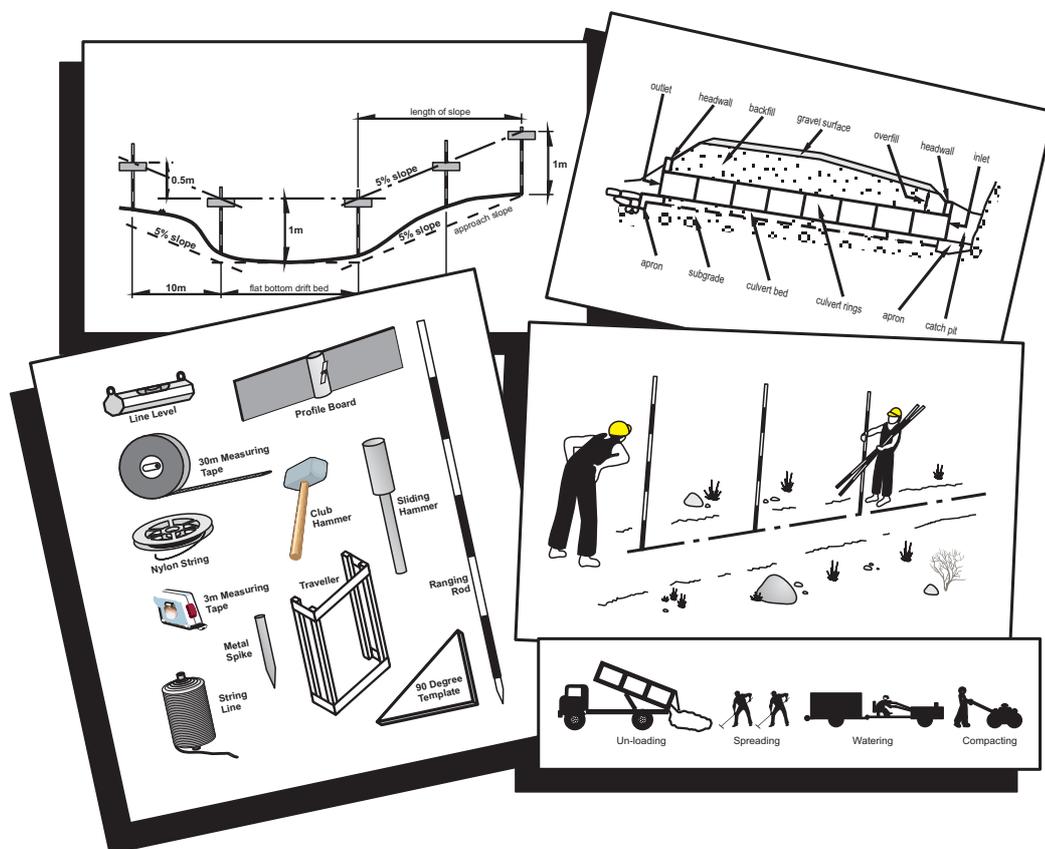


Labour-based Road Construction and Maintenance Technology

COURSE NOTES

1



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Module 1

Appropriate Road Works Technology in Developing Countries

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1.1 Introduction

Labour-based technology should be viewed as an option. There is a danger of approaching these methods as if they were something strange or, worse, backward. The simple fact is that in economies with a low wage level and a shortage of foreign exchange, one would be foolish to ignore consideration of technologies which emphasise the use of the available resource, labour and which limits the use of foreign exchange for equipment. Whether one method or the other is appropriate in particular circumstances or for different types of projects is a question for evaluation. One however has to consider the alternatives based on the actual prevailing conditions rather than on received "wisdom" from the industrialised countries.

Numerous studies carried out by several agencies including the World Bank and the ILO in many countries including Lao PDR, have demonstrated that when the right conditions are present in a given area, labour-based technology is the most cost-effective approach to rural infrastructure development. These conditions include:

- sufficient numbers of under- or unemployed persons in the areas where the work is required plus local availability of construction materials;
- low wage levels (under US\$ 4.00 per day according to World Bank studies);
- shortage of conventional construction equipment and high capital costs;
- Government commitment to the development of employment and generation of income in the rural areas;
- small contractors skilled in labour-based technology and capable of supervising the work efficiently; and
- competence of the public sector agencies responsible for rural infrastructure works in the areas of contracting and supervision of contractors' performance.

Lao PDR would generally fall into that group of countries where the use of labour-based methods should be seriously considered. The first four criteria are already met and the latter two can easily be developed, as proven in many other countries facing the same challenges in their road sectors.

1.2 History

Traditionally, policy makers in developing countries have been reluctant to see the potential of making efficient use of the under- and un-employed labour in the provision of rural infrastructure. Notable exceptions were some Asian nations such as India, Pakistan, Indonesia and China, where labour traditionally has been used in all types of construction works. Many developing countries, including Lao PDR, imported construction methods that made extensive use of heavy equipment.

The reliance on equipment-based, high technology, construction methods has evolved for a number of reasons: the desire of politicians and engineers to emulate the more developed countries, the tendency among international consultants and contractors to favour construction methods with which they are familiar, and the biases inherent in the tied-aid stipulations of international and bilateral assistance agencies, the concern of the latter being to help exports of their own countries. A particular important factor has been the educational background of the technical leadership in most developing countries. Often acquired in engineering schools that advocated the latest technology and production methods, this background conditioned planners and engineers to favour the use of heavy equipment in all circumstances. Equipment-based methods were perceived to have productivities, costs and performance that were predictable; they were associated with high quality results; and they were surrounded by an aura of technological progress. Hence, the use of equipment in construction was particularly attractive, and in some cases unavoidable, since financing would not otherwise have been forthcoming.

At the same time, the substitution of labour for machines appeared to have negative connotations. Large numbers of labour are needed to approach the output of a single piece of equipment. Doubts were entertained about the ability of unskilled workers to produce high quality work. Labourers were regarded as being undisciplined, unruly, unreliable and consequently, requiring extensive supervision. In sum, the extensive use of labour was judged to increase the risk of higher costs, to bring about longer construction periods, and to produce results of dubious technical quality. These risks tended to make public sectors in most developing countries - the front line of potential users - resist the use of unskilled labour in construction.

Reliance on equipment has shown to have some disadvantages. It can result in a technological dependence on the countries that provided the equipment. Equipment-based operations also entail heavy expenditures of foreign exchange. Such costs might be an unavoidable burden for urgently needed high technology projects. But for the construction of smaller, more scattered and technically less demanding rural projects, politicians and administrators began to look for ways to put local resources to work. If much of the work could be done by hand, the rural poor would not only receive the benefits of the finished product but would, in addition, secure the much needed income from its construction, considerable employment from its maintenance, and a sense of participation, civic pride and unity.

1.3 Definition

There are several categories of construction programmes that use large numbers of unskilled labour:

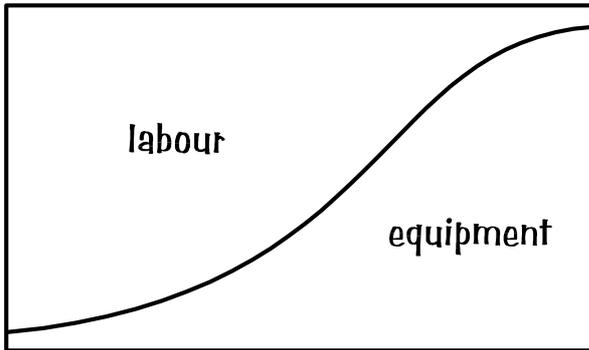
- Relief Programmes responding to natural or man-made catastrophes, (i.e. droughts, severe floods, war, etc). Their prime objective is to provide food and income to the affected individuals. Although such programmes may also improve infrastructure, this is considered as a by-product.
- Employment Generation Programmes - These projects give little attention to cost and quality effectiveness. Once more, asset creation is a secondary objective.
- Asset-Creation Programmes - These attempt to improve infrastructure at the lowest possible cost, maintaining accepted quality levels and applying the most *appropriate* technology. Simultaneously, they supply employment opportunities in the rural areas, providing supplementary cash income to farmers. A sub-category is self-help programmes, which are schemes that do not pay wages to their workers, since the labour is regarded as the ultimate beneficiaries and owners of the created assets, and the project is merely an attempt to assist them in helping themselves.

This course focuses on the planning and implementation of the latter category of programmes, and more specifically, how this type of programmes can be organised in the rural road sector of Lao PDR.

An "appropriate" technology is defined as one that is both technically and economically efficient for a defined level of quality. Thus, appropriate construction technology exists over the entire range of methods. In each case, the appropriate mix of labour and machines will be determined by the technical nature of the project, available resources, prevailing prices and the socio-economic environment in which the project is executed.

The labour-based approach starts from the position that labour is a relatively abundant and cheap local resource during large periods of the year, if not throughout the year, and thereby seeks to determine the most appropriate work methods.

To avoid a common misconception, it is important to distinguish between labour-*based* methods and labour-*intensive* methods. In contrast with labour-based technology, the labour-intensive approach seeks to maximise the use of labour with minimum use of mechanised equipment, often at the expense of cost and quality efficiency.



labour-intensive

labour-based

equipment-based

Labour-based technology can be defined as the construction technology which, while maintaining cost competitiveness and acceptable 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 resources.

Besides the focus on labour, the use of locally available materials and resources is an important feature of labour-based works programmes.

The term *local resources* includes not only labour, but also other human, institutional, material, educational and vocational resources in

the public and private sectors. A proper allocation and best use of these resources, combined with external assistance, is capable of promoting sustainable growth of both employment and asset creation.

Local resources can be:

- manpower/womanpower,
- local institutions: government, central and local; private including cooperatives, communities, farmers' associations, non-governmental organisations, etc.,
- local entrepreneurs: petty contractors, other local contractors, industry, artisans, traders, etc.,
- local skills: educational, vocational (school leavers, artisans),
- local materials: timber, stones, bricks, etc.,
- locally available equipment: transport (e.g. farm tractors), and
- local finance (contributions in kind or funds).

1.4 The Laotian Context

1.4.1 General

Lao PDR is distinguished topographically by a very mountainous area extending north and south throughout most of the country and a small area of lowland on the southern and southwestern borders. The mountainous area, which covers about nine-tenths of the entire country, can be divided into a northern section of heavily forested mountain ranges and plateaus cut by deep, narrow valleys and gorges and a southern section containing more sparsely forested limestone terraces. As a result of this rugged terrain and long distances between settlements, internal and external communications become difficult and costly.

The main climatic features are determined by the monsoons. The wet summer season prevails from about May to October, with rainfall averaging about 1780 mm, and a dry cool season extends from about November to February. The remainder of the year is hot and humid.

Lao PDR is a landlocked country with most of its natural resources unexploited or unsurveyed. The economy remains small and undiversified, with a per capita income estimated at about US\$ 335, making it one of the least developed countries in the world. The economy is dominated by agriculture which accounts for about 60% of GDP and two commodities (timber and electricity), providing about 70% of export earnings. As such, the economy is vulnerable to climatic conditions and external factors beyond the Government's control. This, coupled with a weak human resource base, presents the country with a major challenge to development.

Among Asian countries, Lao PDR has one of the most undeveloped road networks. During the past nine years, Lao PDR has been investing between US\$ 20 and 45 million annually in road rehabilitation. While these investments are sizeable in terms of total capital budget of the Government, the effect on the overall length of the road network has been limited. The past decade's investments have added approximately, 200 km of improved new roads each year, i.e. about 2 % of the national and provincial road network.

With few exceptions, road improvement works has mainly been focusing on establishing a functionable trunk road network in the country. The main emphasis of these investments has been on two major components, (i) Road 13 from Pakse in the south to Pakmong in the north and (ii) in roads providing access to the rich agricultural and densely populated area on and around the Bolavens Plateau in the south.

Until recently, the provincial and district road network has received little attention.

1.3.2 Rural Access

Isolation is a fundamental cause of poverty. Isolation is reflected in the lack of access of the population to goods and services. If the population has no access to basic services such as water supply, health and educational services, they will even be unable to satisfactorily meet their basic needs. In addition, lack of access to, or isolation from, technology, agricultural inputs, markets and outlets for cash crop production means that there is neither the incentive nor the capability to generate economic surplus. Moreover, lack of access to information and to available government services means that the population is cut off from the mainstream of economic and social development in the country.

The important point here is that lack of access is a major factor contributing to the continuing poverty of the rural population. Major efforts are now being undertaken to improve the social and economic situation in the country. Nevertheless, it is vital that the problem of access is tackled in a comprehensive and integrated manner.

Therefore, a shift in emphasis towards improving and maintaining provincial, district and other rural roads is justified. Road infrastructure is limited and where it does exist, it is poorly maintained, causing a serious constraint to economic and social development.

That being said, it should be recognised that in the poorer provinces, the immediate potential for economic development is also limited. Most households barely produce enough rice to be self sufficient. Roads cannot, in the first instance, lead to significant increases in income. The immediate benefits are likely to be improved access to health and education. However, without proper roads, it is difficult to provide the basic social services which may in the second round result in increased social and economic development.

Roads therefore are a necessary but not sufficient element in rural development in Lao PDR. These roads could also contribute directly to the benefit of the rural population through the use of labour-based construction and maintenance methods.

1.5 Viability

Many engineers will claim that there are serious limitations to the use of labour-based works technology. The most important criticism is that labour-based methods produce poor quality outputs. However, projects carried out in many countries during the last 15 years, including in Lao PDR, have convincingly demonstrated that labour-based projects can provide excellent quality results provided that there is effective control and provided that quality standards are adhered to.

In general, the competitiveness and quality of labour-based projects is determined by:

- the availability of suitably trained supervisory staff,
- the introduction of appropriate planning, programming and control systems,
- the use of incentive schemes, and
- the availability of adequate hand tools and light equipment.

If these aspects are not neglected, labour-based projects can produce good quality works at competitive costs.

1.5.1 Cost

It is often assumed that labour-based projects are expensive. In this regard it is important to remember that the cost of labour-based projects is mainly determined by two factors (i) the *wage levels* for casual workers and the *productivity* achieved.

In Lao PDR, the opportunity cost of unskilled labour has been found to be about US\$ 1.7 per work day, although there are seasonal variations with labour supply being at a premium during the sowing and harvesting periods of the agricultural cycle.

At the labour wage of 2.00 US\$/day, there seems to be no problem of labour supply. In Oudomxay, where the ILO labour-based road project operated in the remote areas, up to 30% of the workers came from more than 10 km away to seek employment. With some assistance from the project, these workers set up camps near the project site. Labour productivity rates were found to be comparable with experience from neighbouring countries.

In the situation prevailing in most developing countries, the cost of an unskilled worker is equal to or less than US\$ 2:- per day. At current equipment purchase and operating prices, labour at such rates is certainly competitive with equipment. In fact, World Bank and ILO research has shown that for road construction and maintenance work labour should be seriously considered at daily wage rates of up to US\$ 5:-. Naturally, a lot depends on the productivity (output per average workday) achieved.

Figure 1 shows the cost effectiveness of using labour-based methods for common work

activities on road works projects.

| Activity | Daily unskilled labour wage (US\$) | | | | |
|---|------------------------------------|------|------|------|------|
| | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 |
| Site Clearing | [Line from 1.00 to 5.00] | | | | |
| Excavation | [Line from 1.00 to 5.00] | | | | |
| Ditches | [Line from 1.00 to 5.00] | | | | |
| Bulk (soft, loose soils) | [Line from 1.00 to 3.00] | | | | |
| Bulk (other soils, soft rock) | [Line from 1.00 to 2.00] | | | | |
| Caissons and open wells (soft loose soils) | [Line from 1.00 to 4.00] | | | | |
| Caissons and open wells (other soils, rock) | [Line from 1.00 to 3.00] | | | | |
| Refilling pipe and culvert excavations | [Line from 1.00 to 5.00] | | | | |
| Loading and unloading bulk materials | [Line from 1.00 to 5.00] | | | | |
| Short haulage | [Line from 1.00 to 5.00] | | | | |
| Labour up to 150m | [Line from 1.00 to 3.00] | | | | |
| Animals up to 500m | [Line from 1.00 to 5.00] | | | | |
| Placing, spreading and shaping bulk materials | [Line from 1.00 to 3.00] | | | | |
| Mixing concrete (cement or bituminous) | [Line from 1.00 to 2.00] | | | | |
| Stone production | [Line from 1.00 to 5.00] | | | | |
| Aggregate 15 to 50 mm | [Line from 1.00 to 3.00] | | | | |
| Undressed stone 50 mm | [Line from 1.00 to 5.00] | | | | |
| Dressed stone | [Line from 1.00 to 5.00] | | | | |
| Brick laying and masonry construction | [Line from 1.00 to 5.00] | | | | |
| Structures | [Line from 1.00 to 4.00] | | | | |
| Pavements | [Line from 1.00 to 4.00] | | | | |
| Laying pipes | [Line from 1.00 to 5.00] | | | | |
| Non-pressure | [Line from 1.00 to 4.00] | | | | |
| Pressure | [Line from 1.00 to 4.00] | | | | |
| Culverts (concrete) | [Line from 1.00 to 4.00] | | | | |
| Culverts (corrugated metal) | [Line from 1.00 to 4.00] | | | | |

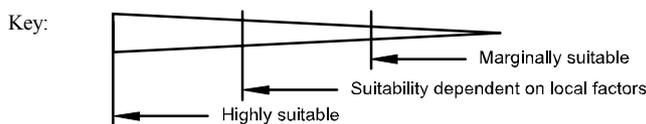


Figure 1: Suitability of Activities for Execution Using Labour-based Methods at Various Wage Levels¹

On the other hand, equipment costs are equally influenced by the productivity and availability of the machines. In most developing countries, both the productivity and availability rates of machines are extremely low, owing to frequent break-downs, non-availability of spare-parts, scarcity of fuel and lack of skilled mechanics and operators. Also, the management of available equipment is often poor and, even when available, equipment is often misused. All in all, this implies that the real cost of using machines is often higher than calculated and the outputs much less than assumed.

¹ Source: Labor-based Construction Programs, A Practical Guide for Planning and Management, World Bank, 1983

1.5.2 Speed

Another criticism concerns the low outputs and therefore the slow speed of labour-based construction works. Here it should be realised that the speed of labour-based works depends on two factors: (i) the *productivity* of the labour and (ii) the *numbers* of workers engaged. It is a fact that productivity of labour can be increased several times if labour on site is effectively organised, motivated and provided with good hand tools.

Also, provided that suitable systems and procedures are introduced and sufficient numbers of trained supervisors are available, it is possible to engage and manage large number of workers on many sites concurrently. For example, a large rural roads construction programme in Kenya employed at its peak period more than 10,000 workers, operating on over 100 sites and producing some 1,000 km of rural access roads per year. Even more impressive is the number of workers who have been employed on enormous construction sites in China.

It is important to remember however that a great deal of preparatory and training work is necessary before such large numbers of workers can be effectively employed.

Small dispersed projects are usually more suitable for labour-based methods, whereas large, concentrated projects such as construction of major highways and bridges, are better suited to the use of equipment. An equipment-based operation in a small and scattered setting, for a relatively limited volume of physical work, must provide for the maintenance and frequent transportation of expensive machinery from one small site to the next. For widely dispersed projects, consequently, labour-based methods can provide faster and less costly solutions even when prevailing wage rates are fairly high. Their advantage arises, first out of the cost of equipment delivery, mobilisation, and operation in hard-to-reach areas where there will seldom be enough work to use the equipment at full capacity, and secondly, out of the high cost of equipment maintenance in areas remote from established workshops.

1.5.3 Quality

Technical standards for road construction are defined by the headquarters management and central government. Detailed design of the work to be done is carried out by the provincial engineer and his staff, and is based on the overall specifications and technical standards of the project.

The selection of design standards is related to road function, volume of traffic and terrain. In Lao PDR as elsewhere, any suggested standard must be based on economic and technical considerations. The total rehabilitation needs are huge and hence, functional standards need to be considered. These can always be revised upwards as traffic increases and more funds become available, in a stage construction process.

Once the road priorities have been made and the detailed road alignments have been

identified, it is possible to establish the correct mixture of labour and equipment-based work methods.

When considering the use of labour-based technology in road works projects, it is important to acknowledge its limitations. In some circumstances, traditional equipment-based work methods are more effective and may provide higher quality outputs, such as large excavation works, rock excavation and haulage of materials over long distances. It would be incorrect therefore to take an ideological view of the use of labour-based methods. Where they are not capable of reaching the required standard, equipment should be used. Nevertheless, the experience so far in Lao PDR shows that in many cases it is not necessary to resort to the use of heavy equipment.

In general, the priorities for road improvement relate to providing all-year road access to regions where such access today only exists during the dry season and in some cases not at all. In most cases, these roads will improve access to district centres or other larger regions with poor road conditions. The main task will be to upgrade already existing earth roads, following the original road alignments. Considering the purpose of the roads and expected traffic volumes, standard gravel roads of 5-6 metre carriage width, with a 10-15 cm laterite surface and a curvature catering for design speeds of 40 km/h should be appropriate.

Earthworks is mainly expected to involve re-excavation of drainage systems and preparation of camber - activities which are well suited for the use of manual labour. Surface materials will most probably need to be transported using traditional equipment (tipper trucks and loader/excavator) and compacted using vibrating rollers. Levelling works, if properly organised, can be carried out by labour. Bridge and culvert works should follow established work methods which have always relied on a high degree of manual labour.

This method of organising rural road works has proven to be a technically and economically sound solution for the provision of all-weather road access to rural areas both in Lao PDR and in several other developing countries. By choosing an effective balance of labour and equipment, these roads can be effectively constructed/rehabilitated to acceptable quality standards at an average cost of approximately US\$ 15,000 per kilometre.

1.6 Road Construction

1.6.1 The Lao Road Sector

Roads in Lao PDR are classified into four groups according to their function:

| | |
|------------------|--|
| National Roads | are of high technical standard, serving the nation's economic, political, and cultural development and national defence, linking the capital with other provinces and linking the country with neighbouring countries and main ports, also serving the most important tourist links; |
| Provincial Roads | serve economic, social and cultural development, tourism and defence within a province, prefecture or special growth area, linking province to province or district to district; |
| Local Roads | contribute to economic development and bringing other benefits to towns and villages, linking either district to district, district to village, or village to village; |
| Special Roads | intend to serve mining, industrial, agricultural or forestry development or required for national defence. |

MCTPC is responsible for the construction and periodic maintenance of the national road network, while the provinces are responsible for the provincial and local roads. Recently, the MCTPC also delegated the responsibility for routine maintenance of national roads to the provinces.

Estimates from the Transport Planning Unit (TPU) summarise the existing network and its condition as follows:



| | Bitumen | Laterite | Earth | Total |
|------------------|---------|----------|-------|-------|
| National Roads | 1,674 | 1,646 | 1,144 | 4,464 |
| Provincial Roads | 360 | 1,970 | 3,566 | 5,896 |
| Local Roads | 78 | 1,073 | 4,711 | 5,862 |

However, this does not fully describe the situation with regard to access to the rural areas. Of the total provincial road network less than 35 percent is thought to be passable in the wet season and only half of the population is estimated to have road or river transport access throughout the year. Only 51 district centres of the total of 133 have all-weather access, and 15 have no road access even in the dry season.

From the above figures, it is evident that the need for rural road development is enormous and varied. In the rural road sector, the needs are not just for development of village and district roads, but also of provincial roads. In some provinces, the most

immediate need is building roads to connect the isolated provinces to the main road network. As the network of rural roads (provincial, district and village roads) is small and in an unmaintainable state, the needs also include reconstruction of roads to a maintainable state and extension of the network to reach isolated district and major villages, particularly in the mountainous regions.

1.6.2 A National Programme

It is possible to think in terms of a nationwide programme of labour-based rural road works. The ILO assisted labour-based road works project has proven that it is possible to carry out rural road works relying on a high degree of locally available resources. Despite operating in some of the more remote areas of the country, this project has managed to deliver desperately needed infrastructure and employment. It has also clearly proved that with proper training programmes provided, it is possible to establish an efficient rural road works programme within and under the management of the existing government technical agencies in the provinces.

As mentioned above, past efforts to improve the road network in the country has concentrated on upgrading the national road network. The next step is now to improve the secondary and tertiary road network to all-weather standards. Due to the current poor condition of secondary roads and the resulting limited access to the districts, any future road improvement programme in the provinces will first need to address the secondary road network. This implies that the first task will be to provide all-weather access to all of the country's 133 districts.

Based on the experience from the past labour-based road works programmes, it is now possible to develop a good picture of the costs of and timescale for upgrading the rural road network in Lao PDR. Although the existing road network still does not provide access to the entire population, it may provide some cost indications for providing a functional rural road network in the country.

The below table describes the cost of upgrading the existing mapped rural roads in the country using labour-based methods supported with a limited amount of equipment:

| Provincial Roads | | Length | Unit Cost ¹ | Total Cost(US\$) |
|--------------------------------------|------|---------------|------------------------|--------------------|
| Reconstruction | 65% | 3,832 | 20,000 | 76,640,000 |
| Rehabilitation and Spot Improvements | 35% | 2,064 | 10,000 | 20,640,000 |
| Local Roads | | | | |
| Reconstruction | 100% | 5,862 | 14,000 | 82,068,000 |
| Grand Total/Average | | 11,758 | 15,253 | 179,348,000 |

1. Includes provision of bridges and other drainage structures

If this work is undertaken during a period of the next 10 years, completing 50% during the first 5 years would correspond well to the government public expenditure programme for 1996-2000.

A key question is whether it is possible to achieve sufficient production rates when applying labour-based work methods. The existing rural road network consists of approximately 11,600 km of provincial and local roads. With the currently planned investment programme it would be possible to finance the improvement of half of this network during the next five year, i.e. 1,160 km per year. This is an average production of 65 kilometres per province per year.

As a comparison with the current force account operations in the ILO road works project, the current capacity of the DCTPCs in Oudomxay and Savannakhet should be able to produce 60 km per year provided sufficient funds were made available. Experience from other countries show that trained and equipped small-scale contractors with a labour force of 150 - 200 workers can each complete 15 km per year of gravelled roads to similar standards. With 4 - 5 trained contracting firms operating in each of the provinces, the required capacity could be achieved.

Clearly, all these figures are illustrative only. Nevertheless, they do suggest that a nationwide programme would be feasible by labour-based work methods in relation to the cost per km presently being achieved, the budget allocations for roads and the potential output of the DCTPCs and the domestic construction industry.

1.7 Road Maintenance

The work of the ILO and others during recent years in the field of road maintenance has demonstrated that it is feasible to involve the local population more extensively in road maintenance works, provided that suitable incentive schemes are introduced and an adequate supervisory and management structure is established. The development and utilisation of small local contractors for road maintenance works is a promising avenue which needs to be explored to the maximum extent possible.

The socio-economic environment and the state of development of a particular area play a determining role. In recent years, however, a great deal has been learnt on the establishment of alternative road maintenance systems. One could categorise those as follows:

- Direct labour employed as permanent or semi-permanent staff, supported by equipment (classical approach).
- Individual or collective maintenance responsibility for a road section.
- Agreements between communities and government.
- Petty contracts for selected road maintenance activities.
- Use of the private sector.

Of course, it is possible to combine or modify the above approaches in many ways. It is evident, however, that the classical approach does not currently operate in a satisfactory manner. Moreover, the overall working environment in which road maintenance is carried out continues to be unfavourable.

In applying any of the alternative options the key element to take into account is the motivation of the workers and their supervisors. Incentives at all levels must be incorporated as part of the system in order to make it sustainable in the long term. As concerns the workers at village level, such incentives may not necessarily have to be material. If there is a significant local interest in the road (or road section), some assistance in the form of tools, construction materials and supervision could be a sufficient incentive to mobilise adequate numbers of workers.

In these cases, planning and programming assistance may be sufficient to mobilise and direct village labour at specific times throughout the year to bring roads back into a trafficable state. This type of maintenance would therefore be provided not as a continuous low level routine maintenance input, but rather as a scheduled and well-directed community input involving a significant number of workers say two to three times per year.

The purpose of this type of intervention would be to put the road back into trafficable state when it would be most urgently required. The timing of the interventions should be discussed and agreed upon between the villagers and the supervising technical ministry and would depend on technical, economic and social considerations. Naturally, this type of maintenance intervention would primarily apply to access roads with very low traffic levels and where communities are prepared to provide (subsidised) collective inputs to safeguard their level of access to the main road network.

In the majority of cases, however, further inputs in the form of money or food will be necessary to establish a continuous and sustainable maintenance system. The level of such inputs could, however, be kept minimal if agreements with communities and/or village organisations are negotiated. In this way, the beneficiaries of the roads are directly participating in and contributing to its maintenance. Regular and sustained inputs can also be commercially negotiated with individuals or lengthmen (who may be grouped together) or through petty contracts.

Alternatively, systems of financial contributions or local taxes could be negotiated with the local beneficiaries.

Using petty contracts for the execution of different routine maintenance activities has been shown to have the following advantages:

- Flexibility of contractors (ability to introduce incentive schemes, control of labour force).
- Less bureaucratic procedures.
- Government released of direct management responsibilities.
- Contractual commitment of maintenance funds (difficult to divert funds to other purposes).
- Political support for well defined activity.
- Development of skilled local contractors.

On the other hand, the private sector has (as yet) little relevant experience in carrying out routine maintenance contracts. However, small-scale village based petty contractors without previous experience quickly assimilate the necessary skills to organise a number of workers. The crucial issue is to adapt the working environment so that the contractors can perform without constraints and without losing confidence in the employer.

One can argue that in the long term there will not be sufficient funds available to pay the full cost of rural road maintenance. In such a situation, much more thought has to be given to involving the communities in the repair and maintenance of the rural roads.

This is an issue which is often susceptible to simplistic solutions. An argument often heard is that rural roads are built specifically for the benefit of the people and they should therefore shoulder the responsibility for maintaining the road.

One has to remember that roads are built to carry vehicles. Many communities recognise the benefits that will come to the community from the better access to

markets, easier access to government services and better connection to the outside. Nevertheless, they do not necessarily recognise the individual benefit that will come to them. After all most of them do not own a vehicle. In Lao PDR, many are subsistence farmers and have no real need of markets. Indeed they may feel that as individuals they cannot see the benefit that will accrue to them. At best, they may be prepared to maintain the road where it runs through the village but, experience suggests that, they will be unwilling to maintain more than that.

This is not to suggest that it is not possible to obtain community support for rural road maintenance. However, it is necessary to put a lot of effort into:

- (i) ensuring that the community fully understands the benefits that will come to them from maintaining the road and
- (ii) providing some form of incentive to the communities.

The lessons to be learned from attempts to involve the local population in the maintenance of rural roads are the following:

However, there are other forms of incentives:

- (a) If the road is to be used mainly for exporting produce some sort of levy can be made on the those benefitting from the sale of the produce.
- (b) If the road is of obvious benefit to the communities then some form of maintenance fund can be set up which can be furnished from a small contribution from the communities, if possible augmented by the local authorities. Such a fund can be used to pay the maintenance workers or to pay local contractors. The fund could also be established by a small amount taken from the salaries of the workers involved in the construction.
- (c) If the road specifically results in the possibility to market crops, a small levy could be introduced on those from which funds could be allocated to maintenance.
- (d) The local authority could provide the basic tools such as hoes and wheelbarrows to the maintenance workers. Such tools can be used by the workers for their own activities.
- (e) Food aid can be used either directly or converted into cash as the means to pay for road maintenance.

For the foreseeable future, programmes of rural roads will be funded by foreign assistance. It would be a mistake, however, to use these projects to pay for the maintenance of the roads constructed. Certainly, donors should be encouraged to set funds aside to develop sustainable systems. However, it has to be accepted that merely putting money into rural road maintenance is not a sustainable solution. Funds that are available in these projects should be used to test out different forms of maintenance as illustrated above. In this way, it would be possible to arrive at solutions which the Lao PDR Government would be able to sustain.

1.7.1 Current Situation

There is practically no preventive road maintenance on the rural roads in Lao PDR, nor is there any proper maintenance set up in the departments of MCTPC in the provinces. The main reason for this situation is the limited funds available for any type of maintenance activities. As a result, the roads keep deteriorating and the repair needs get more and more desperate. Even roads rehabilitated in the recent past have again deteriorated for want of regular maintenance.

Some development agencies have been involved in maintenance of roads constructed or rehabilitated by these agencies themselves for some time. During the last two years, ILO has been maintaining the roads constructed and rehabilitated by it. Presently, ILO is maintaining 30 km of roads in Oudomxay and 20 km in Savannakhet by the lengthman system and some sections using village-based contracts. In addition, Oudomxay Province has recently established a routine maintenance by the "length-man" system on its national road network.

1.7.2 Routine Maintenance

Routine Maintenance Tasks

- Repair, fill and compact pot holes and ruts;
- Erosion control of shoulders and slopes
- Clear side and mitre drains to allow free passage of water;
- Clear culverts and other water ways;
- Cut grass and bushes;
- Maintain road signs in place;
- Perform minor repairs to culverts and retaining structures;
- Repair and replace scour checks.

Routine maintenance of low traffic rural roads is a widely dispersed activity, requiring small resource inputs over a large number of widely separated points. This activity is best suited for manual labour. The amount of work needed to keep a length of road in good condition depends on several factors, such as type of road surface, traffic volume (number, type and size of vehicles), the severity of climatic conditions, especially rain fall, type of soil; the susceptibility of the terrain and road gradients to erosion, and the presence of bush and vegetation.

Under average conditions, one full time worker should be able to cover the routine maintenance works each year of 1-2 km of single lane gravel road, with traffic of about 25 vehicles per day. This activity can be most economically performed by persons living along the roads and engaged for road maintenance. Locally recruited workers are also under social pressure from their neighbours to do the job well. Former road construction workers are ideal maintenance workers, because they already have some training and experience in the work involved.

1.7.3 Recurrent and Periodic Maintenance

Periodic road maintenance works involve activities such as reshaping of the road surface, re-gravelling and repair or reconstruction of damaged drainage structures. Such works could be organised the same way as rehabilitation and new construction works using labour-based methods under a contract system, works carried out by small-scale private contractors (with a limited amount of equipment), and supervised and managed by staff of the DCTPCs.

1.7.4 Emergency Maintenance

Emergency maintenance can obviously not be planned, although it will be required most likely during, and just after the rainy season. Emergency works involves activities such as the reinstatement of sections of roads washed away by floods or heavy rainfall, removal of landslides and fallen trees and repair of culverts, drifts and bridges. By using local labour, emergency works can be quickly mobilised and urgent repair works can be completed at an early stage thereby limiting the extend of damages caused by rainfall, landslides, etc.

1.8 Possible Impact

In the past, little attention was paid to rural infrastructure development as priority was given to developing large scale infrastructure, and as a consequence rural infrastructure has remained largely underdeveloped. Support to this sector is therefore necessary to reduce this enormous backlog. In addition, as there is a strong link between rural infrastructure and rural development, the development of rural infrastructure will address the development needs of the 80 percent of the population who live in the rural areas, 53 percent of whom live below the poverty line.

Labour-based road works programmes are not an end in themselves. They would form part of an overall strategy focusing on use of local resources in the rural areas. For it is self evident that the task facing the government in terms of rural development is enormous. Whilst external funds will of course be necessary, it is obvious that the country will have to depend as much as possible on its own resources.

Immediate Effects

In the labour-based road works projects currently being executed in the country, labour costs constitute 40 percent of the total construction costs. In terms of employment



creation, if the entire rural road network were improved using labour-based methods this would create an additional 58,000 work years of employment over the next 10 years. Perhaps more importantly, it would put \$7.2 million into the rural economy every year over the coming 10 year period.

One should also distinguish between short term employment for road improvement works and long term employment for road maintenance. Providing routine maintenance to the entire rural road network using the lengthman system would involve 11,500 workers having full time employment.

Even more significantly, the foreign exchange component of the programme would be reduced from 70 to 20 percent. This would mean a total foreign exchange saving of some US\$ 90 million, most of which would be spent on wages in the rural areas and purchase of local goods, materials and services.

Long-term Effects

The improved roads will contribute to the process of rural development by contributing to agricultural productivity, through expanding access of farm families to markets as well as to health, education and other social services, now severely

inhibited by the lack of an adequate and well maintained transport system. This of course would be true whether labour-based or equipment methods were used. What has been observed in other countries where labour-based projects have operated, is the effect on the local economy of the income from the labour-based work. Clearly, some of the money will be used for the purchase of basic items of food, household articles and clothing. However, it will probably also be used for obtaining better health care, education services and farm inputs. In addition, it provides the possibility of the local people making use of the roads through payments for transport services.

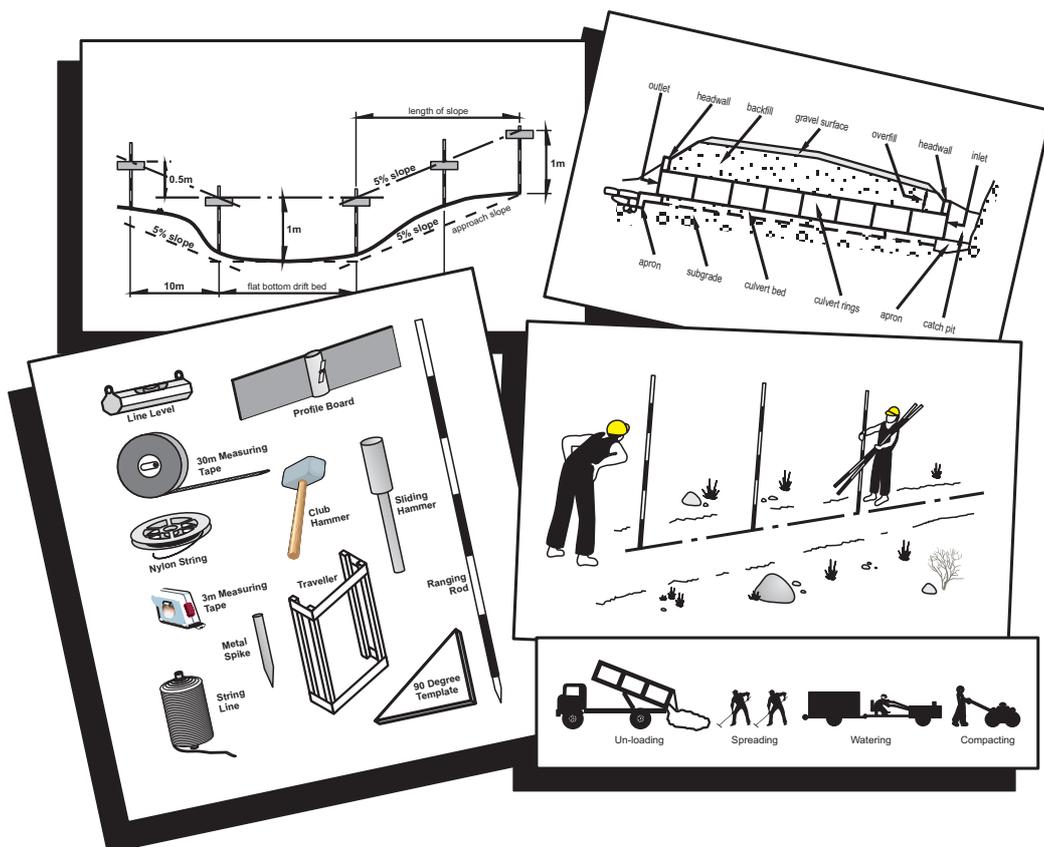
Studies on labour-based programmes have shown that it is these secondary benefits of the use of the income derived that is the most important element of these programmes.



Labour-based Road Construction and Maintenance Technology

Module 2

Technical Planning





Module 2

Technical Planning

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2.1 Road Selection

2.1.1 Selection Process

Roads to be constructed, improved or maintained under a certain programme are not just selected in an arbitrary manner. Each programme may have its own tailor-made identification and selection procedure. However, the process is in most cases similar and passes through a number of selection stages:



Figure 2.1 Road Selection Process

(i) Initial Identification

The initial identification step is the preparation of a list of roads proposed to be constructed/rehabilitated/maintained. This initial list will, in most cases, be prepared with local community involvement. Generally, the selected roads must meet pre-determined criteria which have been set by the programme management at central level, in collaboration with planning and funding authorities.

The list is then forwarded to the next highest authority (i.e. Rural Development Committee) for further discussion in terms of District and Province priorities and the need for other development projects. Afterwards, the list with the selected roads is forwarded to the implementing agency for screening (i.e. DCTPC).

(ii) Screening

The implementing agency usually carries out the screening of identified roads in order to disqualify those roads that a) do not meet certain criteria, b) are not technically or economically feasible, or c) are not likely to have the expected impact.

(iii) Appraisal

For those roads passing the screening phase, appraisal is usually undertaken. Appraisal is a more detailed assessment of the justification for the road works in question. Often, a cost benefit analysis is carried out as part of an appraisal. If this is done, this implies that construction/rehabilitation costs need to be estimated and socio-economic data assembled (population densities, agricultural potential, traffic volumes, etc.).

(iv) Ranking

A programme may not be able to absorb all selected roads which have passed the screening and appraisal phases. In addition, some roads will be of higher importance than others. An overall ranking of the selected roads, on the basis of overall weights

of some important evaluation factors, will be necessary in order to decide which roads should receive priority and in what order. The criteria used for ranking may be simple, e.g. the road with the lowest cost per head of population served could be improved first. However, at this stage other social criteria may also be introduced.

(v) Approval

Eventually, roads selected according to the above mentioned procedure require, as a final step, approval from provincial or central authorities and/or an external funding agency. No work can start before such approval has been given and funding has been secured.

2.1.2 Criteria

Whoever is asked to select roads must be given the exact criteria for which potential roads should meet. Usually, selection criteria are developed by the implementing agency (i.e. Ministry of Communication) together with the appropriate development planning authority (i.e. Ministry of Planning) and the funding agencies.

Ideally, the selection and prioritisation of individual rural road construction and rehabilitation projects should at first be carried out before the choice of technology is decided upon. Basically, there are three criteria which need to be considered:

- (i) technical feasibility,
- (ii) economic justification and
- (iii) social considerations.

Once the road priorities have been made and the detailed road alignments have been identified, it is possible to establish the correct mixture of labour and equipment-based work methods.

(i) Technical Feasibility

- The road must connect to a well-maintained engineered road, thereby adding on to the existing functional road network in the region.
- When considering a new project, it is important to make a rapid assessment of the future road alignment, investigating the need for expensive structures such as bridges, heavy earth works through rocky and steep terrain, and difficult soil types, etc.
- Building materials such as gravel and water should be available in a reasonable distance.
- Facilities for future maintenance (labour, tools, equipment and supervision) must be available.
- There should be sufficient funds available to continue periodic and routine maintenance.
- If labour-based work methods are a prerequisite (e.g. on Food for Work programmes), then a minimum of 100 persons should be available and willing to work for the project under the terms and conditions offered.

(ii) Criteria for Economic Justification

Various investment models are available to carry out the economic analysis. The benefits normally considered in an economic evaluation are:

- direct savings in the cost of operating vehicles,
- economies in road maintenance costs,
- time savings by travellers and freight,
- reductions in road accidents (although these often *increase* on improved roads), and
- wider effects on the economic development of the region.

Investment models are also available to estimate the total transport costs associated with different road surfaces including vehicle operating costs, maintenance costs and renewal costs under a variety of traffic, climatic and maintenance conditions.

Rural roads, however, represent the grass roots of the road network which feed traffic into the secondary and primary roads opening access to the rural areas. Rural roads have low traffic volumes and are generally constructed with gravel surfaces. For these roads, the economic justification for the investment rests mainly on the expected impact on social and agricultural development. Both these outputs are time related and have a large element of uncertainty.

