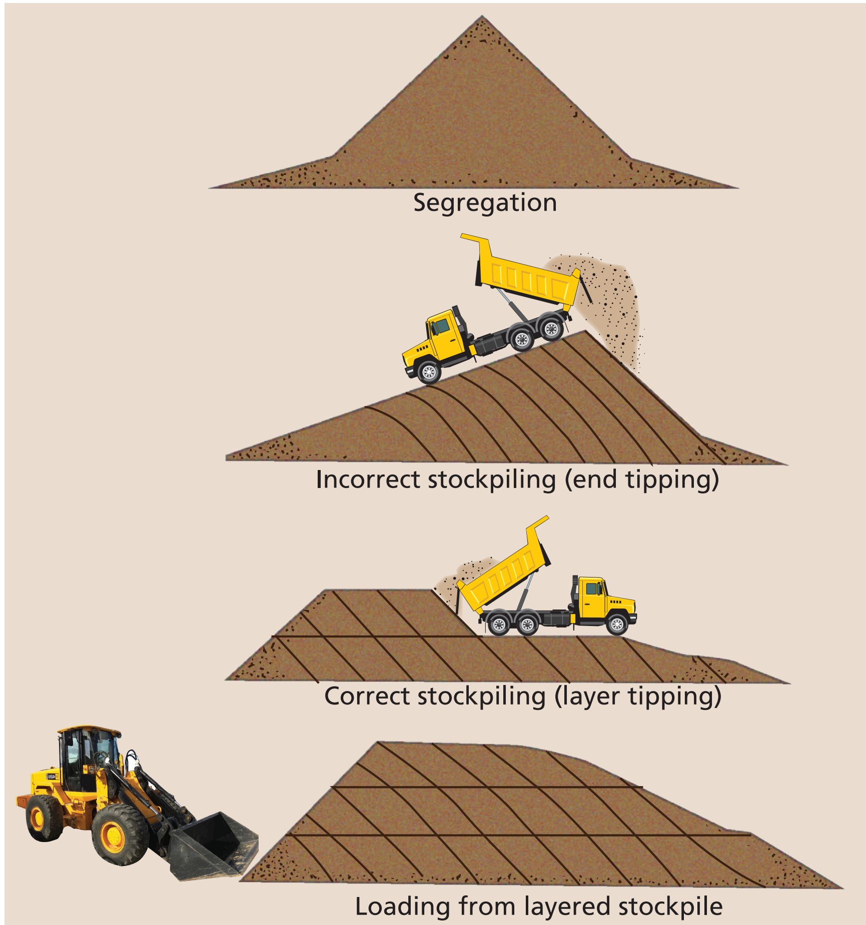

Figure 18-12: Correct and incorrect stockpiling to avoid segregation
Source: Roughton International (2000).

Figure 18-13: Not recommended method for blending in borrow pit
Source: SADC Guideline (2003).

When materials are mixed in the borrow pit the proportions will normally be less accurate than when mixed on the road. When mixing on the road materials are loaded from two different stockpiles in the borrow pit as shown in Figure 18-14.

Figure 18-14: Loading from two separate stockpiles in the borrow pit
Source: SADC Guideline (2003).

When materials are mixed on the road it is important that the correct quantity of the dominant material (i.e. the largest proportion) is evenly spread on the road and lightly compacted before spreading the subordinate material in the correct quantity on top. The two materials must then be carefully blended on the road before final compaction.

18.7. MATERIAL PROCESSING AND CONTROL

18.7.1 General

There are various methods of improving the quality of "as dug" gravel road construction materials. Common materials defects include the presence of oversize particles and too much or too little fine grained "binder" material. Various procedures and treatments can be used to improve the engineering characteristics of "as dug" materials. The selection of the appropriate treatment will be strongly influenced by the severity of the problem and usually must consider economic issues.

Typically, it is cost effective to use the best quality materials that are available. Good performance of the material on the road will result in significant cost savings that will nearly always outweigh the expense associated with processing. Unfortunately, some of the benefits are not easy to quantify and to take account of in a cost/benefit analysis.

18.7.2 Dealing with Oversize Material

Manual removal or breakage: The maximum aggregate size in a gravel wearing course should be no greater than half the layer thickness. This ensures that all large particles can be bound tightly in an interlocking structure as shown in Figure 18-15. The presence of oversize material in unpaved roads results in rough roads that are difficult to maintain.

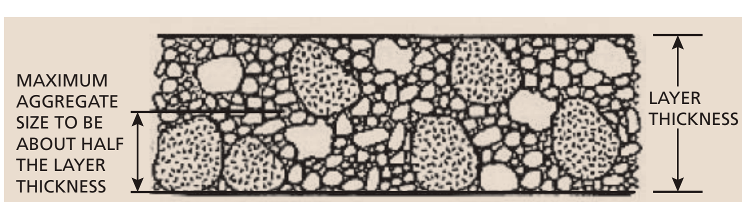

Figure 18-15: Maximum aggregate size to be no greater than half the layer thickness

The various methods of dealing with oversize material either in the borrow pit or on the road (during material placement) are shown in Figure 18-16. Each method is briefly reviewed below.

