Pemerintah Daerah
Kabupaten Malang

International
Labour
Organization

MANAGEMENT OF RURAL ROADS IN INDONESIA USING A PARTICIPATORY MODEL

TECHNICAL GUIDELINES
FOR SUPERVISORS

Labour-Based Rural Road Construction under the
Community-Government Partnership Program in Malang Regency

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This manual was produced with funding from the ILO Job Opportunities for Youth Project (JOY), following a request from the Public Works Department of Malang Regency to provide guidelines to supervisors involved in rural roads development under the Government and Community Partnership Program in Malang Regency.

The guidelines have been compiled using material from various sources, including existing technical manuals and guidelines from the ILO and other organizations. Relevant reference materials available with ILO projects in Indonesia and other countries has also been used in the preparation of this compilation. Annex 1 provides and overview of the various reference manuals and guidelines that have been used in developing the manual.

The authors would also like to express their appreciation to the Government of Malang and its Public Works Department for their active interest, cooperation and support in the preparation of the manual. The valuable comments and feedback received from the staff of the Public Works Department in Malang has also been very valuable in finalizing the contents of the manual.

Without the support by the ILO Jakarta Office and the staff of the ILO JOY Project it would not have been possible to publish this guideline and the authors are grateful for their commitment and support in coordinating and facilitating activities required for the publication of the manual.

A special thanks goes to the community-based supervisors in the Malang Regency who provided valuable feedback and suggestions during the meetings and workshops that were organized in the process of defining the actual needs of this intended group of end-users of the manual.

Bagus Mudiantoro and Bas Athmer
Consultants

April 2010

Foreword

It is my great pleasure to introduce the manual **"Community Road Development in Indonesia Using Labour-Based Methods"** that has been prepared in close collaboration between the International Labour Organisation (ILO) and the Government of Malang Regency, East Java Province, Indonesia. This manual has been prepared for supervisors who are involved in the construction of community roads under the "Gotong Royong" Partnership Program between the Communities and the Government of Malang Regency.

Malang Regency is one of 38 districts in East Java Province. With a population of about 2.7 million people it is the second-most populated District in the Province. It is also the second largest District in East Java Province; its total area is around 3,535 km2. Considering its very large population and area, the provision and maintenance of adequate productive and public infrastructure, in particular roads, poses a formidable challenge. The total road network in Malang Regency includes 115 km of national roads, 119 km of provincial roads, 1,603 km of district roads and 4,509 km of rural village roads. In particular for the rural roads there is a large investment gap in the Regional Budget (APBD) of around 50% to meet the requirements. It is estimated that an additional 4,491 km of rural village roads need to be constructed and/or improved to fulfill the local demands and priorities.

Within this context and inspired by the traditional spirit of mutual cooperation and community participation, called Gotong Royong, The Government Administration initiated in 2003 activities with communities to explore the possibilities of engaging in a partnership to give a boost to community-based infrastructure development. The communities expressed their enthusiasm and keen interest in the proposed cooperation and the outcome of the deliberations and consultations between the communities and the Malang Govenrment was the launch of the Community – Government Partnership Program in 2003.

An important element of the Partnership Program is the active cooperation and participation of the involved Government parties and communities alike. Through a program of regular village visits and consultations (sambang desa) by the Regent of Malang and the Heads of Units (SKPD), the communities in local (and remote) villages and hamlets were able to identify and express their real demands and priorities regarding road development. This activity is an important step in the Gotong Royoing process. Other important steps incude socialization and mobilization activities, supervision and the evaluation of the completed works (through project visits – sambang proyek). All activities are being carried out through a participatory process.

For identified and agreed activities, the Government and the communities enter into an agreement that outlines the co-financing and management arragments. Community contributions are usually made in labour, land and in providing local construction materials. Sometimes cash contributions are also made.

As a result of the Gotong Royong Partnership Program 2,398 km of new roads were constructed from 2003-2009, with a value of about Rupiah 255 billion (of which Rupiah 176 billion, or 69%, contributed by the communities). Through this approach it has been possible increase rural road accessbiility to 77% of the demand. Before the start of the Gotong Royong Partnerhsip Program only 50% of the rural communities had road accessibility.

Apart from the improvements in road accessibility, the Partnership Program brough about intangible, but extremely valuable and important, benefits as well. The Regency has witnessed a resurgence of the spirit of mutual cooperation since the launch of the Gotong Royong Program. This traditional form of cooperation and partnership had dissappeard already for several decades but has been reinstated again due to the Partnership Program and the communities demonstrate a high degree of commitment and responsibility in the implementation of the Gotong Royong Partnership Program.

An indication of the commitment of the local communities to participate in the Gotong Royong Partnership Program is also reflected in the fact that communities' contributions have gradually increased over the last 7 years. At the moment the communities contribute about 70% of the total investment costs. It should be noted that the Program is not exclusively targeting rural road development. It also includes investments in other sectors like irrigaiton and the construction or improvement of public building.