The extent to which the local economy adjacent to the proposed road will benefit from the investment is dependent on its economic potential such as unused land, irrigation facilities and labour, transportation facilities and costs. To forecast an increase in agricultural production, producer surplus and assessment of resultant producer benefits is a complex and difficult task.

This effect on the economy is extremely difficult to predict and virtually impossible to model, and any assessment made will have a high element of uncertainty, and rely on a series of external factors.

In terms of maintenance economics, there are, however, clear guidelines which can be followed. A basic rule for any road works programme is to protect previous investments and therefore to allocate available funds according to the following order:



- (1) First, provide routine maintenance to the sections of the network which is in a good and maintainable condition. "Good" condition is regarded as when the road section requires a minimum of routine maintenance, which can be provided through a lengthman system.
- (2) Secondly, provide spot improvements and periodic maintenance to halt the deterioration of road sections in fair condition, thereby upgrading them to a maintainable condition.
- (3) Thirdly, rehabilitate existing roads which have fallen into total disrepair.
- (4) Once the three activities above have been secured, including regular maintenance for the newly upgraded road sections, one should be looking into new construction and expanding the road network. Once again, new projects should only be accepted when sufficient maintenance resources are available or can be secured when the construction of the new roads have been completed.

(iii) Social Criteria

The following are amongst the social criteria that may be used for ranking rural road rehabilitation projects:

- Present condition of the road. Communities without any access should be given high priority. The better the existing access, the lower the priority.
- The availability of access year - round. Communities without access only during some parts of the year should have high priority.
- The area influenced by the road. The larger the area of influence, higher the priority. The correct determination of the area served is important but is difficult to identify. The limits of the area are generally provided by watersheds, rivers or the proximity of adjacent roads. In the situation of rural roads in Lao PDR, the area within walking distance of two hours from the proposed road can be taken.
- The inhabitants served. The greater the number of inhabitants to be served, the higher the priority.
- Present transportation costs per km. Road transport costs are related to the road condition. The higher the present costs, more these costs will decrease by road improvements.
- The area of cultivable land within the area of influence. A rural road programme should benefit as many farmers as possible. Roads leading to fewer farms and houses should be given lower priority.
- Increased area of cultivable land. By improving access, the inhabitants may be encouraged to cultivate more land within the area of influence of the road.
- Orientation of local produce to the market. The greater the volume of marketable produce, higher should be the priority for road improvement.
- The potential increase in marketable production. Increased production is related to road conditions, because improved access to markets will encourage the inhabitants to produce more goods to sell.
- The availability of social and economic services. Most of the social and economic services (medical, educational, and agricultural inputs) end where the trafficable road ends and go no further. Improved access can extend these services to isolated communities.

From the above, it is clear that a certain volume of data needs to be collected before a ranking can be established. Furthermore, it is also evident that some of the criteria may be in conflict with each other (i.e. maintenance economics versus areas without road access). It is therefore important that the political leadership in the rural areas are fully involved in the final weighting of the criteria and final selection of projects to be included in the road works programmes.

2.2 Road Design

2.2.1 General

Design standards for particular programmes are usually developed at Headquarters and then forwarded to the site engineers in the form of instructions or as a technical manual. The scope of design work at headquarters is limited to general considerations - not to specific plans at each individual site. Decisions on final details require knowledge of terrain, soil quality, placement of structures, location of quarries, etc. Available maps, drawings and statistics are not likely to contain the details required for each individual road project. Obtaining such information generally requires a field survey.

Technical design aspects to be dealt with at headquarters are the standard parameters for typical work items. These standards encompass ranges of values within which the site engineer is allowed to operate. Design standards normally provide general guidelines relating to the following items:

- *Location:* Reference to places to be served and major obstacles to be avoided, such as marshy areas, crops and difficult river crossings.
- *Alignment requirements:* Instructions for setting out the course of the road.
- *Technical performance:* Specifications of maximum gradients, minimum horizontal and vertical curvature, sight distances, super-elevation, cross-fall, etc.
- *Materials requirements:* Specification of the type, quality and method of compaction, curing and tests to be performed.
- *Structures:* Recommendations on the use of local building materials such as stone and timber, and on the design of bridges, culverts and road protection works.

Road location and alignment are of particular importance when applying labour-based work methods. High alignment standards aiming to reduce the number of curves and soft gradients would require, particularly in hilly or mountainous terrain, considerable longitudinal earth movements which cannot be carried out economically by labour. Therefore, the site engineer should be aware of the need to select an alignment where earth works are mainly lateral (cut to fill), and where horizontal and vertical alignments will not lead to any significant longitudinal haulage.

Table 2.1 illustrates the kind of design data that Headquarters should provide. After the design parameters have been set for a certain type or class of road, it is up to the implementing authorities at provincial or district level to tailor the design to the physical, logistical, engineering and management constraints imposed by a given location and adjust the design to the precise technological mix to be employed.

| | |
|---|--|
| <p>Horizontal and Vertical Alignment</p> <ul style="list-style-type: none"> • Maximum grade • Minimum horizontal radius • Minimum vertical curvature • Horizontal sight distance | <p>Typical Cross Section</p> <ul style="list-style-type: none"> • Road width • Maximum earth side slopes • Pavement width • Layer thickness • Ditch details • Width cleared of vegetation |
| <p>Materials Data</p> <ul style="list-style-type: none"> • Soil or rock type • Compaction and moisture content • Curing requirements • Aggregate gradations • Mix proportions • Strength requirements • Tests to be performed | <p>Typical Structural Design</p> <ul style="list-style-type: none"> • River crossings • Culverts • Drifts • Retaining walls • Soil protection measures |

Table 2.1 Design Specifications

The selection of design standards is related to road function, volume of traffic and terrain. The design process as such deals with the following main steps:

- Establish road function.
- Assess the design traffic and its characteristics.
- Assess other factors which should affect the design (terrain, type of sub-grade, sub-grade strength, availability and cost of construction materials, etc.).
- Select geometric design standards (road cross-section, design speed and speed related standards).
- Select appropriate pavement design (total pavement thickness, thickness and type of materials for each component layer).
- Assess the need for road structures (bridges, culverts, retaining walls, etc)
- Assess the availability of labour in the vicinity of the road work sites.
- Assess the availability of local contractors.

The selected design should be justified economically and the optimum choice varies with the construction and road user costs.

One more influencing aspect is, whether new roads are constructed or existing roads are improved or rehabilitated to a maintainable standard. Existing roads were once constructed, applying certain geometric standards which will influence the improvement standards to be applied.

2.2.2 Rural Roads in Lao PDR

In Lao PDR as elsewhere, any suggested standards must be based on economic and technical considerations. The total rehabilitation needs are huge. Hence, functional standards are recommended. These can always be revised upwards as the traffic increases and more funds become available, in a stage construction process.

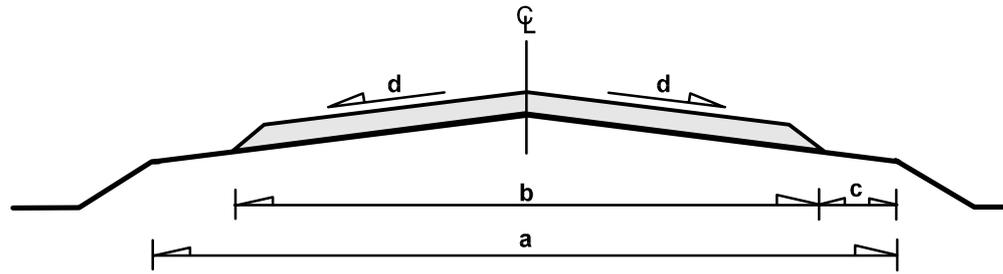
Traffic levels in Lao PDR are low. On the main roads, traffic volumes range between 15 and 336 vpd, though at most traffic count sites average daily traffic is below 150 vpd¹. Information on traffic on provincial or rural roads is scarce since traffic surveys have so far only been carried out on the national roads. However, based on village surveys and evidence some five years ago, the National Transport Survey (NTS) estimated that a population of about 1000 households within 20 km of a passable road could generate a traffic volume of 3 vehicles per day. This could now be an underestimate as there is evidence of substantial increases in traffic volumes on the main roads since 1991 and the requirement for permits to travel outside the province has been removed. The study also estimated that, on the basis of transport cost savings alone, because of the high costs of alternative forms of transport, a rural road costing between US\$ 5,000 and US\$ 10,000 per km could be economically justified with a population of 300 to 400 households within an area of influence which could stretch up to 20 km from the road. The assessment did not take account of the potential for economic development or the benefits of better access to services.

MCTPC has recently developed a design manual which has now been officially approved, however, on a provisional basis to be tested out before a final version is established. Unfortunately, this manual has been developed for the use of traditional equipment-intensive work methods without any serious consideration as relating to the use of labour-based work methods and other locally available resources.

The MCTPC Design Manual contains guidelines on appropriate geometrical design of roads depending on the expected traffic loads of the roads divided into seven different classes. Of particular interest is the design guidelines prepared for class V, VI and VII roads which are summarised in Figure 2.2. For comparison, this figure also provides the key dimensions for the roads built by the ILO labour-based road project in Oudomxay and Savannakhet.

The current and expected traffic volumes on rural roads in Lao PDR are in the range of 20 to 50 vehicles per day, maybe with a few exceptions with an average daily traffic of 50 to 100 vpd. Such traffic volumes would prescribe Class VI and VII design standards according to the MCTPC guidelines.

¹ Estimates from the Transport Planning Unit, MCTPC



| Parameter | Ref. | Class V | | | Class VI | | | Class VII | | | ILO | |
|------------------------------|------|---------|------|-----|----------|-----|------|-----------|------|-----|------|-----|
| | | F | R | M | F | R | M | F | R | M | F | M |
| Type of Terrain ¹ | | | | | | | | | | | | |
| Average Daily Traffic (vpd) | | 100-300 | | | 50-100 | | | < 50 | | | < 50 | |
| Design Speed (km/h) | | 60 | 40 | 20 | 60 | 40 | 20 | 40 | 30 | 20 | 30 | |
| Formation Width (m) | a | 7 | 7 | 6.5 | 6.5 | 6.5 | 6 | 6 | 6 | 5.5 | 5.5 | 5.5 |
| Carriage-way Width (m) | b | 5.5 | | | 3.5 | | | 3.5 | | | 5.5 | |
| Shoulder Width (m) | c | 0.75 | 0.75 | 0.5 | 1.5 | 1.5 | 1.25 | 1.25 | 1.25 | 1.0 | 0 | 0 |
| Cross-fall (%) | d | | | | 3 - 4 | | | | | | 8 | |
| Max Gradient (%) | | 7 | 8 | 9 | 7 | 8 | 9 | 8 | 9 | 10 | 10 | |
| Max Axle Load (tonnes) | | | | | 9.1 | | | | | | 5 | |

1 Flat, Rolling and Mountainous terrain

Figure 2.2 Standard Cross Sections

2.2.3 Small Bridges and Structures

For small bridges and other drainage structures, there is a great potential for utilising local industries if the design standards take into consideration locally available skills and materials.

Lao PDR is still blessed with adequate supply of high quality timber which can be used for bridge construction and maintenance. Supply of materials and construction works of this type should be possible to award to local companies.

Culvert pipe production can be organised as a local industry which requires very little equipment and mainly relies on skilled labour. If the local industry receives sufficient advance notice on future requirements, the supply of pipes can be organised through local manufacturers.

Locally available stone should be used for abutments, piers, wing walls and retaining walls. The supply of stone can be awarded to petty contractors and farmers.

2.3 Road Alignment

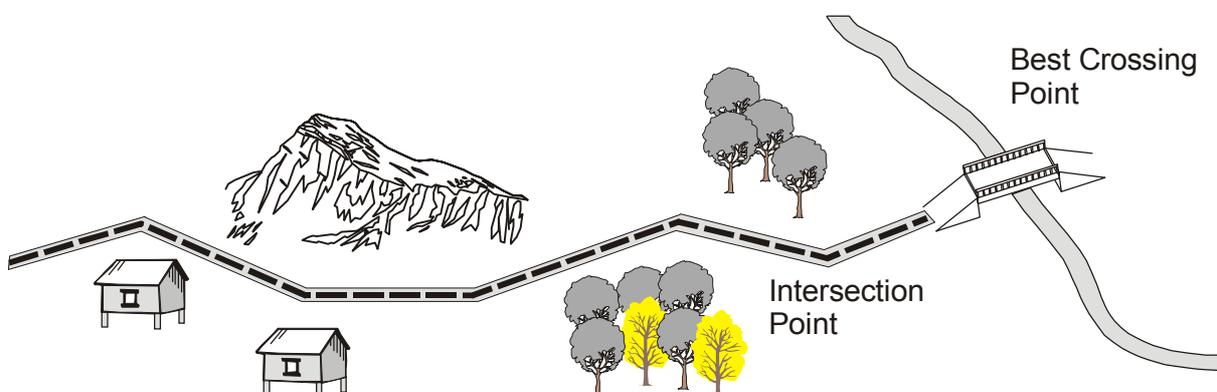
Selecting the most appropriate road alignment is the most important part of any road planning and design process. If the wrong alignment is chosen, it can result in delays to construction works, over-use of resources and a road which is difficult and expensive to maintain.

The types of surveying work commonly demanded of road engineers and technicians are:

- rough topographical surveys preparatory to selecting routes,
- surveys of catchment areas preparatory to designing bridges and culverts,
- soil surveys to check adequacy of subsoils and quarry materials,
- more accurate surveys of the selected site or route to enable quantities of material to be estimated, and
- setting out of the actual works.

When surveying possible alignments for secondary and tertiary roads, it is often sufficient to drive a four-wheel drive vehicle along the proposed routes. The routes can be marked on large-scale maps, and the reading of the vehicle's odometer can be used as a measure of distance.

The aim of a topographical survey is to establish the most economical site or route for the proposed works. For a low-cost project such a survey would normally consist of a walk over the area of choice, noting possible alignments or sites, potential quarry sites, and soil conditions. A line level, linen tape and short tape are the minimum requirements for such reconnaissance work.



The alignment should be selected to avoid areas of bad or difficult drainage, areas of bad soil or large earthworks, areas of rock outcrops or heavy bush clearing. In addition, where drainage structures are needed, the road alignment should be selected so that the structures are located at the best crossing point.

Good location of the road alignment is the best way to reduce costs - try to avoid areas that will consume a lot of workdays overcoming natural obstacles.

The alignment finally selected is often a choice between several alternatives. Each of these alternatives needs to be studied in detail, working out how they can be solved, and the amount of work and costs involved. For example, one could avoid an expensive structure by means of a longer route that went around the water course. In this case, one would have to consider the cost of the structure against the cost of the increased road works.



Remember:

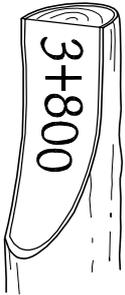
Whatever solution you choose, you must make sure that the road will be safe and that the solution will work. You must choose the most economical route, but you must not try to "save" costs by not properly overcoming, or by ignoring, problems. Avoid building road sections that will be likely to be damaged in the future and will cause maintenance problems.

If the right solution is too expensive during the construction phase, it will certainly be too expensive to solve using limited maintenance funds.

Engineers and technicians working on road projects may find the following notes on design useful:

- Plan the route so as to minimise material movement.
- Select watershed locations and follow contour lines in mountainous terrain as much as possible.
- Plan the route to avoid numerous or large river crossings. Select crossings where bridge construction will be simple or where ferry crossing will be possible at all seasons.
- When shallow watercourses cross the route, consider the feasibility of a "submerged bridge" with pipe culverts, fords, or paved causeways.
- Consider proximity of suitable road materials when choosing the route.
- Avoid rocky areas and areas with heavy bush clearing.
- Locate the route so as to allow for future upgrading by realigning (e.g. easing of curves and gradients) and widening.
- Plan sufficient passing places. The road stretch between the passing places should be visible from both sides.
- If possible, clear the trees up to a distance back from the road equal to the height of the trees (more when the road runs east-west to facilitate drying after rain).
- Avoid two curves with a short straight in between. It is better to combine them into one long curve.

- Avoid any horizontal curve at the top of or shortly behind a vertical curve where the driver will not be able to anticipate them.
- Avoid steep gradients. Try to keep longitudinal gradients below 10%.
- Allow for adequate drainage. Poor drainage is the most frequent cause of failure of a road; a waterlogged road loses much of its load-bearing strength.
- Make drainage ditches wide and shallow. Wide drains allow water to run at lower speed than do narrow drains, which produces less erosion of the channel. Also, wide drains are less easily blocked and more easily maintained than narrow drains.
- Be considerate with existing farming activities in the area. Avoid any situations which may trigger soil erosion.



The final centre line is first selected by means of a series of straight lines. These lines link together at points of intersection. The intersection points are located with the use of ranging rods, and properly marked by pegs. Once the intersection points are fixed, check with the local landowners to see if there is any objection to the proposed lines. Pegs are used to mark the alignment and the levels of the road. They are made of wood and can be produced locally. They should have a length of approximately 40cm. The chainage of the road is marked onto the pegs with a water proof marker. Before construction works starts, reference pegs are placed outside the road formation. Ensure that these pegs are hammered deep into the ground so that it will be difficult to remove them.

2.4 Estimating Works

Before the actual design work can begin, the engineer has to identify the possible technical problems of each works location. Assessment of the technical problems is an important part of the work of the engineers and technicians. Special attention should be given to:

- drainage,
- horizontal and vertical alignment,
- soil conditions,
- structures needed, and
- sources of supply of materials and water.

The technical assessment of works to be implemented by labour-based methods basically follow the same procedures as for machine-based methods. However, the use of labour-based methods should be taken into account so that:

- longitudinal haulage of earthworks is limited, and
- construction in weak soils and rock is avoided where possible.

It is important that the choice of alignment or location takes into account the technology that will be used. The engineer preparing the plans has to assess the problems and work out how to deal with them using the resources available.

The technical assessment for the work should record the following information:

- design cross-section dimensions,
- existing vegetation cover,
- existing soil type and conditions,
- approximate earthwork quantities involved,
- design gradients,
- structures required,
- drainage measures required,
- gravel or laterite requirements,
- quality and sources of supply of laterite, crushed stone, water, etc.,
- quarry preparation work and hauling distances,
- required work force and availability of labour, and
- type and number of equipment items needed.

The ILO labour-based project has developed a series of detailed procedures for carrying out technical assessments of new road construction projects, as shown in the following chapters.

2.4.1 Road Alignment Inventory

When collecting information regarding the site conditions, it is important that it is recorded in an organised manner which can easily be referred to at any time during the duration of the road works project. For this purpose, it is helpful to use a standardised form where the details of the envisaged works is recorded. The "Proposed Road

Alignment Sketch", is a form which records the initial assessment of planned works on a road construction project. In this form, detailed information can be recorded for any given section of the road.

| PROPOSED ROAD ALIGNMENT SKETCH | | | | | | | | | | | | | | |
|--------------------------------|----|---|-----|-----------|-----|------------|------|-------------|----|-------------|-----|---|-----|-------------------------|
| Road Name: | | | | Date: | | | | Sketch by: | | | | | | |
| District: | | | | Province: | | | | Supervisor: | | | | | | |
| Chainage | PI | | D/S | | EMB | Excavation | | Culvert | | Scour Check | M/D | | STR | Remarks |
| | R | L | R | L | | Cut | Fill | Size | M | | R | L | | |
| +000 | | | | | | | | | | | | | | |
| +100 | | | | | | | | 0.6 | 7m | | x | x | | |
| +200 | | | | | | | | | | | x | x | | |
| +300 | | | | | | | | 0.6 | 8m | | | | | |
| +400 | | | | | | | | | | | x | x | x | small bridge 8m span |
| +500 | | | | | | | | | | | x | x | | |

Once the initial road alignment has been determined, the Supervisor and Engineer will carry out a survey of the road to estimate the amount and location of construction works. Information about road curvature, earthworks (cut to fill, embankments, etc.), drainage structures (bridges, culverts, mitre drains, scour checks, etc.) is then plotted in the road alignment sketch at its exact chainage along the road alignment.

2.4.2 Estimating Quantities

When a final choice of the exact position of the road alignment has been made, the next step is to carry out a full estimate of quantities of work. The expected work quantities form the basis of the cost analysis and determine future inputs of labour, materials, tools and equipment.

| ACTIVITY | Unit | KM | | | | | Total | Task rate | Workdays |
|----------------------------|------|------|------|------|------|-------|--------|-------------|--------------|
| | | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | | | |
| A. SITE PREPARATION | | | | | | | | | |
| Clearing | m2 | 1700 | | | | | 1,700 | 75 | 23 |
| Stump and Rock Removal | No. | 6 | | 1 | | | 9 | 4 | 2 |
| Grubbing | m2 | 3000 | | 3000 | 3000 | | 9,000 | 55 | 164 |
| Setting Out | m | 1000 | 1000 | 1000 | 1000 | 1000 | 5,000 | 50 | 100 |
| B. EARTH WORKS | | | | | | | | | |
| Excavation to Level | m3 | 105 | 730 | 135 | 45 | 96 | 1,111 | 1.5 | 741 |
| Ditching & Sloping | m3 | 1075 | 165 | 748 | 725 | | 2,713 | 1.6 | 1,696 |
| Forming Camber | m2 | 5500 | 5500 | 5500 | 5500 | 5500 | 27,500 | 80 | 344 |
| Watering and Compaction | m2 | 5500 | 6130 | 5500 | 6256 | 11800 | 35,186 | 90 | 391 |
| Reshaping | m2 | 5500 | 5500 | 5500 | 5500 | 5500 | 27,500 | 80 | 344 |
| C. EMBANKMENT | | | | | | | | | |
| Fill less than 50 cm | m3 | | 282 | | 360 | 3041 | 3,683 | 1.8 | 2,046 |
| Fill over 50 cm | m3 | | | | | | 0 | | |
| D. GRAVELLING | | | | | | | | | |
| Excavation, Load, Haul | m3 | 990 | 990 | 990 | 990 | 990 | 4,950 | by contract | |
| Spread and Compact | m3 | 990 | 990 | 990 | 990 | 990 | 4,950 | 8 | 619 |
| Average Haul Distance | km | | | | | | | | |
| TOTAL | | | | | | | | | 6,470 |

Based on the information recorded in the road alignment sketches, it is possible to carry out a first estimate of the construction quantities. This form is more detailed than the Proposed Road Alignment Sketch, since it records envisaged quantities of work on all future work activities. It may therefore be necessary to re-visit the road alignment to carry out more detailed assessments of the quantities of work. Based on these field surveys, the detailed information on volume of works is compiled in the "Estimate of Construction Quantities" form.

Once the estimated volumes of work has been compiled for the road project, it is possible to calculate the number of work-days for each activity and for the project as a whole.

With the work quantities established, it is now possible to prepare a time plan and cost estimate for the project, based on the resources available to carry out the works (i.e. labour, materials and tools and equipment).

2.4.3 Construction Targets

The setting of construction and productivity targets is essential for project monitoring. The comparison between well established targets and actual achievement allows for a realistic judgement of the performance of a work unit or site. Targets must not only be set for outputs in terms of quantities, but also in terms of quality.

The degree of details of targets varies with the level of project organisation:

- at site level targets are established for individual activities,
- at field unit level only the summary or control targets for a number of sites are required,
- at provincial level targets per field unit would be established and monitored, and
- at headquarters level the national and overall project targets are set and monitored.

To be able to set targets, the following information must be known:

- the technical standards to be achieved,
- the quality standards to be achieved,
- the quantity and difficulty of the work,
- current task rates and productivity, and
- resources required and available (labour, materials and transport, etc.).

However, there are other factors that influence productivity and operational plans. Some of these are beyond the control of the management, but must be allowed for:

- climate and rain seasons,
- cultural customs and traditional skills, and
- work incentives.

Once targets have been established, the planner can calculate the cost targets. The work plans may have to be revised in line with availability of funds. Most projects will have a total plan, to achieve final project objectives, and annual plans to plan the work over a financial year.

For operational planning only main targets are necessary, such as:

- workdays per km,
- cost per km,
- number of km completed

2.4.4 Time Management Planning

Construction timing is an important part of operational planning. Generally, two planning phases are used - a long term planning phase (annual work plan) and short term planning phases (monthly or weekly work plans).

Annual Plan

The annual plan is prepared by the Provincial Engineer at DCTPC in consultation with the management at Ministry level. The list of priorities and the assessment of work quantities provide the data required for preparing the work time schedule.

Generally, the annual work plan will contain the following:

- name and location of the works,
- target quantity of work for each works location,
- type of work by works location,
- workdays and equipment-days (targets) for each works location,
- starting and finishing month for each works location,
- estimates of cost for each works location, and
- summary totals.

When calculating the times for construction, the planner must allow for mobilising and starting up, and final completion and clearance of the sites.

Mobilising and starting up includes:

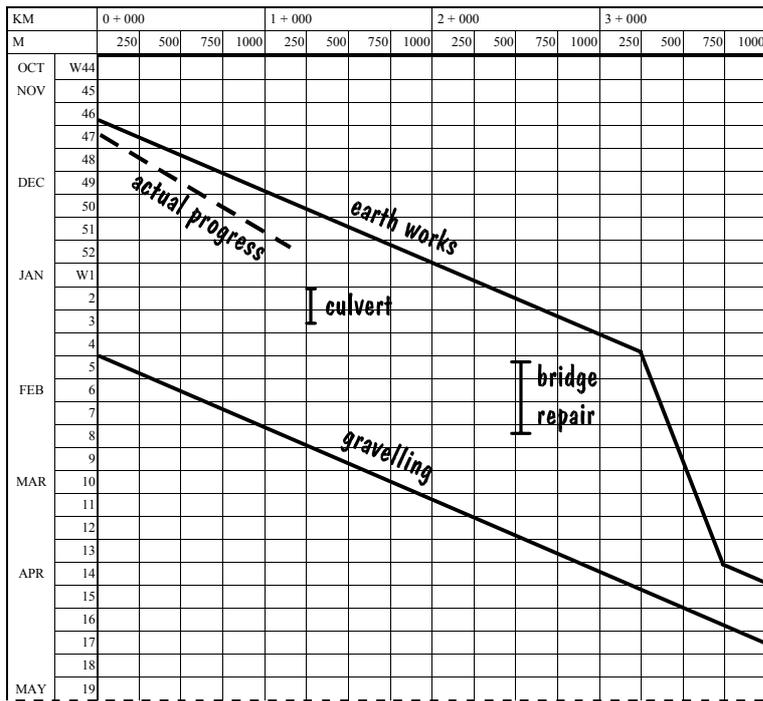
- local announcements for the intention to employ a labour force,
- setting up the site camp,
- initial surveying of works, and
- recruitment of casual labour.

Construction should start in a logical, staggered way. Some activities will have to start first before other activities can follow. Labour must be employed as needed according to the increase of activities at site level.

Completion work includes the final clearing up of the work site, the dismantling of the camp buildings and, finally, an opening ceremony.

The plan of operation is prepared with diagrams such as bar charts and time-location charts. They are distributed to all management levels so that the supervisory staff at each level can prepare for their own responsibilities in carrying out the work on time within the overall plan.

Time-location charts are particularly helpful for planning of road construction projects. The estimated physical progress is plotted as a line graph where the horizontal axis represents the road chainage (location) and the vertical axis represents the date (time).



Once the entire work progress graph has been prepared, it is possible to read from this graph the expected progress of works at any given time of the project period.

Each management level produces more detailed plans in their respective part of the operations.

Short Term Plans

Short term plans are actual work plans at site level. Short term targets for all major activities must be set.

Naturally, planned targets are not always met, but it must be the aim of the engineer and

technicians to achieve the long term objectives. This means changes when necessary on a short term basis. To enable managers to get progress back on target if production slips, it is important that there is accurate monitoring of progress and the flexibility to take new decisions when and as required.





Module 3

Management and Organisation

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3.1 Project Cycle

Engineers and technicians involved in labour-based projects not only have duties as technical staff, but to a large extent also play an important role as managers. As a manager it is necessary to carry out the three main tasks of management: as a planner, as an administrator and as a leader.

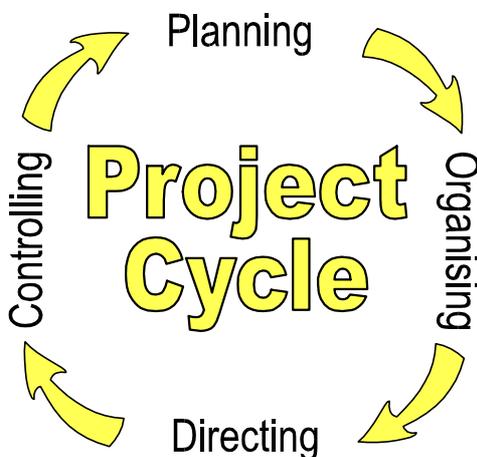
Labour-based work methods are competitive and can be more economical and provide lasting benefits, if they are well supervised, controlled and managed.

This means that training must be provided at all levels, and cooperation and coordination must be established between the management at each level. Each supervisor, technician, engineer and administrator must know how to execute his/her duties effectively, and where he/she fits into the overall management organisation.

Managers who fail in a labour-based project normally do not fail because of their lack of technical ability, but because they are poor managers in terms of work organisation and personnel management.

There are four main tasks of management that follow each other in a logical sequence. These are:

- planning,
- organising,
- directing, and
- controlling.



The elements of analysis, decision making and communication are applied to each of these tasks when they are undertaken.

Management is a continuous process that never ends. There are numerous activities related to labour-based road works that are necessary in order to secure proper management. These are briefly set out on the next pages to illustrate the extent and variety of the management process.

(i) Planning

| Main Activity | Detailed Activities |
|--------------------------------|--|
| working out a course of action | <ul style="list-style-type: none"> - make forecasts (work out where course of action will lead), - set objectives (determine the desired end results), - develop strategies (decide how and when to achieve the results), - prepare programme (set out the priorities, sequence and timing of steps), - budget (allocate financial resources), - set procedures (standardise methods to be used), - develop policies (make standing decisions regarding important recurring matters). |

(ii) Organising

| Main Activity | Detailed Activities |
|---|--|
| arranging and relating work for the efficient achievement of planned objectives | <ul style="list-style-type: none"> - establishing an organisation structure (draw up an organisation chart) - establishing relationships (define communication lines for coordination) - write job descriptions (define duties, relationships, responsibilities and authorities) - establishing position qualifications (define entry qualifications for each level) - recruit qualified people for each position - train and orient (make staff familiar with their new jobs) |

(iii) Directing

| Main Activity | Detailed Activities |
|---|---|
| bring about effective action towards planned objectives | <ul style="list-style-type: none"> - delegate (assign responsibility for results) - motivate (persuade and inspire staff to take effective action) - coordinate (relate efforts in the most effective combination) - manage differences (encourage independent thought and resolve conflict) - manage change (stimulate innovation in achieving planned goals) |

(iv) Controlling

| Main Activity | Detailed Activities |
|--|--|
| ensure progress towards objectives according to the plan | <ul style="list-style-type: none"> - establish reporting system (determine what essential data is needed how and when) - develop performance (set production norms and task rates) - measure results (assess deviation from goals and standards) - take corrective action (adjust plans, retrain to achieve standards, monitor, re-plan and repeat if necessary) - reward (praise, remunerate and discipline) |

Delegation of duties to subordinate staff is essential if the management is to be able to complete all its tasks. Managers will often be more concerned with planning for the future than organising the present. Delegation enables the manager to concentrate on those parts of his/her job that need his/her special skills, experience and knowledge.

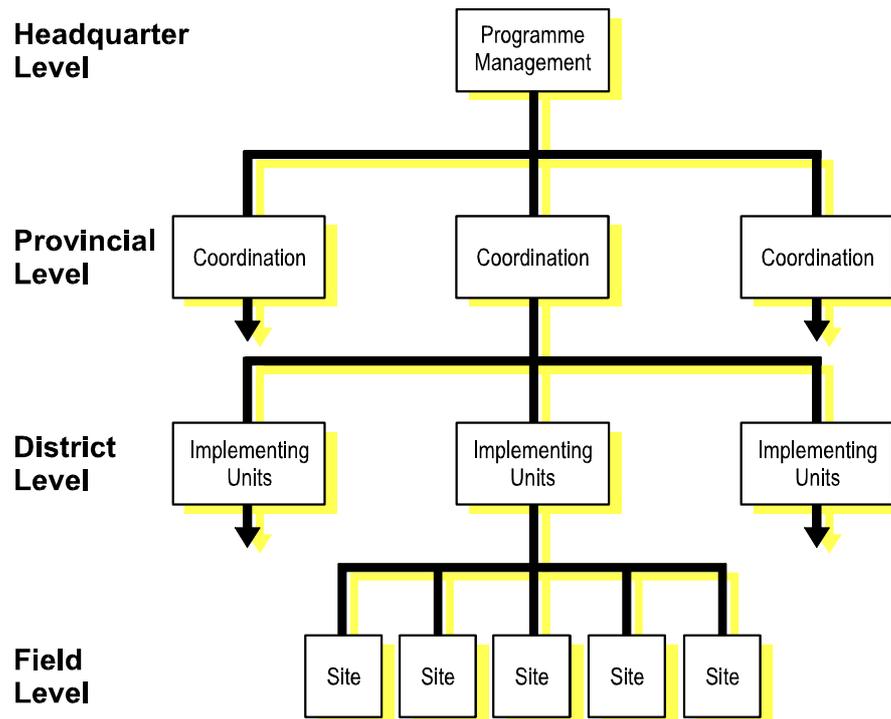
Delegation of duties requires the managers to train and develop the subordinate staff such as field supervisors and foremen. The better these staff members carry out their duties and the more of the routine duties that can be delegated to them, the more time the manager can spend on his/her planning and preparation duties.

Delegation is also a good way to train people for promotion and more responsibilities. Senior staff has a responsibility to share knowledge with and develop the ability of junior staff under their control.

3.2 Levels of Management

3.2.1 Overview

Before we consider the individual support sections, we will look at the organisation of management as a whole. The size and type of labour-based construction programmes has a direct influence on the organisational arrangements. Small scale projects tend to operate independently from centralised organisations, whereas large programmes require a central coordinating and controlling management organisation. This section discusses the basic organisational set-up for a large scale programme, i.e. a road works programme covering several provinces.



Different project managers have different approaches to organisational set-ups, but they would generally be following the same basic principles. Each management level has specific duties and responsibilities. Sometimes, these duties overlap and they are not necessarily the same for all projects, but the following pages provides a general indication.

3.2.2 Headquarters

The management at headquarters or ministry level is essentially of overall nature. It is important that delegation is given to the province-level staff to run the day to day management, but it is of equal importance that the reporting system allows the ministry-level staff to check the overall performance of the project.

Duties and Responsibilities

- liaison with the donor and the internal financial authority on all financial policies,
- budgetary and financial control of expenditure,
- establishing technical standards and administrative policies for the programme,
- approving and forwarding plans and reports to donor agencies and higher authorities,
- coordination with other government departments and donor agencies to ensure satisfactory cooperation and to avoid conflicts,
- approval of annual work programmes and budgets,
- training needs assessments and coordination of training programmes,
- bulk procurement of equipment and tools,
- approving works to be executed, and
- general monitoring of field work performance and resolving major and widespread problems.

Staff Required

A large scale programme may require several managers, each charged with separate functions and duties, e.g:

- Programme Coordinator,
- Planning and Monitoring Engineer,
- Equipment Engineer,
- Chief Administrator, etc.

3.2.3 Provincial Level

At provincial level, managers can carry out their task, and at the same time effectuate liaison with other relevant provincial departments and organisations dealing with rural infrastructure development.

Duties and Responsibilities

- coordination with ministry headquarters for preparation of annual provincial work programmes and budgets,
- determining resource requirements in terms of trained manpower, equipment and tools, materials and funds,
- carry out approved work programmes,
- storage and allocation of resources to field production units,
- guide and assist field engineers in approved work methods and procedures,
- inspect and assure that all completed work comply with agreed technical standards,
- control of site progress reports, summarising them and submitting them to

- headquarters on time,
- monitoring of field unit performance in terms of productivity and directing corrective measures, and
- representing the programme at provincial levels.

Staff Required

In a large programme where the provincial level management controls field units in several district, eventually several managers will be required. For example:

- Provincial Coordinating Engineer (in overall charge of operations in the province),
- District Engineers (in charge of a number of field units),
- Equipment and Logistics Manager and/or Transport Officer (in charge of distribution and transport),
- Accountant/Pay Clerk (in charge of finance, payments),
- Office Administrator (in charge of office support personnel and secretarial services),
- Stores Manager.

3.2.4 District Level

While headquarters and provincial organisations deal mainly with overall management duties, the district level organisations actually implement and produce the programme outputs. The performance of this level at this level determines the efficiency and quality of the works. Managers at this level need to be aware of and understand what is required at the level above him. However, more important, he/she must be in full control of the level below where the production takes place.

Duties and Responsibilities

- organisation and direction of all technical and logistic activities needed to carry out the road works,
- inspection of all work in progress and applying corrective action as necessary,
- organisation of wages for labourers,
- guiding and assisting unit supervisors in approved work methods and procedures,
- recording and monitoring productivity and taking necessary corrective action if and when needed,
- preparing and forwarding regular reports summarising data of work progress and resource use,
- recommending any amendments and changes that would benefit field unit performance, and
- liaison with provincial authorities and other district level development authorities.

Staff Required

A field engineer/supervisor, can be in charge of a number of field units and be responsible for the overall direction and control of all work elements, including administration and production.

3.2.5 Site Level

It is at site level where management becomes most demanding. At this level the management staff have to take responsibility of a group of 50 to 200 casual workers, tools, materials and equipment, and ensuring that these resources are utilised in a planned and efficient manner.

Duties and Responsibilities

- Planning and programming of physical works,
- Surveying and setting out works,
- Inspection and supervision of works,
- Recruitment and dismissal of labour,
- Preparing and organising payment of workers,
- Organisation and distribution of workers,
- On-the-job training and instruction,
- Ordering, receipt and storage of tools, equipment and materials,
- Inspection and supervision of sub-contractors,
- Liaison with local communities,
- Monitoring and reporting of project inputs and physical progress.

Staff Required

- Site Supervisor,
- Foremen,
- Gangleaders,
- Drivers and Equipment Operators,
- Storekeeper,
- Watchmen,
- Skilled and unskilled workers.

3.2.6 Chain of Command

The chain of command defines the flow of information through the programme organisation - that is reports, orders and requests. For example, information from headquarters pass through provincial and district levels before reaching the site.

Not all information should reach all levels in the original form, rather it should be filtered or rewritten at intermediate levels. For example, instructions and information from headquarters on work methods are meant for the field staff, but the provincial management must do more than just pass the letter on to the field. They are also responsible for re-training subordinate staff and coaching them in new or changed techniques, and must make sure that all instructions are understood and implemented.

On the other hand, changes on general policy will not be communicated to the field staff if it does not directly affect site works. It will be filtered out at provincial or district level. Similarly, the flow of information from the site to district headquarters has to be compiled so that only essential summary information reaches the provincial level, and can be acted on quickly.

3.3 Administration and Logistics

3.3.1 General

In some labour-based works projects, the performance on site is made difficult by unsatisfactory back-up services provided by the support sections such as administration, transportation and stores. The task of the engineer/manager is to make sure these support sections perform efficiently.

Logistical support has a big effect on the actual field production and total costs. Over-staffed and inefficient support sections can add greatly to the overall costs of the project and it is important to establish good logistic support services early in the project and to maintain efficiency throughout the life of the programme.

Many engineers and technicians have little experience in managing support sections, and tend to neglect the importance of administrative and support sections and are concentrating their efforts on productive activities.

For the successful operation of a labour-based road works programme the logistics are very important. A centralised office at provincial or district level can have a beneficial effect on field activities.

It is essential that engineers and technicians understand all supporting activities and can manage them as efficiently as possible. If support sections do not function smoothly and effectively, managers will be involved in considerable extra effort to put things right. For example, if routine procedures for reporting, filing, payment of wages, etc. are not followed, the management will waste a great deal of time correcting mistakes and carrying out simple clerical duties. Time wasted by inefficient supervision of support activities result in the engineers and technicians having less time to spend on technical duties.

Normally, provincial headquarters will manage the following operations through support sections:

- ordering, procuring and storage of goods and equipment (major bulk purchases will be made by headquarters, local purchases at provincial level - bulk purchases will be sent to the provincial base for storage and issue to the sites),
- financial management (preparation and execution of payments at local level, including wages, keeping financial records, keeping within budgetary limits),
- personnel management (employing local personnel, keeping personal files, imposing discipline, meeting contract conditions),
- office management (dealing with correspondence, keeping a registry, maintaining files, radio communications), and
- reporting (summarising data, submitting summaries to headquarters, filing, maintaining stock of blank forms).

Depending on the size, design and organisational set-up of the programme there may also be:

- mechanical workshop services (repairing and servicing project vehicles, equipment), and
- culvert production (manufacturing concrete culverts required for field works).

3.3.2 The Stores Section

The Stores Section is responsible for the supply of the goods on time, in good condition and where required.

The objective of the Stores Section is to meet the authorised tools and materials requirements of the sites. Stored goods include:

- field items (hand-tools, setting-out instruments, miscellaneous small items),
- building materials (cement, reinforcement rods, timber, sand, crushed stone etc.),
- spare parts (fast moving spares for repair and servicing), and
- fuel and lubricants.

The quantities stored depend on the expected work outputs and the frequency and availability of bulk purchasing.

The type of stored goods depends on the work methods, the project design (use of contractors or government departments for some support functions) and what is commonly used and manufactured in the country or province.

Provincial stores must be organised and managed in such a way that the following conditions are met:

- goods are stored in a logical and orderly way according to their type and purpose,
- stores are arranged to allow for the efficient issue and replacement of goods,
- goods are kept under safe custody,
- goods are kept safe from weather damage, and
- store records and reports are produced regularly and accurately.

The Engineer in Charge of the provincial operations has overall responsibility for the stores and the Stores section. A Store Manager is responsible to the engineer for all routine stores matters, such as:

- procurement,
- issuing,
- receiving,
- controlling,
- storage,
- reporting, and
- security.

Stores Assistants are employed to handle goods, keep records and prepare reports. Security Guards are appointed to safeguard goods at all times. An Accounts Clerk maintains accounts control and make payments to suppliers.

(i) Procurement

Procurement is done by using, either the existing procedures of the government department, or the formal procedures established for a specific project organisation.

All procurement and tendering procedures that are to be used must be laid down in detailed circulars and guidelines by the programme management. The Engineer and the Store Manager must be fully aware of the approved procedures, as they will be held responsible for losses and illegal transactions.

Close communication must be maintained between the Stores Section, the Financial Section, the Field Units and the Engineer in Charge.

It is the duty of the technical staff to estimate the quantity and type of stores to be purchased and store well in advance to allow the Stores Section sufficient time to obtain the goods. Usually, a three month lead time should be given.

(ii) Receiving and Storing

After goods have been procured, they have to be received and stored. All deliveries must be accompanied by a delivery note from the supplier, or from another project unit (if goods are being transferred). One copy of the delivery note remains at the store and one is returned to the supplier.

Goods are checked by the Store staff to make sure that quality and quantity are as specified in the order or supply contract documents. Goods that do not meet the specifications, cannot be accepted by the receiver, who should then indicate on the delivery note how many items have been refused and why.

The exact number of goods received (if different from the quantity on the delivery note) must be noted on the delivery note and counter-signed by the person making the delivery.