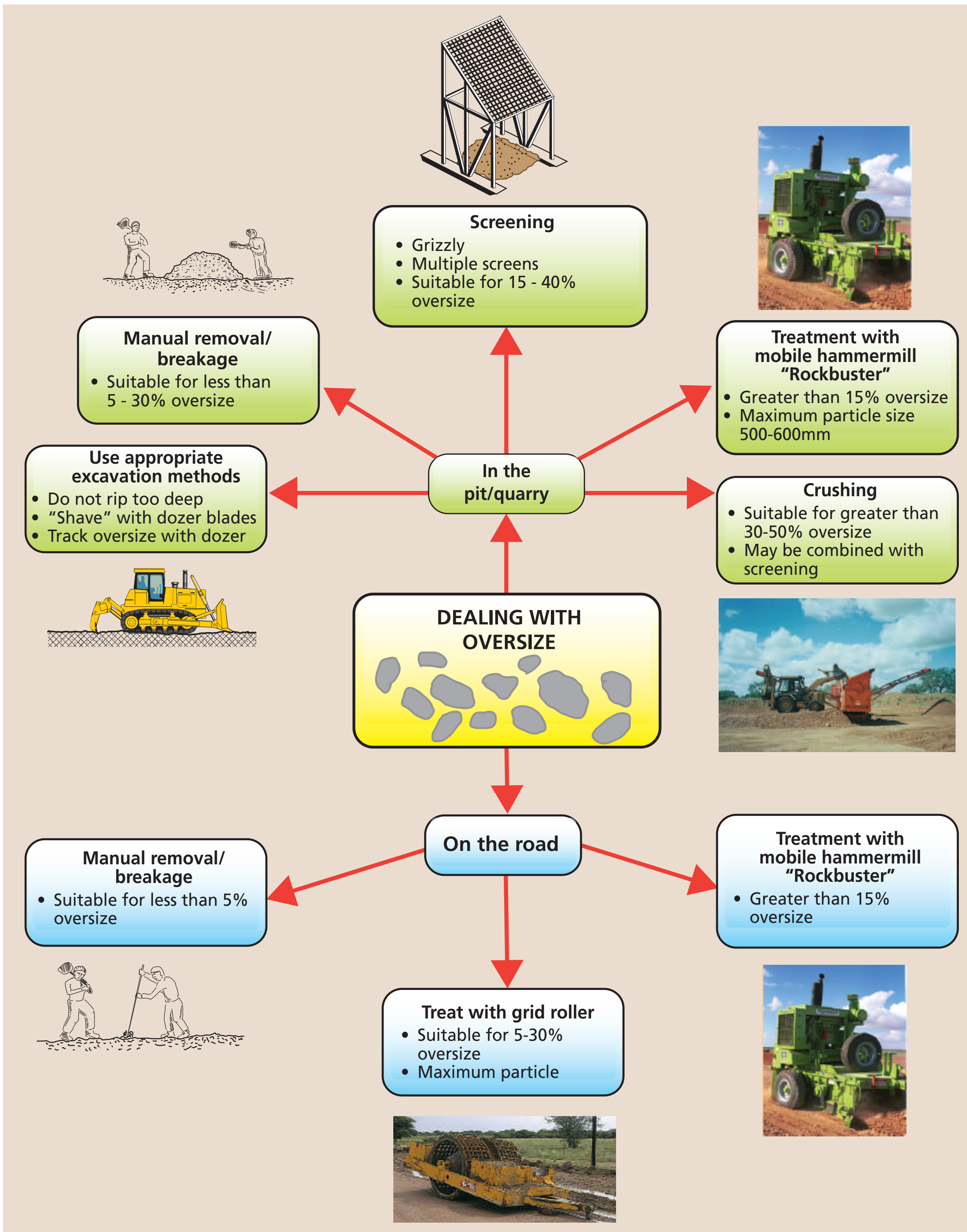

Figure 18-16: Dealing with oversize material

Source: Roughton International (2000).

Where the proportion of oversize is material relatively small it may be treated effectively by manual removal or crushing either at the borrow pit or on the road. Figure 18-17 shows a mobile vibrating screen used to remove oversize in the borrow pit. It may be beneficial to crush the oversize material and add it to the stockpile to optimise material usage and minimise wastage and spoil.

Figure 18-17: Mobile vibrating screen used to remove oversize aggregate in the borrow pit

Field experience has indicated that manual treatment of oversize (removal or breaking) may not be successful where the proportion exceeds about 20%, even when large teams of labourers are employed for this purpose. However, the upper limit will depend on the diligence of the labourers, the way they are supervised and the ease with which the particles can be broken down. In the case of weaker materials, any large particles that are not manually removed will be broken down during compaction.

The removal of hard oversize fragments at the construction site leads to considerable wastage and potential obstruction of side drains. It is therefore recommended that whenever possible, oversize material is treated or removed in the borrow pit. Special plant is required to break down the large particles during construction, for example a mobile hammer mill or grid roller may be used for this purpose during pavement laying.

Screening: Screening to remove oversize particles at the borrow pit can be a low cost solution when the proportion of oversize is in the range 15% to 40%. The screen comprises a frame supporting a mesh or slotted panel with an aperture designed to prevent large particles passing through. The oversize material removed by screening is rejected unless crushing plant is available.

Various methods of screening exist and each method is appropriate for use in different situations.

Screening to remove oversize aggregates is an important and cost effective material processing technique. Figure 18-18 illustrates the various types of simple screens.

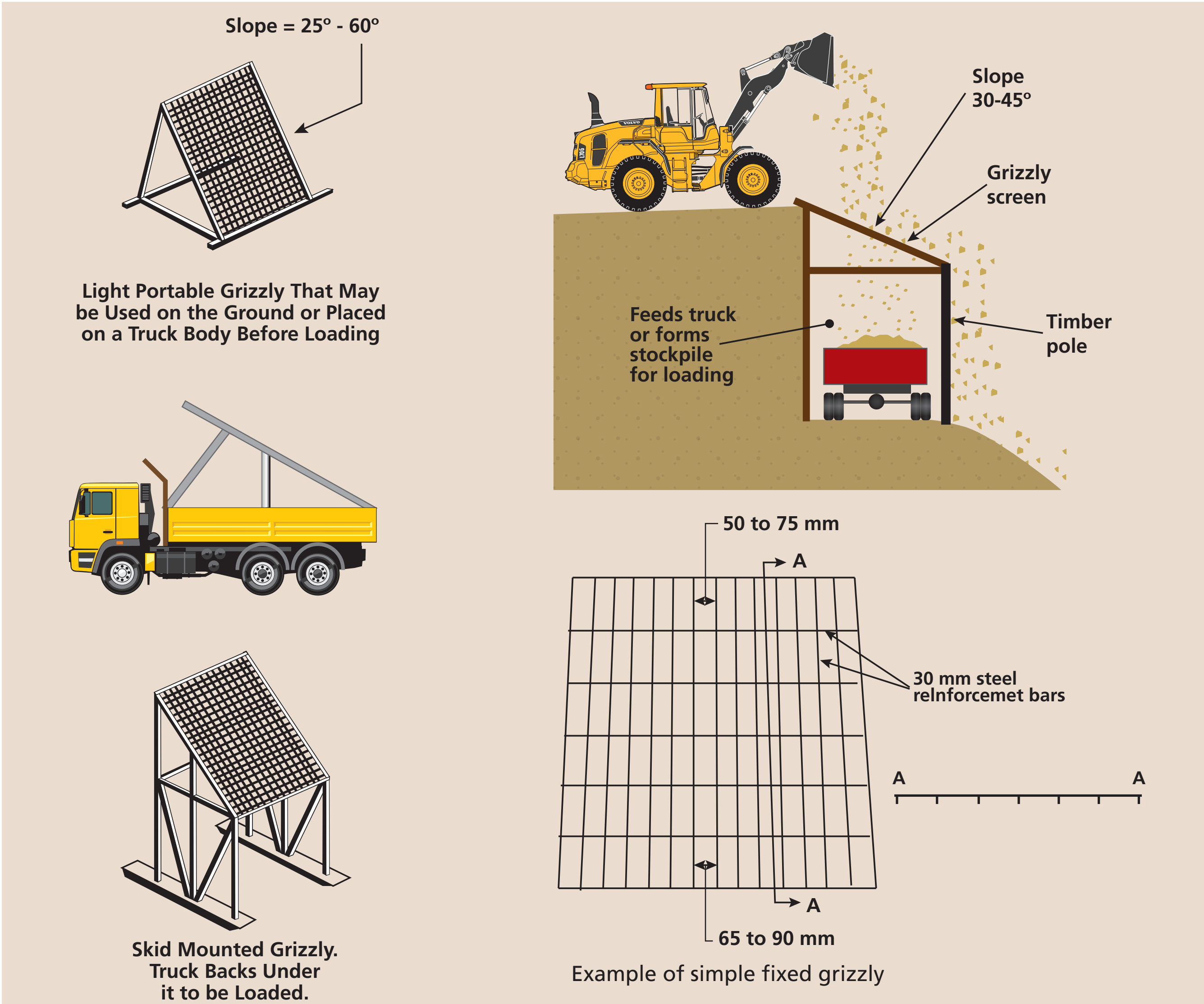

Figure 18-18: Examples of screens and grizzly

Source: Roughton International (2000).

Crushing: Crushing of oversize aggregate is normally reserved for surfacing/concrete works and not used for gravelling or pavement layers construction as this is an expensive option. Even primary crushing of rippable materials with a small mobile crushing machine may lead to aggregates that cost more than three times as much as natural occurring materials. As a result, production of high cost crushed gravel road surfacing materials may only be viable in clearly identified circumstances. Factors that should be reviewed before committing to the production of crushed aggregates include:

- Cost of hauling natural gravels from outside the area compared with the cost of producing crushed local materials.
- Relative quality of crushed stone compared with alternatives.
- Alternative of using a mobile hammer mill rather than conventional crushing equipment.
- Viability of stabilising local fine grained materials with, for example, lime or cement.
- Influence of climate and topography on the viability of using a particular material.
- Possible environmental benefits of the crushing of oversize.
- Use of mobile crushers, which are very effective and have a high mobility.