The assistance provided by the ILO - through the **"Job Opportunities for Youth Project"** - in making the development and publication of this manual possible, is highly appreciated. ILO's assistance reflects its recognition of the scope for participatory community-based rural infrastructure development through the Partnership Program in Malang and this is very encouraging for the Government and the people of Malang. Through this manual, the Government of Malang and its people hope that the quality of the road development works will further increase, thereby optimizing the return to the investments made by the communities and the Government of Malang. At the same time it is envisaged that the manual will provide opportunties for local supervisiors to enhance their skils, thereby improving their employability.

Finally I would like to express the hope that the positive experiences with the participatory approaches adapted under the Malang Gotong Royong Partnership Program can be replicated in other parts of Indonesia or in other countries.

Our development vision for our Regency is for it to become a Safe, Prosperous, Forward and Fair Malang. I wish you welcome to Malang Regency.

Sujud Pribadi
Regent of Malang

Preface

Rural roads are considered of key importance in triggering and facilitating local economic development. They provide access to economic and social facilities and services like markets, financial institutions, and government service providers, suppliers of agricultural inputs, schools and health services. A good rural road network also improves mobility and allows for a cost-effective movement of people and goods. All over the world the benefits of a good rural road network on local economic development have been demonstrated. With the key emphasis of the ILO's Job Opportunities for Youth (JOY) Project on Local Economic Development (LED), the importance of the development and maintenance of the rural road network in the context of facilitating and contributing to local economic has been recognized by the Malang Government Authorities and the ILO alike.

Under the dynamic leadership of the Regent of Malang District, a Government – Community Partnership is being implemented that focuses on the improvement and maintenance of local infrastructure. The emphasis of this program is on local community roads. The program is being implemented in Malang District since 2003 and is based on the traditional Gotong Royong (Self-Help) concept. Through the Program, the local communities and the Government cooperate in the development of local infrastructure. The communities provide voluntary contributions, mainly in the form of labour, whereas the responsible Government line agency, the Roads Department of the Ministry of Public Works (Bina Marga) provides financial resources and technical expertise.

Although the Government – Community Partnership Program has already made impressive progress over the last seven years, the need to further improve the quality of the works, aiming at maximizing the return on the investments, was realized. To address this issue, the Office of Public Works in Malang and the ILO JOY Project agreed that it would be very useful to develop a technical manual for the supervisors who are involved in the rural road development and maintenance activities under the Partnership Program. Supervisors play a crucial role in the implementation of construction activities and it is widely recognized that the quality of the works is directly related to the quality of the supervision.

The current manual is the outcome of various assessments, discussions, consultations and workshops that have been organized during the last year. Considering the nature of the Gotong Royong initiative in Malang and the employment objectives of the Malang Government, it was agreed that the emphasis in the manual should be on the use of labour-based approaches and technologies. These approaches and technologies are very suitable for the type of road works that are typically undertaken under the Malang Partnership Program. The fruitful and constructive cooperation between the Office of Public Works in Malang and the ILO JOY Project has resulted in the current manual. The aim of the manual is to provide the supervisors with a tool that will enable them to further improve the quality of the road works, thereby optimizing the return to the investments, and eventually also facilitating local economic development.

Through the continuous development of a knowledge and skill based among the supervisors and the labourers involved in the construction activities, it is also believed that this will improve the employability of the involved supervisors and labourers. Evidence in similar projects indicates indeed that labourers and supervisors will find it easier to find employment in the private construction industry once their skills and knowledge have increased.

April 2010

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Abbreviation

BoQ: Bill of Quantity

DBM: Dry Bound Macadam

DBST: Double Bituminous Surface Treatment

DFL: Design Flood Level

HFL: High Flood Level

ILO: International Labour Organization

JOY: Job Opportunities for Youth

LB: Labour-based

LED: Local Economic Development

O&M: Operation and Maintenance

Rp: Rupiah

PW: Public Works

PWD: Public Works Department

SBST: Single Bituminous Surface Treatment

SNI: Standar Nasional Indonesia

USD: United States Dollars

Chapter 1

Introduction

ILO's Program Job Opportunities for Youth (JOY) in East Java seeks to improve employment opportunities for youth. Its objective is to create income earning opportunities for young women and men in Indonesia, through complementing national policies and local initiatives that lead to more employment intensive growth.

One component of the program, the Local Economic Development component (LED) seeks to identify and maximize the economic potentials of the two districts where the project is implemented. Within its scope of activities and as per the project document, the LED process includes the promotion of employment intensive (also referred to as labour-based) infrastructure investments.

Through JOY, the ILO provided technical assistance in March-April 2009 to the local government and the Public Works Department of Malang in enhancing their understanding and capacities about the application of labour-based (LB) methodologies for simple and small community-level infrastructure development.

This was done through the delivery of basic orientation and training course on the application of LB approaches and technologies within the context of the Gotong Royong initiative in Malang. The training was delivered to technical staff of the district Public Works Department (PWD), community supervisors and key Government staff of the District and selected sub-Districts.

The objective of the Gotong Royong initiative in Malang is to make an optimum use of locally available labour and materials and to accelerate village infrastructure development. The initiative, that started in 2003 and applies labour-based methods, also aims at revitalizing the currently fading Gotong Royong spirit among the Indonesian people. Communities, through the village administration, can request the Malang Kabupaten for a Gotong Royong partnership project, under the condition that the community is ready to provide local materials, labour and the land necessary to undertake the proposed initiative.