Invoices for goods supplied are certified by the Store Manager that the goods really have been received in good condition and in the correct number, and that they have been taken on charge in the store ledger.

All stores once received are immediately entered into the store ledger (store record). Each item in the store will have a store record which will record the following details:

- description of item,
- unit price and total value,
- suppliers name,
- number issued,
- date received,
- stock balance,
- number delivered, and
- minimum and maximum stock levels.

Each organisation must develop their own system. The above procedures and information is the minimum requirement to ensure an efficient store management.

(iii) Issuing

The issuing of goods must be regulated by procedures and regulations to avoid unexpected shortages, wrong issues and theft.

It is advisable to authorise only some senior staff to request supply of goods. Requests must be made in writing and be signed by the requesting officer. It is advisable that the engineer approves the issue by signing before goods can be ordered.

Issues must be checked to ensure consumption by the units does not exceed predetermined expected levels.

The requisition form, requesting issue of supplies, should contain the following data:

- description of item,
- number required,
- actual number issued,
- date issued,
- name of user or site, and
- signatures of officers, requesting, issuing and receiving.

(iv) Store Control and Auditing

Stores in any organisation contain very attractive and valuable items. It is therefore important to establish a comprehensive control system. Stock level checks must be regularly carried out. Recommended periods for checks are:

- valuable and attractive items - every three months,
- dangerous items (e.g. explosives) - every month, and
- general stores - at least once a year.

In addition, spot checks (surprise checks) of some selected goods at any time are essential. This keeps store staff alert by showing that management is concerned with the accuracy of stores reports and the security of the goods.

3.3.3 The Accounting Section

From whatever source the project receives funds, it is the responsibility of the project manager to control these funds and keep full and updated records of all financial transactions.

In a labour-based programme, the most important financial transaction is the payment of labour, staff and contractors. Other financial transactions would be procurement of tools, equipment, materials, services, and various utilities such as rent, electricity, telephone charges and office stationery.

Headquarters would include a Financial Controller to be in overall charge of programme finances.

Funds that are controlled by a provincial unit will require an Accounting Section to manage all accounting matters. This section would control the following elements:

- financial allocations (funds issued to the unit),
- bookkeeping and ledger control (keeping records and commitment ledgers),
- preparation and issue of payments (procedures for spending the funds), and
- monitoring (on what and how the funds were spent).

(i) Financial Allocations

In most cases, funds issued to the provincial unit will be project funds. These funds will be allocated according to estimates of expenditure based on work programmes and expected overheads.

The correct use of these funds requires detailed and careful supervision. The government, the project agency and the donor organisation will all expect full financial statements on all expenditures made.

The engineers and technicians must be familiar with the accounting and financial reporting procedures. They must be able to fully account for each and every financial transaction of funds under their responsibility.

To understand the process of allocating funds, incurring expenditures and reimbursement, managers have to be familiar with the project budgetary process. Budget processes will vary slightly from one programme to another, but generally there are three elements:

- financial ceilings for all major project components (construction, maintenance, personnel, equipment, etc.),
- estimates based on detailed plans, and
- expenditure.

(ii) Bookkeeping and Ledger Control

In order to keep control over funds allocated to a project, an accounts ledger must be maintained. This ledger records the following details:

- *Account Number and Name*: A unit may operate several accounts, e.g. for construction of roads, for maintenance, for operation of transport, etc. Projects may issue funds by means of several allocations during a financial year.
- *Allocations Received (= credit), Amount and Date*: Before any expenditure can be made, a financial liability must be made for this particular order. These liabilities are entered in the ledger for the appropriate account as a debit and deducted from the balance.
- *Intended Expenditures (= debit), also called liabilities*: Project procedures may say that there must be an endorsement from the Accounting Section stating that there are sufficient funds to meet the expenditure. Without this endorsement, the order is not valid.
- *Actual Expenditures (= debit)*: When payment of deliveries, services or wages

has been made, the amount is entered as expenditure (debit) and deducted from the balance. If the order had been previously entered as a liability, the sum paid is subtracted from outstanding liabilities.

- *Total Commitments (liabilities plus expenditures)*: All debit entries in the ledger must be added up to produce the total commitments against the account.
- *Balance of Funds Available*: The balance line is the summary of all credit and debit entries and is completed after each ledger entry. It shows funds available under each account.

Only experienced and reliable accounts clerks should be given the responsibility for ledger control. Accuracy in bookkeeping is essential. The ledgers should be regularly checked by the management to make sure that no mistakes are made, such as expenditure recorded on wrong account ledger. The management will also have to ensure that expenditure of funds is according to plan, and when there is a need for revising plans or requesting extra allocations.

(iii) Preparation and Issue of Payments

Payments for small amounts, up to a certain limit are usually done in cash. For this, each project manager will be allowed a petty cash facility. Petty cash facilities are in the form of refundable imprests or advances that must be accounted for by receipts.

For all larger amounts, payment orders or vouchers are issued. Payment vouchers are used to show:

- which account to use and the available balance,
- for what purpose the payment is meant,
- the amount to actually pay, and
- who the payment is to be made to.

Payment vouchers must be supported by certified copies of order documents, invoices and store receiving documents. Payment vouchers and supporting documents must be examined before payment or the issue of cheques can be authorised. The examination is made by the Accountant to ensure that:

- payment vouchers are supported by the right documents,
- prices and rates charged are according existing regulations and contracts,
- authority for the payment has been obtained,
- the account code number is correct,
- calculations are correct,
- persons named on the vouchers are those entitled to receive the payment, and that
- no alterations have been made to original documents.

When a voucher has passed all these examinations, the voucher can be authorised for payment. The Accounts Section should make every effort to process payments quickly to avoid delays to productive activities. The technical staff can avoid delays if they make orders and prepare payment vouchers in good time and accurately.

Many delays are caused by engineers and technicians not following the correct

procedures. Special attention must be given to payment of labour. Wrong or delayed wage payments will seriously reduce productivity and may lead to a high degree of absence from site, resulting in a reduction of work outputs.



**PROMPT AND CORRECT PAYMENTS OF LABOUR
WAGES ARE VITAL FOR OPTIMAL SITE PRODUCTION**

The project Financial Controller should establish the procedures and forms to be used and will familiarise staff with them.

(iv) **Expenditure Monitoring**

The manager in charge of a project is responsible for the monitoring of the expenditures incurred during a certain period. An accounts ledger does not provide a clear picture of costs by headings in relation to cost targets.

Expenditure monitoring is also a performance check. Like the monitoring of construction outputs and technical quality, it is an important part of the management process. To monitor expenditure, all expenditures are allocated on a separate ledger under their actual headings. There are two kinds of headings, *category headings* and *purpose headings*.

Category Headings

Costs recorded in the accounts ledger are allocated to their actual category, for example:

- staff wages,
- labour wages,
- equipment,
- hand-tools, and
- overhead costs.

Cost targets or percentages are established for each category heading. In this way, a manager is able to closely observe expenditures and detect over or under expenditure by category heading. This will be used to help analyse performance and provide information for improved estimations in the future,

Purpose Headings

Costs recorded in the accounts ledger are allocated their actual purpose, for example:

- road construction,
- bridge and culvert works,
- laterite spreading, and
- transport.

This allows a manager to closely observe the cost of a specific project or activity, This however, requires a good accountant in order to produce the required information in a reliable and useful form, and should not be attempted if accounts control at a simpler level is proving difficult.

3.3.4 Office Administration

Every manager has to have an office for administrative purposes. The administrative section of an office is a support section and the tasks of that section is to help to achieve the objectives of the project. Therefore, the administrative work has to be as efficient as possible.

It is the managers duty to organise this section to carry out work efficiently. Clearly defined procedures, duties and responsibilities must be established. Everybody in the office needs know to the way in which he/she has to do the tasks assigned to him/her.

The registry, especially, must function well. The registry is responsible for receiving and recording incoming mail, controlling the movement of files, and for filing all important papers and documents in the correct file so that they are readily available whenever they are needed.

Communications is another important responsibility of the administrative section. Telephones should have a properly trained operator who can control the use of the telephone and keep records of calls in and out and take messages accurately.

If there is a communication radio in the office the radio operator should be properly trained in correct handling and to use the correct "radio language".

Mail leaving the office should be recorded noting who the letter was sent to, when and what the letter was about.

Standard procedures for communications, mail and filing should be written down for office staff to refer to when they are not sure.

For large projects, the running of a good office must be taken seriously. The engineers and technicians will depend on the office staff for many of their duties. A badly run office will waste much valuable time and could be the cause of not meeting deadlines for reports, plans, budgets, etc.

3.3.5 Personnel Management

A labour-based project deals with a large number of personnel. Good management of personnel is essential if the project is to succeed. A manager in charge of a project unit must be equipped, or learn, the necessary knowledge and skills of personnel management.

There are two main groups of personnel: permanent staff and temporary staff (casual workers).

(i) Permanent Staff

Projects will usually either recruit personnel from government departments, or employ people on fixed term contracts that expire once project funds are exhausted.

Permanent staff will fill such posts as engineers, technicians, accountants, clerical

staff, storekeepers, supervisors, drivers and operators.

Conditions of employment may vary from project to project, but they must be clearly agreed between the government, the project and the staff before recruitment begins.

The project manager may have to accept staff assigned to him or he may be able to select his staff, and he may be able to recruit outside the department if suitable staff is not available.

Project performance usually improves if the project has the right to dismiss or return unsuitable staff. This, because most projects operate to demanding production targets and strict control requirements, and therefore the ability and dedication of project staff is vital.

(ii) Temporary Staff

Specific procedures and regulations usually apply to the employment of temporary (or casual) employees. These concern the employment process, the terms and conditions of employment and the payment of wages.

(iii) Recruitment Process

Where enough labour is available, casual workers are recruited from the vicinity of the work sites. If more labourers apply for work than there are job opportunities, then every job seeker should be given an equal opportunity by means of a lottery system. Equal opportunity for work is most important.

The announcement of a recruitment drive in an area should be made well ahead of the start of works. The announcement will state:

- date, time and place of recruitment,
- conditions of employment,
- type and purpose of work, and
- who is eligible for work.

To facilitate sufficient recruitment of workers, it is important to plan the work well in advance so that the local villagers can be given due notice about the future labour requirements of the project. The labour is recruited on a temporary basis, and the local population needs advance notice so that they can plan and organise their other obligations (i.e. on the farm or in the household) before they can participate in the road project.

It is advisable to work with village representatives and administration officials who know the locality and can explain the project to the people.

In addition, the most labour intensive activities needs to be timed to periods of the year when labour availability is good, i.e. in the agricultural slack season. Try to avoid the sowing and harvesting periods for the activities which require a large number of workers.

Only senior staff should conduct recruitment. It is not advisable to let the supervisors who will be in charge of the workers conduct recruitment.

(iv) Terms and Conditions of Employment

The terms and conditions of employment should be the same for everybody to ensure fairness and equal treatment. The following subjects should be explained to all workers:

- project name
- who is the employer
- duration of employment
- wage rate
- discipline regulations
- termination of work
- performance conditions

(v) Wages and Payment

The presence of each labourer on the work site must be recorded in detail so that correct payment can be made. A register, or muster roll, is used for this purpose. Muster rolls are kept and recorded daily on site by the Site Supervisor.

The Accounts Section uses the muster rolls to prepare payments for all labourers on a monthly basis (or other period agreed with the workers).

The date and place of payment must be announced to the labourers early enough to make sure everybody attends on the pay day. Wages can only be collected by the rightful person and they must be identified presenting their ID Card for inspection when they receive the money.

The organisation of pay day requires special attention by the project management. They must make sure that the muster rolls reach the Accounting Section in good time to enable them to calculate the exact wage to be paid to each labourer and the total amount needed.

The Accounts Section then has to:

- get authority to withdraw money from the bank, collect the money in sufficiently small notes so that the exact amount can be paid to each labourer,
- arrange for transport and security to carry the money to the work site,
- make payments to the right persons and get the signature of each labourer, declaring that he/she has received the wages due and that the amount was correct, and
- prepare a report on the payments made and return any unpaid wage back to the bank.

This is a complicated exercise and often requires lengthy procedures and checks to ensure the authority and security of large amounts of cash to a large number of work sites. If the on-site staff do not ensure that muster rolls are submitted on time and the correct procedures and regulations are thoroughly followed, then payment will be delayed and the labourers will be unhappy. This will cause problems for the site supervisor that may affect site production.



**TIMELY AND CORRECT PAYMENT IS THE RIGHT OF EVERY LABOURER.
ALL PROJECT STAFF MUST MAKE EVERY EFFORT TO ENSURE THIS.**

(vi) Motivation

All staff working in a labour-based project should understand the needs and expectations of the people he/she is responsible for and motivate them to perform their jobs well. The following factors may have an effect on job attitudes:

- feeling of achievement,
- recognition of work well done and status,
- responsibility given and competence in work,
- project policy and administration efficiency,
- behaviour of supervisors,
- working conditions,
- relationships with fellow workers,
- security at home and at work site, and
- prospects of promotion.

Motivation is very important when dealing with casual workers. When managing casual labour, specific incentives have to be used in order to get a high and sustained level of productivity from the work force. There are four basic incentive schemes that are used in labour-based programmes:

Task Work: In this system the worker receives one days wages for a set amount of work. The worker is given a task to complete and when this is done, he/she is free to leave the site - once the work has been approved. This is then counted as a full day of work on the muster roll for pay purposes.

The incentive is not that the workers can earn more money, but that they can leave earlier and have more spare time (for example for working in their fields).

Piece Work: In this system the worker is paid a fixed amount per unit of output (so much money per m³, or so much money per m² levelled etc.). The daily output is left to the decision of the individual worker, the more output he/she produces, the more he/she gets paid.

The incentive is that if the worker decides to work harder or make longer days he/she gets more money "in his/her pocket".

Group Task Work: In this system, a group of workers are given a certain length of road to complete, normally 100 to 500 meters of length, and they will be given a certain amount or days to complete their task.

The incentive is that if the group so decides they can work harder and finish in a shorter time but still with the agreed amount of money to take home.

Payment in Kind: In areas where food supply is limited, payment in kind may act as an effective incentive. However, there are certain international standards which must be observed when paying with food for work. Unless the Government has declared an emergency situation in the area, the food payment should be combined with a cash component equivalent to 50% of the minimum wage established for this type of work.

Task work is effective when time is valuable to the workers, that is, when they have

other money earning opportunities after work, or they have land on which to grow food or keep animals.

To be effective and fair, the tasks must be estimated correctly and set out properly. The supervisor therefore needs to know in detail how to set out task work and which task rates to use for the various activities in different circumstances (hard or loose soil, wet or dry soils, thick or sparse bush, etc.).

Task rates or piece rates can be set on most activities. In general, it is better to set a poor task rather than organising the workers on daily paid work. It is the responsibility of the site supervisor to calculate and set the task. For this, it is necessary to establish (i) the quantity of works (area, volume or numbers) and (ii) the difficulty of the work (loose or hard soil, etc.).



The correct amount of work one worker has to complete in one day, has to be established by detailed measurements of productivity under various conditions. For this, the daily and weekly reporting system will provide good support for the supervisor. When a new site is established, it may initially be necessary to organise some of the work on a daily paid basis. Based on the productivities during the first couple of weeks, it is possible to establish and refine the task rates on the work site.

A correct set task should allow the average worker to finish their day's work in approximately 75% of the normal working hours.

It is the responsibility of the site supervisor that the workers receive their tasks in the morning immediately when they arrive, and that the amount of work is fair and just. The size of the task must therefore be carefully monitored to ensure that the amount of work given to each worker is neither too little, nor too much.

| | | | |
|--|------------------------------|--------------------------------------|------------------------------|
| Clearing and Grubbing | 50 - 150 m ² /wd | Drain Excavation | 1.5 - 3.0 m ³ /wd |
| Levelling | 1.5 - 3.0 m ³ /wd | Camber Formation | 75 m ² /wd |
| Earth Excavation and up to 20m transport | 1.5 - 2.5 m ³ /wd | Turfing | 10 - 20 m ² /wd |
| Hand Compaction | 100 m ² /wd | Gravelling (spreading and levelling) | 5 - 10 m/wd |

The table above shows some average task rates, however, these should only be used in an initial phase, before more appropriate quantities have been determined through site trials. Once agreed, the workers should stay on site until their task is completed.

Piece work usually produces more output per day, but requires good control to record the output of each labourer each day for pay purposes. It also requires more flexible setting out procedures to ensure more work is set out and available if the labourers want to achieve more output. This often means increased work for the supervisor.

Group task work also gives good production rates, and the labourers can within the group decide themselves when they like to finish their work day as long as they meet the set dead-line.

If it is not possible, due to government and/or donor controls, to increase wages to make them attractive enough to recruit sufficient workers, it is sometimes possible to let people earn more by introducing group task work or piece work and by adjusting the size of the work pieces.

Although money is important, it is not the only motivation. Equally, important is:

- fairness and equal treatment of workers,
- good relations between the supervisor and the workers,
- recognition of work well done,
- clear and easily understood work instructions, and
- a fair system of recruitment.

Good management of labourers by the supervisors is extremely important for achieving production targets. A well organised and happy work force is usually a productive work force. The engineers and technicians must look out for problems with workers and take appropriate steps to deal with such issues at an early stage.

(vii) Discipline

Every senior officer will experience difficulties in maintaining discipline among his staff at some time. Discipline is the force that makes a person or group obey rules regulations and procedures. There are various forms of discipline:

- Positive discipline motivates a person to do what he knows is expected of him with the hope of receiving reward or recognition.
- Negative discipline motivates a person to do what is expected of him because of fear of punishment if he does not perform in the accepted manner.
- Self discipline motivates a person to do what is expected of him, not because of fear of punishment or expectations of reward, but merely to satisfy himself.

Each form of discipline must be used according to the circumstances, but positive and self discipline produce the best results. Self discipline depends on providing interesting work and the opportunity for initiative and improvement.

Some basic rules to help maintain discipline are:

- always provide a good example to others,
- never make discipline decisions based on rumours,
- make observations before you judge,
- ask senior staff for advice,
- do not decide in a hurry when personally affected, and
- providing equality to all workers is essential.

(viii) Administration of Personnel Matters

Management of personnel, both permanent and casual, requires the keeping of files and records relating to every employee.

Permanent staff will each have a personal file. The file will contain personal details such as age, qualifications, size of family, salary records and disciplinary matters.

The file will represent the employment record of a particular person. These files are confidential and are kept safe. They should not be available to anybody, but only to authorised senior managers.

For casual workers a register is kept, recording the names and employment history of every person who is employed as a casual labourer by the project. Usually, only a few details are needed such as the sex of the person and the length of time working for the project and the position held.

These details are used to produce summaries of the employment process. This can help in controlling the project. It is important to know if people stay with the project for long periods or if the turnover of labour is high. High turnover, that is, people leaving after a short time and being replaced by new people, is often a sign of too low wages and/or bad labour management.

For record purposes, each labourer is given an employment identification number. The labourer will keep that number for as long as he/she works for the project. These numbers will be consecutive so that the last figure issued will represent the total number of people who have been employed at that time.

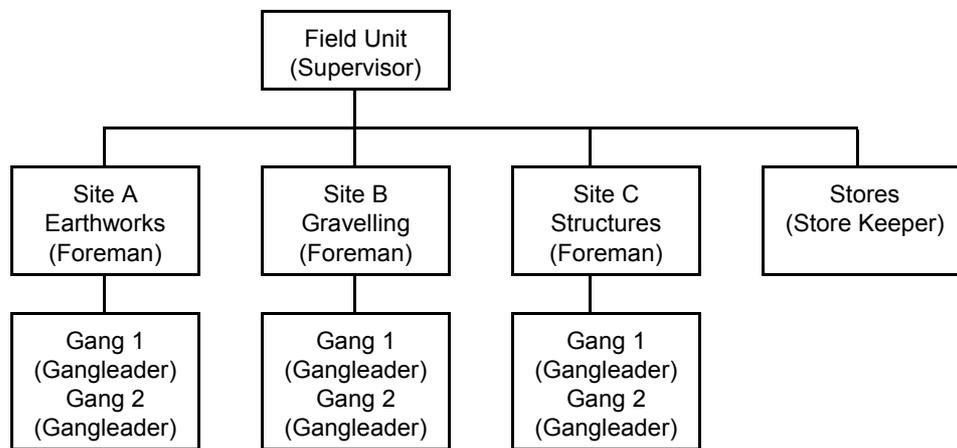
It may be that the project has a special objective to employ a percentage of certain categories of people, such as returning refugees, women, etc. Then it would be necessary to record these details. This is easiest done by adding prefixes to the employment number, such as "w" for women, and "m" for men, etc.

The registers of casual employment is kept at provincial headquarters and compiled from the details of the muster rolls. A monthly summary of the registers is sent to central headquarters to enable the project management to produce reports on employment patterns and for project control.

3.4 Site Management

3.4.1 Organisation

Labour-based construction requires a specific organisation down to site level. Organisation structures vary, but generally they contain the following framework:



The Field Unit Supervisor can be in charge of a number of sites. The size of the work sites will vary, depending on the type of work being carried out and the expected level of output, but a trained foreman should be able to manage 50 - 100 labourers.

The size of the gangs varies between 10 - 25 workers, depending on the nature of the work. Each gang is controlled by a gangleader or headman. The gangleaders should receive some practical on-the-job training and has to be able to read and write. For large programmes, gangleader training courses are recommended.

A gang may specialise on one particular activity, such as clearing, grubbing or camber formation, but there should be flexible working, where the size and work of the gang can be changed at short notice. If group task work is used, a gang may be assigned to carry out an entire operation, i.e. all activities from bush clearing up to camber formation.

3.4.2 Work Programming

Work programming is to arrange and distribute the construction works between the gangs of workers in such a way that the best use is made of available labour, materials, tools and equipment. This includes planning the works, taking the following items into account:

- in which order work operations and activities should follow, the *construction sequence*,
- the numbers of workers in each group, i.e. gang size and *balancing*,
- how to motivate the labour, using *incentives*, such as task work, and
- how instructions are given and received in an efficient manner, avoiding misunderstandings and incorrectly executed works.

Construction Sequence

Once the site camp has been established and supplied with materials, tools and equipment, the road construction works can commence.

Road construction works are divided into a number of *operations*, each sub-divided into a series of *activities*. The separate operations on a construction site have to follow each other in a logical sequence. The table below gives a general view of the works sequence on a road construction site:

| Operation | Activities |
|---------------|---|
| Support | work at site camp, setting out alignment |
| Site Clearing | detailed setting out, bush clearing, grubbing, tree and boulder removal |
| Earthwork | excavation and filling, spreading and levelling, drainage and camber formation, embankments |
| Compaction | watering, compacting and final levelling of earth works |
| Structures | drifts, culverts and small bridges |
| Gravelling | excavation and transport of gravel, un-loading, spreading, watering and compaction |

Normally, each activity is carried out by a separate group of workers. If the activities are too close to each other, the work might be disrupted (e.g. an excavation gang might have to wait for a clearing gang to finish). On the other hand, when activities are spaced too far apart, the length to supervise will become unnecessarily long.



Remember:

An activity should follow the preceding one as closely as possible without causing interference or over-crowding. The distance between the first and last activity should preferably not exceed 2km.

When commencing on a new project, it is important to stagger the above operations, allowing approximately a week before starting the next operation. This will also allow the supervisor to organise the work properly and give basic instructions and training to the newly recruited labour.

Daily Work Planning



A supervisor must always plan ahead by at least one day. After the workers have completed their daily work, the supervisor records the outputs achieved on each of the activities. Based on the production achieved and the overall plan for the project, a plan for the following day is prepared. This plan sets the daily production targets for each of the planned activities.

To prepare these work plans properly, the supervisor needs to know what has happened on the site before. Without information such as what resources were needed to produce a given output, why certain targets were not met, etc., proper planning is impossible. To get the right information on time, a well functioning reporting system is required.

Gang Balancing

Balancing of gang sizes, i.e. ensuring that the labour is used in the most efficient way, and that each of the operations on average proceed at the same pace, is the daily task of the site supervisor. The size of the gang will vary according to the work being undertaken, and depends on:

- the amount of work to be done on each operation,
- the task rates being used,
- the available labourers, and
- the sequence of operations.

Good gang balancing is important because it also determines the length of the construction site. If the gangs are not well balanced, the result may be that the work site spreads out and becomes too long to supervise in an efficient manner, or that it becomes too concentrated and the workers are working in a small and congested area. The amount of work will vary along the road line. Therefore there will be a demand for adjusting the number of workers in each gang.

Example:

On Section A of a road, there is a lot of bush clearing and very little excavation needs, and on the following Section B there is a small amount of clearing but heavy excavation works. This implies that after clearing and earthworks have been completed on Section A, a number of workers needs to be transferred from the clearing gang to the earthworks gang. If this is not done, the clearing gang will advance too fast and the earthworks operation will proceed too slow in Section B - resulting in a stretched work site which may become difficult to supervise.

Finally, try to avoid that the workers are given too monotonous and straining tasks. Experience has shown that certain tasks, such as hand-ramming, is difficult for a worker to carry out the entire day. This can be avoided by combining different tasks - for example combining hand-ramming with levelling of excavation works.

3.4.3 Inspection and Supervision

Giving and receiving instructions is a major part of the responsibilities of the site supervisor. The manner in which instructions are given influence the manner in which they will be carried out. Before giving instructions, it is important to specifically know:

- what work you want to have done,
- how it should be carried out,
- who will do it, and
- the difficulties involved in doing it.

Instructions can be given either directly to the person who will carry out the work, or indirectly through a gangleader. Direct instructions to all concerned workers including their gangleader should be used as much as possible. Indirect instructions can be given through a gangleader when he/she as well as the workers are familiar with the task and the work methods. Ask questions to check that instructions have been understood.

If the task is not familiar, careful attention must be given to explaining the work in detail to the entire gang. In many cases, it would be useful for the supervisor to actually demonstrate the work and how it is properly done.

When receiving instructions, repeat them to yourself, and ask for clarification if something is unclear. Then repeat the instructions to the person who gave them to ensure that there are no misunderstandings.

Whenever practical, instructions should be given in writing or written down when received. This applies in particular to instructions concerning measurements and technical designs.

Control of Works

The supervisor needs to inspect and approve the work before the workers are released for the day. He/she should be notified by the gangleader, who informs him/her that a particular task has been completed and is ready for inspection.

When inspecting completed works, check that:

- the set-out measurements have been kept correctly,
- the edges are straight and well trimmed,
- the soil is placed correctly, and
- *all* the work as defined in the task is completed.

If the work has been satisfactorily completed, the group or individual may be released for the day. If the work is not complete, it should be corrected before the group or individual worker is allowed to leave the site.

If the task is not completed before the end of the normal working day, the supervisor needs to find out the cause of the delay - whether the cause lies with the workers or with his/her own setting of the task.

If the reason for non-completion is one of the following, the workers should be released:

- major difficulties were not envisaged when the task was set (i.e. heavy roots, big rocks, etc.),
- incorrect measurement or calculation of the task,

- smaller work force than ordered (if a group task was set),
- bad weather conditions during parts of the day.

If the reason for non-completion lies with the workers, they should complete the task before being released, even if it is after the end of the normal working day.



Remember:

The workers should only be registered in the muster-roll when they have fully completed their daily tasks.

If necessary, the workers may return to the work site the following day to complete their task.

3.4.4 Site Camp

Before road construction works can commence, a site camp needs to be set up to accommodate the supervisors, materials, tools and equipment. The site camp needs careful planning to provide site staff with a basic comfort, and adequate storage and security for equipment and materials.

Location

The selection of a suitable camp location should be made by the supervisor and the engineer. The following items should be taken into consideration:

- ✓ it should be close to the construction site, preferably in walking distance,
- ✓ it should have access to drinking water,
- ✓ it should be located on high, well-drained land,
- ✓ it should have sufficient space for parking equipment after working hours, and
- ✓ it should be easily accessible to project vehicles bringing equipment and materials.

The size of the camp depends on the size of the project, what type of works will be carried out and how far the site is located from headquarters. In most cases, the site camp can be set up in a local village through which the road will pass. Then, suitable accommodation and stores can be rented from the local villagers. In more remote places, the entire site needs to be established by the project.

Standard requirements for a site camp are:

- ✓ accommodation for the supervisors and equipment operators,
- ✓ a site office,
- ✓ a site store,
- ✓ appropriate cooking facilities,
- ✓ toilet and bathroom facilities, and
- ✓ extra site store for fuel, oil and lubricants.

For a road construction project covering more than 7 to 8 kilometres, the camp will probably have to be moved once, twice or even several times. These moves have to be planned well in advance so that the necessary transport can be arranged.

3.4.5 Handtools

Tool requirements depend on various factors such as the size of the project, soil types, terrain and the type of works which are planned. The below table indicates the required hand tools for a project employing a labour force of 100 workers or 200 workers.

| Item | 200 workers | 100 workers |
|--------------------|-------------|-------------|
| Profile Board | 100 | 70 |
| Ranging Rod | 100 | 70 |
| Hoe | 150 | 70 |
| Hoe Handle | 150 | 50 |
| Shovel | 75 | 50 |
| Spade | 30 | 20 |
| Pickaxe | 75 | 25 |
| Pickaxe Handle | 75 | 25 |
| Crowbar | 10 | 5 |
| Bush Knife | 10 | 5 |
| Axe | 15 | 5 |
| Bowsaw | 7 | 4 |
| Grass Slasher | 15 | 10 |
| Heavy Duty Rake | 40 | 30 |
| Hand Rammer | 25 | 20 |
| Wheelbarrow | 60 | 40 |
| Sledge Hammer | 3 | 3 |
| Bucket | 10 | 8 |
| Watering Can | 10 | 8 |
| Fuel pump | 1 | 1 |
| 30m Measuring Tape | 3 | 3 |
| 3m Measuring Tape | 3 | 3 |
| Line Level | 3 | 3 |
| Nylon String | 300 m | 300 m |

Maintenance



Ensure that the tools on site are in good order, that the tools are sharp and that the handles are firmly fitted and not damaged. When you find damaged tools on site, report this to the store keeper and have them repaired or replaced immediately. This will increase work efficiency and enable the workers to complete their task work on time.

On large projects, it may be useful to employ a person to maintain and repair hand-tools. Alternatively, it is always useful to check with the local villagers if there are any blacksmiths or carpenters available in the neighbourhood.

Make sure that the camp is equipped with effective sharpening tools and a sufficient supply of spare parts. The tools required to carry out routine maintenance are cheap and simple to use.

The cutting edges of axes, hoes, mattocks and grass slashers are normally sharpened with wet-stones. The edges of other cutting tools are best kept sharp by a selection of flat, half round and round files. For saws, small triangular shaped files, with a side about twice the depth of the teeth are appropriate.

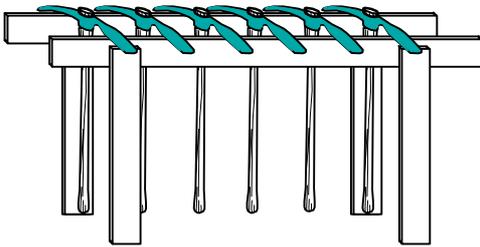
A simple vice should be available at the site store to enable the store keeper to work efficiently. A vice will enable hand tools to be firmly gripped when maintained or repaired.

Have a sufficient supply of spare handles on site. A loose or damaged handle is dangerous and should be fixed immediately. Purchase good quality handles made of hard wood which are properly designed according to established standards. Do not rely on makeshift handles made locally on site.

Wheelbarrows need a lot of maintenance to remain serviceable. Each day, all bolts and nuts should be tightened. If a bolt is lost, it should be replaced before the wheelbarrow is used again. If the wheelbarrows have pneumatic tires, supply the store keeper with a pump and patching equipment.

Storage

Tools are issued by the store keeper to the workers every morning and returned in the afternoon after completion of works. Ensure that the workers are issued the correct type of tools according to the work activity they will be carrying out. The store keeper is responsible for keeping full records of the tools and controlling the daily issue of tools to the workers. The total amount of tools on site needs to be counted regularly and reported back to headquarters.



The size of the store depends on the amount of tools to be stored. When the road site is very isolated, the store has to be well stocked and therefore tends to be larger in size.

Tools should be stored in a dry and secure place. Stock the items neatly so that they can easily be counted. Stock different items separately and stock items of different sizes separately.

If necessary, employ a watchman to guard the stores when the storekeeper is off duty.

3.4.6 Equipment

By definition, labour-based road construction and maintenance methods consist of an appropriate combination of labour complemented with a limited use of equipment. Equipment for labour-based road works is mainly utilised for operations such as haulage of materials and water, compaction and rock breaking. Well-designed and maintained equipment is important as they determine the productivity as well as the quality of the works carried out. Malfunctioning equipment is very often the most common item jeopardising the progress of a road project.

Regular mechanical maintenance of the equipment avoids breakdowns and ensures a long equipment life time. The site supervisor *must* ensure that the operators are aware of the required maintenance and service of their equipment and that it is carried out at regular intervals.

Each piece of equipment has an Operators Manual, which specifies when and where lubrication and adjustments are required. As a rule of the thumb, the following activities should be carried out on a daily basis:



| Clean and Check |
|--|
| <ul style="list-style-type: none">✓ lubrication oil level✓ radiator water level✓ hydraulic oil level✓ hydraulic hoses and couplings✓ grease nipples/tracks✓ battery terminals and battery water✓ connections from alternator✓ all the V-belts and their tension✓ tire pressure/tracks✓ transmission oil level✓ brake and clutch fluid level✓ nuts and bolts of buckets and tracks |

With each piece of equipment, there should be a basic set of tools for carrying out preventive maintenance and minor repairs. These tools should be handed to the operator. To minimise any loss, he/she should be held personally responsible for any loss of these tools.

It is the responsibility of the site supervisor to ensure that regular maintenance of all project tools and equipment is carried out.

3.4.7 Materials

Supply of materials should be made well in advance of its planned consumption. Ensure that sufficient materials are available on site before commencing the works for which the materials are planned. Also, notify the engineer in good time when stores need to be replenished.

When materials are received on site, it is the responsibility of the store keeper to inspect and verify that the stores are in good order and correct quantity. Finally, the materials are recorded in the stores ledger.

Fuel, Oil and Lubricants

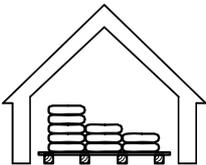
Fuel, oil and lubricants should be stored separately, away from the other supplies. These items can be a fire hazard, if not treated properly. Make sure that there are no open fires nearby, such as fire places for cooking, etc.

Fuel is normally stored in drums. Make sure that all consumption of fuel, oil and lubricants are properly recorded and accounted for.

Culvert Rings

Culvert rings are normally stored at the road site at the planned location of the culvert. They need to be handled with care, in particular when off-loading to avoid that they break. When ordering culvert rings always order a couple of spare rings in case of breakage.

Cement



Cement is very expensive, so it must be handled and stored with care. Avoid breaking the sacks when handling and keep it in a dry and flood secure place. Stack the cement bags off the floor. Always use the oldest cement first.

Pegs

Wooden pegs for the setting out activities are normally produced on site. They should be made well in advance so that the sites have sufficient supply when they are needed. Production of pegs should be organised under the responsibility of the store keeper. If necessary, an additional person can be hired for the collection of wood and cutting of the pegs.



Module 4

Appropriate Setting Out Methods

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4.1 General Observations

This module describes some appropriate methods of setting out road construction and rehabilitation works.

Surveying and setting out activities comprise of a large and important part of the responsibility of technical staff working on labour-based road works.

Appropriate setting out methods always relate to the level of accuracy required for the various steps involved in road works. For labour-based road works it is fully possible to use conventional methods of surveying and setting out. However, when dealing with a large labour-force rather than a few selected pieces of heavy construction equipment, experience has shown that the setting out methods and procedures need to be adjusted to the new work methods.

This module describes in detail methods and procedures for setting out works for a large labour-force executing road rehabilitation and construction works. These work methods have proven efficient and adequately accurate for rural road works in Lao PDR and a number of other developing countries.

Basically, the methods follow traditional principles of setting out road works. The major difference for labour-based work methods is that the setting out needs to be carried out to a more detailed level than when using heavy equipment. Essentially, the setting out for labour-based works needs to be carried out to a level defining the exact amount of work to be carried out by each worker during a day.

This implies that setting out is a time consuming activity for labour-based road construction sites. To solve this problem it is necessary to train sufficient staff to cater for the setting out requirements of each work site. It is therefore imperative that the methods are simple, sufficiently accurate and does not rely on complicated and expensive surveying equipment.

In order to efficiently plan and organise a work site, it is important that the management staff of a site fully understands the methods and procedures of setting out labour-based works. These methods may seem too tedious and time consuming, however, one should bear in mind that the methods are easy to learn and therefore it is possible to delegate this work to subordinate staff.

On conventional road construction sites, the responsibility for setting out is very much left to a surveyor plus an assistant. For labour-based road works, it is recommended that more staff is involved in this activity such as site supervisors, foremen and gangleaders. In addition, on larger projects, one would normally organise a separate setting out team only dealing with this activity.

4.2 The Profile Board Method

4.2.1 The Basic Principle

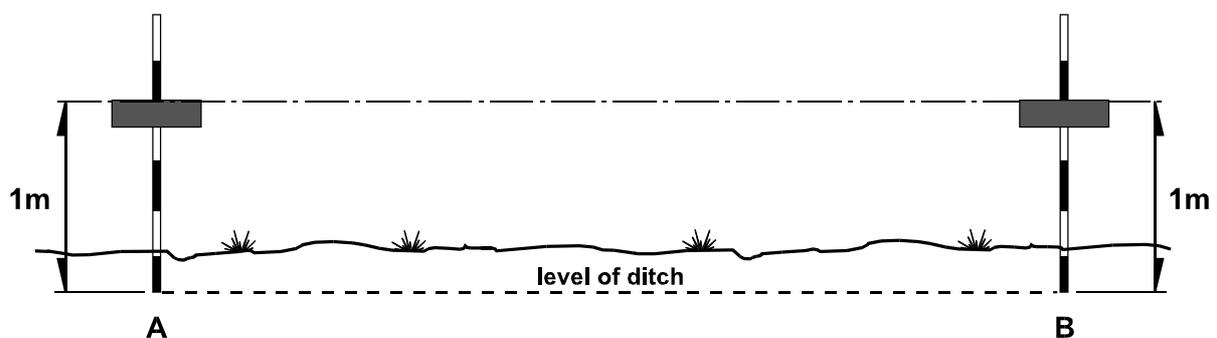
A commonly used setting out procedure is based on the use of a series of profile boards and a string line level giving control of levels during construction. As a result, the method has become known as the "Profile Board Method".

The basic principle when using profile boards is that when we set them out we are putting up a series of level boards that show us the level 1 metre above the completed construction levels. With practice, it becomes easy to work with these tools and roads can be built properly, economically and at high quality standards.

Imagine that you need to dig a ditch from A to B at the level shown in by the dotted line:

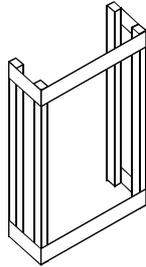


To ensure that we obtain the correct level in the ditch, we would put up profile boards at positions A and B, 1 metre above the level we want the ditch to be:



4.2.2 Equipment

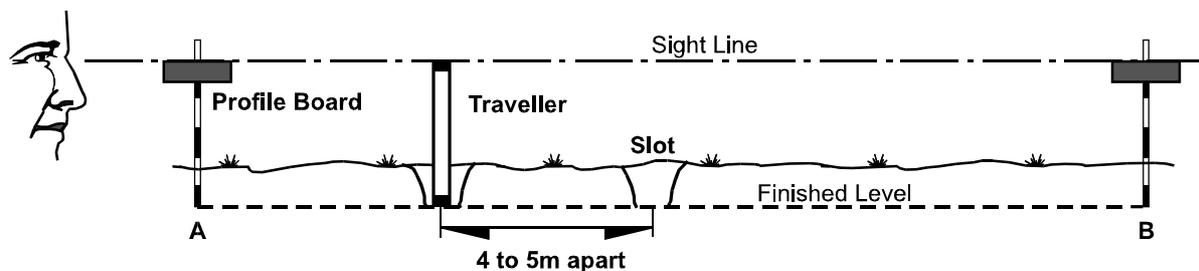
The Traveller



We need a third profile board that we can move around. It is known as the travelling profile or *traveller*. Along the line from A to B, we excavate slots to the level of the ditch. If we place the traveller in a slot and sight from profile board in position A to the profile board in position B, we can see if the traveller lines up with the two fixed profile boards. If the traveller is too low, the slot has been dug too deep. If the traveller sticks up above the sight line, the slot needs to be dug deeper.

To provide good guidance, slots are dug at regular intervals, say at every 4 to 5 metres along the sight line.

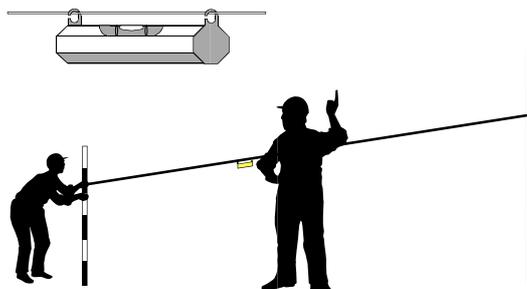
When sufficient slots have been dug, the workers can start excavating the ditch by joining up the slots. The traveller can then be used to check that the finished work is to the correct level and that there are no high or low spots.



The Line Level

The level of each of the profile boards can be controlled by using a *line level*. The line level is a short spirit level (about 100 mm long) with a hook at each end to hang it from a nylon string.

This instrument needs two persons to operate - one at the end of the line, and the second to watch the spirit level. The line operator moves the string up or down until the bubble is centred in the middle between the spirit level marks. The string line will then indicate the horizontal line.



The line level can be used to:

- ✓ transfer the exact level of one profile board to another profile board, thereby ensuring that both are at the same level,
- ✓ measure up or down from the horizontal level shown, and set another profile board so that there is a certain difference of level between the two profiles, and
- ✓ find the slope between two fixed profile boards, and which one is higher.

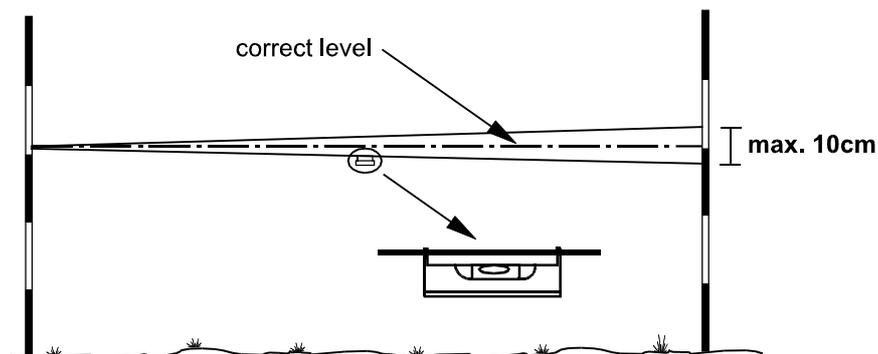


Points to remember when using a line level:

- ✓ The string used should be a thin nylon fishing line, enabling the line level to easily slide along the string.
- ✓ The line level must be placed half-way between the two ranging rods. Use a measuring tape to find the exact middle point.
- ✓ Keep the string tight - do not let it sag.
- ✓ The line level is an delicate instrument, look after it - do not throw it around and treat it roughly.
- ✓ Check the accuracy of the line level regularly in the field.