In steep hill country with high rainfall, well graded angular gravels stand up well to scour and traffic abrasion due to their good mechanical interlock. Hence, the use of crushed river gravel as opposed to rounded gravel may be justifiable for a gravel wearing course due to the resulting reduction in maintenance costs.

When natural gravel is not easily accessible and the only option is to produce crushed aggregate, consideration should then be given to constructing a bituminous surfacing. This may be a more economical solution in the long term (life cycle costing), and allow for conservation of local materials.

18.8 EXCAVATION AND TESTING

18.8.1 General

The quality of materials produced and the quality of the road constructed are dependent, to a large extent, upon the following:

- Careful selection of suitable material and avoidance of contamination with overburden or underlying unsuitable deposits.
- Continuous monitoring and supervision of any processing activities.
- Appropriate stockpiling methods.

An experienced borrow pit supervisor should be appointed to control all extraction and processing operations. This is particularly important if the materials are variable or if the plant operators are changed frequently.

The tender documents should clearly state that the contractor should have an experienced borrow pit supervisor in his staff.

18.8.2 Sampling and Testing

Prior to any gravelling/construction operations, laboratory testing should be carried out to determine

- The characteristics of the excavated materials in all borrow pits that may be required to supply the section of road to be re-gravelled or constructed.
- Appropriate materials processing methods (if required).
- The expected characteristics and uniformity of the processed materials.

The type of tests and frequency are shown in Table 18-2.

Table 18-2: Recommended Testing of Borrow Pit material

TESTS	FREQUENCY (Every)	COMMENTS
Atterberg Limits (PL, LL, LS)	2 000 m^3	Increase frequency if variable or marginal suitability
Grading Analyses	2 000 m^3	Increase frequency if variable or marginal suitability
Compaction and CBR	4 000 – 6 000 m^3	Dependent on uniformity of material
Particle Strength (AIV & ACV)	4 000 – 6 000 m^3	Dependent on uniformity of material

18.9 MATERIALS MANAGEMENT

18.9.1 General

Material supply strategies are often determined by field supervisors from undocumented knowledge (local experience). This may result in the exploitation of a diminishing number of local traditional natural gravel pits. In many areas, these existing material sources are rapidly becoming exhausted. The need for material prospecting, adequate borrow pit evaluations and material processing is very often not fully recognised. As a result, the best road construction materials are not always used and expensive over-haul is required due to perceived construction material deficiencies.

Some countries have established a national or regional borrow pit/quarry inventory that assembles and stores data concerning the location and engineering properties of road building material resources.

18.9.2 Record keeping

Records concerning the actual use of material need to be prepared following completion of a project. Observations concerning in-service performance of materials should be documented so that the quality rating of the material may be assessed. The following data should be recorded:

- The actual source of materials used to supply each section of road.
- The location of the borrow pit (geo-referenced).
- The characteristics of the materials used to supply each road section.
- The cost per m^3 of material at the road side and the haulage cost per tonne-km.

An estimate of the quantity of exploitable material remaining in each source after completion of construction.

18.9.3 Materials Database

The purpose of a materials database is to assemble existing records and ensure that valuable data are preserved, centralised and made readily available to all interested parties for future use. Paper records are bulky and are easily misfiled, lost or destroyed. The development of a computerised database is an ideal and cost effective solution to the problem of preserving existing borrows pit records and enabling all new information to be linked with historical data for analysis and evaluation.

In its simplest form a computerised materials resource database can be established using a spread sheet programme such as “Excel”. This is encouraged as an intermediate measure, for gathering information on a road by road basis prior to the establishment of a more powerful and appropriate database management system.

Figure 18-19 shows an example of a Design Materials Resource Database.

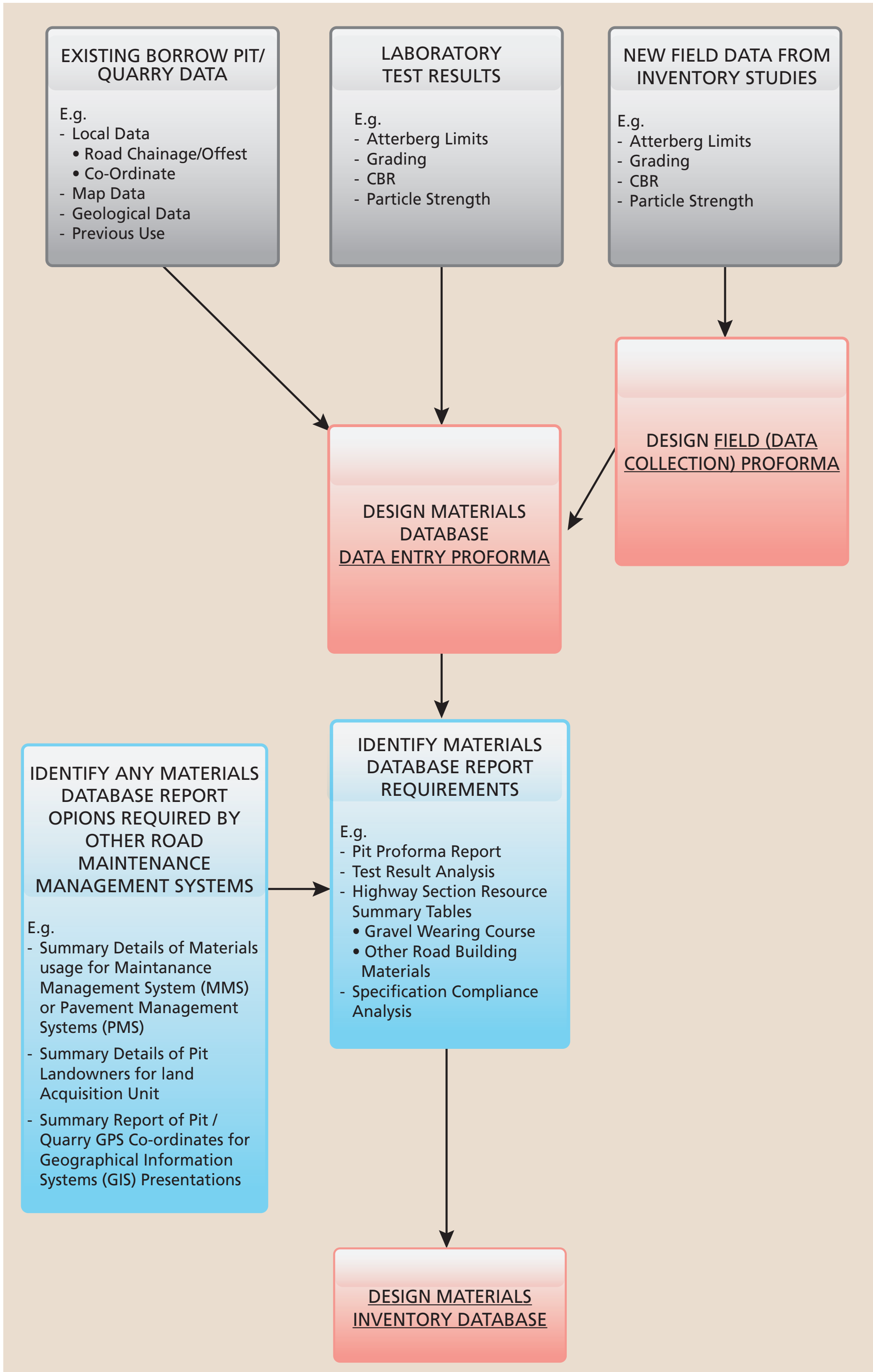

Figure 18-19: Example of a Design Materials Resource Database

Source: Roughton International (2000).