Activities under the Gotong Royong initiative are implemented in various sectors, with the majority of efforts directed to the improvement of rural roads. Until 2009, the PWD in Malang had channeled about 80 billion Rupiah (about 8 million USD) to finance partnership program between communities and the district government to develop rural infrastructure. The partnership program has covered 1,141 villages throughout the Malang Regency. The total community contribution under the partnership program is about 176 billion rupiah (17.6 million USD) and the total cost of all implemented projects is almost 256 billion Rupiah (25.6 million USD).

Following the initial support provided by the ILO JOY Project in 2009, the PWD Malang has requested ILO to provide follow-up support. The particular request was to provide assistance in developing a practical technical manual covering the various design and implementation aspects of rural road development, using labour-based approaches and technologies. Intended users include District-level PW supervisors and community-based supervisors involved in the construction, rehabilitation and maintenance of low volume rural road infrastructure.

The PW Department in Malang had already prepared a first working draft and requested the JOY Project to review this manual and provide technical assistance to improve its quality. The outcome of the technical assistance provided through the ILO JOY project is the current manual.

The purpose of the current guideline is to provide technical guidance to community-based supervisors and PWD supervisors in the design, construction, rehabilitation and maintenance of low-volume rural roads that are implemented under the Gotong Royong initiative. The guide can also be used by professional PWD trainers to provide training to supervisors.

Skilled and knowledgeable supervisors are KEY in ensuring that projects are being constructed as per required design standards and specifications. This manual aims at providing supervisors with the skills and knowledge required for the effective supervision of rural roads development and maintenance works. This will ensure an optimum return to the investments made and a maximum life-time of the constructed infrastructure assets.

The scope of this manual is to provide supervisors with guidelines that will enable them to check whether basic conditions and requirements of rural road design, construction and maintenance are being adhered to. Depending on the scope of work, the design and construction of rural roads may include complex engineering work. This means that the availability of sufficient adequate engineering capacity will be required. Without such professional engineering inputs it will not be possible to ensure quality control in the design, construction and maintenance of rural roads and this will negatively affect the quality, durability and thus the life-time of the created infrastructure assets.

Experiences with community-based local infrastructure development initiatives indicate that adequate engineering inputs are required for the design and construction of more complex work.. Normally the involvement of the local communities is limited to operations like clearing and earthwork moving operations. It is therefore extremely important that professional inputs are secured for more complex operations like sealing of the road surface and the construction of bridges, culverts and other drainage structures and retaining walls. The current manual covers a wide range of aspects related to the design and construction of rural roads. The introduction of these aspects will enable the supervisors to understand the complexity of certain operations and the need to secure professional expertise.

The manual lends itself very well to be used as a guide for trainers who are involved in the training of supervisors. Various illustrations and photos are included that facilitate the use of the manual. The workshops that were conducted for community-based supervisors revealed that the supervisors indeed require extensive training to enable them to carry out supervision in an effective way.

Gotong Royong Initiative in Malang

Chapter

2

The Malang Regency Partnership Program, also called the Gotong Royong Initiative is implemented in Malang Regency in East Java Province of Indonesia. Local communities and responsible line agencies like the Department of Public Works (Bina Marga) are actively involved in this Partnership Program in which they are working together.

The Malang Partnership Program is an innovative initiative that has attracted a lot of interest from the local communities who have demonstrated their willingness and readiness over the last seven years to participate pro-actively in the program. The program aims at developing and improving local infrastructure and builds on the traditional Gotong Royong system of providing mutual assistance. Under Gotong Royong communities undertake voluntary work or provide in-kind contributions or land for activities that contribute to the development of public infrastructure in the community.

The main emphasis of the Partnership Program in Malang is on the development, improvement and maintenance of community infrastructure, with a special emphasis on low-volume roads. Various projects like PNPM Mandiri IP and PNPM Mandiri Perdesaan participate in the initiative.

Programs like the Government Partnership Program in Malang can be very effective for the development, improvement and maintenance of small and simple community-level infrastructure like low-volume rural roads. This is particularly the case if the local communities are willing to provide self-help labour and other voluntary inputs on a sustainable basis to address local development constraints that they consider priorities.

Another condition is the need to have a sufficient large reservoir of available labour. Strong social cohesion, active support from local leaders, a local sense of ownership and a pro-active attitude among communities are also important factors that increase the chance of success.