Checking the Line Level

Take two ranging rods across the road and transfer a level from one rod to the other. Mark the level on the second rod. Then keeping the string in the same position on the first rod, take the line level and turn it around on the string. Adjust the string on the second rod until the bubble is in the middle again and mark the new level. Check to see if the two marks are at the same place. If not, measure the difference between the two marks. If the difference between the two marks is less than 10 cm, you can get the right level by taking the point half way between the two marks. If the difference is greater than 10 cm you should replace the line level for an accurate one. It is always a good idea to turn the line level around every time you use it and take the middle of the two marks as the horizontal level.



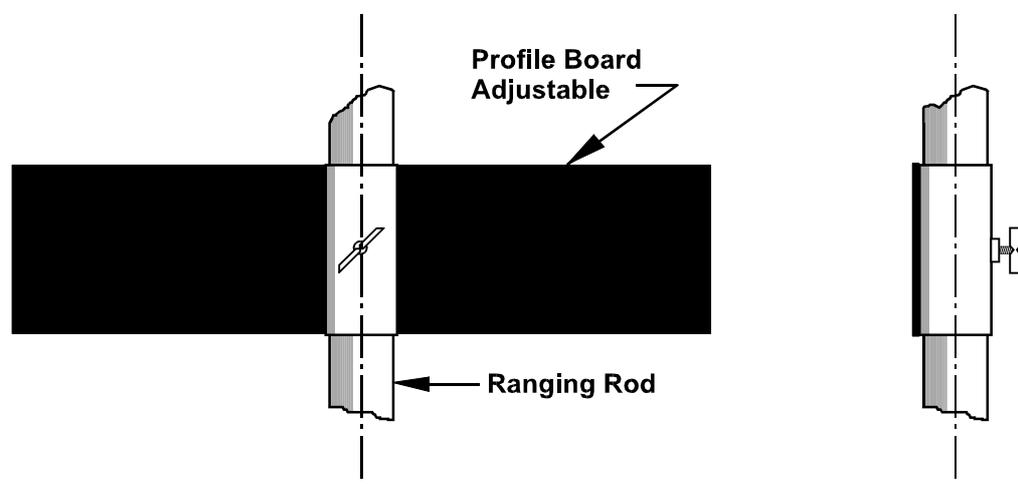
The line level has a range of up to about 50 metres. It is easy to carry around and with care can be used for setting out levels and slopes not less than 1 in 300.

Other Equipment

The other requirement of the profile method is the use of adjustable profiles that can be moved and locked in the desired position.

A long lasting profile board is made from thin steel plate which is welded to a short length of metal tubing that can slide up and down and be clamped to a metal ranging rod. A useful size for the metal profile boards has been found to be 40 cm by 10 cm, painted red to make it easy to be seen.

The ranging rods are made of hollow metal tubes, often 12.5mm diameter galvanised water pipe, with a pointed end of sharpened reinforcement steel. They are painted red and white to make them easy to see during setting out.



A very useful additional tool is a *sliding hammer* with a weighted head that fits over the ranging rod and can be used to drive the ranging rod into the ground.

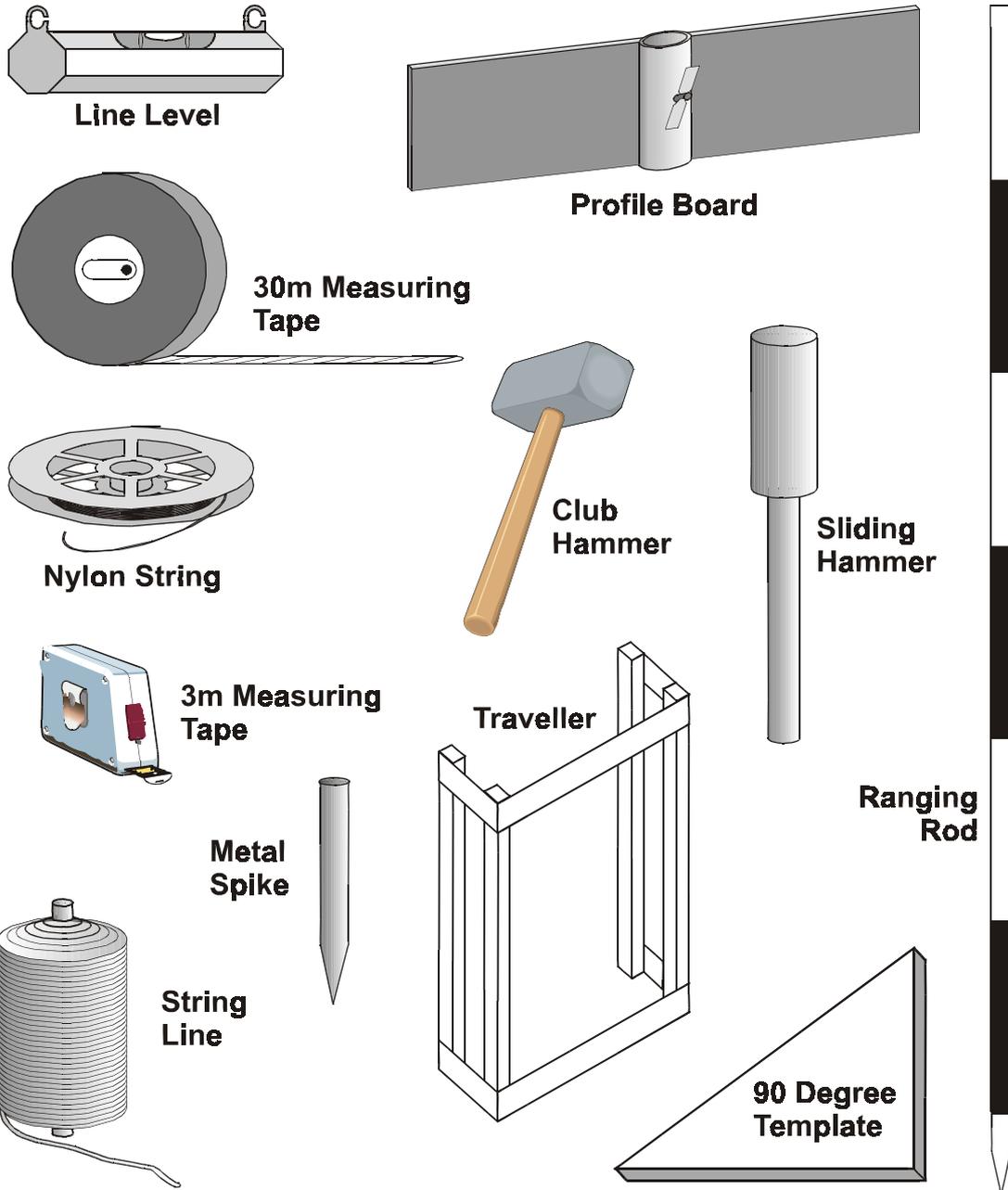
The traveller can be made of wood or metal, although metal is desirable as they are frequently and roughly used and should therefore be of strong construction.

In very compact, or rocky ground, it is useful to first make a hole for the ranging rod by first producing a hole by hammering down a metal spike produced from high tensile reinforcement steel. Crow bars can also be used for this purpose.

The profile boards, ranging rods and travellers are inexpensive and can easily be made by a local metal work business.

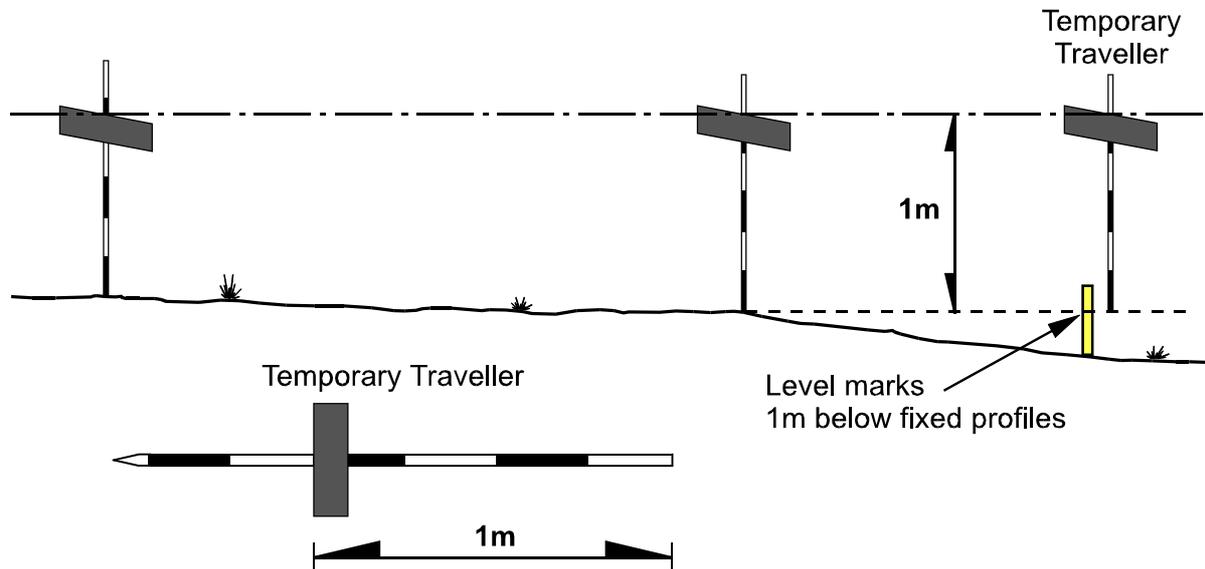
Before starting your setting out works, make sure that you have a sufficient supply of ranging rods and profile boards. A supply of 20 rods and 20 profile boards is regarded as a minimum to effectively carry out the job.

Equipment Required for Setting Out



4.2.3 Temporary Travellers

It is also possible to make measurements below the line sighted between two profile boards by using a *temporary traveller*.



The temporary traveller is easily made on site by measuring the length needed from the blunt end of a ranging rod to the further edge of the profile, which is then clamped in position. The temporary traveller is then ready for use.

When used with fixed set out profiles, the traveller will give an indication of the finished construction levels anywhere along the sight line of the set out profiles.

This is very useful for the site supervisor when setting out. The most frequent use the supervisor will make of temporary travellers, will be to mark earthwork levels on the edge of road pegs. But there are other uses for these travellers:

- ✓ to guide and check excavation below earthwork levels (eg. for excavation for drift base construction),
- ✓ to find out whether large boulders are above or below road levels before they are finally decided upon,
- ✓ to estimate the amount of fill needed if the road is "lifted" or crosses low areas - this will help estimate the work involved and help decide on the best road levels,
- ✓ to locate the end of drains and approaches, and
- ✓ to provide a quick check on work, levels, string lines etc.

However, for guiding drainage work the labourers and gang leaders should use the specially built travellers. This is because the profile on a temporary traveller can become loose and the supervisor may not be present to check and re-set the traveller length.

4.2.4 The Use of Profile Boards

When we set out work with profile boards and use a string line level to control the level of the board, there are a number of uses we can make of them:

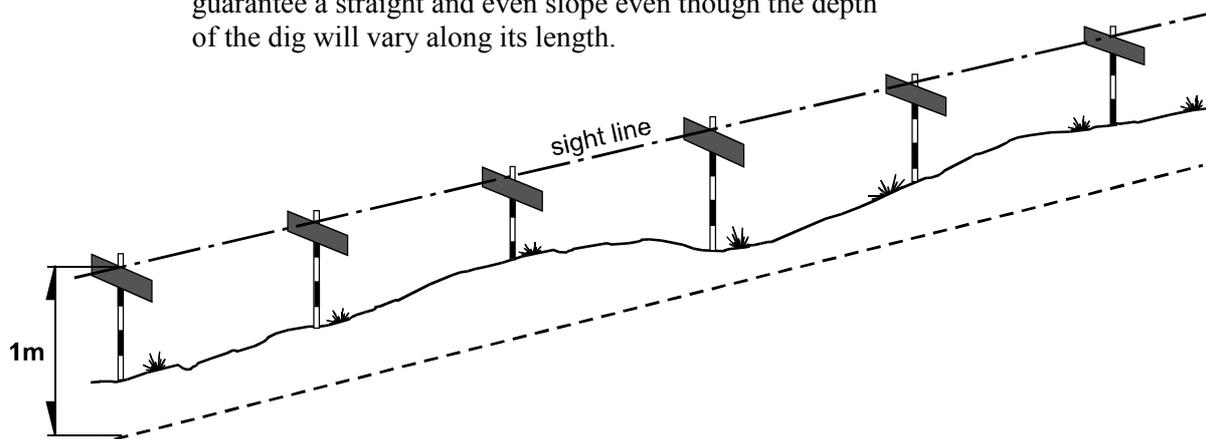
- (i) We can transfer a level from one side drain to the other side drain and thereby ensure that the drains on both sides are built to the same level of depth.
- (ii) We can set out a slope at the gradient we want. This is especially important for drains, the camber and drift approaches.
- (iii) We can check for low spots in the terrain, when setting out the road alignment.
- (iv) We can set out vertical curves.
- (v) We can estimate how much cutting and filling is involved, before we start construction works.
- (vi) We can find out the length of a mitre drain or outlet drain before we start works.
- (vii) We can find the length of a drift approach before we start works.

These uses give us good control over construction works, ensuring that the road is built the way we want it and to a uniform and good quality standard.

Finally, it makes it possible to coordinate a large number of workers so that each one's work will fit in with everybody else's work.

Side Drains

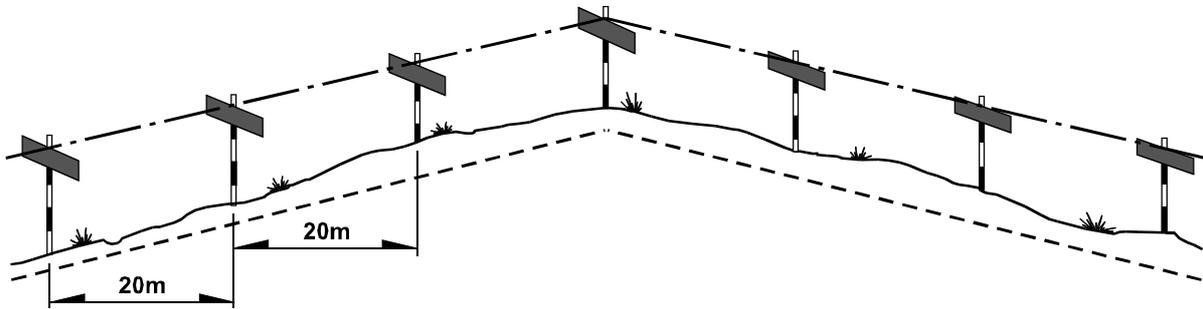
The example below show how a side drain can be dug using profile boards to guarantee a straight and even slope even though the depth of the dig will vary along its length.



Vertical Curves

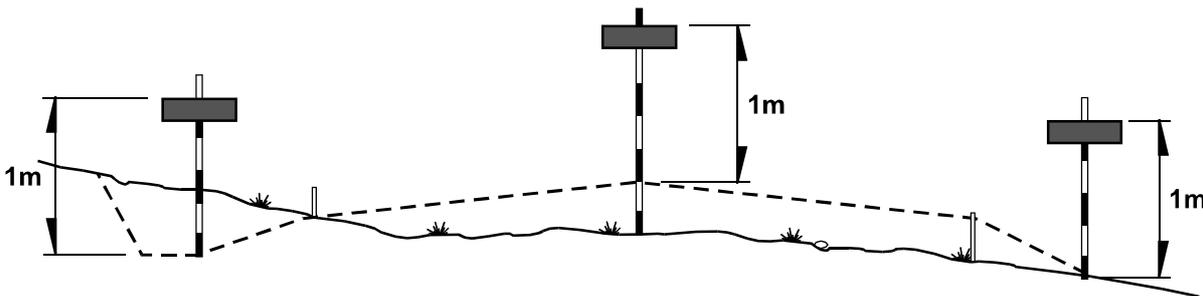
The figure below shows how a vertical curve can be set out over a hill or across a dip in the terrain. The profile boards are set out to give a standard depth of dig to the drain and then adjusted by eye to give a smooth curve.

The spacing of 20m between the profile boards is enough to make a series of straight lines appear as a curve when the road is finished.



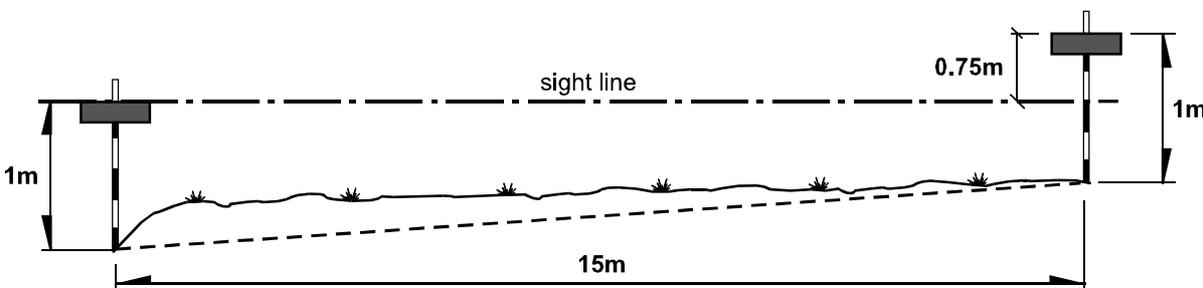
Cross Sections

The following example shows how the profile boards indicate that no ditch is required on the low side of the road and how much filling is needed to produce the camber. Profile boards also enable us to set out the correct level at the shoulders of the road.



Slopes

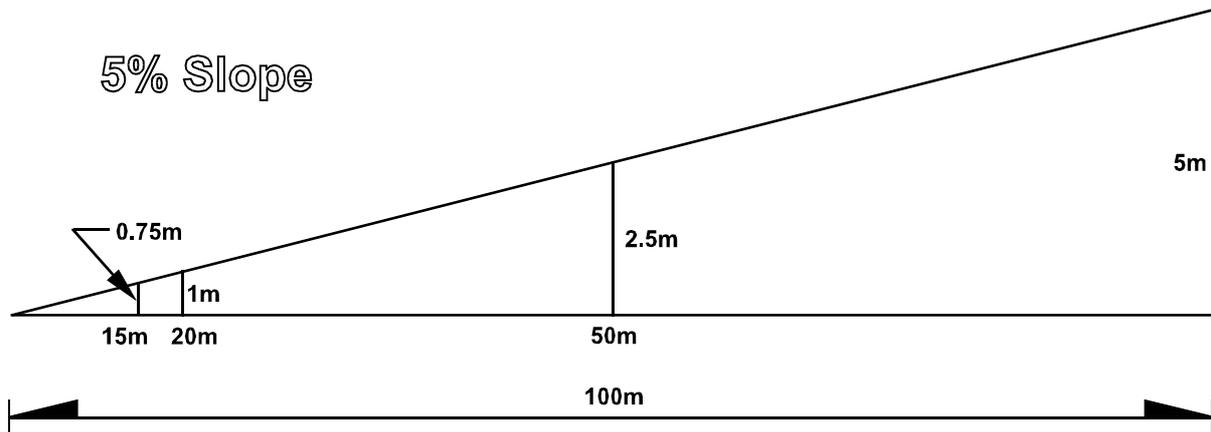
We can set out a gradient or slope by using profile boards. For example, if we transfer the level of one profile to the ranging rod 15 m away and set the profile board 0.75 m above this mark. The two boards are then set at a slope of 5%.



It is possible to use profile boards in this way to make sure that mitre drains are dug at not less than the minimum allowable slope.

The difference in level is calculated as follows:

A 5% slope means that there is a 5 metre difference in level over a distance of 100 metres.

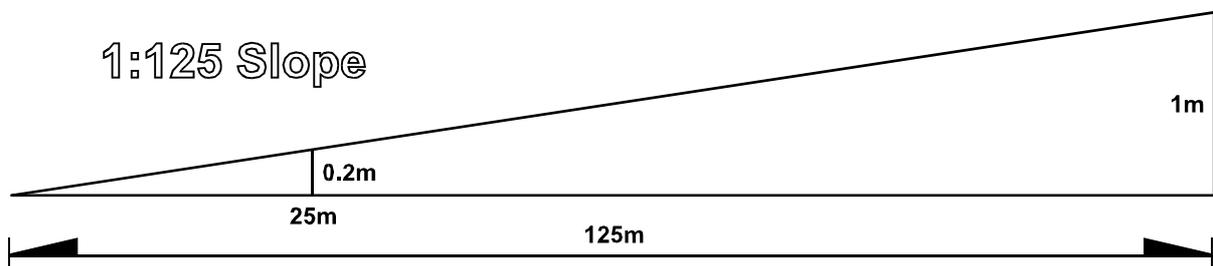


To find the difference in level over a short distance, multiply your measured distance by 5m and divide by 100m. For example:

$$15m \times \frac{5}{100} = 0.75m \text{ (75cm)}$$

As a result, we can set out any gradient we wish.

For mitre drains, the least slope that is allowed is 1:125.

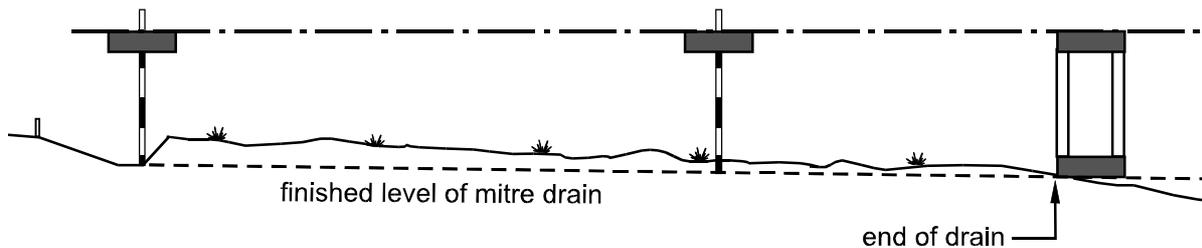


If we select a convenient distance between the profile boards (say 25m), we calculate the difference in level of the mitre drain profiles as

$$25m \times \frac{1}{125} = 0.20m \text{ (20cm)}$$

Length of a Mitre Drain

Another use is to establish the length of a mitre drain before starting work. After setting the slope profile boards to the right gradient, we can use the traveller to see how far we have to go to get the three profiles to line up. The position where the traveller rests on the ground and lines up with the two fixed profile boards show where no excavation is needed and is therefore the end of the drain.

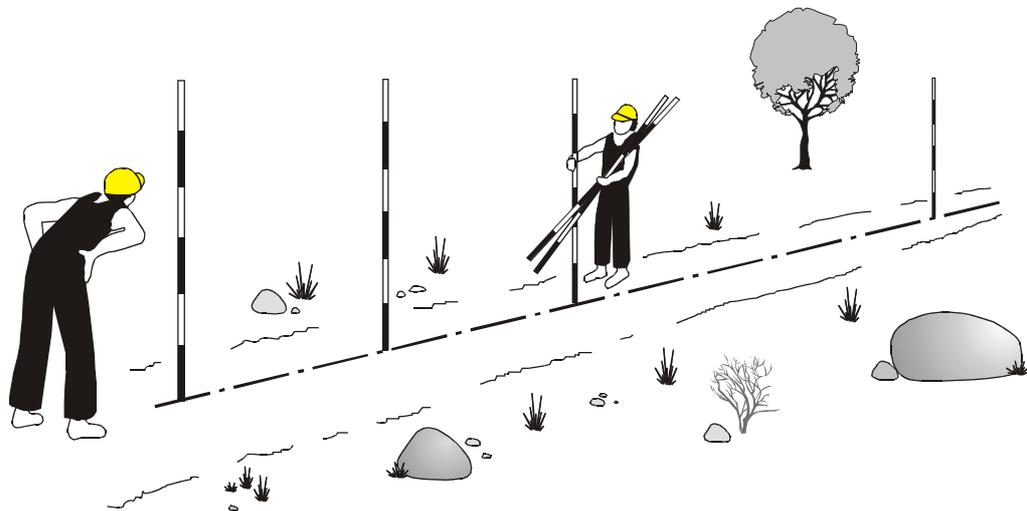


Finally, it should also be mentioned that the Profile Board Method is effective to use when setting out works for gravelling, drifts and culverts. This is described in detail in the following chapters.

4.3 The Centre Line

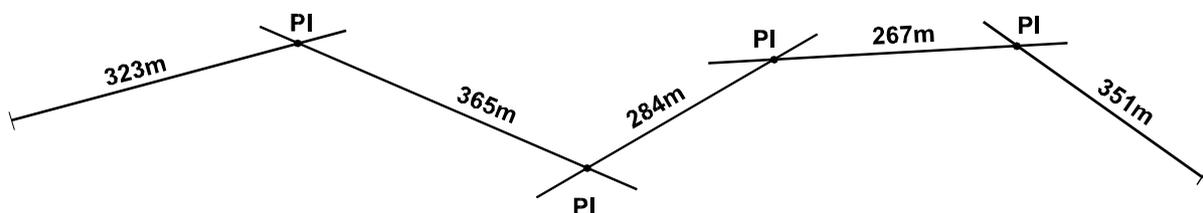
4.3.1 Setting Out Straight Lines

Straight lines are set out by marking points every 50m to 100m with ranging rods. Between these ranging rods, intermediate points are set out at every 10m. Normally, sections of not more than 50 to 100m are set out at the time. In mountainous terrain, sections of less than 50m may be chosen.



4.3.2 Setting Out Curves

Your centre line has now been selected by means of a series of straight lines meeting at points of intersection. Eventually, these straights will be joined by curves that will be set out during the detailed setting out.

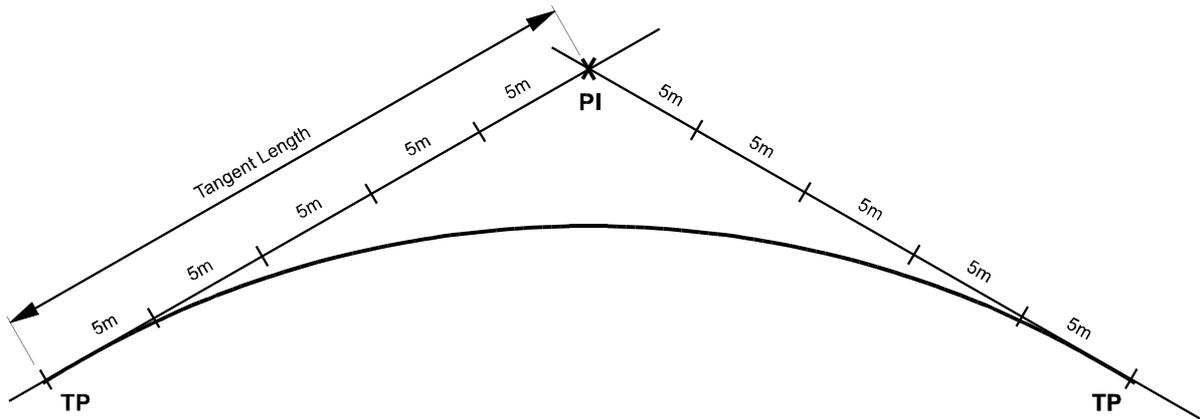


Measure the distance between the intersection points and keep this as a first estimate of the length of the road to be constructed.

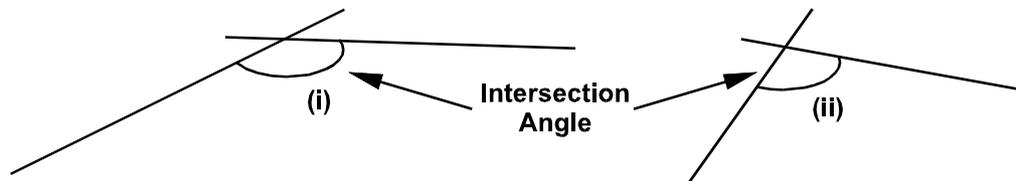
4.3.3 The Intersection Method

The intersection method is a simple and effective method to set out curves. It requires simple equipment and can be easily understood by the foremen.

Step 1: First place a peg at the point where the two straight lines meet (intersection point PI). Then locate the *tangent points*, TP. The first tangent point is where your curve begins, and the second where it ends. Divide the tangent lines in equal lengths, by setting out a number of ranging rods along the tangent lines at say 5m intervals.



With longer tangents, you will achieve a longer curve with a larger radius. Deciding the length of the tangents is best done by experience. You will gain experience in how to select the best tangent length. First look at the intersection angle between the two tangents:

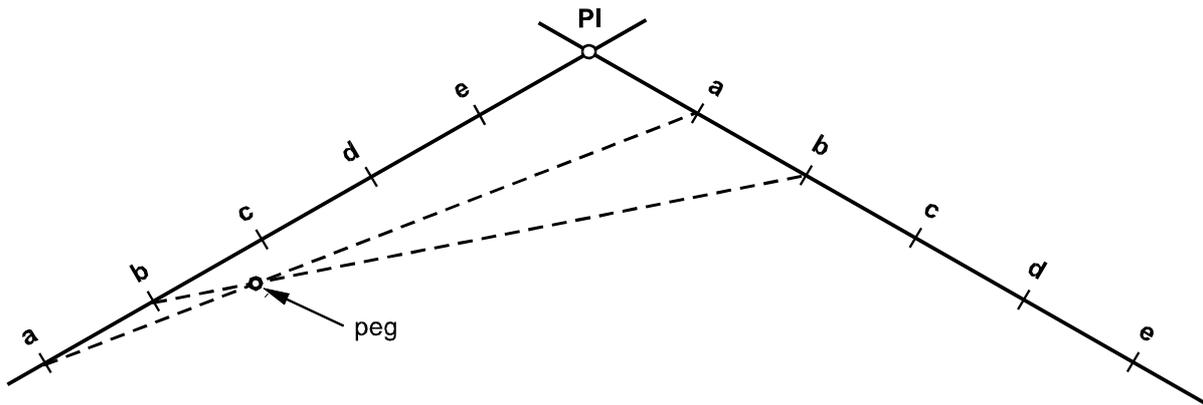


A large intersection angle (i) will produce an easy curve with a big radius. The tangent length can then be short (however, not shorter than 20m).

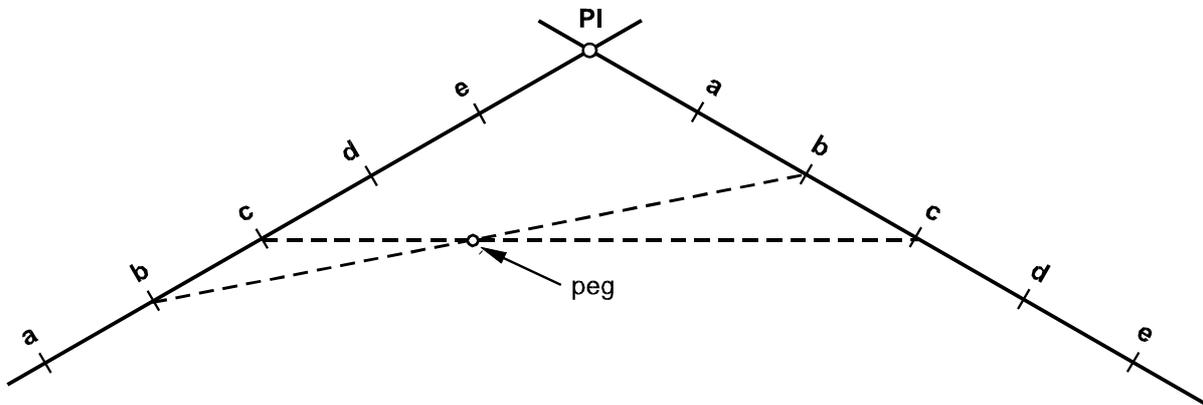
A smaller intersection angle will give a sharper curve with a short radius. In such situations, the tangent lines should be made longer (30, 40, 50 or 60m) to increase the radius of the curve.

Sometimes, you will want to adjust the tangent length to control where the centre line of the curve goes (see below: Adjusting the Position of the Curve).

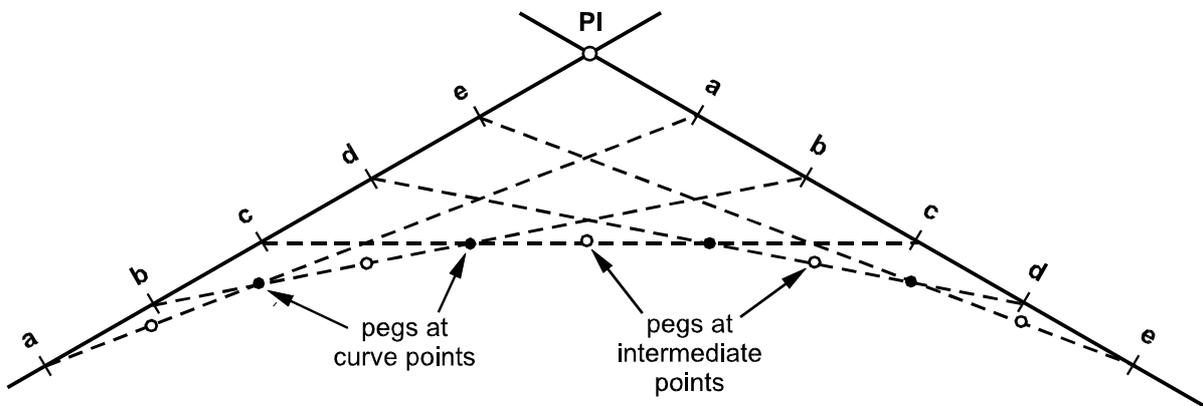
Step 2: Give each ranging rod a letter as shown in the figure below. Sight along line a - a with an assistant holding a ranging rod in your sight line. A second assistant stands at point b and sights along the line b - b. Move your assistant along line a - a until he also stands on line b - b. Mark this spot with a ranging rod and a peg. This is your first point defining the curve.



Now repeat this exercise by sighting along b - b while an assistant is sighting along c - c to find your next curve point.



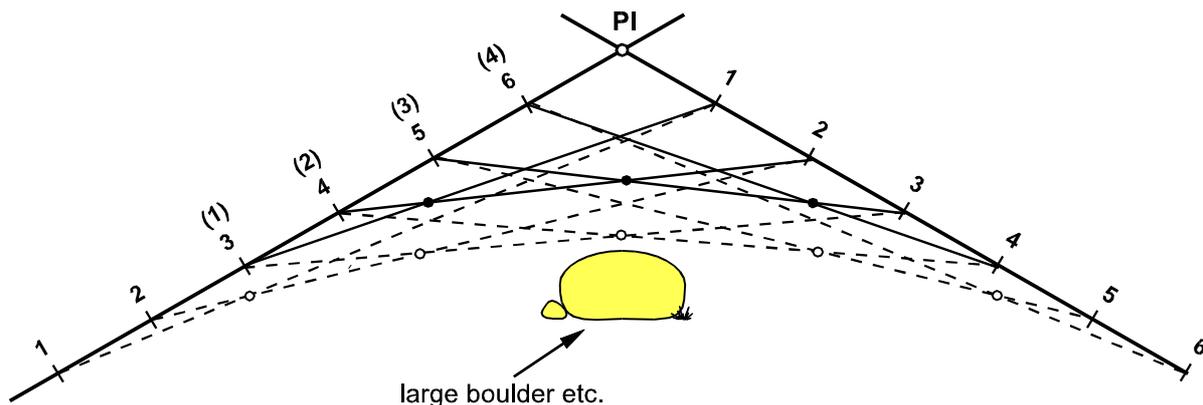
Complete the exercise for line c - c, d - d, etc. Finally, use these curve points to set out intermediate points along the curve at 5 m intervals. Inspect the curve and make sure that all the points provide a smooth curve.



Adjusting the Position of the Curve

You always get one curve point less than the number of ranging rods on the tangent length. For example, 5 ranging rods will give you 4 curve points (as above).

Even numbers of ranging rods gives uneven numbers of curve points, then the middle curve point will be opposite the intersection point, PI. Where the middle two lines intersect is the middle point of the curve (as below with 3-3 & 4-4 and 2-2 & 3-3).



If we increase the length of the tangent lines, we find that the curve moves further away from PI. We can use this when we need to set out the centre line of the curve to avoid obstacles such as trees, buildings, boulders, etc.

4.3.4 Setting out Curves "by Eye"

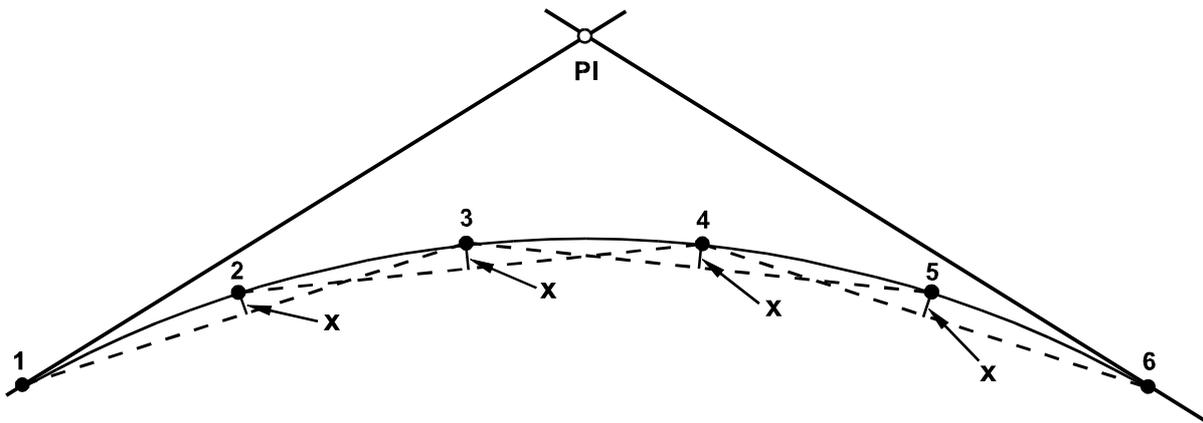
When setting out a curve it is necessary to adjust pegs "by eye" until they appear to follow a smooth curve.

This is a useful skill that has to be learned by every supervisor and technician.

A quick way to control and adjust the setting out of the curve is to line up the first and third peg and measure the off-set of the second peg to this line. Then repeat this exercise by lining up the second and fourth pegs and measuring the off-set to the third peg to this line. Walk around the curve and check and adjust these off-sets until you are satisfied that they are nearly equal.

This will give you a good enough curve to set out the dimensions necessary to build the road.

When the radius of a curve is large (when the angle between the straights is large), it is more practical to set the curve out "by eye" directly rather than by the intersection method. This should only be done on large radius curves with short curved lengths. When the intersection angle is small and the radius small, you should always use the intersection method.

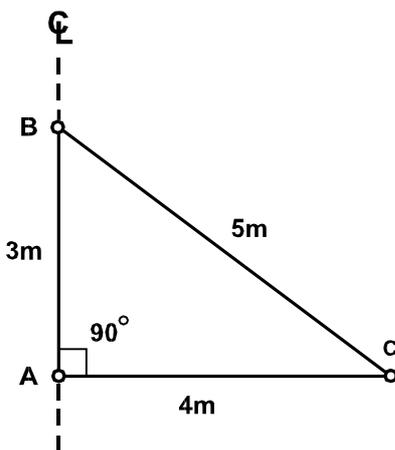


This method may also prove useful in mountainous terrain where there is limited space for using the intersection method.

4.3.5 Off-set Pegs

Once the centre line has been set out, it is necessary to mark the line in a proper way. This is carried out by setting out solid off-set pegs 90 degrees to the side of the pegs indicating your centre line.

In case the road needs to be constructed on an embankment, off-set pegs should be placed on each side at the foot of the planned embankment, at 10m intervals along the road line.



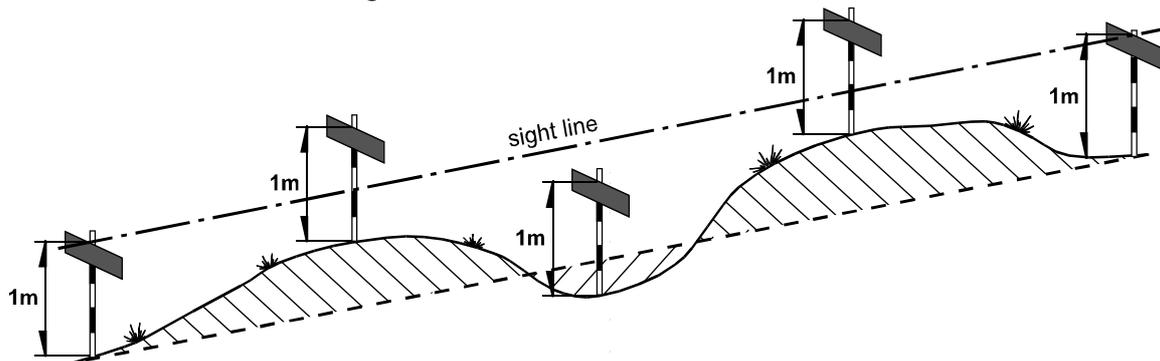
To set out the off-set pegs, you must first construct a 90° angle from the centre line. This can be done by using the 30m tape. Measure 3m from the first ranging rod (A) along the centre line and place a temporary peg at this position (B). Then find the 8m mark on your tape (C) while holding the tape at the 12m mark at point (A). A ranging rod is then positioned at the 8m mark on the tape, creating a line between A and C, 90° to the centre line. Repeat this exercise on the opposite side of the centre line and check that the three ranging rods are on line. You can now measure out the position of the off-set pegs by sighting along the three ranging rods.

Alternatively, it is possible to manufacture a template which can be used for setting out 90 degree angles.

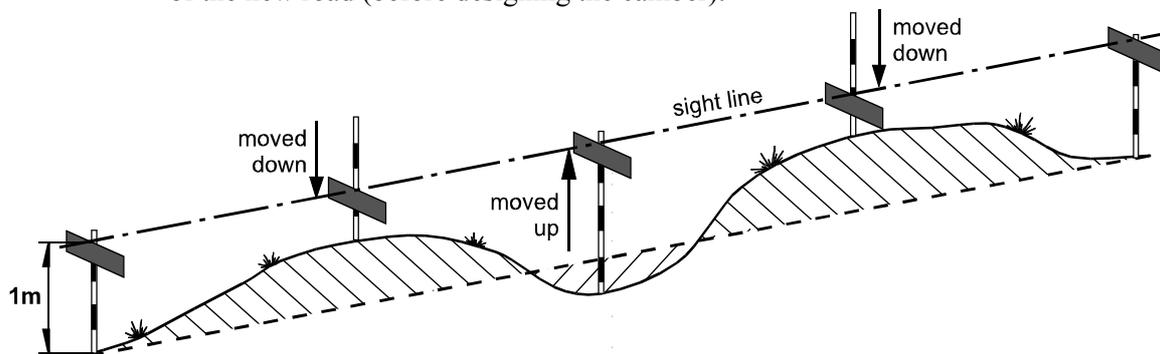
4.3.6 Vertical Alignment

When the horizontal road alignment has been established, the next step is to set out the *vertical alignment*. Vertical alignment sets out the level of the road in relation to the surrounding terrain. The method shown below is based on the use of profile boards to optimise the road level, avoiding unnecessary earth movement.