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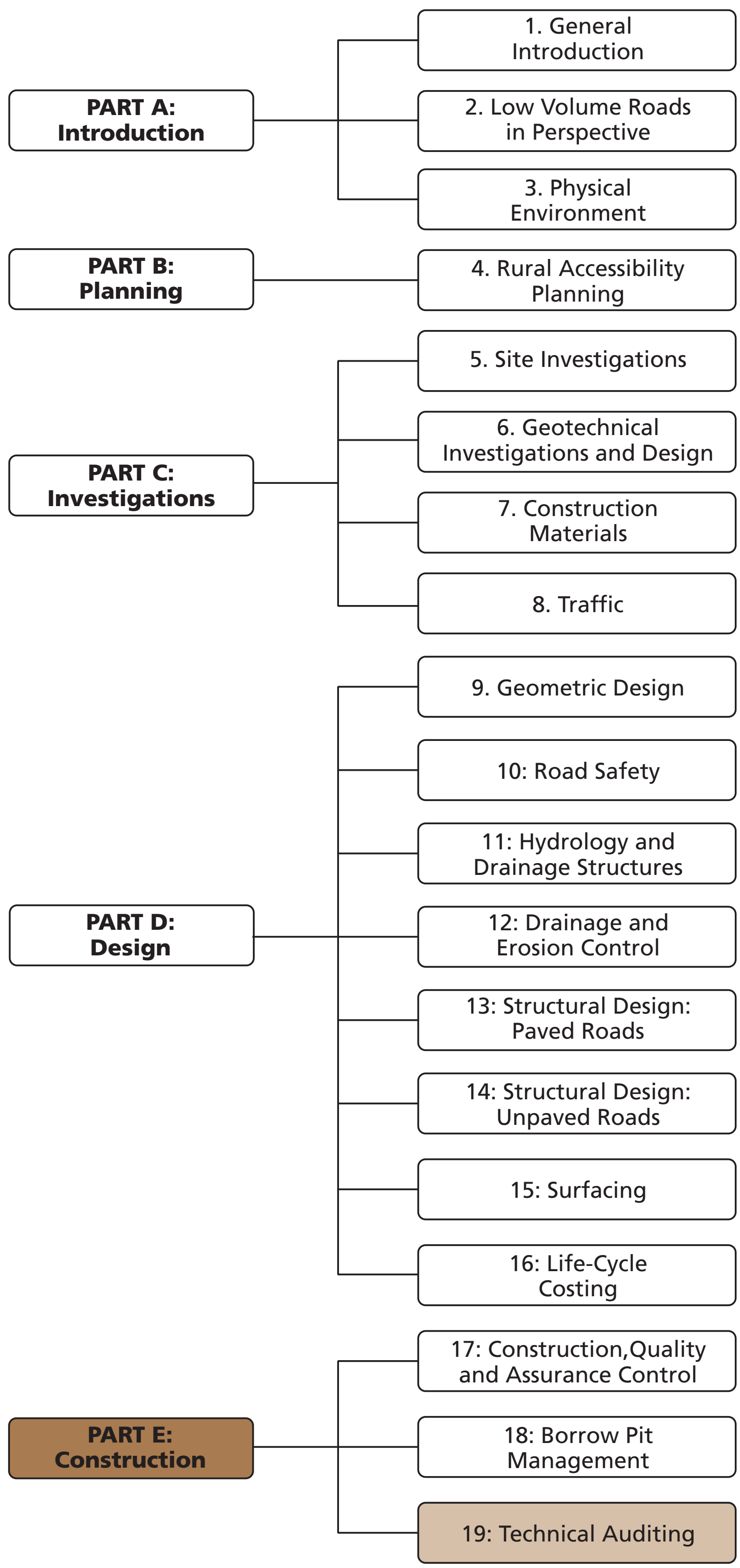

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19.1 INTRODUCTION

19.1.1 Background

The management and financing of Tanzania's road infrastructure is currently undertaken in a much more commercialized and business-like manner than previously. The road authorities – TANROADS and LGAs - operate under performance contracts within their respective ministries (MOWTC and PO-RALG). These organizations have a primary responsibility to ensure that the funds provided for road provision are used effectively and efficiently and that the providers of these funds, and ultimately the Government of Tanzania and its people, receive value for money.

In the prevailing commercialized environment in which Tanzania's roads agencies operate, characterized by a greater degree of accountability than hitherto, it is essential that the professional services provided by all parties to the contract are carried to acceptable standards in an efficient and cost effective manner. Therefore, ways and means must be found to regulate the construction industry and its service providers to ensure that the required standards are not compromised. One of the ways of doing this is by carrying out regular technical auditing of road projects. The primary aim of these audits is to check compliance with the requirements of the contract during all stages of the project cycle and, ultimately, to ensure that the Government, and the people of Tanzania, receive value for money.

The responsibility for undertaking technical audits resides with Tanzania's roads agencies responsible for executing road projects. Such audits are quite separate from the more broadly based ones that may be conducted by the Road Fund Board or other agencies after the project has been completed to verify such aspects as the manner of procurement and management of the works.

19.1.2 Purpose and Scope

The main purpose of this chapter is to outline the scope of a typical technical audit and to indicate the appropriate requirements and techniques to be employed for such audits that cover all stages of the project cycle. The primary aim of these audits is to verify that the road is planned, designed and constructed to the prescribed specifications and that the Contractor performs and is paid as per the contract conditions.

The chapter covers auditing of projects related to the following six main stages of the project cycle, namely: 1. Identification, 2. Planning, 3. Preparation, 4. Contract Award, 5. Implementation and 6. Evaluation. The procedures described should be amended, where necessary, to comply with the requirements and procedures of the Controller and Auditor General.

19.2 FUNDAMENTALS OF TECHNICAL AUDITS

19.2.1 Definition of Technical Audit

A Technical Audit may be defined as a formal, systematic procedure for undertaking an independent, objective, assessment of a project to determine the extent to which it has complied with various prescribed procedures, standards and specifications set down in the project documents.

19.2.2 Technical auditing versus supervision/quality control

A clear distinction should be drawn between technical auditing and supervision/quality control which are not synonymous terms. The difference between these terms is both legal, in relation to the roles and responsibilities of the key parties to the contract, and technical in terms of the roles and responsibilities of the technical audit team and the degree of detail applied when auditing the project. It is therefore critically important that the technical audit process, which is generally not contractually linked to either the Contractor or Supervising Engineer, is kept well apart from the supervision process prescribed in the conditions of contract.

19.2.3 Why Undertake a Technical Audit

An appropriately formulated technical audit can detect and predict problems that can arise during the various stages of the road provision cycle, thereby enabling any shortcomings to be rectified before they are implemented. Thus, the audit process should commence as early as possible in the project cycle. There is little benefit in initiating a technical audit either during construction or when a problem is suspected or realized as the findings of such audits cannot influence the outcome of quality of the work on the project.

Typical problems that can be detected by an appropriately formulated technical audit include:

Human errors

Human beings are prone to making errors in any undertaking in which they engage. Neither Clients, Consultants nor Contractors are immune from this human failing. These errors can occur during any of the stages of the project cycle, and end up being very costly during project implementation. If an appropriate experienced independent Auditor is engaged at the right time, these errors could be detected early and corrective action taken. Moreover, designers, supervisors and Contractors are likely to be more diligent in their work if they are aware that it will be subjected to external review or evaluation.