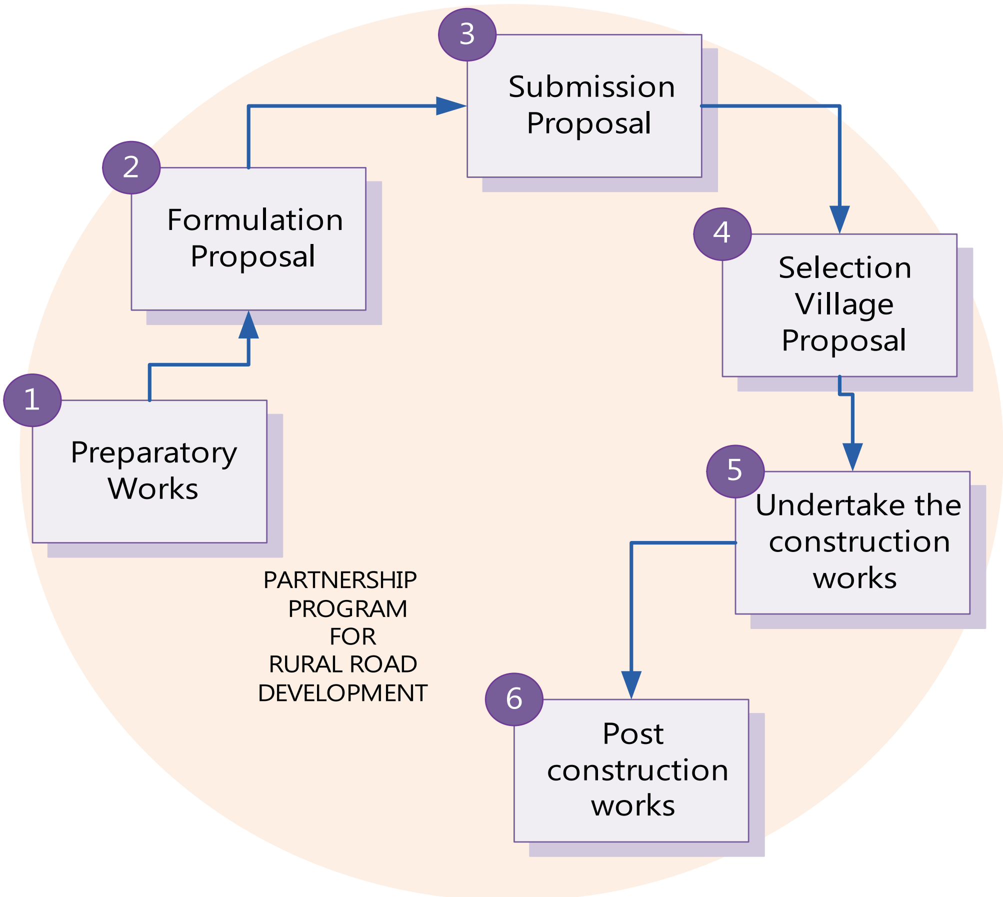
It appears that all above conditions are met within the Malang Partnership Program and the program could possible by considered at some stage for duplication in other parts of Indonesia. What needs to be given more attention however is an improvement of the quality of the work. The current shortcomings in this respect have been recognized by the PWD of Malang and that is the reason why the current manual has been developed.

The manual aims to provide the supervisors of PWD and of the Community Development Committee with guidelines that will assist them in maintaining the required quality standards for relatively small and simple infrastructure. These works should be within the (potential) capacity of the local communities. Depending on the types of work to be undertaken, technical support from the PWD may be required. Considering the scope of work undertaken and the local conditions, the guideline promotes the use of labour-based approaches and technologies. Such approaches require a particular organization and management of the labour-force and these aspects are also included in the manual.

The philosophy of the Malang Partnership Program is that the communities become the main actors of development. They are involved throughout the project cycle, i.e. from planning and programming to implementation and maintenance.

Six steps can be distinguished in the implementation of the Partnership Program. These are shown in figure 1.

Figure 1: Steps in Implementation of Partnership Program



1 **Preparatory Works:** The Community with guidance from the Village Head, establishes a Village Development Commitee (PPD). The PPD will be responsible for the development planning of the village. The PPD formulates the priority development activities to improve the condition in the village, especially in term of infrastructure requirements.

2 **Formulation of Proposal:** The PPD prepares the simple proposal for the village development plan. The Partnership Program requires a community contribution

in cash of at east 40% of the total cost of the proposed project. That pre-condition is a key criteria for PWD to decide whether the project proposal will be approved. Another key criteria for PWD is the availability of sufficient funds under its local annual budget to provide the Government contribution. If these conditions are met, PWD will invite the PPD to complete and submit the proposal.

3 **Submission Proposal:** The PPD, through the Village Head, submits the partnership proposal to the Bina Marga Rural Road Facilitation Section of PWD at District level. An example of the format used for the submission of proposals is presented in Annex 1.

4 **Selection Village Proposal:** After PWD has verified that the requesting community will provide the required community contribution, PWD will check the design, specifications and cost-estimates of the submitted proposals. If the proposal complies with the district budget standards for rural roads, PWD will verify whether sufficient funds are available in the District Annual Budget (APBD). If this is the case the next step takes place.

5 **The Construction Phase:** PWD and the PPD will enter into a Partnership Agreement once the proposed project has been approved. In principle the PPD will be responsible for undertaking and managing the civil works. During the construction phase, the PWD will supervise the activities regularly and provide necessary technical support through the responsible PWD staff at sub district level (Kecamatan).

6 **Post Construction Phase:** After the construction phase, the community is responsible for the maintenance of the infrastructures. The community has to finance the maintenance operations and has to decide on how to finance and organize the maintenance. The PPD can for example facilitate the establishment of a village Operation and Maintenance Committee (KPP) and provide support in the formulation of O&M plans.