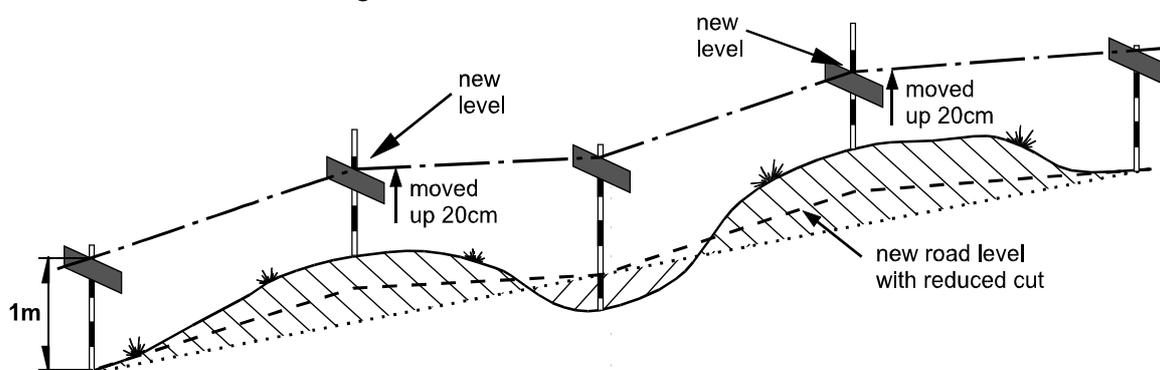
Step 1: First, fix profile boards on the ranging rods along the centre line at a fixed level, say 1 metre above the ground level.



Step 2: Then sight along the profile boards. Get your assistant to adjust the level of each of the intermediate profile boards so they are all on line with the first and the last profile. All the profile boards will then be at a level 1 metre above the level of the centre line of the new road (before designing the camber).



Step 3: If the level of the centre line is too deep into the terrain, i.e. involving too much excavation works, you can move the profile boards up or down to reduce the levelling works, achieving a balance between the volumes of excavation and fill.



Finally, make sure that the profile boards along the centre line has been correctly placed. All other levels for the road structure will be set out based on the profiles along the centre line.

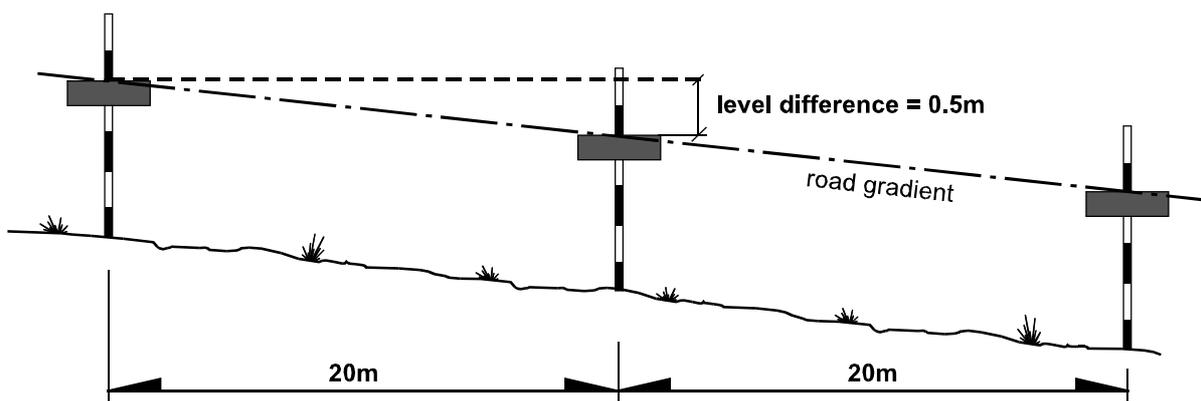
4.3.7 Road Gradients

When setting out the centre line of a road, it is important to check the gradients along the road profiles. Transfer the level of one profile board to the next ranging rod and measure the difference. The slope or the gradient is then calculated as follows:

$$\text{Slope of road} = \frac{\text{level difference}}{\text{length}} \times 100 = \% \text{ slope}$$

So, if the difference of levels is measured to 0.5m between two profile boards with a length of 20m between them, the gradient is calculated to:

$$\frac{0.50}{20} \times 100 = 2.5 \%$$

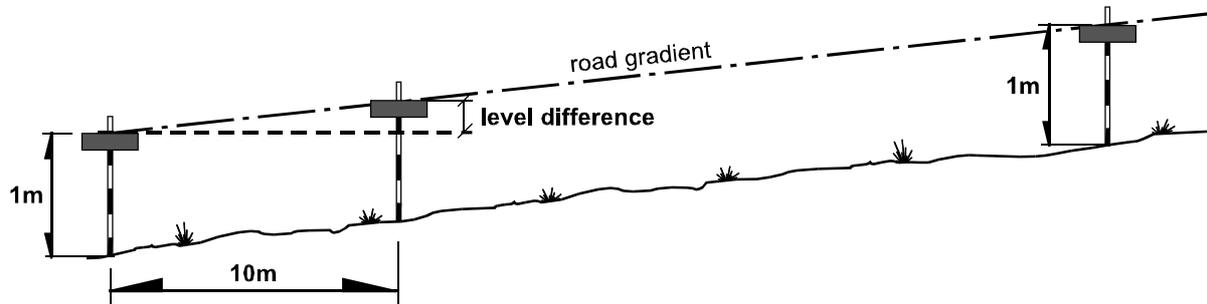


This procedure is very useful in order to find low spots along the road line and to check that the slope of the side drains will not cause erosion or silting. If the road gradient is found to be unsuitable, the road levels can and should be changed before construction works start.

It is also useful, when selecting the road centre line, to check that the slope of the existing terrain to make sure it is not too steep or too flat before fixing the location of the centre line.

This is done by setting a profile 1m above the ground at the start of the section in question, and another 1m above the ground on the proposed centre line at the end of the section. A third profile is set 10m from the first profile along the line from the other two. Using a line level, the difference in level between the two profiles 10m apart is measured and the percentage slope of the terrain can be calculated.

$$\text{slope} = \frac{\text{level difference}}{10} \times 100 \%$$



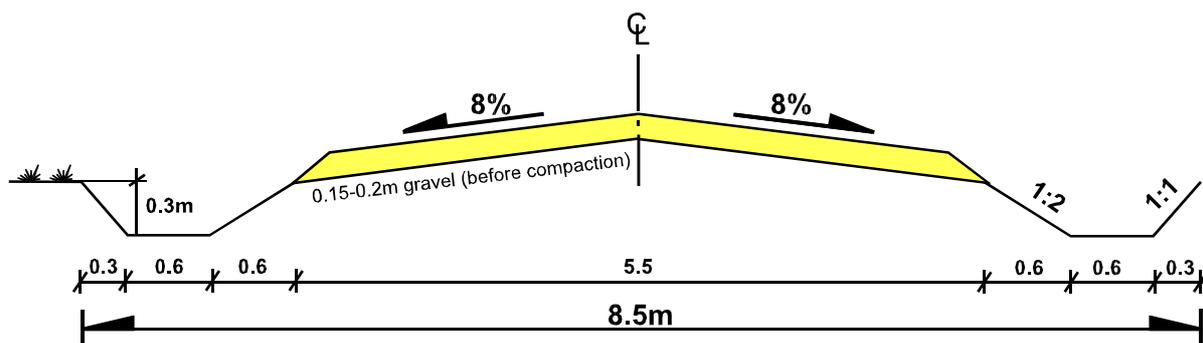
This way, the gradient can be checked before the centre line is fixed, avoiding unsuitable gradients. Try different centre line locations to select the best possible gradient for the road.

4.4 Ditching, Sloping and Camber Formation

This section describes step by step the setting out the road camber of a road section in rolling and hilly terrain. If the road needs to be elevated on an embankment, refer to the section covering Embankment Construction in Module 5 Construction Procedures.

Normally, the road camber is set out together with the side drains. Once the position and levels of the centre line has been determined, it is possible to construct the camber and side drains.

To illustrate the setting out method, the geometrical dimensions as illustrated in the figure below has been chosen. These dimensions happen to be the key dimensions of the cross-section utilised in the ILO labour-based road project, however, any cross-section can be chosen using this method.



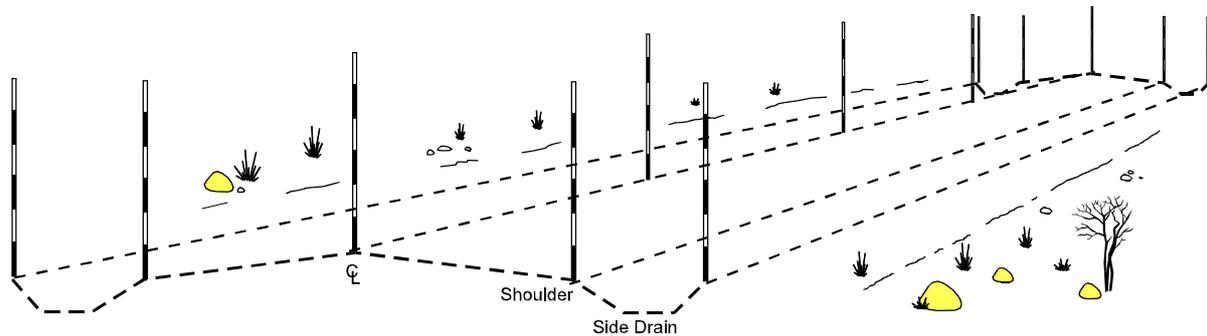
When setting out the road camber and side drains, it is important to reduce the amount of excavation to a minimum by following the existing level of the terrain along the road line. The procedure described below is an efficient way of setting out the road levels, achieving a well placed road with good drainage and which does not involve massive excavation and/or fill works.

Step 1: Using the previously set out centre line, set out ranging rods at 10m intervals along the centre line for a section of 50 to 100 metres. At the start of the section, measure out the position of the road shoulders and the outer end of the side drains from the centre line. Repeat this exercise at the other end of the section.

Place a wooden peg next to each of the ranging rods.

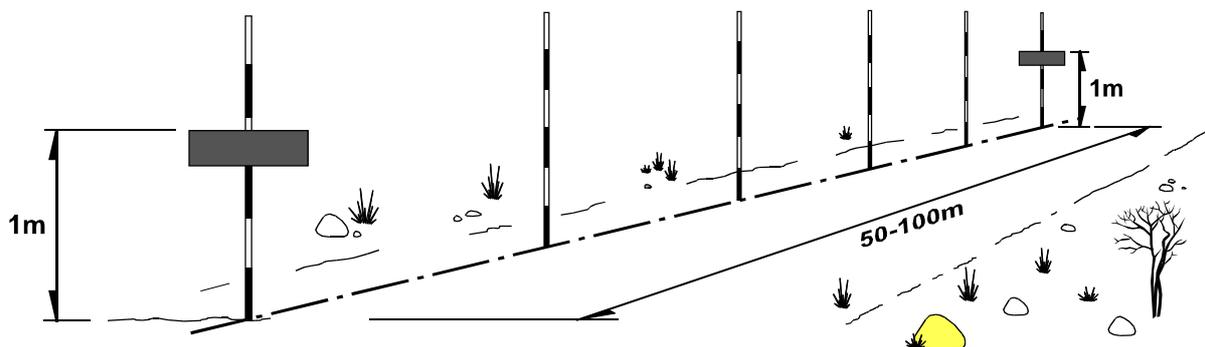
Step 2: Once the key positions of the road has been set out at the start and the end of the road section, sight in intermediate ranging rods at every 10m along the road shoulders and side drains.

Place wooden pegs next to each of the intermediate ranging rods.

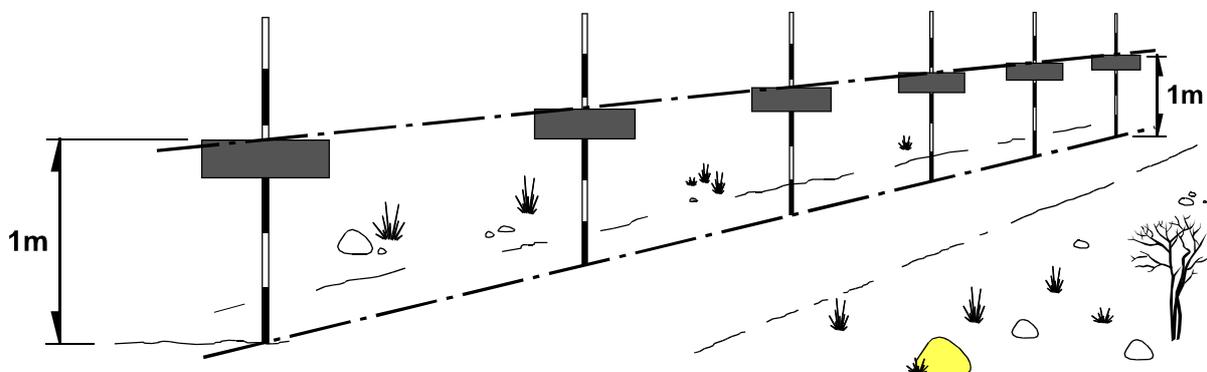


Step 3: On the centre line of the road, fix the first profile board. This profile may be already in position as the last profile from the previous setting out. If not, measure 1m up from the existing ground level, and mark this level on the ranging rod. Fix a profile board to the ranging rod so that the top edge of the profile board is at the mark made on the rod.

Step 4: Go to the centre line ranging rod at the other end of the road section and repeat the procedure, measuring up 1m from the ground level.

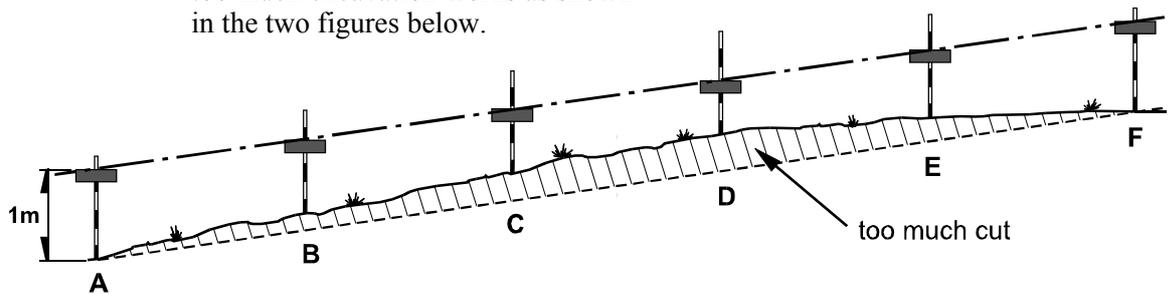


Step 5: By sighting in the intermediate profiles from one end, fix profile boards on the intermediate ranging rods along the centre line so that they are all at the same level.

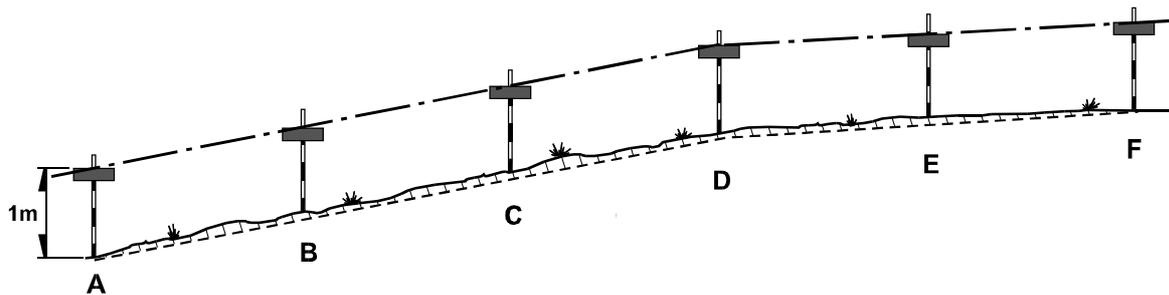


Step 6: Check the height of each profile board above the ground level. If the height is approximately 1m, there is no need to adjust them and you can use the level of the profile as it is.

If the height of the profile boards is greater or less than 1m by 10cm, then inspect the line. There may be humps or depressions along the line. The set out line will in most cases smooth out these variations. However, it may be that the set out line is over a hill or a dip in the terrain. In such cases, it is necessary to adjust the profiles to avoid too much excavation works as shown in the two figures below.



Adjust the profile at position D so that it is 1m above the ground and then lift the profiles at B, C and E to sight in line with the profiles at A to D and D to F. This exercise will reduce the amount of excavation works.



General Rules

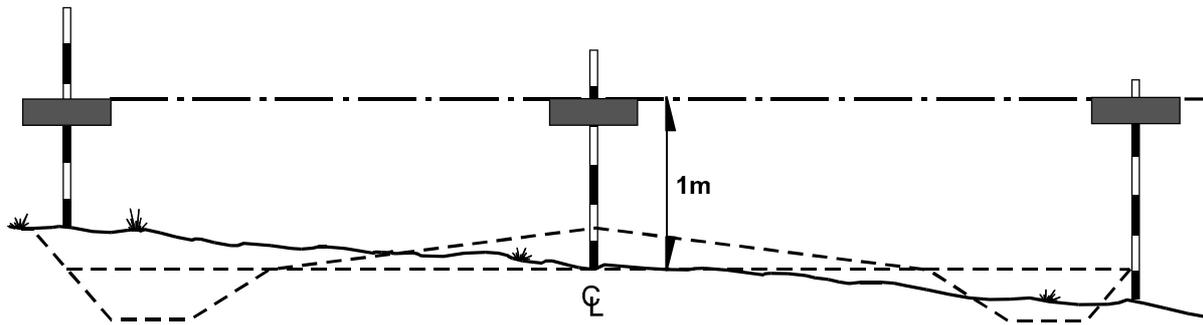


1. It is better to lift profiles than to drop them.
2. Try to keep lifts and drops less than 10cm.
3. Try to match the road levels to the terrain.
4. Use the profiles to get a picture of the vertical road alignment.

Before starting on the next step, make sure that the side drains can be emptied. It is important to spend time on this step to get the levels right. All other levels will be set out based on the profiles along the centre line of the road.

Step 7: Transfer the levels to the ranging rods at the outer end of the side drains. Start with the beginning of your road section. Using a string and a line level, transfer the level of the profile board at the centre line to the ditches on the both sides of the road. Once the levels are set out with profile boards, mark the levels on pegs next to each ranging rod.

Repeat this procedure for the same two ranging rods at the other end of the road section and for any intermediate profile along the centre line that was lifted or lowered to reduce excavation works. Then, sight in the intermediate side drain levels.



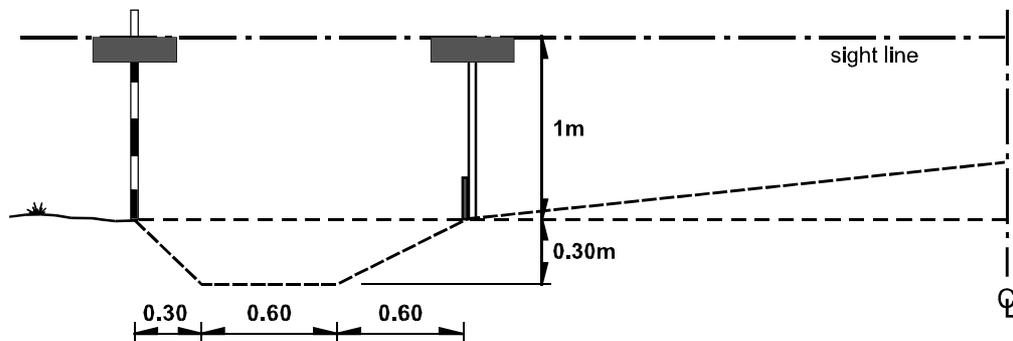
You will notice that the height of the drain profile on the low side of the centre line is more than 1m in most cases. This is because we have started from higher grounds, and since the road is level, the lower side drains will be less deep.

Step 8: Mark the levels for the centre line on pegs placed next to the ranging rods along the centre line. Now use the centre line profile boards to set out intermediate pegs placed at every 5 m along the centre line. This is easily carried out with a 1m traveller. Mark these pegs at the point where the bottom of the traveller touches the peg, when lined up with the profiles. On all the centre line pegs, mark the level of the crest of the camber 0.25m above the 1m level on the pegs.



You have now set out the profiles for the levelling of this road section.

Step 9: Place the levels of the shoulders along the road. For this, it is useful to have a traveller 1m high. If we line up the traveller along the line between the two side drain profiles, the bottom of the traveller will show the correct level of the shoulder.



Place pegs every 5m along the edge of the shoulder, and using the traveller, mark these pegs at the point where the bottom of the traveller ends when it lines up with the profiles.

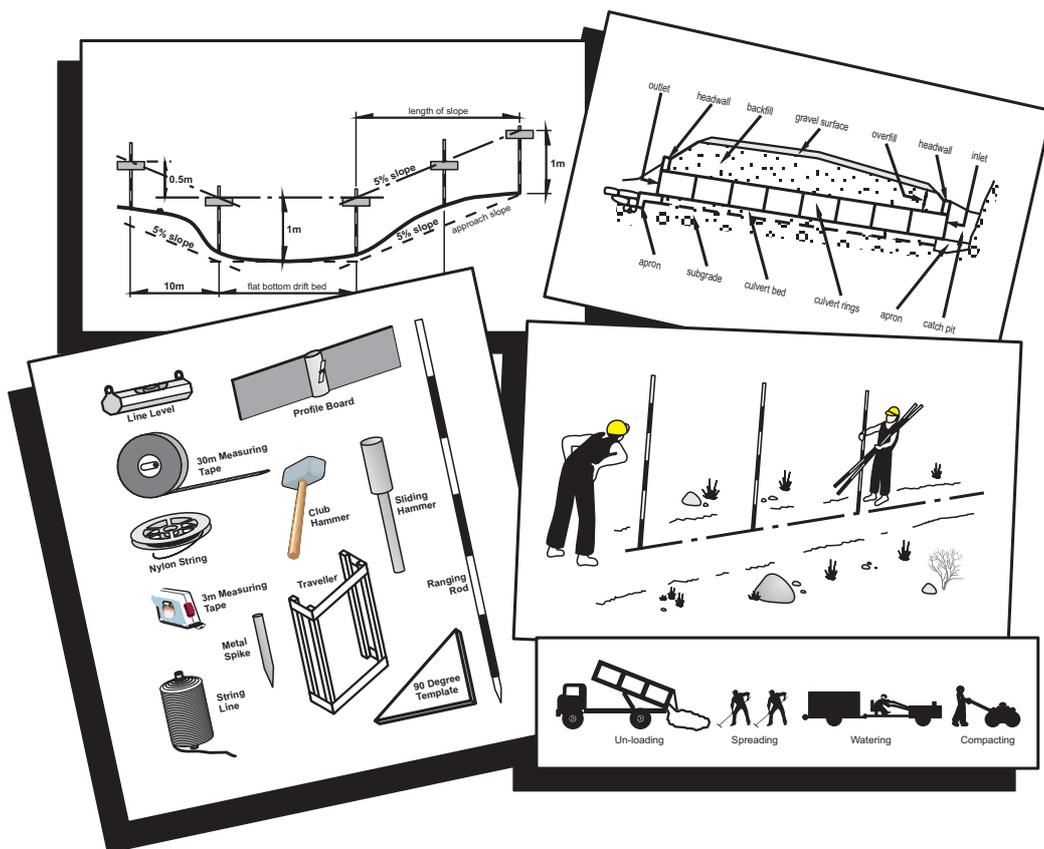
Step 10: Locate and set out the mitre drains. It is important that the mitre drains are set out before the excavation works for the side drains and camber is commenced.

Step 11: Set out with string line the side drains that needs to be excavated. Remember to leave out the mitre drain block-offs.

Labour-based Road Construction and Maintenance Technology

Module 5

Construction Procedures





Module 5

Construction Procedures

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5.1 Introduction

This module attempts to illustrate how labour-based work methods can efficiently be applied to low-volume road construction and rehabilitation works. As mentioned in Module 1, the essence of labour-based technology is to utilise to the maximum extent locally available resources, labour representing one of the most significant. This implies that the technology needs to be adapted to the local environment (i.e. topography, soil conditions, local skills, available equipment, etc.) in which the works will be carried out. As a result, labour-based road works technology will have different features, in terms of choice of work methods, equipment and organisation, depending on where it is implemented. For this reason the technology will vary from one country to another, as well as from one region to another.

Past experience has shown that labour-based work methods are most suitable for programmes which are disbursed over a large area (e.g. rural roads), rather than concentrated projects such as major highway construction works. Although that may be a general observation, it is still important that engineering staff investigate both options, labour- and equipment-based work methods, not only for a project as a whole but also consider the two options when carrying out detailed work planning at operation and activity level. The result may well be that the use of labour-based methods is competitive for certain activities even on large scale construction projects.

There are several options regarding how labour-based road works technology can effectively be applied in the road sector. The choice of work methods and procedures described in this module, only represents one solution. However, it is important to recognise that the methods described in this document has already been tested and proven successful in Lao PDR.

5.2 Clearing

Hheavy bush clearing involves cutting down and removing trees, the clearing of dense bush and scrub and the digging up and removing root systems to prevent regrowth.

This work should be organised on a task work basis, allocating work by the area or by specific job task (such as the removal of one or two large trees), depending on the type and difficulty of the work.

Heavy bush clearing and the unnecessary cutting down of trees should be avoided wherever possible by careful selection of the centre line. Maybe, it is possible to adjust the alignment so that the tree felling can be avoided. If a tree needs to be cut, use experienced workers and keep everyone else well away. After felling, cut the tree in pieces and remove them from the road side. Once the tree is cut, dig up and remove the roots. Holes after root extraction needs to be filled and compacted properly using hand rammers.

Heavy grass cover should be cleared. Light grass cover can be incorporated in the construction earthworks without too much of a problem, and afterwards regrows, forming protection against erosion on the shoulders. Heavy grass tufts can be used to line side slopes in cross cut conditions or on embankments, and should be separated from the soil to be used for road construction

Boulder Removal

Boulder removal can involve hand carrying small boulders, rolling clear, breaking or digging and burying large boulders.



This work is often time consuming and expensive and should be avoided if possible when selecting the alignment. Where there is excessive boulders in the soil, which creates problems for drain excavation, the possibility of lifting the road levels should be considered.

Task work on a group or specific job basis should be used to organise the labour force.

Topsoil Removal

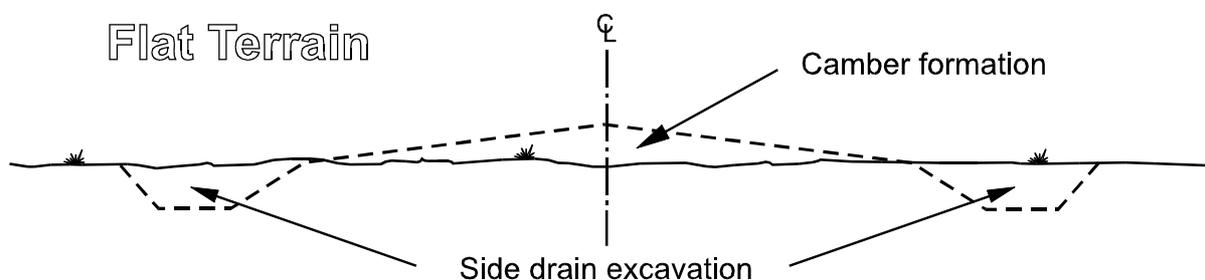
Topsoil removal is usually only needed where the topsoil is deep (10-15cm), very organic and obviously much lower in strength than the soil below. Unnecessary topsoil removal has very little effect on the strength of the road. Topsoil removal is most likely to be needed in river valleys and flood areas that build up silt. Most agricultural land and open areas are eroded, with a very thin topsoil layer which can be mixed in with the earthworks for the road construction.

Topsoil removal is executed using task work on an area basis, the area being determined by the thickness of the topsoil.

5.3 Earthworks

Basically, road construction earthworks involves digging drains and using the material to build up the camber, excavating cut to fill to form the road and building up the road on embankments in flat areas with poor drainage.

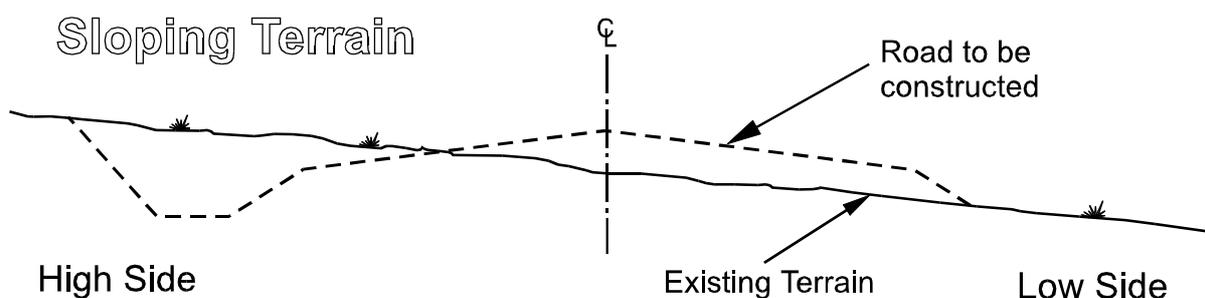
Let us first consider the situation where the road is built on land that is level, or nearly level, between drains - that is, with very little cross slope.



The earthworks is then simply to excavate the side drains and use this material to form the camber. Ensure that the volume of the side drains is slightly more than what is needed to form the camber. Usually more material is needed than indicated, either because of low spots in the ground or because of unsuitable soil or because the land is never consistently level.

5.3.1. Cut to Level

The challenges really begin when the road is built on cross sloping ground. The steeper the cross slope, the more excavation is needed to build the road. Always avoid steep cross slopes where possible. Locate the road on ridges where possible - this will reduce earthworks as well as reduce drainage works.

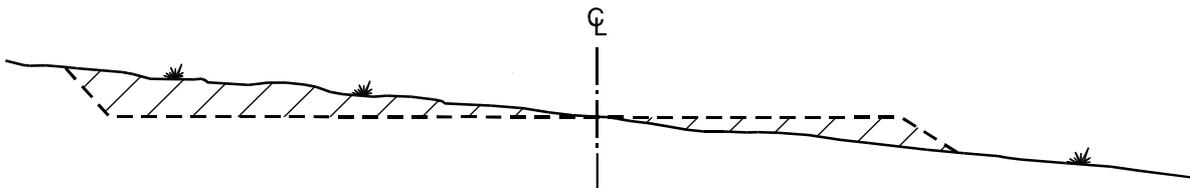


Road construction in cross sloping terrain have the following features:

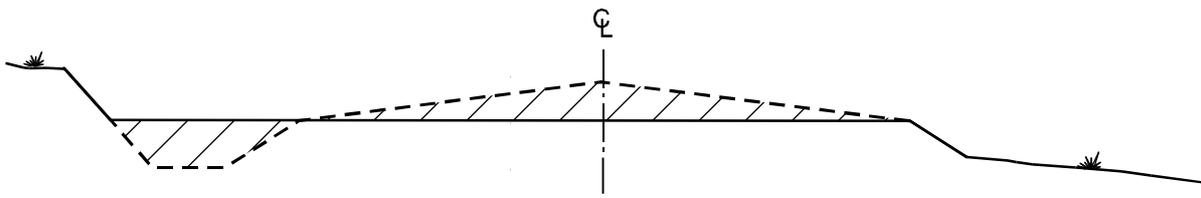
- the high side drain will have to be dug deep,
- the low side drain is normally not needed, and
- the road will have to be built on a fill on the low side.

The best way to do this is to split the work into two separate stages.

Stage 1: Excavate the high side and build up the low side and form the side slope on the low side.



Stage 2: Excavate the high side drain and form the camber.



The advantages of this method of working in stages are:

- the excavation approximately balances the amount of fill needed,
- the fill material can be obtained as close as possible to where it is needed - reducing the need for longitudinal haulage,
- by levelling the formation only as far as the edge of the road and then sloping down to the natural ground, reduce the excavation and, in most cases avoid the need for a side drain on the low side.

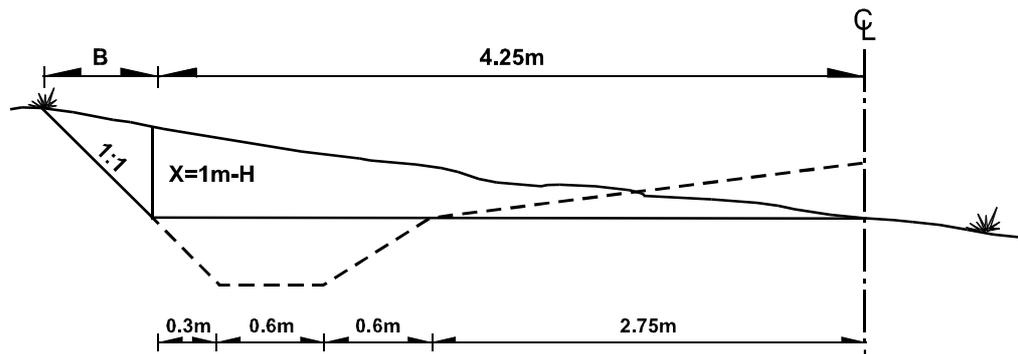
The excavation and fill are balanced each side of the centre line, but the width of the excavation has to give sufficient room for the side drain to be dug. This fixes the setting out dimensions for excavation on the high side.

Example:

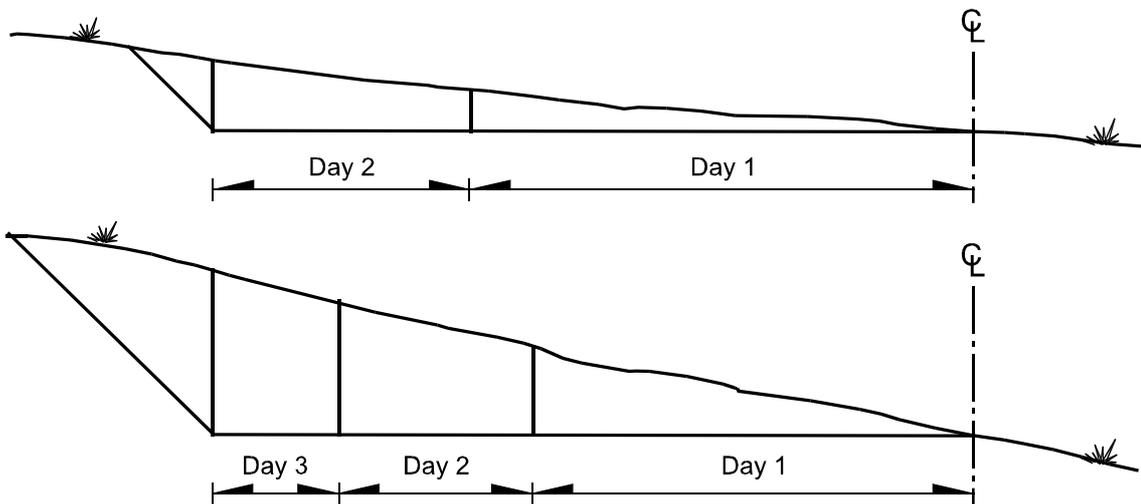
Assuming a road carriage width of 5.5 m and a side drain width of 1.5 m, the total levelling width on the cut side of the centre line would be:

$$5.5\text{m} / 2 + 1.5\text{m} = 4.25\text{m}$$

The example above is illustrated in the figure below.

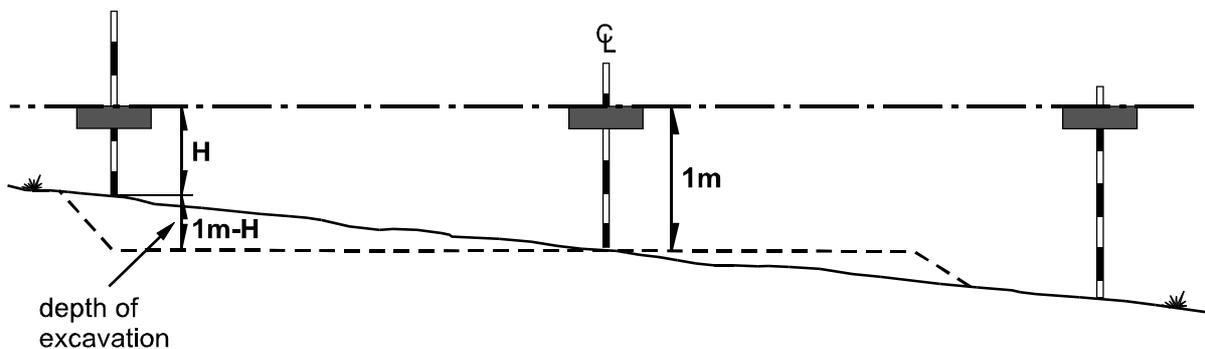


On steeper cross slopes, there may be too much excavation for a practically sized gang to finish in one day. In these cases, the excavation is divided into two or three days work. By calculating the volumes involved, we can estimate the setting out dimensions which will give roughly equal amounts of work for the days involved.



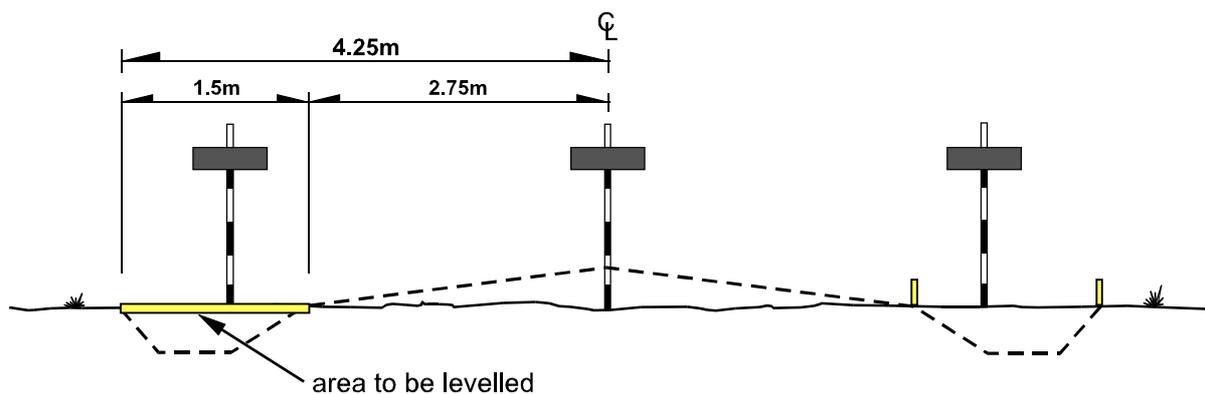
When the centre line profiles are set out at 1m above ground level, we can measure the height of the high side profile to tell us:

- ✓ how steep the slope is,
- ✓ the depth of the cut, and
- ✓ the volume of the levelling works and back-sloping.

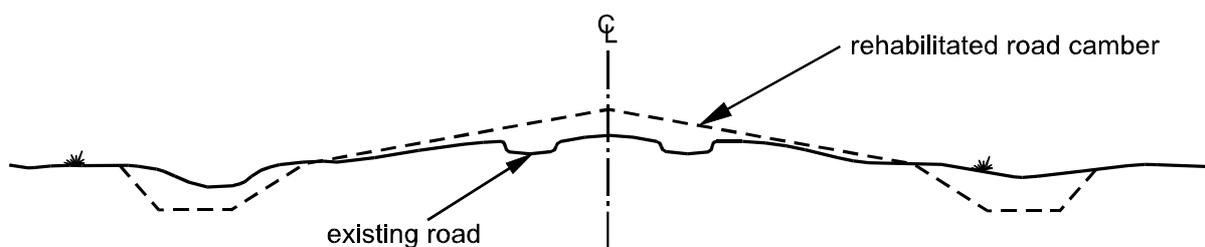


When there is little cross slope (the average height of the high side profile is 90 or 95cm), it is possible to dig the high side drain without levelling first. However, there are advantages to levelling in these conditions. Setting out the side drain is easier on a levelled surface and the side drain easier to build to the correct shape. The supervisor will usually level these minor cross slopes.

The setting out in these cases will be different as there is no advantage in levelling right through to the centre line. The levelling would then be done from the road shoulder to the outer side of the side drain (from 2.75m to 4.25m, measured out from the centre line in the example above).



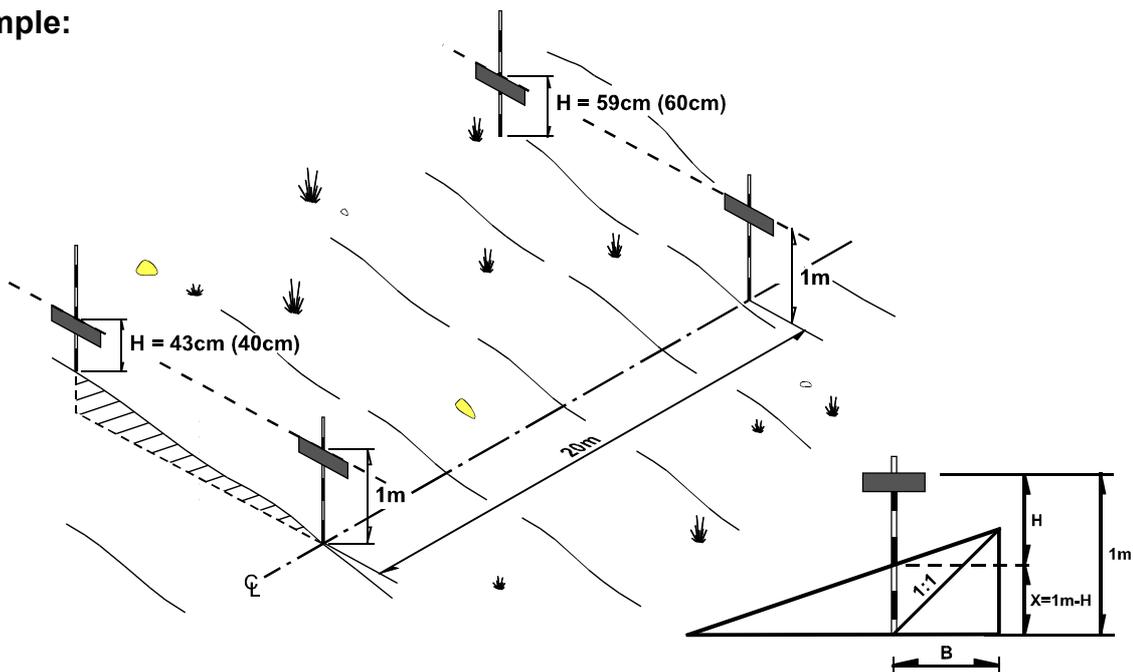
Please note that the above levelling practice only applies for new construction. When rehabilitating an existing road, levelling works should be kept to a minimum, leaving the existing road camber in place and only adding onto it where it has been worn down.



We can calculate the volumes to be excavated for the most common profile heights to be found in practice. These volumes can be given to the supervisor in table form and can be used to work out the workdays needed to carry out the excavation and are used to report the volume of completed works.

The slope of ground is not the same along the length of the road. To set out the work we have to find the average slope over a 20m section.