Incompetence

The designer or supervisor of the Engineer ing project may be incompetent and an Auditor will be able to establish this before costly mistakes are made. Clients, either out of ignorance or with the intention of "saving money" sometimes engage incompetent persons to carry out design or supervision of complex Engineering projects. On the other hand, Contractor s are often guilty of the same short-coming - failure to engage competent personnel to implement the works.

Corruption

Contractors, sometimes in collusion with supervisors, may take shortcuts during project implementation. For instance, inadequate or wrong reinforcement in structures may be used, inadequate compaction in road construction may be allowed or concrete may not be allowed to cure as required before proceeding with further construction. A technical Auditor will detect these shortcomings up at an early stage of the project and raise a red flag.

Poor quality control

Effective quality control is extremely important during project implementation. If this is lacking or there is laxity in implementing the required quality control, the technical Auditor will raise the matter with the auditee and alert the Client.

Professional ethics

There are, unfortunately, some professionals who do not adhere to a code of professional ethics and who do undertake projects for which they are ill-qualified. Some may deliberately over-design an Engineering facility in order to inflate its cost while others may fail to carry out adequate field investigations. As a consequence, their designs may be based on inadequate data and could lead to under- or over - design. An audit of such projects would reduce the likelihood of such shoddy practice occurring.

19.2.4 Typical types of road audits

There are basically four types of road audits that may be considered. These are outlined in Table 19-1. This chapter deals primarily with Technical Audits although aspects of Procedural Audits, Road Safety Audits and Environmental Audits can be applied at the various stages of the process.

Table 19-1: Types of road audits

Procedural Audit	Technical Audit	Road Safety Audit	Environmental Audit
Deals with administrative and financial procedures. Reviews and checks if Government regulations are followed in the use of financial resources.	Deals with the road provision project cycle for both maintenance and upgrading and new construction. Aims to determine the extent to which the road has been planned, designed and constructed to the prescribed specifications and that the Contractor performs and is paid as per the contract conditions.	Deals with the safety aspects of a new or an existing project to ascertain if the project in any way would worsen the road safety situation. Detailed recommendations are put forward in cases where standards are not achieved as intended.	Deals with the environmental and social aspects of a project. Assumes that an ESIA has been carried out prior to the execution of the project and that the end result can be compared with what was intended. Recommendations for improvements are put forward.

19.2.5 Benefits of Technical Auditing

The benefits of technical auditing include:

- Identifying potential problems early in the course of the project cycle (planning, investigation, design, procurement, construction stages).
- Instilling a sense of greater diligence in the attitude of all parties to the contract.
- Reducing the scope for corruption, particularly at the Contract Award and implementation stages of the project.
- Detecting misinterpretations of data, inaccurate reporting, departures planning directives or project objectives.
- Confirming the implementation of prescribed requirements such as quality assurance, quality control and work plans.
- Minimising the risk and severity of failures that may occur as a result of design deficiencies in the road project.
- Minimising the need for re-work and physical remedial works caused by design or construction deficiencies by taking early corrective action.
- Benefiting from any lessons learnt for application to other projects.
- Satisfying the requirements of the Road Fund Board that TANROADS and LGAs should carry out an independent audit of all projects that they fund.
- Enabling the Client to ascertain whether the parties involved in the contract (including the Client) have provided the Government and people of Tanzania with value for money.

The cost of a technical audit is normally significantly less than the cost of changing a design or the cost of remedial works after the contract has been awarded and construction started. The cost of the audit would be a small price to pay for upholding the highest possible standards that all parties to a contract are expected to attain, not only to ensure compliance with prescribed standards, but also to enhance the quality of their work.

19.2.6 Types of Road Projects Which May Be Audited

In principle, technical audits are applicable to all types of activities in the road sector, on all types of roads. The main categories of road projects include the following:

Construction and Rehabilitation

- New construction.
- Upgrading (including geometric improvements).
- Rehabilitation (including pavement reconstruction and structural overlays).

Maintenance

- Routine and preventative maintenance.
- Periodic maintenance (including regravelling, reshaping, rejuvenation, resealing and regulating overlays).

Construction and rehabilitation projects tend to be more complex and costly to undertake than maintenance projects which tend to be more straight forward and less costly. Thus, although maintenance projects can be audited, it is more usual to focus auditing attention on construction and rehabilitation projects.

19.2.7 When to Undertake a Technical Audit

Technical audits can be undertaken at any or all of the main discrete stages of the project cycle. The various stages of technical auditing should not be seen as rigid as all projects are not the same in terms of size, complexity and type. For example, a large, new road construction project may well entail all six stages of technical auditing whereas a minor routine maintenance project may warrant only a Stage 6 audit, i. e. Evaluation. For projects that are constructed in sections, a technical audit may be conducted at the completion of each section of construction.

19.2.8 Who Should Undertake a Technical Audit

Criteria

A technical audit is best carried out by a team of people who are independent of the Client, Consultant or Contractor so that the audit process is undertaken with fresh eyes in an unbiased manner. The Client has the ultimate responsibility for accepting that the level of independence is adequate and credible. To avoid the development of an inappropriate "culture" between of the Consultant or Contractor involved in executing the project, members of the audit team should be commissioned from other organizations with no ties to the Client's, Consultant's or Contractor 's organisations.

Size of the audit team

The most appropriate size of a technical audit team depends on the complexity of the audit task. There is no optimum number of people suggested, although teams of more than four people can be unmanageable. The benefits of having an audit team, rather than a single person, include:

- The diverse backgrounds, experience, knowledge and approaches of different people.
- The cross-fertilization of ideas through discussion.
- Simply having more pairs of eyes to collectively undertake the audit.

While skills in Road Engineering are the most crucial attribute, technical audit teams should possess balanced skills appropriate to individual projects. It would be preferable to avoid having a one-person team just to reduce costs in undertaking an audit. The cost of undertaking such an audit is small relative to its potential benefits.

Appointment of audit team

The Client should appoint the audit team in accordance with any over-arching requirements of the Controller and Auditor General. A list of potential Auditor s compiled by the Client that includes their skills and experience can assist with the selection process. To avoid potential conflict of interest, it is desirable to appoint independent Auditor s, i.e. persons not involved themselves in the types of activities that they are required to audit.

For each technical audit, one person in the audit team should be appointed as the team leader, to manage the team and audit process.

Skills of audit team

While continuity within core audit teams through the stages is desirable, audits at the different stages may require different skills as follows:

Stage 1 – Identification: Requires consideration of the country's development strategy and sectoral objective requirements - issues with political connotations that may best addressed by Government personnel rather than by an external Auditor .

Stage 2 – Planning and Appraisal: The issues to be examined are quite different (broader and often more conceptual) than for later stages. Thus, a big picture view, taking in the potential for wider implications to all road users is important. It would be desirable to include team members with planning and economic appraisal skills.

Stage 3 – Preparation: Include team members who are familiar with the types of details required at the design stage of the project, for example, with experience in road construction materials, design and preparation of contract documents.

Stage 4 – Contract Award: Include team members who are familiar with the types of details required at the tendering stage of the project, for example, with experience in preparation of tender documents and tender evaluation procedures.

Stage 5 – Implementation: Include team members who are familiar with the types of details required at the construction stage of the project, for example, with experience in quality control, quality assurance, construction practice, specifications for road and bridge works.

Stage 6 – Evaluation: Include team members who are familiar with the types of details required at the evaluation stage of the project, for example, with experience in pavement investigations including visual and road condition surveys, sampling techniques, interpretation of test results.

Attributes of audit team

The experience and skills of the audit team should be broadly as follows:

Team leader: The Team Leader should:

- Be an appropriately qualified professional Engineer with wide-ranging experience covering feasibility studies, LVR design, construction and contract management.
- Have demonstrated management and reporting skills.
- Have up-to-date professional experience.