Surveys, Designs and Cost Estimates

Chapter

3

3.1 Surveys

Survey activities

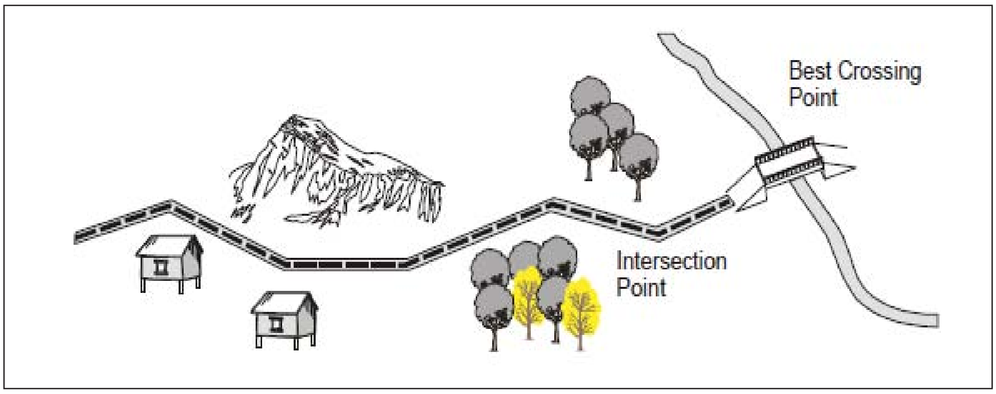
Survey Activities include the following:

1. Preliminary rough topographical survey to select the best alignment;
2. Survey of catchment area to determine the need for bridges and culverts;
3. Check adequacy of (sub-)soils, quarry materials and other local materials;
4. Detailed survey to determine design and to estimate work quantities.

General survey guidelines

General Survey Guidelines are summarized below:

- The selection of the correct alignment is the most import part of the design, especially for new roads. If the wrong alignment is chosen, this may lead to very high costs, erosion and technical construction problems.
- Try to avoid alignments with drainage problems or that require excessive (earth) work.
- Check whether there are issues related to land acquisition.
- Identify locations along the road where bridges and culverts will be required to ensure a safe passage of water away from the road;
- Check which constructions materials are locally available. The availability of local construction materials may be a factor in deciding on the preferred design option.



Specific survey guidelines

Specific Survey Guidelines are listed below:

- Plan the alignment route that minimizes material movement;
- Follow contour lines in mountainous terrain as much as possible;
- Plan the alignment to avoid numerous or large river crossings;
- Select crossings where bridge construction will be simple;
- When shallow watercourses cross the road, check if it is possible to construct a "submerged bridge" with culverts, fords, or paved causeways;
- Consider the proximity of suitable road materials when choosing the route;
- Avoid rocky areas and areas with heavy bush clearing;
- Locate the alignment so as to allow for future upgrading;
- Plan sufficient passing places for vehicles. These passing places should be visible from both sides;
- If possible, clear trees up to a distance back from the road equal to the height of the trees;
- Avoid two curves with a short straight in between. It is better to combine them into one long curve;
- Avoid building road sections that will be likely to be damaged in the future and will cause maintenance problems;
- 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 12%.
- Allow for adequate drainage and design drainage ditches wide and shallow.
- Keep the existing farming activities in the area in mind when selecting a design. Avoid designs that may trigger soil erosion;
- Decide on the most appropriate road surfacing option. Keep in mind technical feasibility, traffic requirements, terrain and climate conditions, the condition of the existing road, the availability of local materials, costs and user preferences.

During the preliminary survey record information about the envisaged work. This will make it easier during the detailed survey in specifying the details of the works to be carried out. An illustrative example of a form that can be used is shown in table 1. Depending on the particular works, more work items may have to be added or some of the work items as shown in the example below may not be required.

Table 1: Example of Preliminary Road Works Inventory Record

During the preliminary survey record information of work to be done

Road name									
District									
Sub-District									
Inventory done by:					Date:				
Works			Chainage (meter)						
			0-100	100-200	200-300	300-400	400-500	500-600	etc
1	Clearing	Left							
		Right							
2	Base reconstruction								
3	Base repair								
4	Earthwork cut								
5	Earthwork fill								
6	Construction embankment								
7	Side drains	Left							
		Right							
8	Mitre drains	Left	At 25m		At 225m		At 400m		
		Right							
9	Culvert	Location		At 150m		At 330m	At 400m		
		diameter		600mm		600mm	600mm		
10	Drift	Location			At 245m				
		Length			10m				
11	Bridge	Location				At 390m			
		Length				8m			
12	Etc.								

3.2 Design

Steps in the design process

Steps in the design process include the following:

1. Establish the type of road (e.g. district road, rural road, urban road);
2. Assess the traffic requirements;
3. Assess other factors that affect the design choice (like terrain, type of soils and their strength, availability and cost of construction materials, etc.);
4. Select geometric design standards (like road cross-section, design speed);
5. Select appropriate pavement design;
6. Assess the need for road structures (bridges, culverts, retaining walls, etc);
7. Assess the availability of labour and their skills;

In mountainous areas it is often not practical or too expensive to maintain high design standards like small numbers of curves or soft road gradients, as this would involve considerable earth movement and lead to very high costs.

Table 2 provides an illustrative example of design items for which design specifications are needed. These are normally provided by technical line ministries like the Public Works Department.