Example:



EXCAVATION VOLUMES FOR 20m

| Profile Height, H [cm] | Depth of Cut, X [cm] | Back Slope B [cm] | Volumes [m ³] | | | | |
|------------------------|----------------------|-------------------|---------------------------|------------|-------|--|-------|
| | | | Cut to Level | Back Slope | Total | Variation of Width ¹ - 1.0m | +1.0m |
| 90 | 10 | 10 | 4.3 | 0.1 | 4.4 | 3.4 | 5.4 |
| 85 | 15 | 16 | 6.4 | 0.2 | 6.6 | 5.1 | 8.1 |
| 80 | 20 | 21 | 8.5 | 0.4 | 8.9 | 6.9 | 10.9 |
| 75 | 25 | 27 | 10.6 | 0.7 | 11.3 | 8.8 | 13.8 |
| 70 | 30 | 32 | 12.8 | 0.9 | 13.7 | 10.7 | 16.7 |
| 65 | 35 | 38 | 14.9 | 1.3 | 16.2 | 12.7 | 19.7 |
| 60 | 40 | 44 | 17.0 | 1.8 | 18.8 | 14.8 | 22.7 |
| 55 | 45 | 50 | 19.1 | 2.3 | 21.4 | 17.0 | 25.8 |
| 50 | 50 | 57 | 21.3 | 2.8 | 24.1 | 19.2 | 29.0 |
| 45 | 55 | 63 | 23.4 | 3.5 | 26.9 | 21.5 | 32.3 |
| 40 | 60 | 70 | 25.5 | 4.2 | 29.7 | 23.9 | 35.6 |
| 35 | 65 | 77 | 27.6 | 5.0 | 32.6 | 26.4 | 38.9 |
| 30 | 70 | 84 | 29.8 | 5.8 | 35.6 | 29.0 | 42.4 |
| 25 | 75 | 91 | 31.9 | 6.8 | 38.7 | 31.7 | 45.9 |
| 20 | 80 | 99 | 34.0 | 7.9 | 41.9 | 34.5 | 49.6 |
| 15 | 85 | 106 | 36.1 | 9.1 | 45.2 | 37.4 | 53.2 |
| 10 | 90 | 114 | 38.3 | 10.2 | 48.5 | 40.5 | 57.0 |
| 5 | 95 | 122 | 40.4 | 11.6 | 52.0 | 43.6 | 60.9 |
| 0 | 100 | 131 | 42.5 | 13.1 | 55.6 | 46.9 | 64.9 |

If the height of one high side profile is 43cm and the next high side profile is 59cm, then the average profile height is:

$$\frac{59 + 43}{2} = 51\text{cm}$$

To make calculations easier, measure the heights to the nearest 10 cm. Then calculate the average as follows:

$$\frac{60 + 40}{2} = 50\text{cm}$$

Rounding off profile heights to the nearest 10cm is sensible because the ground is uneven, and over a number of calculations, any slight difference are cancelled out and we get an accurate estimate of the work involved.

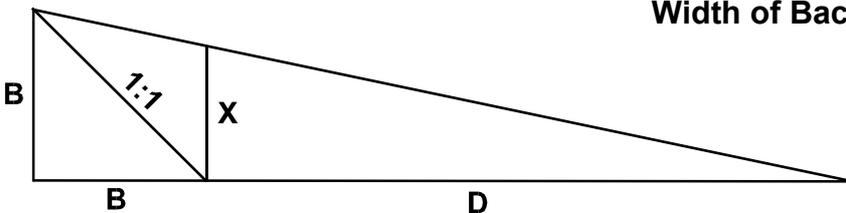
Once the average of the high side profiles is calculated, the volume of excavation needed can be estimated. In this example, we can read the volume against the 50cm average in the table, in this case 24.1m³.

Notes:

1. including volume of back slope
2. Road width = 5.5m and side drains = 1.5m.
3. The table above only applies for situations where the two centre profile heights are 1m above the existing terrain. For other situations where this is not the case, new volumes need to be calculated manually.

In the example above, the standard volumes for excavation had already been calculated and collated into a table. For other road cross-sections, these volumes need to be calculated manually before a table can be prepared. The following geometrical calculations are based on a back-slope gradient of 1:1.

Calculation of Excavation Volumes



Width of Backslope B:

$$\frac{B}{B+D} = \frac{X}{D}$$

↓

$$B = \frac{D \cdot X}{D - X}$$

Area of Cross Section:

$$A = A_1 - A_2$$

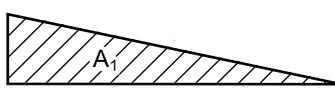
$$= \frac{(B+D) \cdot B}{2} - \frac{B \cdot B}{2}$$

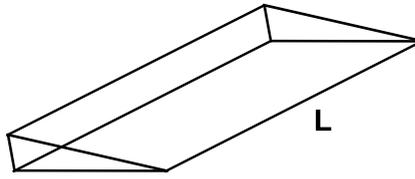
$$= \frac{(B+D) \cdot B}{2} - \frac{B \cdot B}{2}$$

$$= \frac{D}{2} \cdot B$$

$$= \frac{D}{2} \cdot \frac{D \cdot X}{D - X}$$

$$= \frac{D^2 \cdot X}{2(D - X)}$$

Volume to be excavated over a road section L is then:

$$V = \frac{D^2 \cdot X}{2(D - X)} \cdot L$$

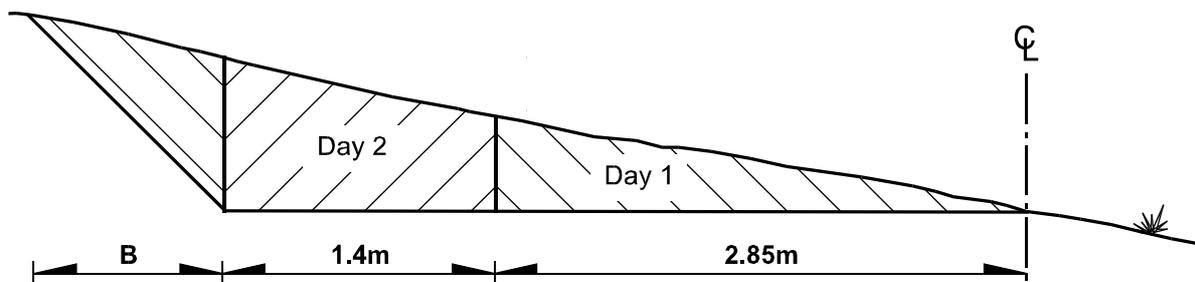
Allocation of Labour

We can calculate the number of workdays needed by dividing by the task rate that has been found to be fair. In this example, if the task rate is 2m^3 per day, the workdays needed can be estimated as:

$$24.1/2 = 12 \text{ workdays}$$

The supervisor will then decide how to organise the work. 12 labourers working on a 20m section may not be practical. He/she may decide to do the work over 2 or 3 days. If the work is done in 2 days, he would assign 6 labourers each day - this would make sure the work is done at nearly the standard production rate. He/she would round the workday totals down to the nearest whole number.

The excavation width for the first day is then set out. The widths of excavation are calculated so that the work involved is roughly the same each day. The width for the first days work will be 2.85m measured from the centre line. The remaining 1.4m will be excavated on the second day. In this way, the same number of labourers are used each day to excavate the task length of 20m.



Once the excavation back to 4.25m has been completed, the supervisor has to decide whether it is necessary to extend the excavation back further to produce more material to form the fill and road camber.

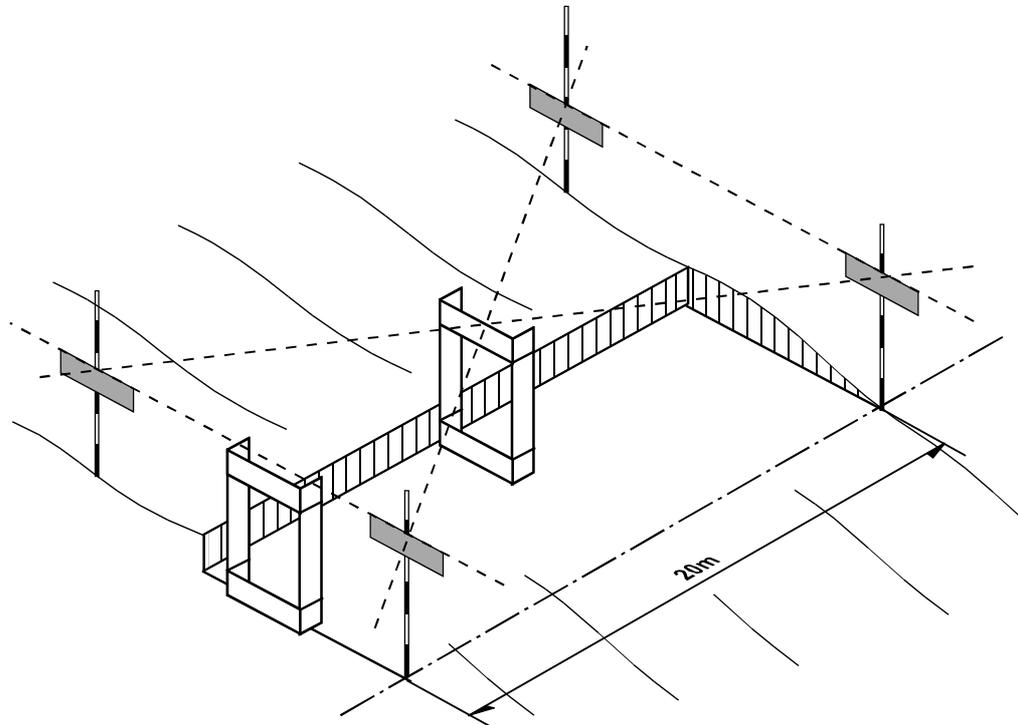
If extra material is needed, set out a further width of 0.5 or 1.0m depending on the amount of material needed. The volume table gives total volumes for extra excavation widths. The volume of excavation of the extra width is found in the table above by taking the volume for the standard width from the total extended volume. In our example, for an extra width of 0.5m, it would be $26.5\text{m}^3 - 24.1\text{m}^3 = 2.4\text{m}^3$. From this, the supervisor would work out that he/she needs approximately one workday extra to do the work.

Back-sloping

Once the excavation is finished, the levelled work is back sloped. The volume of the back sloping is included in the excavation totals to avoid difficult calculations on site by the supervisor when reporting completed works. He/she also needs to assign labourers specifically for this task. The table also shows the volume for the back slope. In the above mentioned example, the volume of the back slope is 2.8m^3 for which one would need to assign 1 labourer per 20m.

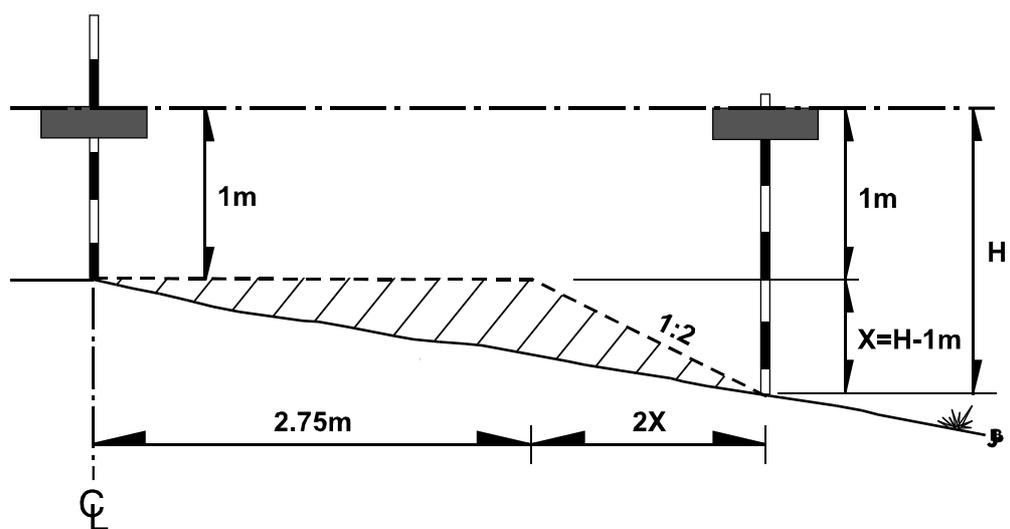
If the depth of excavation is 25cm or less, it is easier to include the back sloping in the drain back slope.

To ensure that the cut is fully excavated, use a traveller to control that the excavated ground is level.

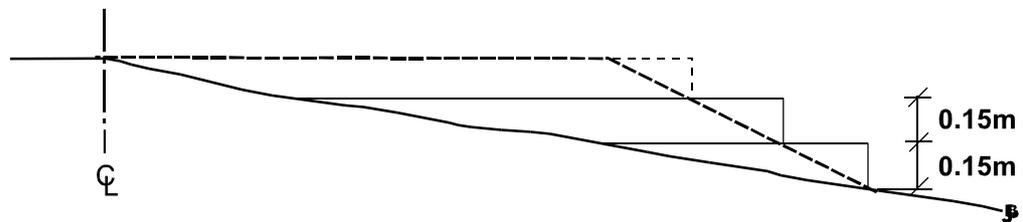


5.3.2 The Fill Side

The next step is to form the low side slope and level the road formation. If the depth of the fill on the low side road shoulder is greater than 0.3m, there is no need for any side drain on the low side of the road. Make sure that the slope of the fill has a slope of minimum 1:2 as shown in the figure below.



In order to produce a good quality fill on the low side, it is important that all soils are properly compacted. The fill is therefore built up in layers of maximum 15cm which are properly compacted before a new layer is added. Also, make sure that the soils have the optimal moisture content when compacted. Compaction of the first layer may be necessary to do by using hand rammers.



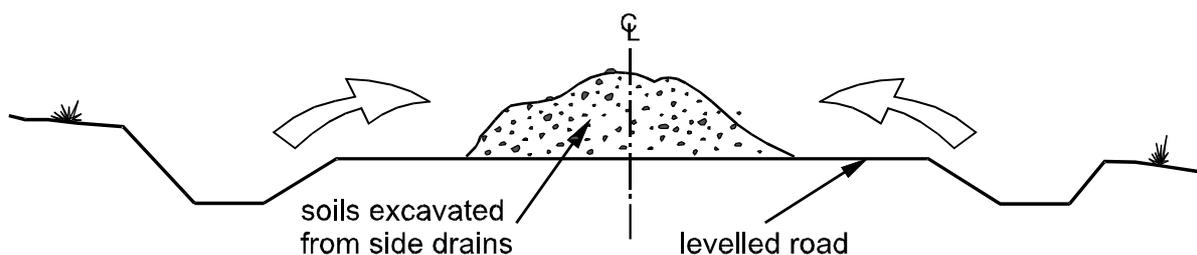
Allocation of Labour

The number of labourers required for the fill side can be estimated as roughly half the number of labourers carrying out the excavation of the cut. The actual number used also depends on the carrying distance.

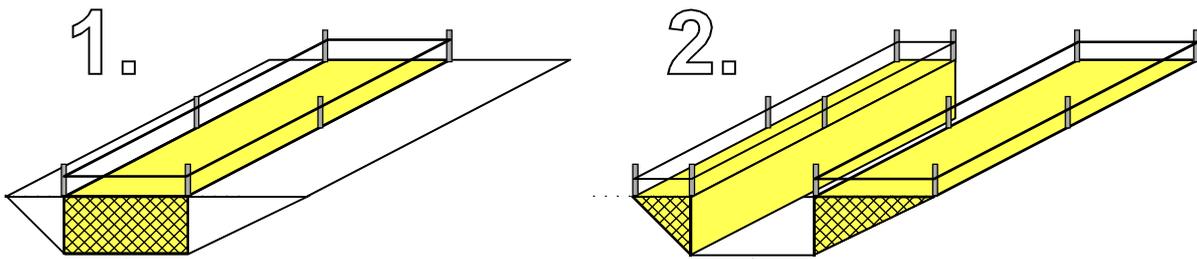
If the work is simply levelling across the road as in the example above, then 3 labourers would be used. If the fill material needs to be carried from another 20m section, it would require 4, or even 5 workers for the filling works.

5.3.3 Camber and Side Drain Construction

Once the excavation and fill have been completed, the road camber is constructed using soils from the side drains and back slope. Excavated soils from the drains should first be thrown to the centre of the road, from where it is levelled out towards each road shoulder to form the camber.

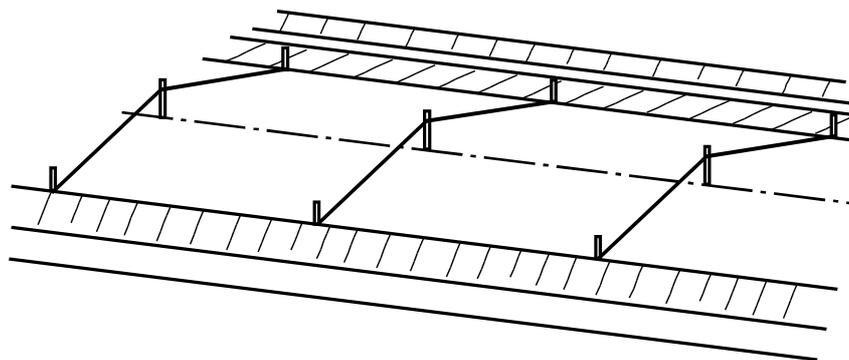


Side drain excavation is done in two stages. First the ditch is excavated, then the side slopes of the ditch is excavated. Normally, one or two days are allowed between each stage to allow sufficient working space for the workers. The side drain excavation is set out using string line and pegs, and controlled by using ditch templates.

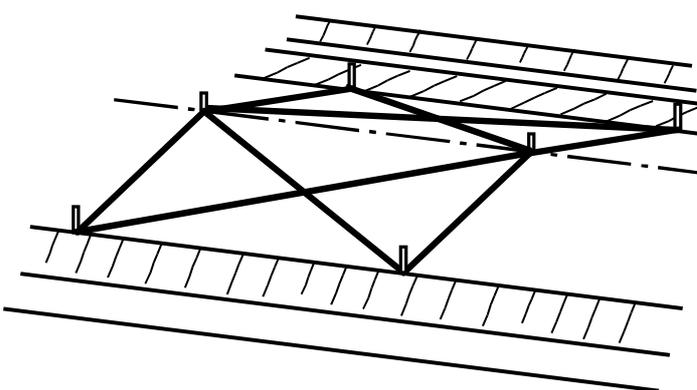


For both ditching and sloping, tasks are set as a length of the side drain for each worker. The sloping task is normally set slightly higher than the ditching task, because excavation of soil on the slope face is easier to carry out than excavating the ditch.

The soils excavated from the side drains are used to construct the road camber. To achieve an exact and properly levelled camber, the work is set out using pegs and strings.



Once the soils for the camber has been levelled, the camber is properly compacted. Make sure that the soils contain optimal moisture content.



After compaction has been completed, it is important to check that the final levels of the road camber is exact and to the prescribed standard and quality. This can either be done by setting out the profile boards again and controlling the level between the profiles with a traveller. A quicker method, however less accurate, is to use string lines to check the level of the completed surface.

If the levels are in-accurate, the irregularities should be removed or filled in. If further filling is required, make sure that this patching is also properly compacted. Finally, repeat once again the checking of the levels to ensure that the earthworks are completed to the correct standards.

5.4 Embankments

Embankments require large amounts of fill material and are expensive to construct. They should be avoided when possible by selecting a longer route on higher ground. However, this is sometimes not possible in low, flat, agricultural land, where often no alternative route exists.

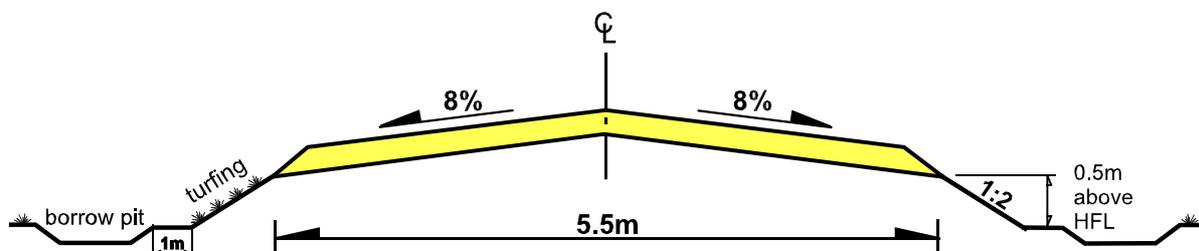
Wherever possible, material should be excavated alongside the road and carried to the road by baskets or wheelbarrows. If land is not available for roadside borrow pits, or if the material is not suitable, then earth will have to be brought in from the nearest source by appropriate haulage transport. The type of the borrowed soils should be of good quality. Organic soils, and if possible, sand and silt should be avoided. If sand or silt are the prevalent materials in the area, side slopes should be protected with at least a 15cm layer of clayey soils and vegetation to prevent erosion.

It is important to keep the height of the embankment to the least requirement. This is normally considered to be 0.5m above normal flood levels.

Highest annual flood levels are used to determine the embankment height. This information should be available from local inhabitants and should be marked on pegs along the centre line when choosing the alignment.

Centre line alignment should be carefully selected to avoid low lying areas requiring extra fills and areas where suitable material is not available from the roadside.

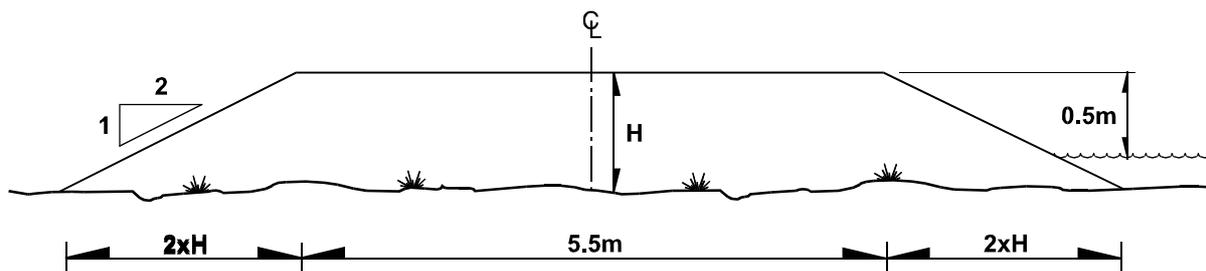
The below figure summarises the key dimensions of the cross-section of embankments utilised in the ILO labour-based road works project.



5.4.1 Earthwork Volume Calculations

Calculation of earthwork quantities is especially important for the planning and control of embankment construction operations. It is necessary to apply a simple and accurate method of estimating embankment quantities at site level.

The standard cross-section dimensions are fixed by national or programme specifications. In this example, we will assume the dimensions used by the ILO project, i.e. a road width of 5.5m, side slopes of 1:2 and a clearance above highest flood water level of 0.5m.



H, the height of the embankment is fixed by the height of normal flood levels plus a clearance of 0.5m.

The area of the cross-section can then be calculated as: $(5.5 + 2H) \times H$ [m²], which is equivalent to cubic metres per metre road length when we calculate volumes.

Example:

An embankment of 0.80m average height would have a cross-section area of:

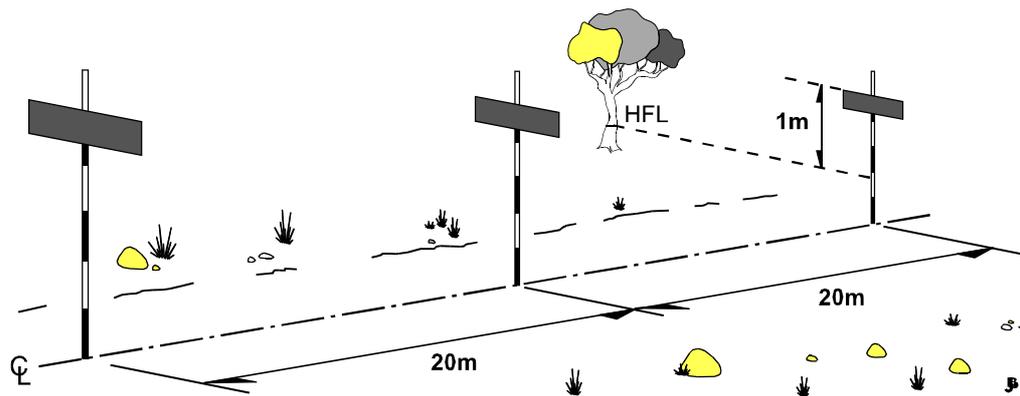
$$(5.5 + 2 \times 0.8) \times 0.8 = 5.68 \text{ m}^2$$

or 5.68 m³ per metre length.

Embankments are only necessary on flat land where there are normally only slight variations in ground levels. In these conditions, it is quite safe to take the height at the centre line profile as the average height of the cross-section.

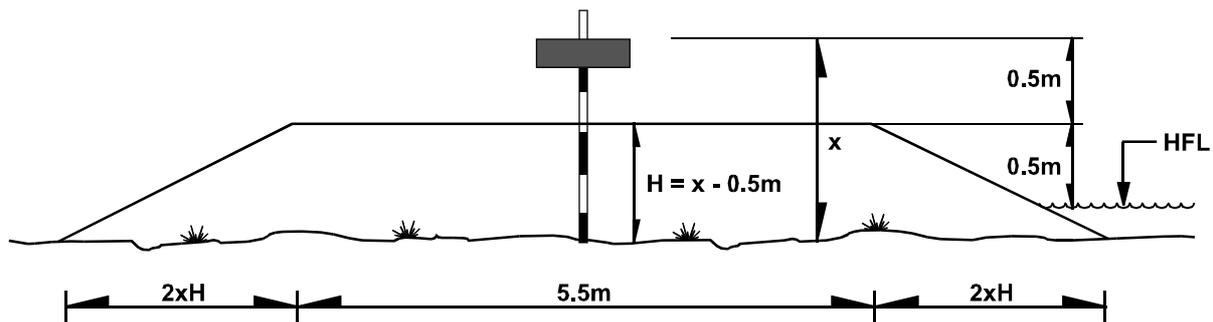
The height of the embankment at any point on the centre line can be quickly found by the use of profile boards.

The high water level is marked on trees or strong pegs at convenient locations along the route according to local knowledge and indications. The centre line is then set out with ranging rods every 20m. Profile boards are fixed on these ranging rods at 1m above the nearest high water level mark.



The centre line profiles are then sighted to check that they line up and are horizontal. Adjustments to the profile levels are made as necessary.

It is then possible to find the height of the embankment at each 20m section by measuring down from the profiles to the ground and subtracting 0.5m. The measurement is rounded off to the nearest 10cm.



To facilitate estimates while in the field, volumes of 1m road lengths can be calculated in advance for a series of embankment heights. The table below shows the volumes of various embankment heights for a 1m road section with a carriage width of 5.5m:

| Embankment Height, H | 1.00 | 0.90 | 0.80 | 0.70 | 0.60 | 0.50 | 0.40 | 0.30 | 0.20 |
|---------------------------|------|------|------|------|------|------|------|------|------|
| Volume, m ³ /m | 7.50 | 6.57 | 5.68 | 4.83 | 4.02 | 3.25 | 2.52 | 1.83 | 1.18 |

These figures can be used to estimate volumes over longer distances, say 100m, during planning or route investigation stages, to get quick, accurate estimates of the volume of earthworks and the workdays needed. In these cases, the engineer would establish high water levels along the route, and add 0.5m to give the sufficient embankment height, H.

The height of the embankment may vary along the road line. Therefore, it would be practical to use the average height over a 20 metre section when calculating the volumes. Once the centre line profiles are established, it is possible, using the profiles, to get a fast, accurate estimate of the volume of earthworks and the workdays

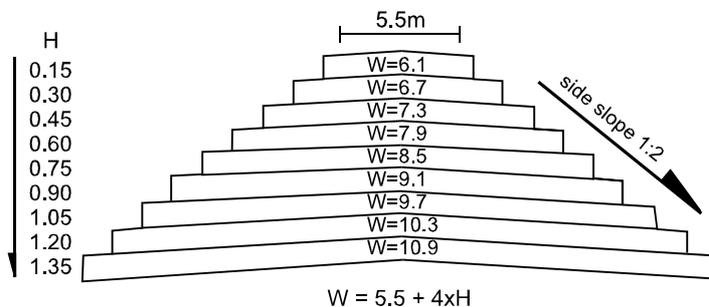
needed. The following example illustrates the method for the cross-section mentioned above:

Example:

If we take the average height for each 20m section and apply these H values to the above table, we find that the first section has a volume of

$$20 \times 4.42\text{m}^3 = 88\text{m}^3,$$

and the second section has a volume of: $20 \times 5.25\text{m}^3 = 105\text{m}^3$.



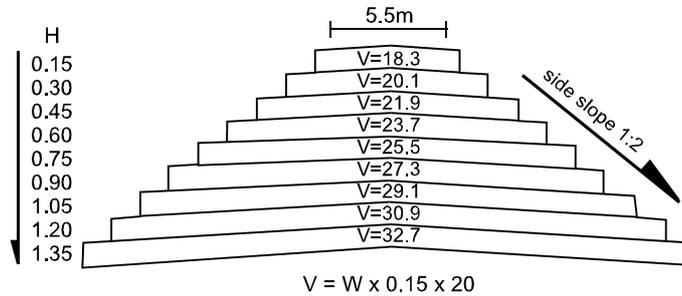
However, for the supervisor this does not give sufficient detail to organise the work on a day to day basis. The embankment will be built up in compacted layers. The width (W), of each layer depends on the gradient of the side slope and the height of the embankment.

The thickness of the layers will depend on the method and equipment used for compaction. Let us assume compaction by a 1 tonne vibrating roller, which can compact a layer about 15cm thick. So, the embankment will need to be built in 15cm layers.

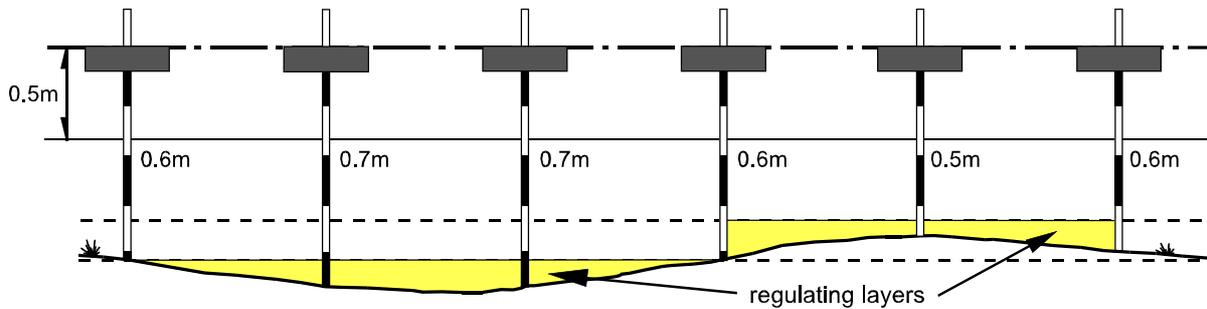
The supervisor needs to estimate the volume of each layer to be able to allocate the right number of labourers for the work each day. For an embankment with a 5.5m carriage width, this is calculated as follows:

- The first layer (at the top) $6.1 \times 0.15 = 0.91\text{m}^3$ per metre or $18.3\text{m}^3/20\text{m}$,
- the second layer $6.7 \times 0.15 = 1.01\text{m}^3$ per metre or $20.1\text{m}^3/20\text{m}$,
- the third layer $7.3 \times 0.15 = 1.10\text{m}^3$ per metre or $21.9\text{m}^3/20\text{m}$.

Once again, these volumes are useful to calculate in before hand, and have them readily available on site when planning the distribution of workers and setting the tasks. The figure below shows the volumes for the same 5.5m carriage width:



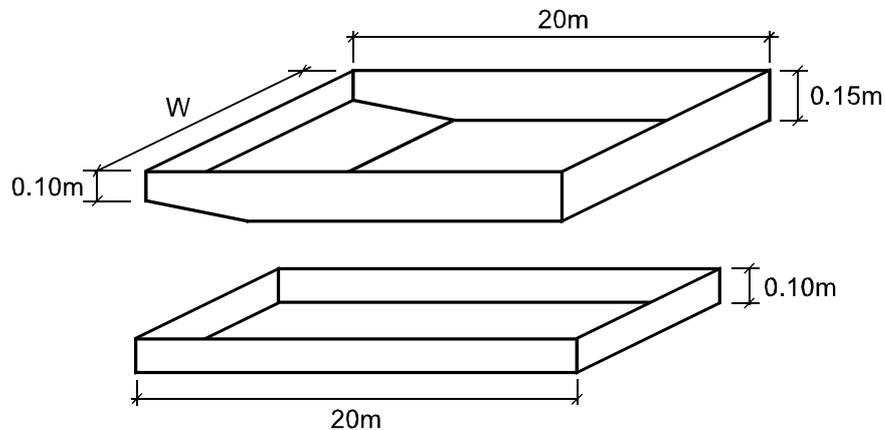
The ground on which the embankment is built will not be level and the height of the embankment will not always be exact multiples of 15cm. There will be a need for one or two regulating layers until we can build up in even 15cm layers.



To calculate the regulating layers, we will need to make some practical assumptions:

- that ground levels are to be rounded to the nearest 10cm, and
- that the ground slope between points can be represented as a straight line.

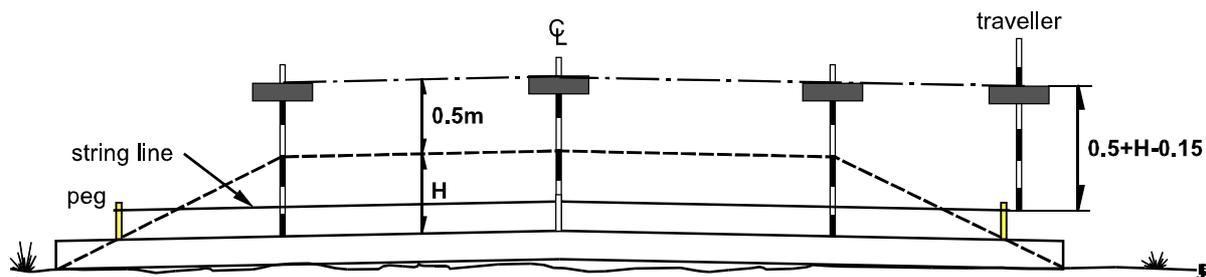
It is then possible to calculate the volumes of layers of different thickness and shape.



5.4.2 Work Force Organisation

The volume of the various shaped layers depends on the width of each layer (W), which depends on the depth of the layers below the top of the embankment and the side slope gradient. This calculation is important for establishing the correct number of workers to be distributed on the embankment construction.

When the supervisor is planning the construction of the embankment, the first thing to do is to level earthworks at the 0.45m, 0.60m, 0.75m, 0.90m or 1.05m levels so that filling can proceed in 15cm layers to the top of the embankment.

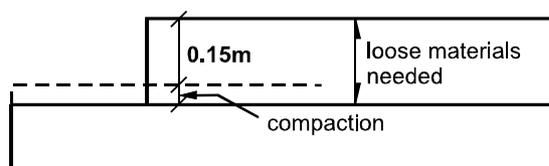


The fill is set out in layers measuring down from the top of the embankment and marked on string line pegs to aid levelling. The level marks is found by using a traveller and sighting off from the profiles.

In some cases, this will involve the use of regulating layers. After the regulating layers have been levelled and compacted, the construction will proceed with 15cm layers. The first 15cm layer may also involve some regulating.

Once the centre line profile measurements have been recorded, the edge of the road profiles should be set out and the centre line profile level transferred to them. The centre line ranging rods can then be removed to make the work area clear for compaction operations. At the same time, a strong marker peg should be driven into the ground at each 20m section and the high water level clearly marked so that construction levels can be replaced if needed.

Once the supervisor has found the earthwork quantities, layer by layer and section by section, he/she is in a position to organise the work force to carry out the work, determining the number of workdays needed for each layer and section.



After each layer is compacted, the next layer will need to be greater than 15cm to fill up to the top of the next layer and make up for the compaction in the previous layer. The earthwork quantities are for excavated compacted soil which will bulk ("expand") when loose and provide the extra material needed.

5.5 Drainage

5.5.1 Overview

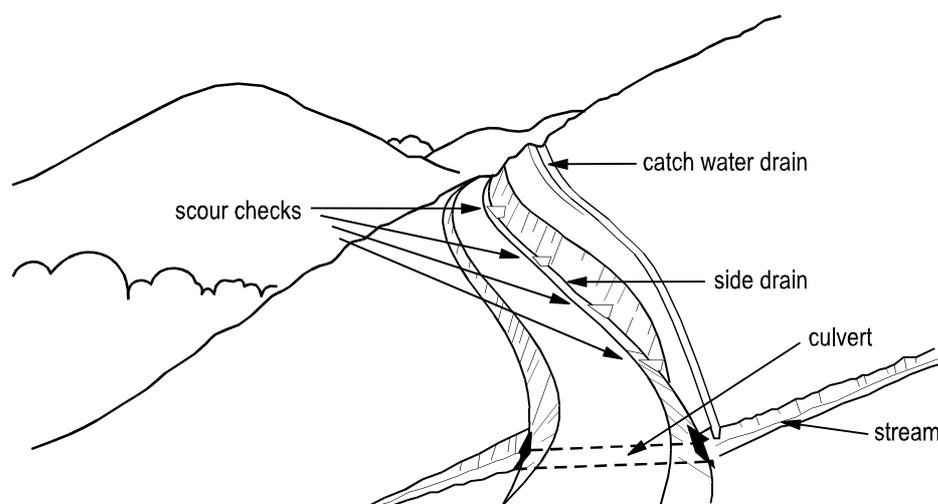
Water is the main contributor to the wear and damage of low-volume rural roads. The water can be in the form of ground water, surface water (streams and rivers) or rain. Water can damage the road in two ways:

- by washing away the soil (erosion or scouring), or
- by making the road body less strong to traffic (lowering the road bearing capacity).

It is therefore important to install an efficient drainage system which allows for the water to flow off the road and away from it as quickly as possible. This is achieved by a system consisting of the following components:

- *road surface drainage* which enables the water to flow off the road surface,
- *side drains and mitre drains* which collect and lead the water away from the road,
- *catchwater drains* which catches surface water before it reaches the road,
- *scour checks* which prevent erosion in the ditches by slowing down the flow of the water,
- *culverts* which lead the water from the side drains under the road to the other (lower) side,
- *small bridges and drifts* which allows the road to cross small rivers and streams in a controlled manner throughout the seasons.

All these components need to work well together. An efficient drainage system is the most important part of rural road construction and maintenance works.

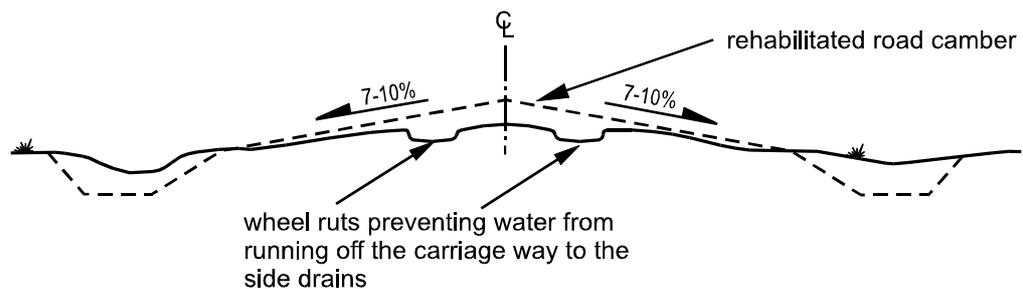


5.5.2 Road Surface Drainage

Road surface drainage is achieved by installing a camber on the road carriage way, thereby enabling the surface water to run off to the side drains. The combination of stagnant water on the road surface and traffic will quickly cause erosion of the road surface. Secondly, if surface water penetrates into the road, it will deteriorate the bearing strength of the road body. To avoid these problems all roads are provided with a camber.

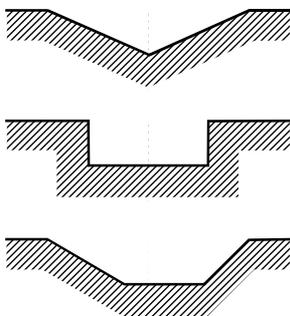
The camber is the slope from either side of the centre line towards the road shoulders. The gradient of this slope varies depending on the type of surface materials. For earth and gravel roads, it is recommended that this slope is in the range of 5 to 10 per cent in order to obtain a sufficient run-off.

Since traffic will eventually erode the road surface, create wheel ruts and causing more erosion in the centre of the road, it is recommended that the road camber of a gravel road is constructed at 7 to 10 percent. This will prolong the life time of the road and allow a longer period of time and use before reshaping of the camber is required.



5.5.3 Side Drains

The side drains need to have sufficient capacity to collect all rain water from the road carriage way and dispose of it quickly and in a controlled manner to minimise damage.



Sides drains can basically be constructed in three forms: V-shaped, rectangular or as a trapezoid.

The V-shape is the standard shape for ditches constructed by a motor-grader. It can be easily maintained by heavy equipment, however it carries a low capacity. The rectangular shape requires little space but needs to be lined with rock or concrete to maintain its shape. When using labour-based methods, it is possible to construct a trapezoid shaped side drain. This shape carries a high flow capacity and by carefully selecting the gradients of its side slopes, will resist erosion.

5.5.4 Erosion Control

The main problems for the side drains are erosion and silting. Erosion is caused by a large quantity of water travelling at high speeds. It is possible to reduce the speed by widening the side drain, but the best way to control erosion is by reducing the amount of water flowing through the drain. This is done by using *mitre drains* to empty the side drain at regular intervals before the volume of water builds up and causes erosion.

Another method to control erosion is to place *scour checks*. These are only used in hilly terrain with steep road gradients where it may not be possible to remove water using mitre drains. Their function is to slow down the water flow by reducing the natural gradient of the drain by allowing the drain to silt up behind the scour check.

Silting is caused by sand and silt settling out of the water. This only occurs with slow flowing, or stationary water. It takes time for the particles to settle, so the further the water has to travel in the drain, the more time there is for the silting to take place. The solution is to empty the side drains frequently by means of installing mitre drains at regular intervals.

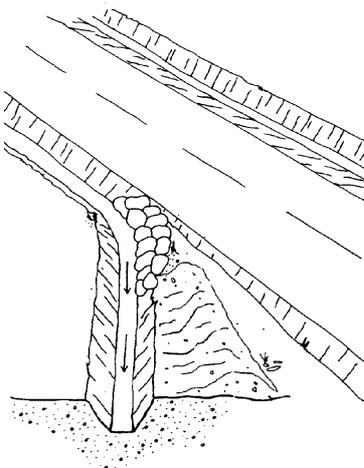
In some cases, it is wise to construct cut-off or interception drains which prevents surface water from reaching the road. These are particularly useful in the surrounding areas to drift approaches, culverts and bridges. They are also effective in channelling away water from the high side of the road in side sloping terrain.



Remember:

The best way to solve problems caused by the flow of water is normally to remove the water from the road before it causes a damage.

5.5.5 Mitre Drains



The location of mitre drains should be determined during the initial stages when setting out the road alignment, thereby ensuring that the road receives a good off road drainage. Make sure that sufficient numbers of mitre drains have been located before side drain excavation starts.

Calculating the correct space between the mitre drains can be quite complicated, in principle the more mitre drains provided, the better. A general rule is to:

- wherever possible, provide a mitre drain for every 100m or less, and
- when the road gradient is very small, provide mitre drains at every 50m along the side drain.

There are some important items to bear in mind when designing mitre drains:

- ✓ Make a strong block off in the side drain, and make it easy for the water to flow along and out of the mitre drain.

Water will always flow the easiest way. The water will try to continue to flow down the side of the road because it is usually steeper and in a straight line. If you want to divert the water into the mitre drain you must make it easier for it to flow where you want it to go.

The best way to provide a strong block-off is to leave 3 - 8m of natural ground on the drain line not excavated. Forming the block-off with excavated material is not as strong. Block-offs act as useful turning points for trucks and other equipment during the gravelling operation. They are also a natural point to off-load and store gravel for future routine maintenance works.

- ✓ The amount of water entering the mitre drain cannot be greater than the amount flowing out. Otherwise, the drain will fill up and over flow, often damaging the block off and causing even greater problems at the next mitre drain. In most cases, the standard mitre drain should be big enough to carry water coming from the standard side drain, except when:
 - the side drains carry more water than usual,
 - the side drain slope is much greater than the mitre drain slope

In such cases, the mitre drain should be made wider than the side drain so that it can carry more water.