Team members: The other members of the team may be more varied in their backgrounds than the Team Leader and should have experience that achieves the balance required for the audit. These team members could be, for example:

- *Materials and/or Pavement Engineer* – should be an appropriately qualified professional Engineer with appropriate experience in pavement Engineering/materials. If only one of these Engineer is preferred, then they should have an in-depth knowledge of the other field. For instance the Pavement Engineer would be required to have an in-depth knowledge of materials and the Materials Engineer would be required to have a sound knowledge of pavement engineering.
- Engineers with experience in drainage, structures/bridges and geometric design could form part of the team where necessary, depending on the complexity of the project. They should be appropriately qualified professional Engineer s in their respective fields.

Observers: Can be included in the technical audit for a variety of reasons, such as a training exercise in order to be considered as future audit team members, or simply to observe the process.

Appointment of audit team

The Terms of Reference for the appointment of an audit team are always project specific and, as a minimum, should contain the following details:

- Background to the project, indicating clearly the stage(s) of the project to be audited (refer to Figure 2-4).
- Overall objective of the audit.
- Detailed scope of the works which could include:
  - particular aspects of the work to be audited;
  - detailed work programme for the assignment indicating expected submission dates for the various reports;
  - minimum professional qualifications and experience of the personnel;
  - standards and specifications for the project;
  - available data and information including feasibility studies, design documents, programme of works and periodic progress reports;
  - specific areas of focus depending on the Client's concerns;
  - assistance that the audit team can expect from the Client.

19.2.9 The Parties to a Technical Audit

The parties to a technical audit are:

- **Client:** The organisation responsible for initiating the audit and to whom the Auditor reports.
- **Consultant:** The organisation responsible for undertaking some/all aspects of the project cycle. During the design and construction stages of the project, the orgnisation would typically be referred to as the Design Engineer or Supervising Engineer respectively.
- **Contractor:** The organisation engaged by the Client to construct the project. During the execution of the audit, the organisation would be referred to as the Auditee.
- **Auditor:** An independent person or team appointed by the Client to undertake the audit.

19.2.10 Relationship of Audit Team with Main Parties to a Contract

The audit team is appointed by the Client, to whom they report directly. Under no circumstances may any member of the audit team advise or issue instructions to the Contractor or Supervising Consultant. Communication should be focused on seeking clarification or information regarding the project, and should avoid any interference with smooth implementation of the project. The Consultant, Contractor and Client must make available to the Auditor any document, as and when required by him/her. Relevant clauses in the tender documentation and/or letters of appointment should make provision for this.

The relationship between the Auditor and the Client must be clearly described in the Auditor 's agreement with the Client. The Auditor can review actions of the Client during the project and any deficiencies or lack of performance should be noted in the Audit Report. This ensures that the audit process is transparent and may assist to improve internal practices within the Client's organisation.

19.2.11 Limitations of Technical Audits

Auditing of engineering projects has a number of limitations that Clients should be aware of as follows:

- In many forms of contract, an Auditor has no role and is not contractually recognised. The Contract is usually between an employer and a Contractor. The roles of the Engineer or his representative are usually spelt out in the contract.
- Auditees do not always give the assistance and cooperation expected. The Auditor 's role is often seen as investigative and some auditees do not therefore feel obliged to co-operate.
- The Auditor may be a competitor to the auditee in other areas and the report prepared after the audit exercise is therefore not taken to be impartial.
- One of the major issues faced by auditing firms is the need to provide auditing services while maintaining a business relationship with the audited entity. Often, it is difficult to maintain the balance without compromising on professional ethics.

Most, if not all, of the potential limitations of technical audits highlighted above can be overcome by undertaking the audit process in a well-structured manner in which clearly defined procedures are followed by each party in an objective and transparent manner. This process is considered in the next section.

19.2.12 Reporting

The reporting of the outcome of a technical audit is a critical aspect of the auditing process. In many cases, such a report could be the most important document affecting the outcome of arbitration or legal proceedings.

All aspects of the audit carried out at any or all stages of the project cycle should be carefully reported and should be comprehensive without being excessively lengthy. The format of the Audit Report needs to be carefully considered and strict confidentiality of its contents should be observed in case it is later the subject of arbitration proceedings.

19.3 THE AUDIT PROCESS

19.3.1 Main Steps in Process

Figure 19-1 shows the general steps to be followed in performing an audit in terms of the sequence of activities and responsibilities of the parties to the audit. For a particular project that has been chosen by the Client to be audited, the audit process starts off with the selection and appointment of the audit team and ends with the implementation of changes decided by the Client.

Once selected and appointed, the audit team will work through the various steps of the audit process shown in Figure 19-1. The specific activities undertaken at each step of the process would depend on the stage of the project cycle being audited as discussed in the next section of the chapter.