Items for which design specifications are needed

Table 2: Design Items for which Specifications are to be Provided by Public Works

Horizontal and Vertical Alignment ◆ Maximum grade ◆ Minimum horizontal radius ◆ Minimum vertical curvature ◆ Horizontal sight distance	**Horizontal and Vertical Alignment** ◆ Maximum grade ◆ Minimum horizontal radius ◆ Minimum vertical curvature ◆ Horizontal sight distance
Materials ◆ Soil or rock types ◆ Compaction and moisture content ◆ Curing requirements ◆ Aggregate gradations ◆ Mix proportions ◆ Strength requirement ◆ Tests to be performed	**Typical Structural Design** ◆ River crossings ◆ Culverts ◆ Drifts ◆ Retaining walls ◆ Bridges ◆ Soil protection measures

3.3 Cost-Estimates

After the design has been finished, the quantities of work can be calculated. Once this has been done, a cost-estimate can be prepared. This is done by multiplying the volume for a work item with the unit rate for that item.

The unit rate for an item specifies how much and what inputs are required for that item. Once the amount of work (Bill of Quantities or BoQ) been calculated for a particular item of work, these amounts can be multiplied with their unit rate to get the total cost and the total inputs that are required.

Figure 2: Use of BoQ and Unit Rates to Calculate Costs and Input Requirements

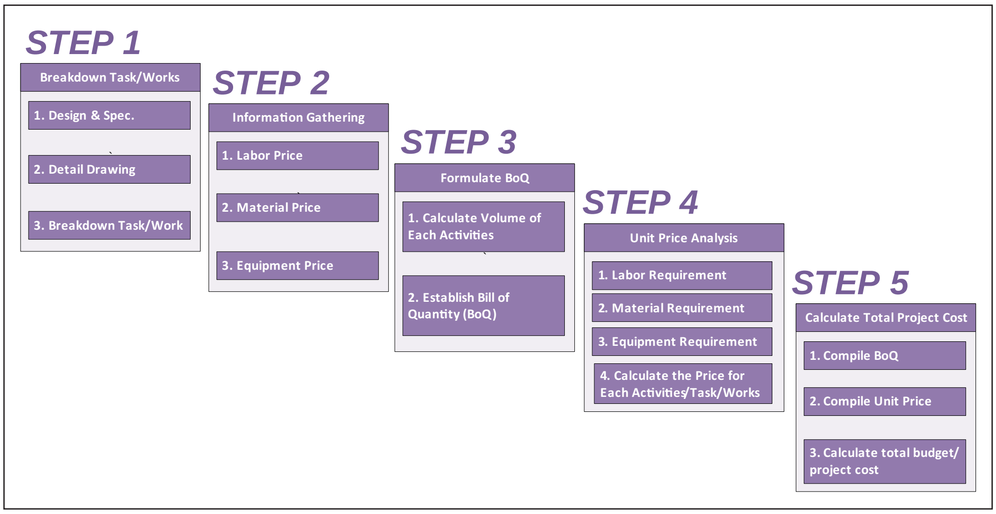
Quantities of work to be done for the different work items X Unit Rates →

- Cost estimate of works
- Labour requirements
- Construction material requirements
- Equipment requirements
- Required tools

The section below outlines, based on an example, how cost estimates (budgets) and input requirements can be calculated. Costs include the costs of materials, labour, equipment, tools and other inputs required for the construction works (and possibly also for preparatory works). As prices for labour, materials, equipment (rental) and other inputs may differ from region to region, the costs for one unit of a particular work item may vary between different regions.

In the preparation of the budget, five steps have to be followed. These steps are summarized in figure 3 and are described below.

Figure 3: Steps in the Preparation of Budgets



Step 1: Preparatory activities include the collection of information regarding the design and specifications, the engineering drawings and the breakdown of the construction works into the specific items of work and their task. With this information it will be possible to identify the different items of works that have to be implemented and the volumes of work for each of these work items. Annex 2 provides information on how to calculate areas, volumes and weight of commonly used construction materials. A number of examples are also provided in annex 3.

Step 2: Information about costs: Gather information about the costs of materials, labour, equipment and other inputs required for the different works that have to be undertaken. These prices are obtained in the market and provide the so called List of Materials Unit Price and the Wage Unit Price List. In the same way the costs for securing other inputs like for example the hiring costs of equipment can be obtained.

Step 3: Calculate volumes of work: This can be done based on the information listed under step 1. This results in the so called Bill of Quantities (BoQ). The BoQ is normally prepared by the Public Works Department. It includes for each and every of the work items (and their activities) the volumes of inputs that are required.

Step 4: Calculate the unit rates for every item of work: This is done with the information collected under step 2. This procedure is called the unit rate analysis and is normally carried out by the Public Works Department.

Step 5: Calculate the total cost estimate of the works: With the information about the unit rates and the BoQ it is possible to calculate the total costs of the works.

An illustrative example of a completed cost estimate is presented in table 3. This examples shows how the costs for 1 kilometer of Double Bituminous Surface Treatment (DBST) can be calculated. The first column shows the work-norms for labour. This is also called the labour productivity norm. It shows how much work can be done by one labourer in one day.