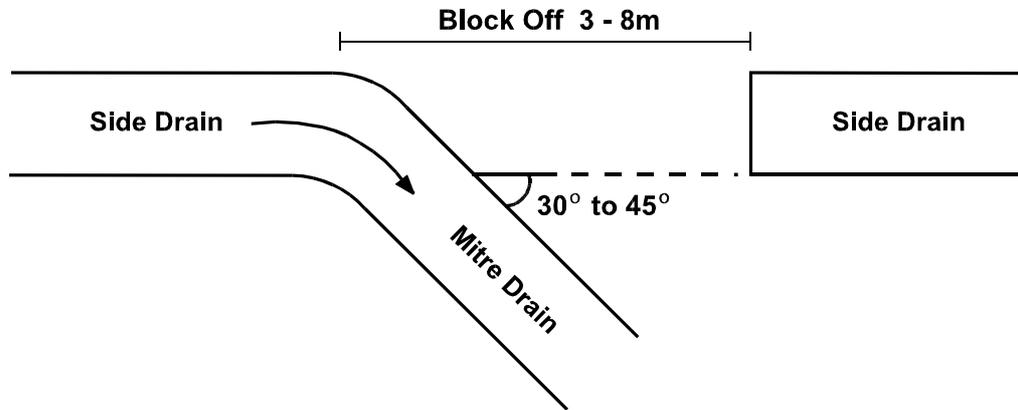
- ✓ The length of the drain depends on the terrain ground levels and the slope of the drain. Mitre drains should be as short as possible. Long mitre drains are expensive, more likely to silt up or get blocked off, and in general more difficult to maintain.

A good slope for a mitre drain is 2%. The gradient should not exceed 5%, otherwise there may be erosion in the drain or to the land where the water is discharged. In mountainous terrain, it may be necessary to accept steeper gradients. In such cases, appropriate soil erosion measures should be considered. In flat terrain, a small gradient of 1% or even 0.5% may be necessary to discharge water, or to avoid very long drains. These low gradients should only be used when absolutely necessary. The slope should be continuous with no high or low spots.

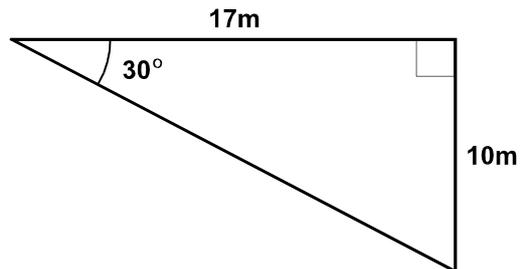
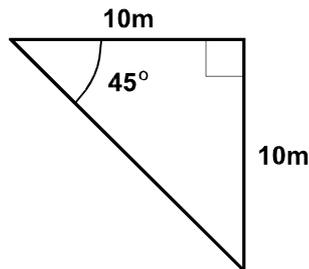
- ✓ Try to select a line for the mitre drains which will connect with natural run-off channels that take the water well clear of the road. If this is not possible, make sure that the next mitre is set out to catch this water before it enters back into the side drains.
- ✓ Finally, it is important that the discharged water does not disturb farming activities in the surrounding areas. By discussing the location where to discharge water from the road with the local farmers, it may be possible to achieve solutions which may assist the farmers rather than destroying the water management of their farm lands.

Angle of Mitre Drains

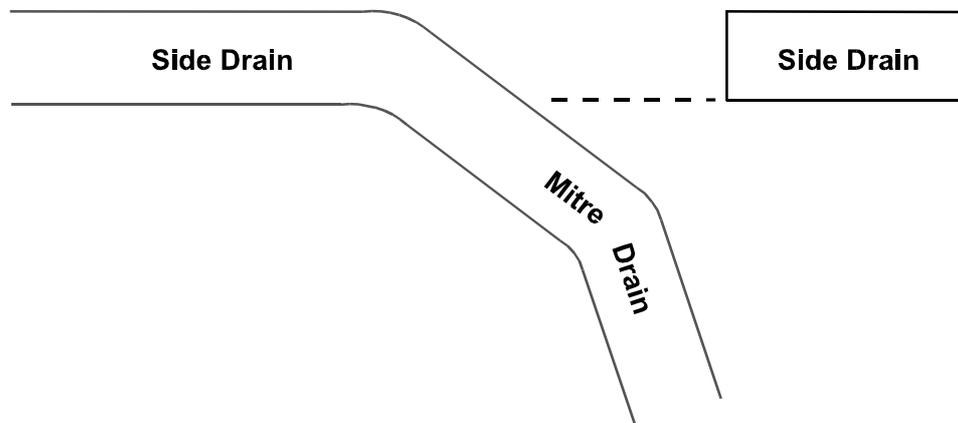
The angle between the mitre drain and the side drain should never be greater than 45 degrees. An angle of 30 degrees is ideal.



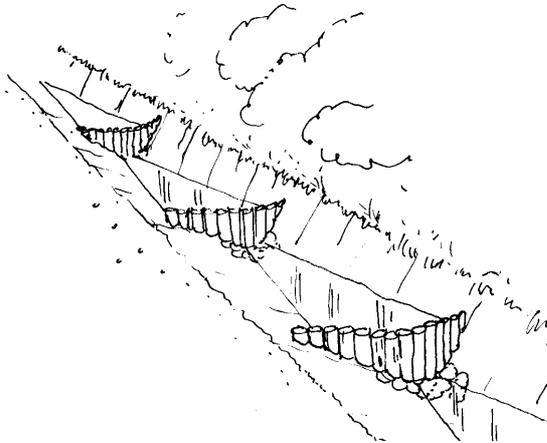
For checking, the angle between the mitre and side drain, first construct a 90 degree angle and then use the measurement of the below triangles:



If it is necessary to take water off at an angle greater than 45°, it should be done in two or more bends so that each bend is less than 45°.



5.5.6 Scour Checks

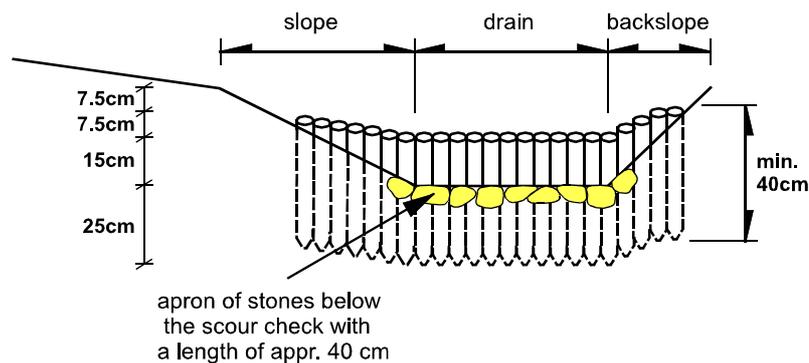


When road gradients are steeper than 4%, the drainage water will gain high speed which may cause erosion of the side drains. Apart from leading the water off in mitre drains, scour checks may reduce the speed of water and prevent the water from eroding the road structure.

Scour checks are usually constructed in natural stone or with wooden or bamboo stakes. By using natural building materials available along the road side, they can easily be maintained after the road has been completed. The distance between scour checks depend on the road gradient. This relation is shown in the following table.

| Road Gradient [%] | Scour Check Interval [m] |
|-------------------|--------------------------|
| 4 | not required |
| 5 | 20 |
| 6 | 15 |
| 7 | 10 |
| 8 | 8 |
| 9 | 7 |
| 10 | 6 |

The basic measurements for constructing a drift is illustrated in the figure below:



After the basic scour check has been constructed, an apron should be built immediately downstream using stones. The apron will help resist the forces of the waterfall created by the scour check. Sods of grass should be placed against the upstream face of the scour check wall to prevent water seeping through it and to encourage silting to commence on the upstream side. The long term goal is to establish complete grass covering over the silted scour checks to stabilize them.

5.5.7 Cut-off Drains

The purpose of cut-off or interception drains is to prevent water from reaching the road, or to direct water to where it can cross the road safely at constructed water crossings such as culverts, bridges, drifts, etc.

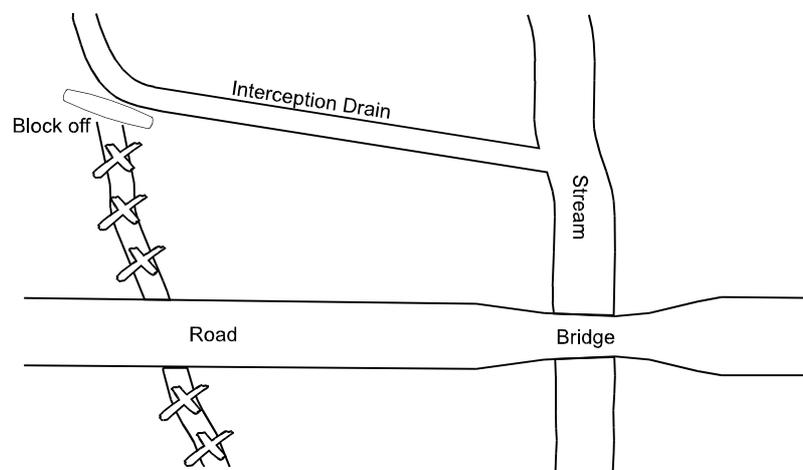
These drains, when properly thought out, properly set out and properly built, can be very useful in reducing damage to the road and reducing maintenance costs.

In most cases, it is cheaper and safer to direct water away from the road, using these drains, rather than providing erosion control measures in the side drains. However, there are certain dangers with cut-off drains that must be considered:

- the water usually carries a lot of silt and if not properly built can silt up quickly,
- as they are off the road they will probably receive less maintenance - especially when they are difficult to maintain,
- when they fail, water will break through in a concentrated flow causing damage, and
- they may be ploughed up or blocked off by people using the land.

These dangers can only be avoided if careful planning goes into the drains before construction and if they are built properly. The following precautions should be taken:

- reduce the danger of silting by making sure there is a continuous down hill gradient and that there is a clear outlet at the end,
- make sure they are easy to maintain and that erosion damage is reduced so that maintenance needs are small (wide with sloped sides),
- make the drain strong - anticipate the possible weak points of the drain where water could break through and strengthen the drain there,
- locate drains carefully after discussion with local people - where people have to cross the drain, provide easy side slopes so that people will not fill the drain.



5.6 Culverts

ulverts allow water to cross underneath the road to a place where it can be safely discharged. The water may be from natural streams or run-off surface water from the road structure.

5.6.1 Siting of Culverts

The siting of culverts should be carried out during the initial setting out of the road alignment. It is important that the culverts are regarded as an integral part of the overall drainage system of the road.

If an existing road is being improved, most culvert sites will be obvious, because the road will have been damaged in some way. In such a situation, look for places where:

- small gullies have formed because water has been flowing across the road,
- sand has deposited on the road because of standing water, or
- drains have been badly damaged because they have been carrying too much water.

When determining the level of the culvert, make sure that there is a sufficient slope in the outlet drain, downstream of the culvert.

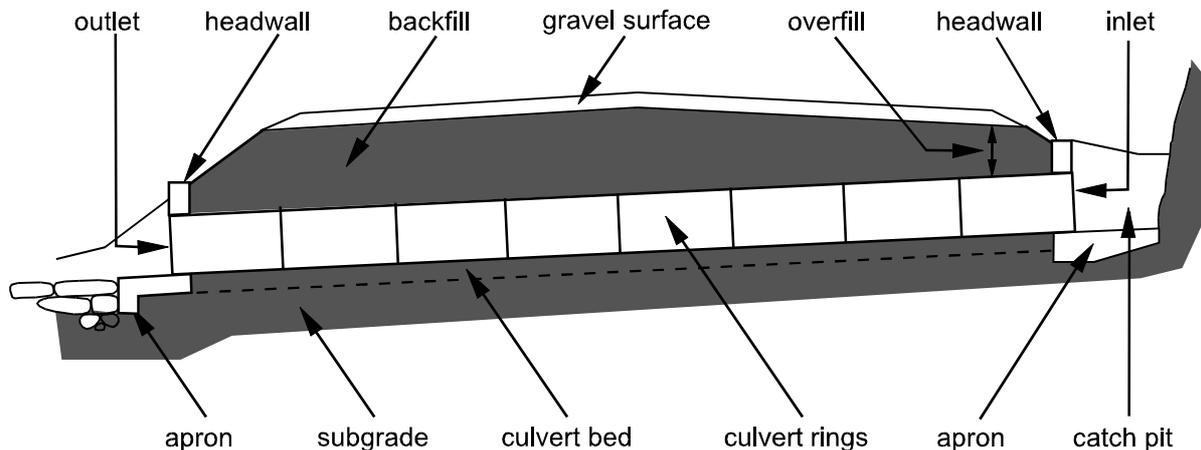
It is important to take great care concerning where the water is discharged. Water collected along the road and discharged through a culvert may produce serious soil erosion in the surrounding areas. When water needs to be discharged on to farm land, it is important to discuss the water management with the local farmers, thereby avoiding to damage or disrupt the farming activities. In some cases, it may be possible for the farmers to make use of the water.

5.6.2 Description

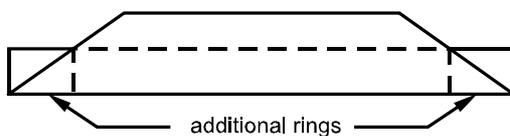
The most common type of culvert is a single line of concrete pipes. The diameter should not be less than 0.6m, because smaller diameters are difficult to maintain and are easily blocked. The most common diameter is 0.6m but also 0.8m is frequently used.

Depending on the circumstances, instead of using large diameters which require a high fill over the rings (the overfill), two or more rows of a smaller dimension can be used.

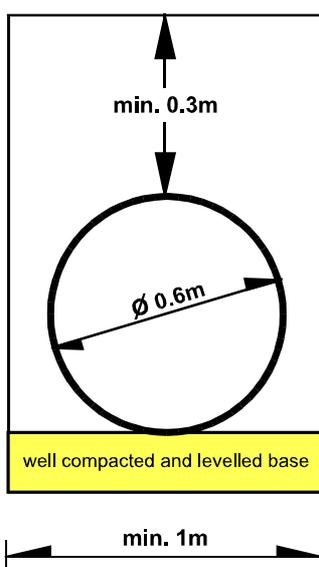
The culvert bed has to be stable and at the correct level, i.e. preferably at the levels of the surrounding terrain. Remove stones which may damage the pipes. If the natural material is not suitable, a bed of gravel should be laid under the pipes. The bed should be constructed with a slope between 3 and 5%, using profile boards and a string line level.



Aprons should be constructed at the inlets and the outlets to protect the culvert bed and the ditch bottom from erosion. They can be made by stones, masonry or concrete. Their length should at least be one and a half times the pipe diameter.



Head walls are produced to protect the backfill from water damage. They can be made of stones, masonry or concrete. If the head walls are omitted, make sure that the side slopes of the backfill is not steeper than 1:2 and that the culvert is long enough to reach the end of the side slopes on each side of the road. If the natural soils are well graded and cohesive, the side slope of the backfill can be increased.



If the natural soils are good, the culvert can be installed using the in-situ soils as a culvert bed. By omitting aprons, head walls and culvert beds of imported materials, it is possible to reduce the cost of culvert installations by approximately 30%.

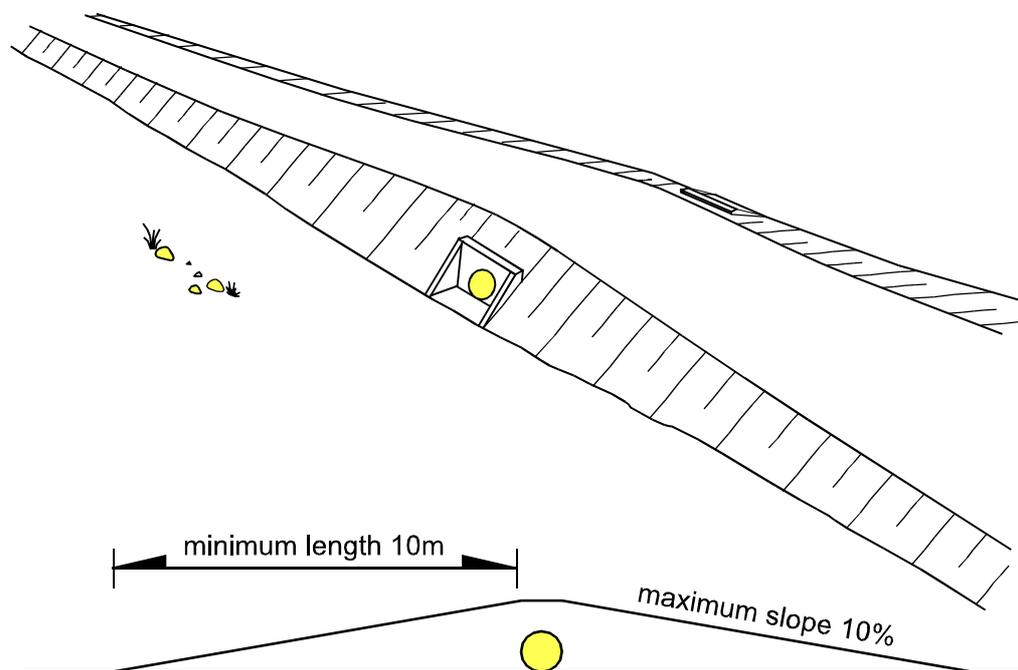
Once the location of the culvert has been determined, the culvert trench is excavated. If a 60cm culvert pipe is used, the width of the trench needs to be at least 1m to achieve good working space when placing the culvert. The excavation works should be organised as task work.

Once the trench has been excavated, check the level of the bottom with a traveller to ensure that it is level and with the desired slope. If necessary, use a 10cm layer of compacted gravel to achieve a solid foundation for the culvert. During excavation, ensure that any water which may enter the trench can run off. This may imply that the outlet drain needs to be excavated first.

The culvert pipes are gently lowered into the trench using a rope. Avoid the pipes falling onto each other. This may damage the pipes. Using crowbars, ease the pipes up tight against each other and ensure that all are in a straight line.

The backfill around the pipes and the overfill should be placed in 15cm layers of suitable fill material, and needs to be well compacted using hand rammers. Be careful not to hit and damage the pipes when compacting. The minimum thickness of the fill above the culvert rings should be not less than half the pipe diameter.

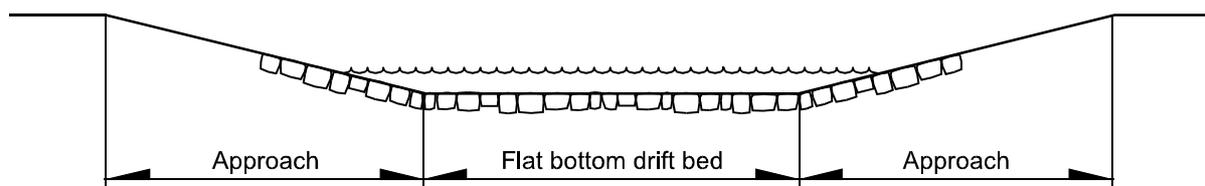
In flat areas, it is often necessary to lift the road on an embankment in order to achieve sufficient fill on top of the culvert rings. In such cases, a ramp needs to be constructed on each side of the culvert to avoid a rapid change of the road gradient.



Finally, give serious concern to the outfall and undertake any additional works required such as properly forming an adequate outlet drain to discharge the water, providing grassing or dry masonry lining in the outlet drain, or stone gabion steps, or other interventions to ensure good erosion protection.

5.7 Drifts

Drifts provide an efficient and economic method of allowing water to cross from one side of a road to the other. In the case of drifts, the water is actually allowed to pass over the surface of the road. As a result, the road surface will need special protection to stand up to the flow of water. This is usually done by making a stone packed or concrete surface where the water will pass. The level of the drift will be lower than the road on each side, to make sure that water does not spill over onto the unprotected road surface.



Drifts are normally constructed to pass river streams which are dry during long periods of the year.

During rains, most drifts will carry shallow flows of water which vehicles manage to pass through. However, occasionally, deep drifts will be flooded for short periods and the road will be closed for traffic.

There are three types of structures that are together known as drifts:

(i) Splashes

These are minor crossings that carry water from a side drain across the road to the lower side. Splashes are located at low points along the road alignment and when the side drain cannot be emptied by mitre drains and the water has to be taken across the road.

(ii) Drifts

These are crossings at large drainage channels and small rivers. They may have to take strong flows of water.

(iii) River Crossings

These are long crossings over a sand river bed. Usually, the river bed would consist of deep sand and the crossing has to be built with a firm foundation.

5.7.1 Drift Warning



Warning of the location of a drift or river crossing should be placed on the side of the road to give traffic sufficient advance notice so they can be prepared to reduce speed and proceed safely down the approach and across the drift.

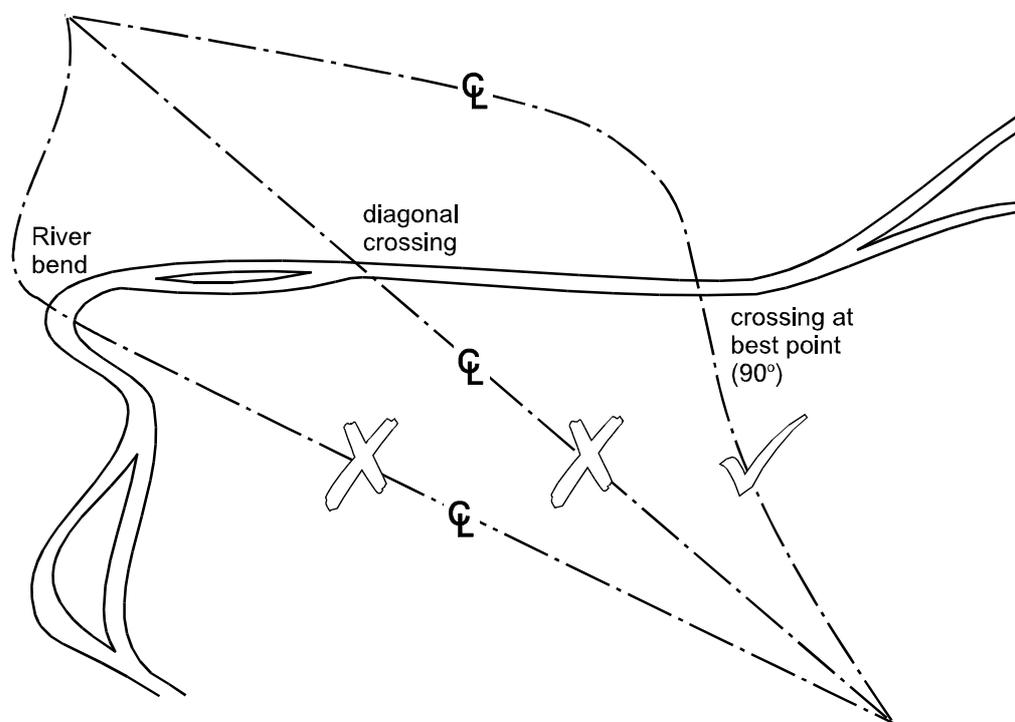
Additional guidance can be given in the form of marker stones painted white at each corner of the drift.

5.7.2 Site Location

The most important step is to locate a suitable site for the river crossing. If the drift is wrongly placed, it may result in both extra work during construction and maintenance afterwards. The main points to consider are:

- The angle between the centre line of the road and the flow of the water should be close to 90°.
- The site should be on a straight length of the stream bed.
- Avoid places where there are signs of scouring or silting. Both will cause future maintenance problems.
- Avoid places where there are steep banks which will involve a lot of excavation and steep approach slopes.

The site should be on a straight length of the road.

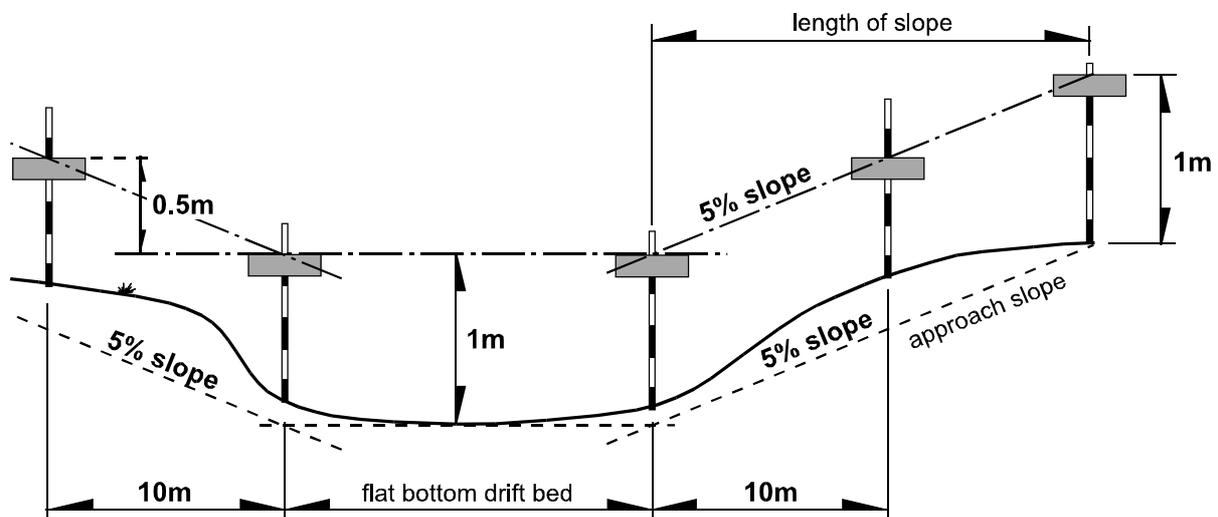


Once the site has been established, it is important to set out the finished level of the drift at the same level as the present level of the river bed. Avoid setting the level of the drift below or above the level of the river bed.

In cases where the river is suffering from silting up, it is best to lift the drift 20 -25cm above the natural river bed. This will speed up the water passing over the drift and reduce the danger of the drift becoming silted up.

5.7.3 Drift Approaches

The ideal slope for a drift approach is 5%. When considering building a drift, set out the approaches first to see how much excavation is required.



Two profiles are set out to a 5% slope at each side of the crossing. The length of the approach can be found by means of a traveller 1m high moved along the line of the slope profiles until it levels up with the slope profiles when standing on the natural ground.

The traveller can also be used to measure the depth of the dig along the proposed approach, and this can be used to estimate the volume of excavation required. It may indicate the need to look for another site for the drift.

5.7.4 Surface Materials

To provide the appropriate surface material for the drift, which will support the expected traffic as well as stand up to the water flows in the rainy season, is an important issue.

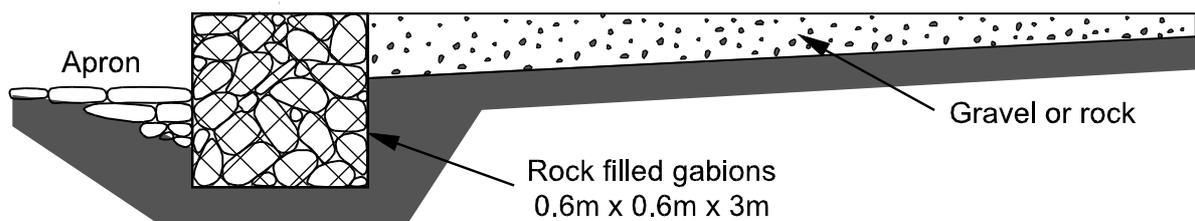
There are a number of possible solutions from gabions with gravel, stone pavings to constructing a concrete slab. The choice depends on the following issues:

- the expected force of the water flow,
- the availability of materials, i.e. gravel, stones, concrete aggregate, sand etc.,
- the strength of the river bed foundation, and
- costs.

For slower flowing water, gravelled drifts with gabions or dry pitched stone paving is adequate. Stone pitching is more suitable for river beds with loose sands and a gentle flow.

At some crossings, it will be difficult to decide if a gravel surface will be practical - it may be washed out too often. In these cases, try the cheaper solution first, the gabions with gravel, and allow a full rainy season before deciding whether it is necessary to upgrade the crossing with a stone pavement or a concrete slab.

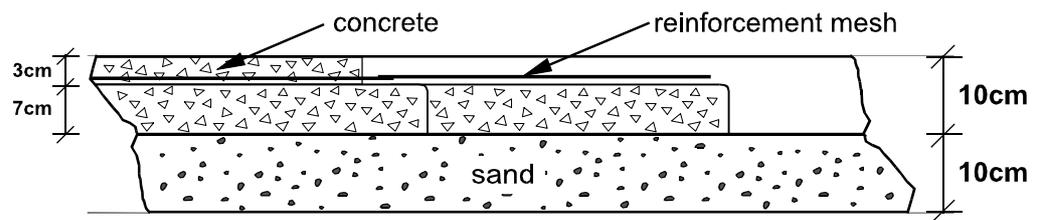
The figure below is an example of a drift which in principle consists of a porous dam which retains the gravel/rock from being carried away by the water flow. The top of the gabion dam is between 15 and 20cm higher than the river bed at the downstream end.



This construction provides a simple and economic solution. A one-metre wide trench is excavated along the downstream edge of the future road. The gabions are then placed in position, filled with rock and bound together with binding wire. Gravel is then placed upstream from the gabion to form the road surface. Remember to prepare an apron on the downstream side of the gabion to resist scouring.

Strong flows of water will erode and wash away gravel surfaces and will dislodge dry pitched stones. This will result in high maintenance costs to keep them repaired and in good condition for the road users. Where large volumes of strong flowing water are expected, a concrete slab or cement bonded stone paving provide the only long-lasting solution.

A typical cross section of a concrete slab is shown below.



Once the concrete has been placed, keep it damp and let it cure for 7 to 10 days.

If the length of the slab is less than 12m there is no need for an expansion joint. On long river crossings, make expansion joints for approximately every 10 to 15 metres.

5.8 Gravelling

Gravelling is carried out to provide a strong surface layer which is passable in both dry and wet weather, and which does not deform under the expected traffic loads. Together with the road camber, a good gravel surface will prevent water from entering into the road body and thereby avoiding surface water from deteriorating the bearing strength of the road.

In principle, the following methods can be used to gravel a road:

- use of a mix of labour and equipment, or
- use labour for all activities except hauling over distances longer than 150 metres.

Transport of gravel can be organised in many ways, depending on the distance from the gravel quarry to the site and the type of equipment available to the project. The following table provides a general picture of the types of transport appropriate for different haulage distances:

| <i>Distance</i> | <i>Transport</i> |
|-----------------|---------------------|
| 10 – 150 m | Wheelbarrows |
| 150 – 2000 m | Animal Carts |
| 500 – 8000 m | Tractors & Trailers |
| 1000 - | Trucks |

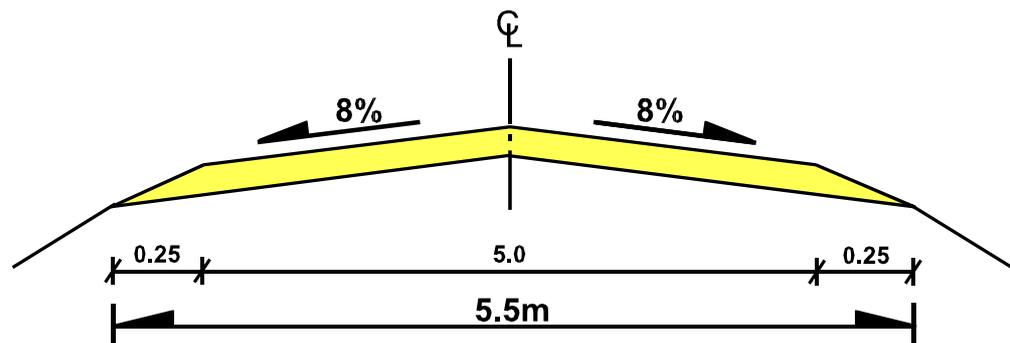
Tractor towing tipping trailers can be a very economical mode of transport when the hauling distance does not exceed 8km. The trailers are more suited to manual loading than lorries which are higher. Several trailers can be used for one tractor so that one is loaded while the other transports material to the site. On the other hand, trucks are better suited to longer haul distances.

Excavation can, depending on the hardness of the rock, be carried out with a front-wheel loader, blasting or hand tools such as pickaxes and crowbars. The crushing can be done either with a (mobile) rock crusher or by hand. Spreading can be done either by a grader or with hand tools. With very short hauling distances (less than 150m), it is even possible to carry out all activities with labour. The hauling can then be economically done with wheelbarrows.

In some cases, newly constructed roads are left un-gravelled for a period of time. This allows the base to settle and traffic to provide compaction. In other cases, the gravelling layer is placed immediately after the completion of earthworks. Gravelling is also often a major part of periodic maintenance works on a road. After a certain period of time, i.e. six to ten years, depending on the traffic volumes, it is necessary to regravell the road.

5.8.1 Standards

The thickness of gravel layers depend on the quality of available materials and the expected traffic loads. For rural, low traffic volume roads, the ILO labour-based project has chosen a carriage width 5m wide which is fully gravelled with a layer of 15-20cm (before compaction). In addition, the road shoulders, with a width of 0.25m each, are gravelled to protect it from erosion as shown in the figure below.



The road camber is maintained at 8% (10% before compaction), similar to the sub-base.

5.8.2 Gravel Source

When selecting appropriate gravel quarries, a number of aspects needs to be considered. These include:

- the quality of the gravel material,
- the depth of soil (or overburden) over the gravel,
- the quantity of good quality gravel available,
- how to excavate the gravel,
- how long access road needs to be constructed to access the quarry,
- hauling distance from the quarry to the road site, and
- land ownership at the quarry site.

Finally, it is important to establish whether or not the quarry is located in low-lying terrain. If so, this may well cause the quarry to become flooded and un-workable when it rains.

Preferably, the gravel pit should be located close to your road to limit hauling distances. It is important to bear in mind that gravelling can be quite expensive and can sometimes cost as much as the construction of the road itself.

5.8.3 Gravel Quality

The quality of the gravel needs to be determined well in advance of the project commencing gravelling works. This enables the project to prepare and negotiate gravel sub-contracts with local contractors well in advance and to time the gravelling works to the optimal period of the year (dry season).

Although the process is called "gravelling", various materials can be used such as laterite, limestone and gravel. Most suitable materials consist of a mixture of stones, sand and clay. The stone particles will lock together and form a strong skeleton which spreads the traffic load to the natural soil. The sand and clay will act as a binder keeping the stone particles in place.

Good gravelling material should contain between 35 - 65% stones, 20 - 40% sand, and 10 - 25% clay. However, in wet weather a high proportion of clay in the mixture would make the layer too soft and slippery. The wetter the area, the more important it is that the stone/sand proportion of the mixture is high and well graded. In a dry climate, a higher proportion of clay can be accepted.

Much care needs to be taken in selecting your material. Suitable surface layers have been made of materials ranging from laterite and coral to very hard crushed stone. Some materials such as coral and limestone have the tendency to harden when they are exposed to air, water and traffic compaction, while other types of rock may decompose, under the combined action of weather and traffic to form clay.

Information about soil characteristics is useful both to help in selecting sites and routes and to facilitate design and specification of the project. Usually, the Engineer will want to send samples to a soils laboratory. It must be recognised, however, that in many places good laboratory facilities are scarce and tend to be monopolised by favoured projects. In addition, laboratory tests can be expensive and time consuming in the types of dispersed projects most suited to labour-based methods.

Engineers and technicians are often limited to making some of the field tests described below. When used with laboratory tests taken on similar samples for other projects and with a sound knowledge built up by observing how similar materials have performed, these field tests can provide sufficient information for making sensible engineering decisions.

Field Testing Methods

Take a sample, moisten it and mould it into a ball. You can feel the sand and stones by the gritty feel of the sample when you squeeze it. When, after drying, the ball retains its shape, you can assume that there is enough clayey binder in the material.

You can also make a flat thick piece from the moist sample and try to penetrate it with a pencil. If the pencil penetrates easily, the material is not suitable because it contains too much binder or clayey material. If it is difficult to penetrate, there is a sufficient proportion of fine and coarse materials which interlocks well.

An easy way to find out the proportions of the various soil fractions in the sample is to carry out a so called 'settling test'. The sample is put in a glass jar like this.

Only half the jar should be filled with the sample. Then add water till the jar is

three-quarters full. Add some salt, as this will improve the settling of the finer materials. Shake the jar, and let the soil in the jar settle. As you will see, the gravel and the coarse sand fractions will settle immediately. The finer sand and the coarse silt fractions settle more slowly. The clay and the fine silt will remain in suspension for some time before they settle. You can see the proportion of each fraction as layers in the jar.



The results of these tests can only provide indications on how these soils could react when subjected to compaction, traffic and weather conditions. If you are still in doubt about the suitability of the gravel, consult your engineer to carry out laboratory tests to confirm your observations.

Water

Good water sources is also important. When the gravel operation commences, the projects needs water haulage equipment available on site, i.e. a water pump, water bowser and an appropriate spreader. Make sure that this equipment is available and in good working condition before gravelling works starts.

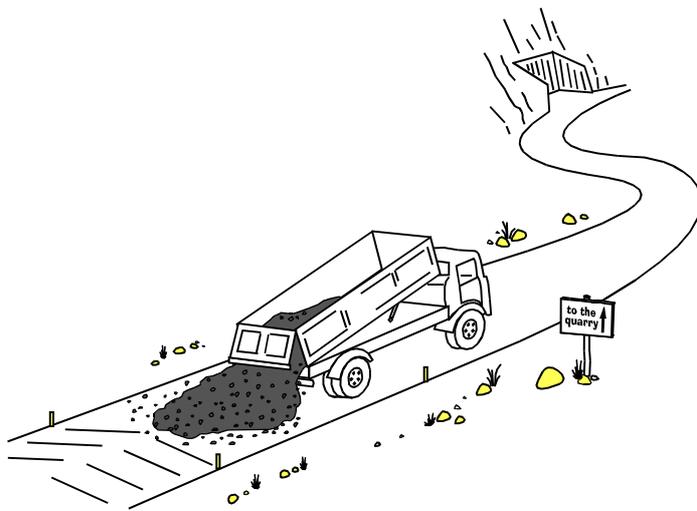
5.8.4 Work Plan

A proper workplan for gravelling is extremely important. This plan should provide information on inputs (number of workers and equipment), productivities, outputs and timing of the work.

Always aim to organise the un-loading in such a way that waiting time for the vehicles is minimised. This implies that the supervisors need to estimate the transport time from the road site to the quarry, and based on the number of trucks available, estimate how often a truck will deliver a load. This will indicate how much time is available for the spreading and levelling the gravel delivered by each truck. Ideally, the workers should be able to spread and level the gravel before a new load arrives on site.

There are two ways to organise the un-loading, gravelling *towards* or *away* from the quarry.

Gravelling towards the quarry can be organised in such a way that the vehicles have very short waiting times for un-loading, even if several vehicles arrive at the same time. However, this method requires the trucks to drive over the road sections which has still not been gravelled, which may cause damage to the road, especially in rainy periods. It may even become impossible to continue the works, as the earth road may become too slippery and muddy.



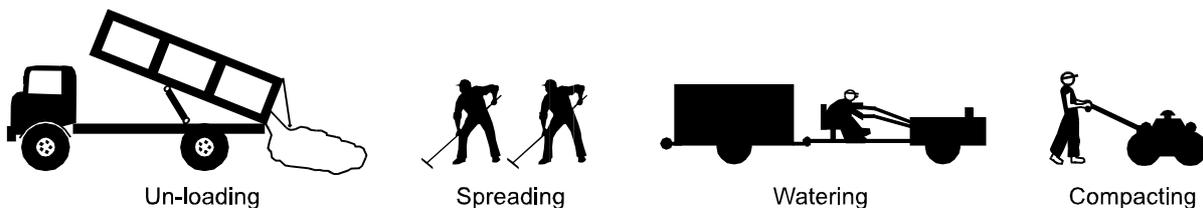
Gravelling away from the quarry implies that the trucks will pass over the newly completed road sections. This method has the advantage that the vehicles frequently pass over the newly levelled gravel and thereby provide some compaction to the gravel layer. However, this method also has some disadvantages. It requires that the delivered gravel needs to be levelled before a new truck can dump its gravel and may therefore delay the un-loading. Finally, a large number of heavy traffic on the road may result in some damages to the newly constructed road.

Therefore, the gravelling operation needs to be carefully planned, depending on the situation and the general conditions under which the project is working.

5.8.5 Work Procedure

Before carrying out any gravelling works, first check that the earth works have been properly carried out and levelled to the exact and required standards. Set up the profile boards once again, and ensure that all levels are correct and that the camber has not been damaged.

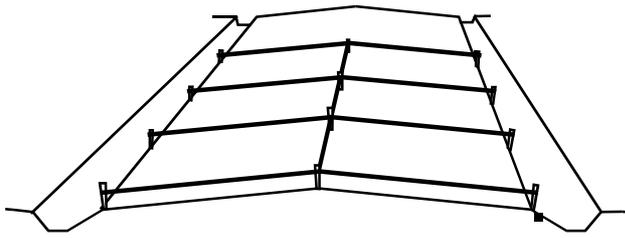
Placing the gravel, involves four activities, namely un-loading, spreading, watering and compaction.



These activities need to be fine tuned with each other, achieving a good balance between labour and equipment.

Unloading

Drivers should be instructed to dump the entire load within an area which you have clearly marked with pegs and string lines. To make spreading easier, instruct the drivers to move slowly forward while dumping, so that the gravel is evenly distributed along the length of the rectangular area.



The area set out for each load of gravel depends on (i) the dimensions of the gravel surface and (ii) the average load which each of the trucks are carrying. In order to get the correct thickness of gravel, this needs to be carefully calculated by the site supervisor.

Example:

If the desired thickness of the gravel is 20cm, then one meter of the road will need:

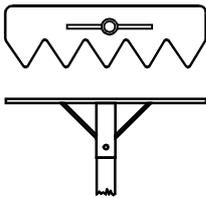
$$0.2\text{m} \times (5\text{m} + 0.25\text{m}) \times 1\text{m} = 1.05\text{m}^3$$

If the average load of a truck is 12 m^3 , this load will cover a road section with the following length:

$$12\text{m}^3 / 1.05\text{m}^3 \text{ per m} = 11.42\text{m}$$

Spreading

Once the material is unloaded, you can start the spreading. Take care to spread immediately before compaction to make use of the natural moisture content of the material. If the gravel is stock-piled along the road for a period of days before levelling and compaction is carried out, it will dry out and will then require more water when compacted.



The workers should use special spreading rakes, as shown here, or hoes to spread the material evenly onto the road base. Work from the centre line towards the shoulder, and spread one side of the centre line at a time.

Oversize pieces of rock should be removed or crushed using sledge hammers.

Compaction and Watering

When the layer has been spread, the last activity of the gravelling operation, the compaction of the layer can be done. Make sure that you have sufficient supply of water, to maintain an optimal moisture content in the gravel during compaction.

If the gravel is spread immediately after excavation, it will contain a natural moisture content very close to the optimal, thereby reducing the demand for watering.

Control of Works

Finally, when the gravel has been spread and compacted, erect profile boards along the centre line and the road shoulders. Then, using a traveller, control that the road surface is at the desired levels and smooth, and that the required camber slope has been achieved throughout the road line.