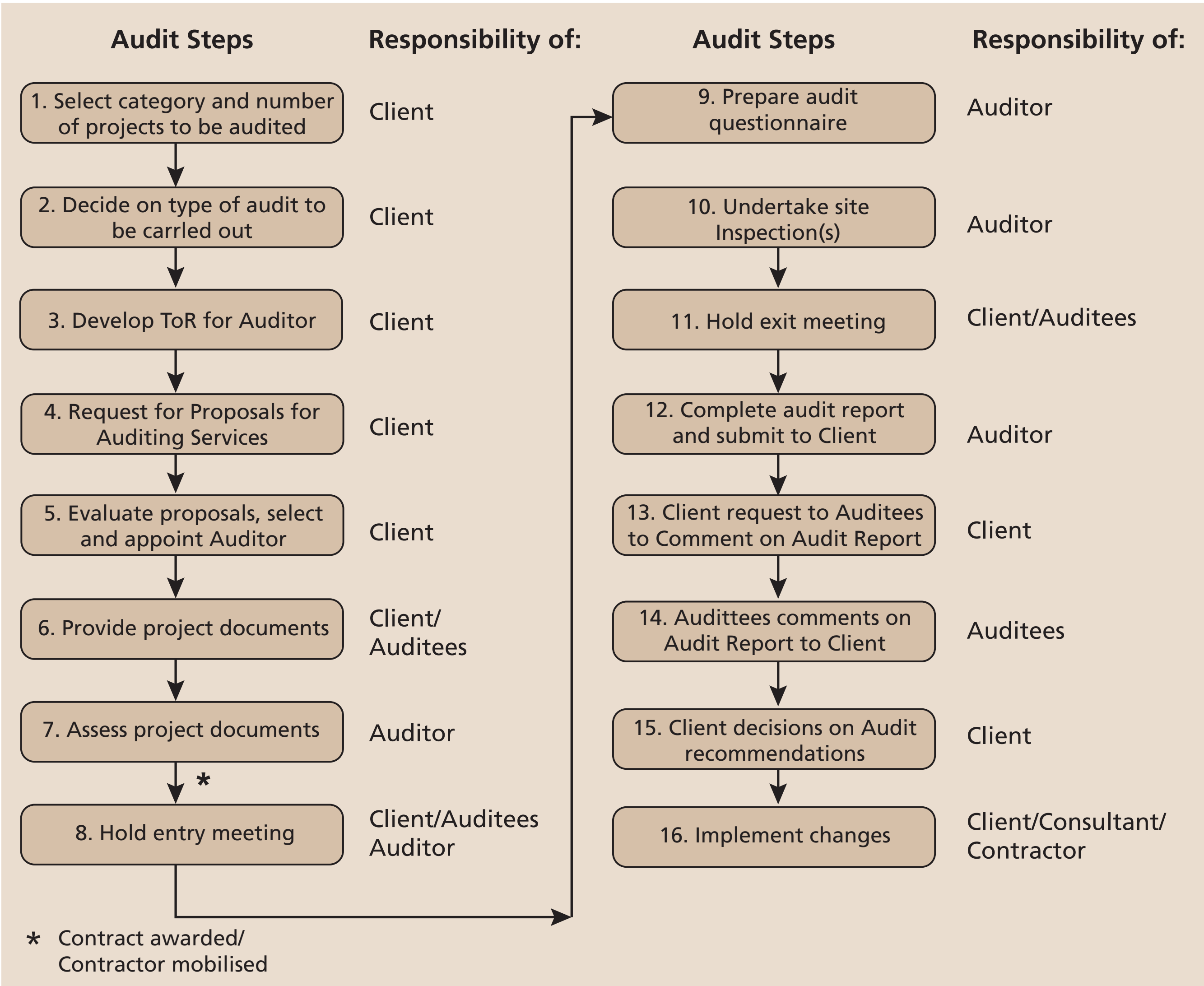

Figure 19-1: Typical steps in the technical audit process

19.3.2 Details of Each Step in Audit Process

1. Select category and number projects to be audited

Objective: *To select the category and number of road projects to be audited.* Much as it may be desirable to audit all projects in all road categories under the responsibility of the roads agency, this may not be possible due to funding and/or capacity constraints. Thus, a manageable and representative number of projects in each road category, typically of the order of 10 – 20%, will need to be chosen from amongst a much larger number.

Responsibility: Client.

Procedure: As for any typical contract.

2. Decide on type of audit to be carried out

Objective: *To decide what particular aspect (stage) of the project cycle should be audited.* This is to ensure that appropriate attention is given to the most critical issues of the project. For example, a large, new road construction project which is donor funded may well require that all six stages are audited whereas a minor routine maintenance project that is carried out in-house may warrant only a Stage 5 audit, i.e. an audit that focuses on the implementation of the maintenance works and the supervision thereof.

Responsibility: Client.

Procedure:

- Consider the type, complexity and cost of the project.
- Consider the most common type(s) of problem(s) that have arisen on similar projects in the past.
- On the basis of the above, decide on the type of audit to be carried out.

3. Develop Terms of Reference (ToR) for Auditor

Objective: *To define clearly the scope of the audit to be performed and its objectives as well as the individual tasks to be carried out.* The ToR will vary in relation to the type of audit being carried out (Stage 1, Stage 2, etc.) and the type of project being audited (new construction, periodic maintenance, etc.).

Responsibility: Client.

Procedure: As for any typical contract.

4. Request for proposals for auditing services, evaluate proposals, select and appoint Auditor

Objective: *To procure the services of an Auditor.* Such services can be procured on a competitive tendering basis or by direct appointment with the latter option being the more typical one employed in a commercialized roads agency where transparency in the procurement of professional services is an important factor.

Responsibility: Client.

Procedure: As for any typical contract.

5. Provide project information to Auditor

Objective: *To provide the Auditor with all the information required to undertake the audit.* This will entail obtaining project information from either in-house staff involved in the project, from the Consultants involved in any of the Stages of the project cycle or the Contractor. Such information will simplify and speed up the process of the audit and enable the Auditor to focus on the most important issues.

The type of information to be provided to the Auditor will depend on the type of audit being carried out

(Stage 1, Stage 2, etc.), and could include:

- Feasibility Study report.
- Design report.
- Tender Documents.

- Construction Progress Reports (for on-going or post construction audit).
- Relevant ad hoc reports or special reports (for on-going or post construction audit).

Responsibility: Client.

Procedure:

- Write to in-house staff involved in the project or the Consultant(s) or the Contractor informing them about the audit and enclosing the ToR for the audit, listing the information required from them and the time by which the information is needed.
- List the information received and provide it to the Auditor at least two weeks before the commencement of the audit.

6. Assess project documents

Objective: *To provide the first opportunity for the Auditor to review the project documents in detail*. This allows the Auditor to assess the adequacy of the information received and to identify any action required prior to the commencement of the audit. In this phase, specific tasks may be allocated to various team members and an audit questionnaire may be prepared prior to commencing the audit.

Responsibility: Auditor.

Procedure:

- Review in detail all project documents provided by the Client.
- Request any additional information or documents considered necessary.
- Prepare programme and introduction for entry meeting.

7. Hold entry meeting

Objective: *To provide an opportunity for all parties to the Audit to meet prior to the commencement of the audit field work. Such a meeting provides an opportunity:*

- To establish lines of communication during the execution of the audit.
- For the Client, and/or Consultant and/or Contractor to brief the Auditor on issues, constraints and specific areas that are relevant to the audit.
- For the Auditor to seek additional data, if necessary, and to discuss any initial observations or seek clarification arising from prior perusal of the background information provided.
- To discuss the programme for completion of the audit and delivery of the report.
- To determine the protocol for delivery of the Audit Reports.

Responsibility: Client/Consultant/Contractor /Auditor.

Procedure:

- Provide background to, and objectives for, the audit.
- Agree on documents to be examined by the Auditor.
- Agree on modus operandi and programme for undertaking audit.
- Summarise key issues discussed which will serve as an official record of the Entry Meeting.

8. Prepare audit questionnaire

Objective: *To facilitate more efficient interviews and site visits with the auditees*. Such a questionnaire also serves the purpose of obtaining information that might not otherwise be volunteered by the Auditee as well as bringing about in-depth discussion on particular aspects of the project that are of particular interest to the Auditor .

Responsibility: Auditor.

Procedure:

- Review in detail all available project information.
- Identify deficient areas that need more in depth investigation.
- Prepare a questionnaire with emphasis on areas where more information would be needed.
- Bring to the attention of the Client and the auditees any areas of major concern so that all parties are aware of the Auditor ’s intention to explore this during the construction phase of the project.

9. Undertake site inspection(s)

Objective: *To allow the Auditor to familiarize himself with details of the project and to collect the necessary information and data for completing the audit*. During the site inspection, the checklist pertaining to the particular type of audit (Annex 2) should be referred to, and filled in, if desired, to ensure that no important issues are overlooked.

Responsibility: Auditor.

Procedure:

- Focus on aspects of the project that have been highlighted in the ToR.
- Review in detail those components that have caused contractual or other disputes.
- Refer to master checklist and fill in details as appropriate.
- Measure/investigate specific features as necessary.
- For maintenance projects, give priority to most critical components of the road (drainage, surfacing) as well as quality of materials and workmanship.
- For new construction, rehabilitation or upgrading projects, pay particular attention to quality of materials, quality of supervision and construction methods.
- Prepare field inspection notes as an official record of this aspect of the audit.

10. Hold exit meeting

Objective: *To provide an opportunity for the Auditor to present and discuss his preliminary findings and conclusions to the Auditees prior to writing up of the Audit Report.* Such a meeting also provides an opportunity for:

- Agreeing on facts.
- Identifying and resolve misunderstandings or errors of fact.
- Informally discussing possible solutions for addressing the problems.

- Providing the basis for preparing the Draft Audit Report.
- Formalising the basis for the minutes of the Exit Meeting incorporating all issues discussed and recorded.

Responsibility: Client/Auditees/Auditor.

Procedure:

- Provide feedback on preliminary findings of audit, covering all major issues identified in ToR.
- Summarize key issues discussed which will serve as an official record of the Exit Meeting.

11. Complete Audit Report and submit to Client

Objective: *To act as a formal record of the audit as seen from the Auditor 's perspective.* The Audit Report also provides the basis for the Auditees to present their comments.