Example of calculating the cost of 1 km of DBST pavement

Take for example the work item *Site Clearing*. In the example of table 3 it is seen that one labourer can do 60 m2 of clearing in one day. In the example the cost of 1 m^2 of clearing is Rupiah 800. In the example 3,000 m^2 of site clearing is required for 1 km of DBST and the total cost for site clearing is Rupiah 2.4 million. Table 3 also shows that the number of labour-days required for site clearing is 50. The number of labour-days is calculated by dividing the total quantity of work required (i.e. 3,000 m2) by the work norm (or labour productivity) for site clearing (i.e. 60 m^2 per labour-day).

It should be noted that the information presented in table 3 only serves the purpose of giving an example. Actual work norms, quantities of work required and unit costs will vary, depending on the specific requirements.

In Indonesia the Indonesian National Standard (Standar Nasional Indonesia=SNI) for civil works is used to determine labour, material and equipment requirements for construction activities.

Table 3: Illustrative example of calculating a cost estimate for one kilometer of DBST

Activity	Work Norm	Unit	Rate per Unit (Rp)	Unit	Qty (BoQ)	Cost	Labour-days
	(1)	(2)	(3)	(4)	(5)	(6) = (3) x (5)	(7) = (5) / (1)
Labour							
Site Clearing	60.0	m2/day	800	m2	3000	2,400,000	50
Prep. Sub grade incl. Benching	1.5	m3/day	32,000	m3	40	1,280,000	27
Cutting boxes and benches	1.5	m3/day	32,000	m3	160	5,120,000	107
Spread Sub base	5.0	m3/day	9,600	m3	480	4,608,000	96
Spread Shoulder	4.0	m3/day	12,000	m3	260	3,120,000	65
Spread Base course	3.3	m3/day	14,560	m3	840	12,230,400	255
Spread Chips 1st Layer	3.0	m3/day	16,000	m3	60	960,000	20
Application of 1st Coat	100.0	m2/day	480	m2	4000	1,920,000	40
Application of 2nd Coat	100.0	m2/day	480	m2	4000	1,920,000	40
Roller Operator 1 Ton	0.06	km	800,000	km	1	800,000	17
Roller Operator 3 Ton	0.05	km	960,000	km	1	960,000	20
Transport of Material	5.0	m3/day	9,600	m3	500	4,800,000	100
Labour for Struct. - Lump Sum		no	20,000,000	no	3	60,000,000	
Labour Support - Storekeeper, etc.	0.003	day/km	17,280,000	km	1	17,280,000	360
Surveys, Setting Out	0.008	day/km	5,760,000	km	1	5,760,000	120
Supervision							
Engineers	0.033	day/km	6,000,000	km	1	6,000,000	30
Technical Officer	0.017	day/km	6,000,000	km	1	6,000,000	60
Supervisor	0.008	day/km	8,640,000	km	1	8,640,000	120
Tools							
Shovel			30,000	no	5	150,000	
Wheelbarrow			280,000	no	5	1,400,000	
Hoes			95,000	no	6	570,000	
Crowbar			115,000	no	4	460,000	
Pickaxe			80,000	no	6	480,000	
Line Level			35,000	no	2	70,000	
Equipment							
Roller 3 Ton			400,000	day	30	12,000,000	
Roller 1 Ton			250,000	day	30	7,500,000	
Tractor Bowser			300,000	day	40	12,000,000	
Tractor Trailer			300,000	day	40	12,000,000	
Structures							
3 Culverts/ km			16,000,000	no	3	48,000,000	
Material							
Gravel			64,000	m3	700	44,800,000	
Base Course			280,000	m3	840	235,200,000	
Quarry Dust			160,000	m3	30	4,800,000	
Sand			60,000	m3	20	1,200,000	
Bitumen 1st coat			10,000	1 km	7200	72,000,000	
Bitumen 2nd coat			10,000	1 km	4000	40,000,000	
Chips 14.5 mm/ 9.5 mm			500,000	m3	100	50,000,000	
Total						686,428,400	1,526

Let us take another example, using the SNI standards. Suppose that we have to calculate the total costs of 103 of earthwork excavation plus the costs of 2 m^3 of the construction of stone foundation. Table 4 shows how the total cost estimate for these works can be calculated. Table 4 shows that in the presented example the total cost for the construction of 103 of earthwork excavation plus the costs of 2 m^3 of stone foundation is Rupiah 1,659,500. At total of 18 person-days of input is required to complete these works. The work norms presented in table 4 are those that comply with the SNI standards.