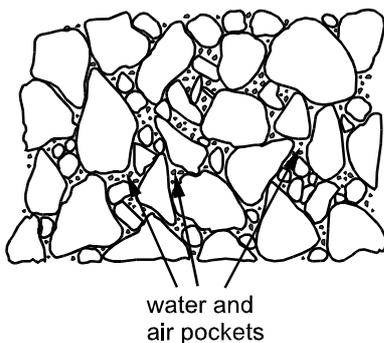
Stock-piling

During the gravelling operation, it is useful to stock-pile gravel along the road for future routine maintenance works. This gravel will later be used for repairing damages to the road surface, i.e. pothole patching, filling of ruts, etc. Ideally, a load of 10 m^3 of gravel should be placed along the road side, at 500m intervals.

5.9 Compaction

Compaction decreases the volume of a layer of soil. By forcing soil particles close together, the soil becomes stronger. By applying compaction to the materials used for road construction, the road body will be strengthened, and better withstand the envisaged traffic loads and natural erosion.

5.9.1 Optimal Moisture Content



Soil and gravel in its natural state consists of solid particles, water and air. Air does not contribute to the strength and stability of the soil - on the contrary, it reduces the stability of a soil. A certain optimum quantity of water (usually between 8 to 20%, depending on the soil type) facilitates compaction and contributes to the soil's strength and stability, because it lubricates the particles and allows them to settle in a dense mass. If the soil contains too much moisture and is too wet, the soil particles are kept apart by the water. When the soil is too moist and you try to compact it, it will simply not compress, but flow out sideways.

Experience shows that if soil is taken from the ditches or a side borrow, and spread and compacted immediately, the natural moisture content is usually sufficient for good compaction. Sometimes, however, the soil comes from a dry stockpile and then needs to be watered.

It makes sense to check this so-called 'optimum moisture content', between too wet and too dry.

This is especially important for gravel layers. A simple way to check moisture content by approximation is to take some of the material you are to compact in your hand. Squeeze it into a ball. If the ball cannot be formed, the material is too dry. The correct moisture content is reached when you can form the ball and the material packs well together. When you apply pressure, the ball should retain its shape.

When you form the ball and flatten it easily when you put pressure on the ball, the sample has a moisture content which is too high. When the water oozes out of the sample without even applying pressure it obviously is far too wet.

5.9.2 Compaction Methods

There are basically four methods of compaction:

- manually or mechanically operated tampers or rammers,
- deadweight rollers,
- vibrating compaction, or
- natural compaction.

Tampers and Rammers

Tampers and rammers compact the soils by impact. Specially designed hand rammers can be used for this purpose.

Hand rammers are cheap to produce, and consist of a long wooden handle with a cast iron or concrete weight at the end. It is lifted and dropped on the surface repeatedly to produce compaction. The weight is usually 6 to 8 kilograms.

Using hand rammers is expensive and difficult to apply evenly over large areas. A lot of manpower and direct supervision is needed to produce a steady output of reasonable quality. Hand rammers are most useful in small and confined areas such as around culverts, pot-holes and other places where it is impractical or difficult access for rollers.



Deadweight Rollers

There are several types of deadweight rollers, ranging from single or double steel drums, towed or self-propelled or with a load container to hold the deadweight. A major concern when choosing the appropriate type of compaction equipment is:

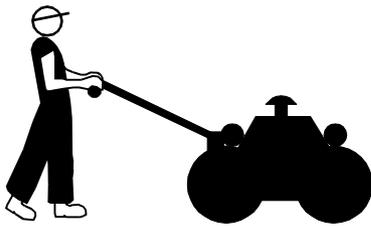
- its availability in the region of your road works activities,
- how to deliver it to the construction site,
- how easy is it to operate and how easily can it be reversed, and
- its cost and reliability.

Large and heavy towed rollers may have good compaction qualities but may prove difficult to turn and operate in hilly or steep terrain. Self-propelled rollers can normally be operated in both directions, however, they are more prone to breakdowns.

Some rollers can be ballasted with weights up to 1 tonne or more, using water sand or stones. When using this type of roller, the first passes can be done with a relatively light ballast in order to avoid traction problems. After the first few passes the ballast can be increased.

Vibrating Rollers

A vibrating roller will generally compact to a greater depth than a deadweight roller. The effect of the vibrating motion will depend on the intensity of the vibrations and the type of material on which it is used.



They also require a lower moisture content than deadweight rollers. However, it is important to maintain an even speed to achieve even compaction. With deadweight rollers this is less important.

The first passes, should be done without vibration, to avoid that the roller gets "bogged down" into the soil. The speed should be around 3 kilometres per hour or slow walking speed. Instruct your operators to run the engine at a slow and constant speed.

Natural Compaction

The simplest method of compaction is by leaving soil to settle naturally by just leaving it for a period of time. The soil by its own weight, rainfall and people, animals and vehicles travelling on it will eventually consolidate enough to carry traffic loads.

This so-called 'indirect compaction' method or natural consolidation is a slow process. It is normally only used on very low fills, and is most effective if the fill material is very moist and must dry out. Given sufficient time, it has been found that roads compacted by natural consolidation can achieve similar densities as roads compacted by equipment. The main disadvantage is that while the soil is not consolidated, it is prone to erode more easily. Normally, it would be necessary to leave the fill for a period six months to achieve an effective degree of compaction.

5.9.3 Quality Standards

The required level of compaction is normally specified relative to a laboratory compaction test. For example, compaction to 95% means that the dry density of samples taken in the field should be 95% of the dry density obtained in a specified laboratory compaction test.

How to obtain a certain level of compaction will depend on the type and size of the compaction equipment and the soil type. The site engineer will prescribe the appropriate method and equipment for compaction.

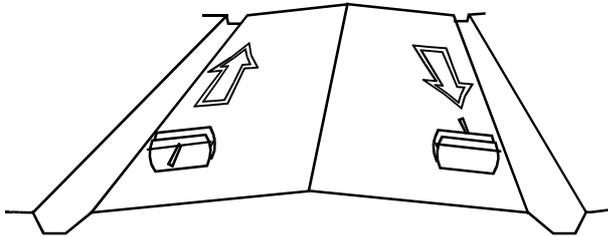
A fairly reliable way of checking on site if compaction has been done to acceptable standards is to use a loaded vehicle. Drive it over the compacted section a few times and see if it leaves any wheel-ruts in the pavement. If ruts are left then more compaction is needed.

5.9.4 Compaction Procedure

To gain even compaction, assign and train specific workers to operate the compaction equipment. They will become experienced at running the rollers at a constant speed for good compaction and will also maintain the rollers.

To produce a good quality road, it is important that all soils are properly compacted. Compaction should be carried out along the road line starting at the shoulder of the

road and gradually working towards the centre line. Compaction of the road shoulders should be done using hand rammers.



Make sure that the camber of the road is always maintained at 8% for both the base layers as well as the gravel layer.

After compaction, it is important to check that all levels are correct and that the surface is smooth and does not contain any uneven spots. This check is carried out by using profile boards and a traveller.

- ☛ Make sure that you have sufficient supply of water, in order to maintain an optimal moisture content in the soils which are being compacted.



5.10 Erosion Protection

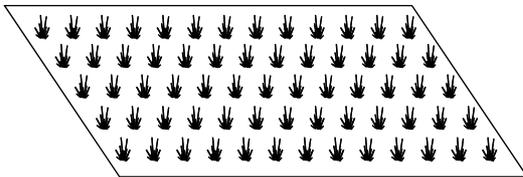
Newly formed slopes on fills and embankments can be easily damaged (by runoff surface water, cattle, etc.). It is therefore necessary to protect the slopes as soon as they have been constructed. The erosion protection can be of different types, the most common being planting grass or other types of deep rooted vegetation. A more expensive but fast and effective method is to use stones for protection.

Grass can provide very effective protection against erosion if the right method of planting and the right type of grass is used. The planting can be done either by

- by planting grass runners, or
- by covering the slopes with turfs.

Grass Runners

Grass which has been removed by the grubbing gang can often be used if it is dug out properly and kept moist. It should be protected from direct sun. The runners are cut



in pieces of approximately 20cm in length and planted in rows in 10cm deep holes with a distance of not more than 30cm. To get the best results, the rows should be skewed so that a zig-zag pattern is achieved. The soil should be compacted around the runners by hand.

Turfing

Covering the slopes with whole turfs gives a more immediate and more effective protection, but is more time consuming to carry out. As with runners, the turfs can be collected during the grubbing activity. For easy handling, the turfs should be approximately 20 x 20cm. Care must be taken when cutting the turf so that the roots are not cut off. Turfs also need to be kept damp and away from the sun when stored. Before placing the turf, the soil should be watered if it is dry.

The newly planted grass needs to be protected from cattle by a layer of thorny bushes, twigs, branches, etc. and watered when necessary.



Module 6

Road Maintenance

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6.1 Approach

The purpose of maintenance is to ensure that the road remains serviceable until the end of its design life. Maintenance is important because it:

- prolongs the life of the road by reducing the rate of deterioration, thereby safeguarding previous investments in construction and rehabilitation,
- lowers the cost of operating vehicles on the road by providing a smooth running surface, and
- keeps the road open on a continuous basis by preventing it from becoming impassable.

Road maintenance offers considerable scope for increasing efficiency by adopting different operational and organisational approaches. Some of these approaches include:

- use of equipment,
- use of contractors, and
- use of labour.

In order to achieve the above mentioned objectives, it is important to investigate alternative approaches to road maintenance which should be tested and introduced if they prove efficient and cost-effective.

Equipment-intensive Methods

The use of heavy equipment is generally a big drain on scarce foreign exchange resources, since most machines, their spares and fuel have to be imported. In addition, the use of heavy equipment requires high initial capital investments. Cases of under-utilisation of machines have been observed due to lack of even minor spare parts and high running costs. Moreover, due to the high initial investments, small-scale domestic contractors are thereby barred from carrying out works contracts which could be possible for them to manage if alternative approaches were allowed for.

Use of Contractors

It is difficult to provide work incentives particularly in road maintenance departments. As a result, work is often carried out inefficiently and both the quality and the quantity of the outputs tend to be inadequate. One way of obtaining more efficiency is to make more use of private contractors. However, proper supervision is vital to all contract

work. Specifications need to be developed and agreed upon and checks made to ensure that they are complied with.

It should be acknowledged that the private sector in Lao PDR has limited experience in carrying out road maintenance works. Small and medium sized local contractors often only operate in the building sector. However, past experience from other countries has demonstrated that it is perfectly feasible and economical to contract out maintenance activities.

This means that simplified administrative and contractual procedures need to be introduced. Moreover, that the executing ministries (the client) has to be able to prepare accurate work estimates and provide further essential back-up services in the form of regular and timely inspections and payment. Finally, productivity data has to be assembled through work studies in order to provide realistic unit rates for the maintenance activities to be contracted out.

Use of Labour

The lack of equipment or working equipment is often a major constraint when carrying out maintenance. Equipment is expensive, consumes fuel and lubricants, and require spare parts which all have to be imported. Equipment also requires skilled operators, skilled mechanics and workshop facilities. If any of these items are not available, the equipment stands idle and road maintenance is not carried out.

By contrast, labour is practically always readily available and can be employed at a low cost. In addition, labour-based techniques are very well suited to a large range of maintenance activities, particularly when labour are well managed on a performance-based payment system. However, labour-based approaches demand intensive and good quality planning and supervision.

Combined Use of Equipment and Labour

In most cases, a combined use of labour and machines would provide the most appropriate solution. In certain areas, cheap labour may not be available at the time when roads need maintenance attention. Certain maintenance tasks can be carried out more effectively by machines while others are best carried out using labour. The most appropriate technology will therefore depend on the nature of the work and the availability of labour and equipment in the area. The figure below shows which activities are best suited to labour and which are best carried out by equipment.

The choice between equipment and labour-based methods affects the basic organisation of road maintenance. Equipment-based works favours a more centralised organisation, whereas labour-based solutions favours decentralised organisations.

The table below provides a brief overview of the viability of using equipment or labour for various maintenance activities.

| Activity | Potential | |
|---|-------------------|--------|
| | Equipment | Labour |
| Ditch cleaning and reshaping | good ¹ | good |
| Minor bridge and culvert repairs | poor | good |
| Building scour checks | poor | good |
| Repair of structures | poor | good |
| Grading un-paved surfaces | good | poor |
| Patching, sanding or local sealing of bituminous surfaces | poor | good |
| Filling of unpaved surfaces and slopes | poor | good |
| Grass cutting | good | good |
| Repairing and replacing traffic signs | poor | good |
| Road line markings | good | good |
| Stock piling gravel | good | fair |
| Regravelling | good | fair |
| Stock piling chippings | good | poor |
| Surface dressings | good | poor |

(1) Requires a V-shaped ditch.

Before it is possible to select the optimal approach to road maintenance in a region, there are certain pieces of information which needs to be collected and analysed. Road data relating to issues such as the function and condition of individual road links, traffic levels and available resources in terms of funds, labour, machines and materials need to be clarified. This includes data on staff skills and training requirements, equipment performance and utilisation, labour productivities, and the effect of critical resource constraints on general performance.

In most cases, the choice between labour and machines is not an either/or situation - it is possible to find cost-effective combining the two approaches. Moreover, past experience has shown that an inventive use of intermediate equipment can be extremely cost-effective for excavation, compaction and hauling, provided that locally available skills and materials are drawn upon in an imaginative way.

In recent years, a great deal has been learnt on the establishment of alternative road maintenance systems. The various solutions can be categorised as follows:

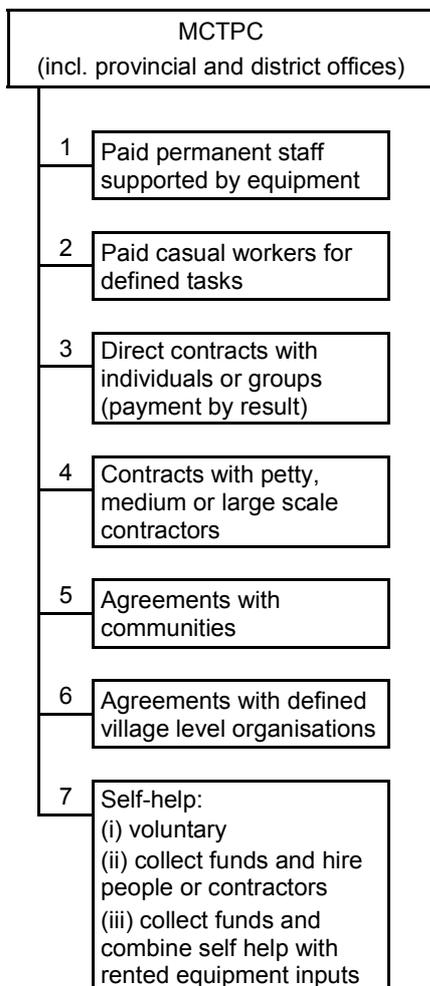
| Alternative Approaches to Road Maintenance |
|--|
| <ul style="list-style-type: none"> • Force account system with employment as permanent or semi-permanent staff, supported by equipment (classical approach) • Individual or collective maintenance responsibility for a road section • Agreements between local communities and government • Petty contracts for selected road maintenance activities • Use of the private sector |

6.2 Organisation

6.2.1 General



Maintenance systems based on the utilisation of local resources have as their key characteristic that they relate to the maximum extent possible to the local environment, involving local people in the planning and execution of maintenance work. The figure below summarises different options which can be applied either separately or in combination.



A combination of approaches 1 and 2 is normally used by line ministries responsible for road maintenance. The effectiveness of these maintenance approaches is largely dependent on the availability and utilisation of transport and equipment. The alternative approaches such as the ones specified under 3 to 7 are likely to require substantial technical and managerial inputs, certainly in the establishment phase. Sometimes, the technical line ministry might be able and interested to provide part of this required technical and material support. More often however, support from external sources would be required to build up a capacity within authorities to execute road maintenance tasks on local roads.

In applying any of the alternative options, the key element is the motivation of the workers and their supervisors. Incentives at all levels must be incorporated as part of the system in order to make it sustainable.

Concerning the workers at village level such incentives may not necessarily be in the form of money. If there is a significant local interest in the road (or road section), some assistance in the form of tools, construction materials and supervision could be a sufficient incentive to mobilise adequate numbers of labour. In these cases, planning and programming assistance provided by the maintenance engineers may be sufficient to mobilise and direct village labour at specific times throughout the year to keep the road in a maintainable state.

This type of maintenance would therefore be provided not as a continuous low level routine maintenance input,

but rather as a schedules and well-directed community input involving a significant number of workers, say two to three times a year. Naturally, this type of maintenance intervention would primarily apply to access roads with (subsidised) collective inputs to safeguard their level of access to the main road network.

The use of community self-help is an issue which is often susceptible to simplistic solutions. An argument often heard is that rural roads are built specifically for the benefit of the people and they should therefore shoulder the responsibility for maintaining the road.

One has to remember that roads are built to carry vehicles. Many communities recognise the benefits that will come to their village from the better access to markets, easier access to government services and better connection to the outside. Nevertheless, they do not necessarily recognise the individual benefit that will come to them. After all, most of them do not own a vehicle. In Lao PDR, many are subsistence farmers and have no real need of markets. Indeed they may feel that as individuals they cannot see the benefit that will accrue to them. At best, they may be prepared to maintain the road where it runs through the village but, experience suggests that, they will be unwilling to maintain more than that.

This is not to suggest that it is not possible to obtain community support for rural road maintenance. However, it is necessary to put a lot of effort into:

- (i) ensuring that the community fully understands the benefits that will come to them from maintaining the road and
- (ii) providing some form of incentive to the communities.

The lessons to be learned from attempts to involve the local population in the maintenance of rural roads are the following:

- (i) The communities must be involved in the process from the planning stage. Indeed, the road to be built has to be seen by them to be something that they need and not imposed on them from outside.
- (ii) In this respect, it clearly helps if the roads are built using local labour as the community is then involved and benefitting from its construction.
- (iii) Some form of incentive has to be provided. This of course is best if it is cash.

In the majority of cases, however, further inputs in the form of regular cash wages will be necessary in order to establish a continuous and sustainable maintenance system. Regular and sustained inputs can also be commercially negotiated with individuals, villages, village organisations (youth organisation, farmers associations, etc.) acting as petty contractors.

In all cases, it is advisable for the technical line ministry to use the local administration in the setting up, implementation and monitoring of locally based maintenance approaches. An ideal road maintenance system would make the

optimum use of local resources would most likely comprise of several of the maintenance alternatives indicated in the figure above.

The optimum maintenance approach for a particular road would be determined by factors such as:

- level of maintenance service required, which in turn depend on the function and purpose of the road),
- the local interest in the road,
- the availability of local labour, equipment, finance and technical supervision.

6.2.2 Structure

Besides the choice of maintenance approach, also the type of maintenance activities influences the organisational set-up. Basically, there are three main operations for which any road works organisation needs to cater:

- routine maintenance,
- periodic maintenance and
- urgent maintenance.

More detailed descriptions of these operations are provided later in this module.

An organisation therefore must (i) be able to cope with the routine maintenance at all times, (ii) have enough capacity to carry out periodic maintenance (e.g. reshaping, regravelling, spot improvements, etc.) and (iii) have extra capacity to carry out suddenly appearing maintenance works (e.g. repair on structures, wash-outs, land slides, etc.).

The extra capacity for urgent maintenance must be ensured at all times to avoid serious disruptions in access to the rural communities. For larger unforeseen defects, eventually additional resources must be made available by the programme management (i.e. major flood damages). For smaller defects, the implementing organisation's own resources must be sufficient.

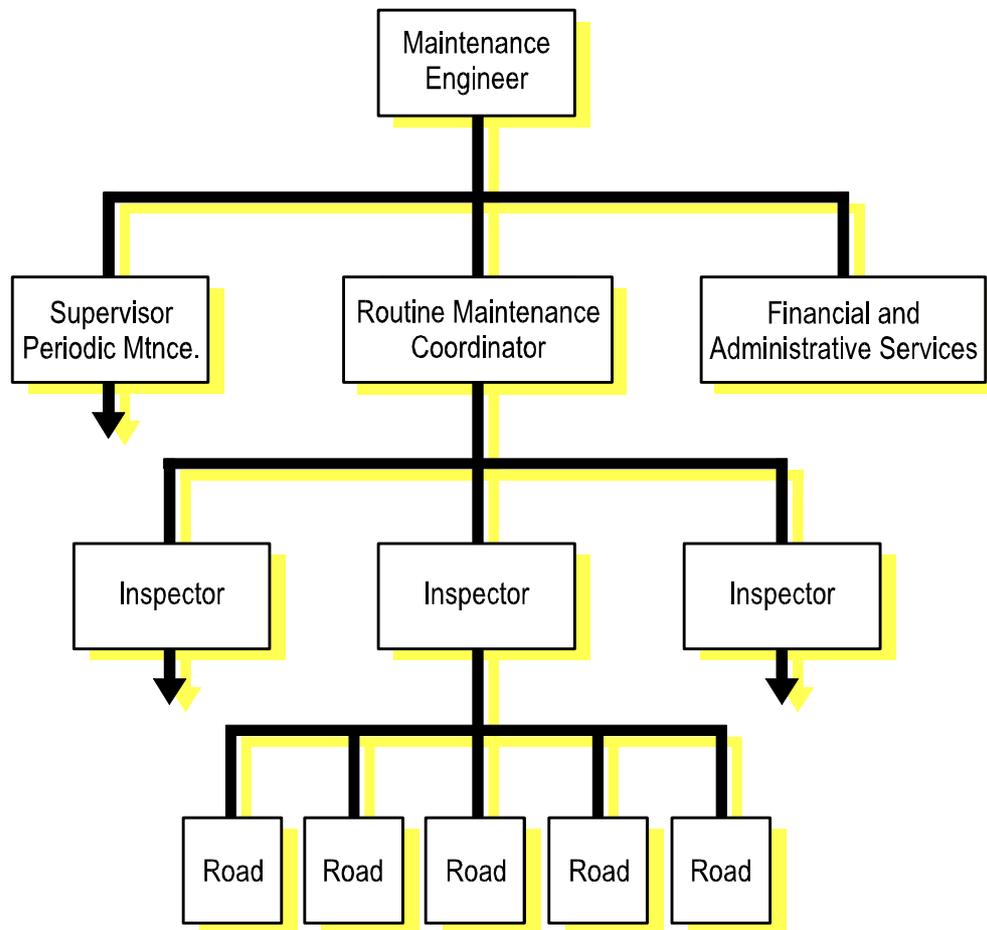
Periodic maintenance, such as regravelling and spot improvements, demands a special organisation which cannot normally be dealt with by the normal routine maintenance unit. For example, regravelling requires the same organisation structure and resources as the gravelling operation during the initial construction phase. Most organisations therefore prefer to establish separate periodic maintenance units from the continuous routine maintenance organisation.

A maintenance management unit would normally consist of the following cadres of staff:

- *Road Maintenance Engineer* in charge of all planning and supervision of all maintenance operations in given area (region, province, etc.). His/her duties would

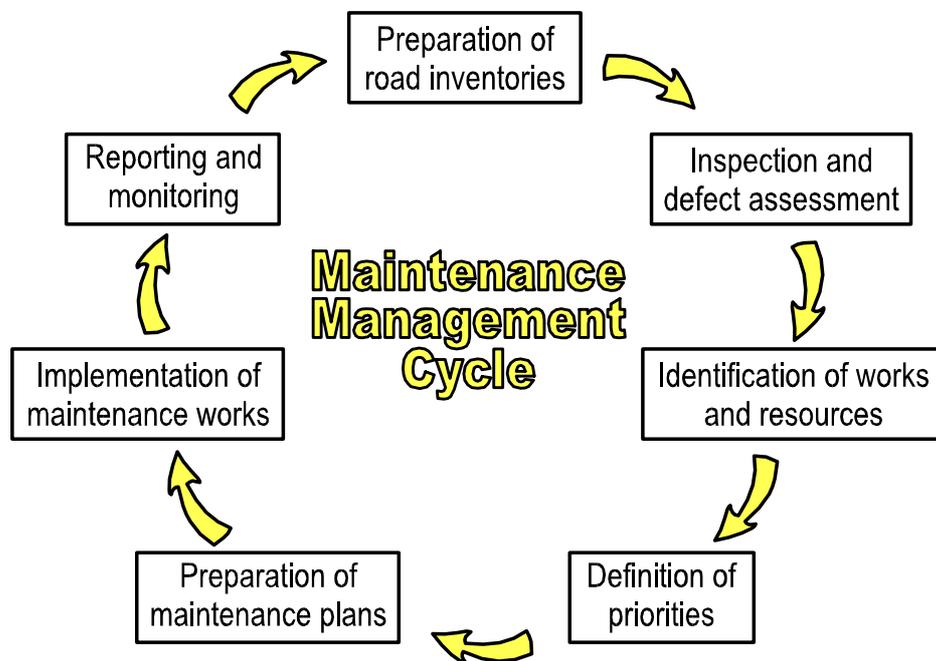
also include cost estimating and control, budget preparation, contract preparation and management and occasional field inspections.

- *Routine Maintenance Coordinator* responsible for programming and implementation of routine road maintenance. These tasks could also be combined with preparing and maintaining the road condition inventories.
- *Inspectors and Supervisors* in charge of implementation of works at field level. This staff is directly responsible for instruction of workers, local contractors, work progress reporting and monitoring.
- *Finance Officer* to process all payments, keep proper accounts, process budgetary allocations and exercise financial control on behalf of the Maintenance Engineer.
- *Administrative Support Staff* such as drivers, secretaries and office assistants.



6.3 Management Activities

All maintenance operations require careful planning, supervision and monitoring. The maintenance management cycle below shows the various steps and their logical sequence necessary for achieving an effective maintenance management system:



The following chapters summarise the main features relating to the various stages in the maintenance management cycle.

6.3.1 Road Inventory

The preparation of a road inventory forms the basis for a road maintenance programme. An inventory should list and describe all features of each individual road. The recorded data form the basic reference for all subsequent inspections and plans.

A well established and maintained system is comprised of two parts:

- a district/area inventory, and
- a road condition inventory.

(i) District/Area Inventory

The area inventory can be a simple road map of the area showing all roads under maintenance. This map should provide information on:

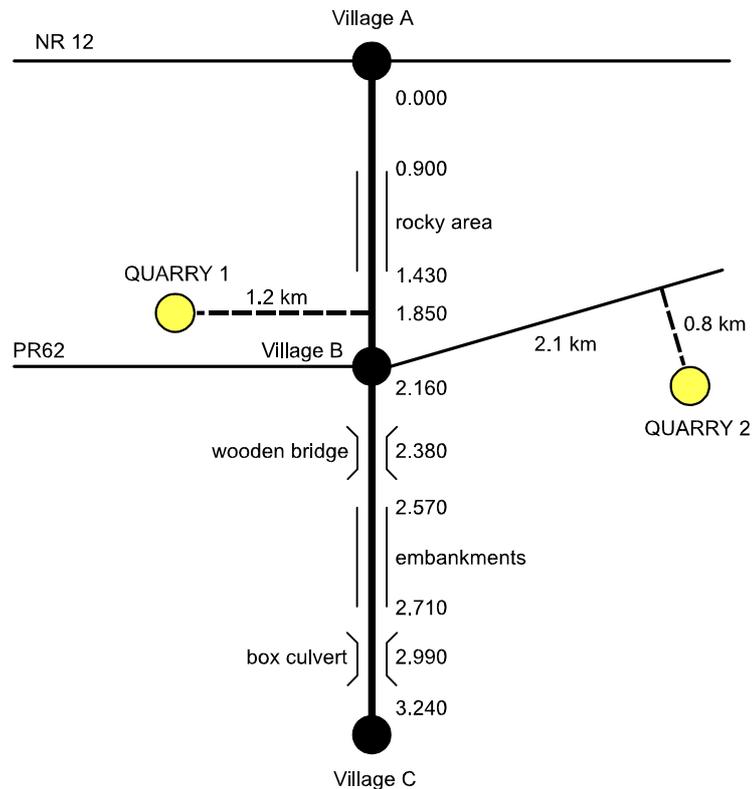
- road classification and category,
- surface types,
- major structures,
- average daily traffic,
- details of maintenance organisation, e.g. location of maintenance camps and division of responsibility.

(ii) Road Condition Inventory

The road condition inventory contains all the details of each individual road in the network. The following items should be recorded:

- | | |
|---|---|
| • Geometry | - alignment - profile - cross-section |
| • Pavement and subgrade characteristics | - soil conditions - gravel or other surface dressing condition |
| • Drainage features | - culverts - drifts - mitre drains - catch water and cut-off drains |
| • Structures | - type - size - location |
| • Junctions | - location - type of connected road |
| • Climate | - rainfall - wind |
| • Traffic | - annual average daily traffic |
| • Maintenance | - details on routine maintenance, i.e. names of petty contractors, - details on rehabilitation and urgent maintenance works, e.g. date, location |

It is helpful to supplement road inventories with simple drawings like *strip maps*. Such diagram maps are useful in the office when preparing the operations plans. It helps the management to see at a glance the whole situation of a particular road.



6.3.2 Assessment of Maintenance Requirements

In order to assess the maintenance needs and to plan maintenance works, it is necessary to carry out regular road condition surveys. Such surveys should be done on a regular basis in advance of the start of the next working season. These surveys form the basis for future work programmes and funding requirements so they need to be carried out well in advance of the next budget approval process.

Road condition surveys enable the road authority to:

- become thoroughly familiar with the road network and its maintenance problems,
- make objective and quantified assessments of the conditions of each road,
- obtain an objective impression of the effectiveness of the existing routine maintenance organisation,
- review periodic maintenance activities carried out since the previous inspection, and
- determine routine and periodic maintenance to be carried out in the next construction season.

Usually, an engineer controls a large road network and with the limited resources and time available, it is necessary to assess the roads in an accurate and time-saving manner as possible. Therefore, it is useful to concentrate on the identification and identification of defects using a few well defined key indicators for the road condition. Such indicators must be defined for each programme, depending on local conditions and requirements. However, there are some features which needs high priority on all roads:

(i) Drainage

Drainage is undoubtedly the most important feature of any road. If this component of the road fails, serious damage will occur on the remaining parts of the road. Indicators for the drainage condition can be defined as follows:

| Item | Indicator |
|--------------------------------|---|
| Culvert/drift | <ul style="list-style-type: none"> • degree of silting-up/blockage • degree of functionality (correct dimensions) |
| Side drains and mitre drains | <ul style="list-style-type: none"> • degree of silting-up/blockage • degree of erosion |
| Catch-water and cut-off drains | <ul style="list-style-type: none"> • degree of silting-up/blockage • degree of erosion • degree of functional length |

To ease inspection works, the degree of silting/blockage can be described using simple measurements, e.g. fully blocked - half silted - correct size - eroded. Such assessments allows the repair work required to be quantified and costed.

(ii) Running Surface

The most important feature of the running surface it the cross-fall. The lack of cross-fall on the road carriage way will prevent rainwater from running off the road and lead to accelerated deterioration of the road surface. For the user of the road, the smoothness of the running surface is the most important feature.

Earth and gravel roads require a continuous surface maintenance. Simple indicators for the running surface of gravel roads can be defined as follows:

| Surface | Indicator |
|------------|---|
| Cross-fall | <ul style="list-style-type: none"> • degree of cross-fall (slope gradient) |
| Condition | <ul style="list-style-type: none"> • length of road section affected by potholes or ruts • length of road section affected by corrugation • thickness of gravel layer • condition of gravel |

The loss of gravel can be measured by digging small holes in the road surface until the subgrade is reached. Measurements should be made at regular intervals along the road at the centre line, in the wheel ruts and at the road shoulders.

(ii) Structures

Inspections of structures should not only be carried out to assess their general appearance. Thorough inspection implies checking all elements of a structure. Elements which are not visible are usually the most important, such as foundations, beams and bearings. The table below provides a check-list of items which needs to be inspected on various structure elements:

| Element | Defect | Effect | Defect |
|---------------------|---|----------------------|---|
| Foundation | <ul style="list-style-type: none"> • cracks • erosion along and underneath | Beams | <ul style="list-style-type: none"> • cracks • bends • corrosion • rotting |
| Head and wing walls | <ul style="list-style-type: none"> • cracks • erosion behind walls • blocked seepage holes | Waterway | <ul style="list-style-type: none"> • vegetation growth • deposits of sand, silt or organic debris |
| Abutments, piers | <ul style="list-style-type: none"> • cracks • erosion behind abutment • blocked drainage | Road furniture | <ul style="list-style-type: none"> • damaged • missing • faded paint |
| Culverts | <ul style="list-style-type: none"> • blocked or silted • cracks • uneven settlement | Banks | <ul style="list-style-type: none"> • eroded |
| Decking | <ul style="list-style-type: none"> • cracks • deflection • cleanliness • drainage | Hand and guard rails | <ul style="list-style-type: none"> • damaged • missing |
| Approaches | <ul style="list-style-type: none"> • drainage • visibility • settlement | | |

6.3.3 Setting Priorities

Usually, the financial resources available are not sufficient to carry out all the maintenance activities identified during the road condition survey. It is therefore necessary to set priorities for what maintenance activities and which road sections are most important.

First priority is usually given to urgent maintenance activities (i) to ensure that the road network remains passable and basic access is provided and (ii) to limit the extent

of damages exerted to a road section. Critical elements of the drainage system, such as culverts and drains need particular attention and first priority should be given to the removal of obstacles which block the water passage away from the road. Small erosion channels must be repaired before the next rains can deepen and widen them. Both these tasks require regular inspection. Lowest priority should generally be given to those tasks which require significant inputs and produce limited results in terms of prolonging the lifetime of the road (i.e. grass cutting and bush clearing).

For each maintenance operation (routine, periodic and urgent) priority lists must be established. They may differ from area to area according to the prevailing conditions.

When priorities are set, the climatic conditions must be considered. For example, grass cutting during the rainy season does not make sense when at the same time the ditches and culverts are left un-touched and are becoming seriously silted.

The following table provides a list of priorities for routine maintenance according to the climatic seasons:

| Season | Priority | Description |
|--------------|----------|---|
| Before rains | 1 | • clean culverts and drifts |
| | 2 | • clean mitre drains |
| | 3 | • clean side drains |
| | 4 | • repair side drain erosion and scour checks |
| During rains | 1 | • inspect and remove obstacles |
| | 2 | • clean culvert and drifts |
| | 3 | • clean mitre drains |
| | 4 | • clean side drains |
| | 5 | • repair side drain erosion and scour checks |
| End of rains | 1 | • repair erosion on shoulders, on back slopes and in drains |
| | 2 | • reinstate scour checks |
| | 3 | • reshape carriage way |
| | 4 | • fill potholes and ruts in carriage way |
| | 5 | • cut grass |
| Dry season | 1 | • repair structures |
| | 2 | • reshape carriage way |
| | 3 | • clear bush |

From the above table it is clear that the most important routine maintenance activities throughout the year is to keep the drainage system in good running order - any other activity is of secondary importance.

This also applies to periodic maintenance as can be seen from the table below:

| Priority | Description |
|----------|---|
| 1 | <ul style="list-style-type: none"> rehabilitation of structures installation of new culverts reconstruction of existing culverts at new levels |
| 2 | <ul style="list-style-type: none"> providing gravel stacks for use in routine maintenance |
| 3 | <ul style="list-style-type: none"> rehabilitation of road section heavy reshaping by dragging, brushing or grading |
| 4 | <ul style="list-style-type: none"> reshaping of road prior to regravelling regravelling/resealing of entire road spot improvement |

Urgent maintenance work require immediate action. Priority should be given to those activities which make the road (even partially) passable. For example, a broken culvert may disrupt the whole road while a landslide only covers part of the carriageway, allowing the traffic to still pass the affected section.

6.3.4 Planning Maintenance Works

For road maintenance, as for all other works activities, it is always advantageous to prepare a work plan. There are two major types of road maintenance plans, long-term and short-terms plans.

The long term plans that are important are the general routine maintenance and the periodic maintenance plans. Long term maintenance plans are established by the road authority. The road authority should know the current maintenance requirements and would know what resources are available over a longer period of time. Based on data from the road condition surveys, it is possible to forecast and plan the works according to the demand for maintenance and resources available.

Example

An assessment shows that the existing gravel layer of a certain road is presently on average 5cm thick, while the thickness of the layer when the road was gravelled 5 years ago was 15cm. Based on that, the road authority assumes that the yearly gravel loss is about 2cm. So if nothing is done, the road will have completely lost its gravel surface within 2 - 3 years. It is then decided that the road should not be left to deteriorate completely, so regravelling is programmed for the following year, or at the latest, two years from now.

Short term plans are the operational plans which are prepared prior to the execution of any specific works carried out on a road section. The basis for these plans would normally be more detailed inspection of the road condition, thereby ensuring that the assessment of work requirements are accurate, and that deviations from the work plan would be minor during work implementation.

For routine maintenance works, short term planning may cover a period of say two to three weeks covering each individual road section for which a worker or group of workers has been assigned to. For periodic maintenance, which normally cover larger amounts of work, the road authority would prepare plans similar to construction and rehabilitation works, including bill of quantities, time charts and detailed specifications of work methods and quality standards.

6.3.5 Implementation

(i) General

The quality standards to be achieved when maintaining roads are basically the same as for road construction works. Therefore, the maintenance staff must be aware of these standards and the work methods used to achieve them.

For the implementation of labour-based routine maintenance, different organisation methods are possible:

- *the lengthman system:* a worker is assigned to carry out all routine maintenance activities over a specific length of the road and throughout the year. He/she is solely responsible for his/her section and carries out all work as instructed.
- *the gang system:* a number of workers carry out all activities as a group, covering a longer road section. They are together responsible for the road section and are guided by a headmen/gangleader.
- another possibility is to have the lengthmen or a group of people working only once or twice a year (for example before and after the rainy season) to carry out all necessary activities in one go. After works have been completed their employment is terminated, and must be re-employed before the next period.

(iii) Work Activities and Task Rates

Routine maintenance

Routine maintenance of low traffic rural roads is a widely dispersed activity, requiring small resource inputs over a large number of widely separated points. This activity is best suited for manual labour. The amount of work needed to keep a length of road in good condition depends on several factors, such as type of road surface, traffic volume (number, type and size of vehicles), the severity of climatic conditions, especially rain fall, type of soil; the susceptibility of the terrain and road gradients to erosion, and the presence of bush and vegetation.

Under average conditions, one full time worker should be able to cover the routine maintenance works each year of 1 - 2 km of single lane gravel road, with traffic of about 25 - 75 vehicles per day (ref. table below). This activity can be most economically performed by persons living along the roads contracted for road maintenance. Local

workers are also under social pressure from their neighbours to do the job well. Former road construction workers are ideal maintenance workers, because they already have some training and experience in the work involved.

| R1: Inspection 1.5 km/day | | PRODUCTIVITY GUIDELINES FOR ROUTINE MAINTENANCE | | | | |
|-----------------------------------|-----------------|--|--------------------------------|----------------|----------------|--|
| ACTIVITY | Unit | TASK DIFFICULTY | | | | NOTES |
| | | 1 | 2 | 3 | 4 | |
| R2A: Clean Culverts + Inlets | As shown | 4 Culverts/day | 1 Culvert/day | 2 Days/Culvert | 4 Days/Culvert | Difficulty = Silt depth in culvert 1. Up to ¼, 2. ¼ to ½, 3. ½ to ¾, 4. Over ¾ Tasks for 600 dia.culverts with 7 rings |
| R2B: Clean Culvert Outfalls | m/day | 55 | 40 | 25 | | Difficulty = Silt depth 1. Up to 10cm 2. 10 to 20cm 3. Over 20cm |
| R3: Repair Culvert Headwalls | No/day | 7 | 4 | | | Difficulty = Type of repair 1. Minor repairs 2. Major repairs |
| R4: Clean Mitre Drains | m/day | 60 | 45 | 30 | | Difficulty = Silt depth 1. Up to 20cm 2. 10 to 15cm 3. Over 15cm |
| R5: Clean Side Drains | m/day | wet areas 65 dry soft soil 55 dry hard soil 30 | 45 40 23 | 30 30 18 | | Difficulty = Silt depth 1. Up to 20cm 2. 10 to 15cm 3. Over 15cm |
| R6A: Repair Scour Checks | No/day | 5 | 7 | | | Difficulty = Type of scour check 1. Wood 2. Stone |
| R6B: Repair Side Drain Erosion | m/day | wet areas 100 dry areas 100 | 80 50 | 60 23 | | Difficulty = Depth of Erosion 1. Up to 15cm 2. 15 to 30cm 3. Over 30cm |
| R7A: Repair Shoulder Erosion | m/day | 100 | 80 | 65 | | Difficulty = Depth of Erosion 1. Up to 10cm 2. 10 to 15cm 3. Over 15cm |
| R7B: Grass Planting | m/day | 100 | 80 | 65 | | Difficulty = Planting width 1. Up to 0.5m 2. 0.5 to 1.0m 3. Over 1.0m |
| R8A: Fill Potholes in Carriageway | wheel-brws/ day | 25 | 18 | 13 | 8 | Difficulty = Hauling Distance 1. No haul 2. Up to 100m 3. 100m to 200m 4. Over 200m |
| R8B: Fill Ruts in Carriageway | m/day | wet areas 70 dry areas 50 | 50 30 | 35 15 | 15 7 | Difficulty = Hauling Distance 1. No haul 2. Up to 100m 3. 100m to 200m 4. Over 200m |
| R9A: Grub Edge of Carriageway | m/day | wet areas 270 dry areas 190 | 200 120 | 130 70 | | Difficulty = Width of grubbing 1. Up to 0.5m 2. 0.5 to 1.0m 3. Over 1.0m |
| R9B: * Reshape Carriageway | m/day | 70 | 50 | | | Difficulty = Type of reshaping 1. Light (Up to 75mm) 2. Heavy (over 75mm) |
| R10: Cut Grass | Light | m/day | wet areas 425 dry areas 310 | 260 230 | 190 170 | Difficulty = Width of grass cutting 1. Up to 1.0m 2. 1.0 to 2.0m 3. Over 2.0m |
| | Dense | m/day | 310 | 240 | 175 | |
| R11: Clear Bush | Light | m/day | 425 | 260 | 190 | Difficulty = Width of bush 1. Up to 1.0m 2. 1.0 to 2.0m 3. Over 2.0m |
| | Dense | m/day | 275 | 225 | 175 | |

* All tasks except reshaping are measured along one side of the road only.

Source: Minor Roads Programme, Kenya

Periodic Maintenance

Periodic road maintenance works involve activities such as reshaping of the road surface, re-gravelling and repair or reconstruction of damaged drainage structures. Such works could be organised the same way as rehabilitation and new construction works under a by force account or contract works carried out by small-scale private contractors (with a limited amount of equipment).

Task rates for such works would be calculated and organised in the same way as road construction works.

(iii) Tools for Maintenance Works

Periodic Maintenance

The main activities defined as periodic maintenance consists of major repairs on drainage systems, rehabilitation of road camber and regravelling. As can be seen, these work activities are quite similar to rehabilitation and new construction works, so, depending on the magnitude of the road deterioration, periodic maintenance works would require the same type of tools as prescribed for construction works.

Routine Maintenance

Required tools and equipment for routine maintenance consist of (i) tools for the lengthman and (ii) inspection transport for the road authorities.

Tools for the lengthman consist of the following items:



- hoe
- sharpening file
- spade
- bush knife
- shovel
- wheelbarrow
- pickaxe
- hand rammer
- spreader

A major item in a routine maintenance setup is the regular inspection and supervision of the lengthmen as well as the timely payment of the works. To carry out these activities successfully, the road authorities must possess proper means to travel along the roads and meet with the lengthmen and/or lengthman contractors. Depending on the length of travel, supervision personnel needs to be equipped with bicycles, motorcycles or inspection cars.

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