Responsibility: Auditor.

Procedure:

- Prepare the first draft report based on the Exit Meeting notes and other information collected during all stages of the audit.
- Submit report directly to Client.

19.3.3 Guidance on preparing the Audit Report

General

The Audit Report should succinctly report on aspects of the project that are of concern to the audit team and to make recommendations for corrective actions. Recommendations may indicate the nature or direction of a solution but they do not specify the details of how to solve the concern. Responsibility for this rests with the Consultant and/or Contractor .

Ranking system for concern

All concerns identified in the report should be of sufficient importance to require action. To assist the Client and Consultant to gauge the relevant importance of the concerns raised, a simple ranking system is desirable along the lines indicated below:

- Serious concern: A major concern that should be addressed and requires changes to the project to avoid serious technical problems.
- Significant concern: A significant concern that requires consideration of changes to improve the technical shortcomings of the project.
- Minor concern: A concern of lesser significance, but which should be addressed as it may improve the overall performance of the project.
- Comment: A concern or an action that may be outside the scope of the technical audit, but which may improve the overall design or be of wider significance.

The ranking system used should be defined in the report, and should take into account the risk of a problem occurring, and the outcome if not properly addressed.

By their nature, technical Audit Reports appear to be negative documents as they typically raise only concerns. Positive design elements are not necessarily mentioned, as the assumption is that all designs contain good elements. However, a notable or excellent element which improves the performance of the project should be mentioned if appropriate.

Contractual implications

In assessing a project the Auditor will be working within the framework of two contracts - one between the Client and the Engineer and another between the Client and the Contractor. Both Contracts should be in the possession of the Auditor. The Contract between the Client and the Engineer for professional services requires the Contract Administration to be done with due care and diligence. The Contract between the Client and the Contractor is more clearly defined in the General and Special Conditions of Contract.

Where the Audit leads to the conclusion that either the Engineer or the Contractor has been in breach of their respective contracts and that this will lead to under performance of the final product then the Audit Report should refer to the contracts and where possible the specific terms and clauses. The Client will then be guided by the result of the Audit in his decision as to whether or not to take appropriate action in terms of the contracts.

Contents of Report

In general, Technical Audit Reports tend to contain large quantities of information but should not repeat contract data. To ensure that they are optimally utilised, they should be carefully structured. It is suggested that as much background and supporting information as possible is included in Appendices or referred as separate documentation and that the Audit Reports themselves concentrate only on the critical issues and their implications.

A suggested table of contents for an Audit Report is presented in Table 19-2.

Table 19-2: Typical Table of Contents for a Technical Audit Report

1.	....	**Preface**
2.	....	**Executive Summary**
3.	....	**Introduction** ● Background. ● Terms of Reference. ● Audit format.
4.	....	**Available Information** ● A list of drawings and documents made available for the audit. ● Other supporting information used. ● Plans which identify the extent of work.
5.	....	**Technical Audit** ● Introduction. ● History of Project. ● Audit Process. ● Findings, conclusions and recommendations. ● Cost Implications.
6.	....	**Procedural Issues**
7.	....	**Formal Statement** ● A signed and dated statement by the audit team.
8.	....	**Acknowledgements**
9.	....	**Annexes** ● Terms of Reference. ● Data collected. ● Comments on draft report from the Auditees.

A draft report should be circulated to the audit team members for comment, corrections and agreement. As the technical audit team has a position of independence, a draft report does not have to be provided to the Client or Consultant for their comments before it is formally provided to them.

1. Client request to auditees to comment on draft Audit Report

Objective: *To provide an opportunity for the auditees to comment on the Auditor 's draft audit report.*

Responsibility: Client.

Procedure: Issue the draft report to the auditees requesting their comments within two weeks on the findings, conclusions and recommendations.

2. Auditee's comments on Audit Report to Client

Objective: *To obtain the Auditee's comments on the draft Audit Report.* In this regard, the Auditees response to the Client will:

- Recommend whether or not each audit recommendation should be adopted.
- Document the reasons for their views.
- Indicate the cost and implications of implementing each audit recommendation.

Responsibility: Auditees.

Procedure:

- Prepare response to draft Audit Report.
- Send specified number of draft reports directly to Client.

3. Client decisions on audit recommendations

Objective: *For the Client to make his final decisions on the Auditor 's recommendations and to advise the Auditees and the Auditor accordingly*. It is the Client who decides finally whether the recommendations of the Auditor are to be adopted. The Client may decide to seek specialist advice in arriving at his final decisions. Where a recommendation is not adopted, the reasons should be documented by the Client.

Responsibility: Client.

Procedure:

1. Complete Decision Tracking Form documenting:
   - The Auditor's recommendations.
   - The Auditee's response.
   - The Client decisions.
2. Prepare brief on feedback advice including Decision Tracking Form (See Annex A);
3. Send the brief on feedback advice to the Auditees and the Auditor.

4. Implement changes

Objective: *To implement the audit recommendations decided by the Client.*

Responsibility: Client.

Procedure: Instruct the Consultant or Contractor to implement the recommendations as listed in the Decision Tracking Form.

Annex A (Typical Example)

Audit Report Recommendations
DECISION TRACKING FORM

Project Title: Morogoro-Dodoma Road___________ **Type of Audit: Stage 5 (On-going construction)-**______

Client: PO-RALG__________________________ **Auditee: Premier Contractors** ________________

Auditor : PQ Consultants_____________________

Recommendation*	Report Ref.	Auditee Comments	Client Decision
1. Design consultant to review finished road level between km 20.00 and km 20+800. **Reason:** Road likely to be overtopped during rainy season. **Cost:** Estimated at T.Sh10 0,000. **Implications:** Prolongation of project by approx. 60 days. **Ranking:** Serious concern.	PO-RALG/PQ-1/3	Will delay completion of project by 70 days. Estimated additional cost of T.Sh 120,000 based on tendered rates.	Auditor 's recommendation upheld. Contractor to raise finished road as recommended by Design Engineer. Additional costs and project prolongation estimated by the Contractor is accepted by the Client.
2. Base course layer between km 30+000 and km 30+200 to be removed and replaced with appropriate quality material. **Reason**: Material not compliant with Contract specification. **Cost:** N/A **Implications:** None **Ranking:** Significant concern.	PO-RALG/PQ-1/3	Supervising Consultant did not condemn the use of the material.	Auditor 's recommendation upheld. Contractor to comply with Auditor 's recommendation at no additional cost to Client. Contractor has a primary obligation to the Client to comply with the Contract specification.
3. Supervising Consultant to verify quantities certified for prime coat. **Cost**: None **Reason:** Quantities over-estimated by 25%. **Implications**: Possible need to adjust next payment certificate **Ranking:** Significant concern	PO-RALG/ PQ-1/5	None	Auditor 's recommendation upheld. Supervising Consultant to verify quantities

Completed Decision Tracking Form Sent by Client to:

1. Auditee: Premier Contractor s____ **Date:**__01__/__05_/_2016 **Auditor : PQ Consultants** ______ **Date:**__0 1_/__0 5_/_2016

*** Auditor to complete and attach to report and send to Client**

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Ministry of Public Works and Housing, Kenya. (1997): ***Technical Audit Operations manual.*** Roads Inspectorate, Ministry of Public Works and Housing, Nairobi.

Ministry of Transport and Communications, Botswana (2001): ***Guideline No.7: Technical Auditing of Road Projects.*** Roads Department, Gaborone.

Ministry of Works, Tanzania (2008). ***Technical Audit Manual.*** Road Fund Board, Dar es Salaam.