Example of calculating the cost of 10 m^3 of earthwork and 2 m^3 of stone foundation

Table 4: Example of calculating the costs of earthworks and stone foundation

		work-norm	unit	wage rate per day (Rp)	Quantity	Unit	Cost (Rp)	Labour-days required
		(1)	(2)	(3)	(4)	(5)	(1) x (3) x (4)	(1) x (4)
1	**Earthwork excavation**							
	Labour							
	Unskilled labour	0.75	person-day per m3	50,000	10	m3	375,000	7.5
	Gang-leader	0.025	person-day per m3	70,000	10	m3	17,500	0.25
2	**Stone foundation**							
	Labour							
	Unskilled labour	3.6	person-day per m3	50,000	2	m3	360,000	7.2
	Gang-leader	0.12	person-day per m3	70,000	2	m3	16,800	0.24
	Skilled labour	1.2	person-day per m3	80,000	2	m3	192,000	2.4
	Foreman	0.18	person-day per m3	80,000	2	m3	28,800	0.36
	Materials			**price per unit material (Rp)**				
	Portland cement	4.1	bags per m3	55,000	2	m3	451,000	
	Stone	1.2	m3 per m3	65,000	2	m3	156,000	
	Sand	0.52	m3 per m3	60,000	2	m3	62,400	
	Total						**1,659,500**	**18**

Tools and Equipment

Chapter

4

4.1 Hand Tools

Hand tool requirements depend on the size of the project, soil types, terrain and the type of works that are planned. Tools that are normally being used are listed in table 5. The table also indicates how much of each of the tools would be required for a workforce of 25 labourers.

Typical hand tool requirements for a labour force of 25 workers

Table 5: Tool Requirements for Typical Labour-based Road Construction

Tool	Use	Quantity
Profile Board and Ranging Rod	Survey, setting out and for measurement	At least 5
30 m and 3/5 m measuring tape	Survey, setting out and for measurement	At least 1 set
Line level, nylon string	Survey, setting out and for measurement	At least 1 set
Hoe, shovel, spades	For all types of earthworks	One per labourer
Pickaxe and crowbar	Excavation in hard materials	Depends on needs
Bush-knife, axe, bow-saw	Clearing and grubbing vegetation	Depends on needs
Rake	Spreading material	At least 5
Wheelbarrow	Transporting materials	5-10
Hand rammers	Compacting difficult accessible small areas	At least 5
Bucket, watering can	Various use, includes watering	Depends on needs
Sledge hammer	Various use, including hammering in pegs	At least 2
Chisel	Various use, e.g. making holes for pegs	At least 2
Pegs	For setting out of work	Depends on needs

Quality tools are needed to produce quality work

Good quality tools increase productivity and the quality of the work. Tools used in agricultural works are often not strong enough for use in road construction.

Tools for earthwork activities are **crowbars, pickaxes, bush knifes, hoes, shovels, spades, hand rammers and wheelbarrows.**

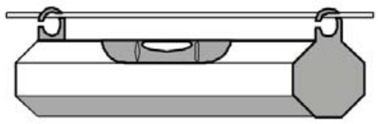
Crowbars should be 1.5 to 1.8 meters long, are made of steel and should have one pointed and one chisel end.

Hand rammers are used for compacting small areas that are out of reach of mechanical compaction equipment (e.g. around abutments of structures). Hand rammers should weight 6-8 kg, should have a sufficiently long handle and the diameter of the bottom end should be 13-15 centimeter. They can be made of solid wood, steel or concrete.

Wheelbarrows are used for the transport of construction material such as soil, sand, aggregate, stone, concrete etc. over distances up to 200 meters. A good wheelbarrow should take a big load (60 to 70 liters) and be easy to balance and tip.

Survey tools are also essential for survey work. Without them works cannot be set out correctly and this will negatively affect the quality of the work. The section below describes the different tools used for setting out work.

A Line Level is a short spirit level (about 100mm long) with a hook at each end to hang it from a smooth nylon string. It can be used to transfer the level of one location to another point and to set out gradients of not less than 1: in 300. Its range is up to 50 meters. It needs 2 people to operate it.

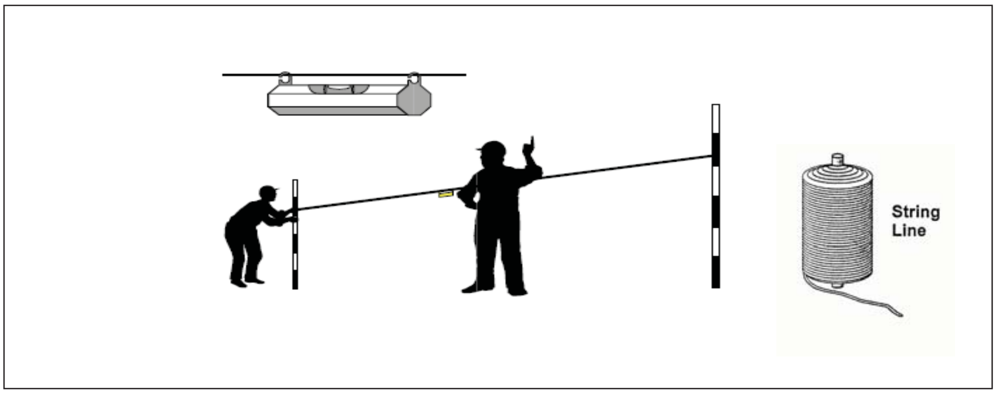


Line level with string

Transfer levels or setting out gradients with a line level

Figure 4 shows how to use the line level to transfer a level. Place the spirit level half-way between two ranging rods. Keep the string line tight – do not let it sag. The line operator moves the string up or down until the bubble is centered in the middle between the spirit level marks. The string line will then indicate the horizontal line.

Figure 4: Procedure to Transfer Levels from One Location to the Other

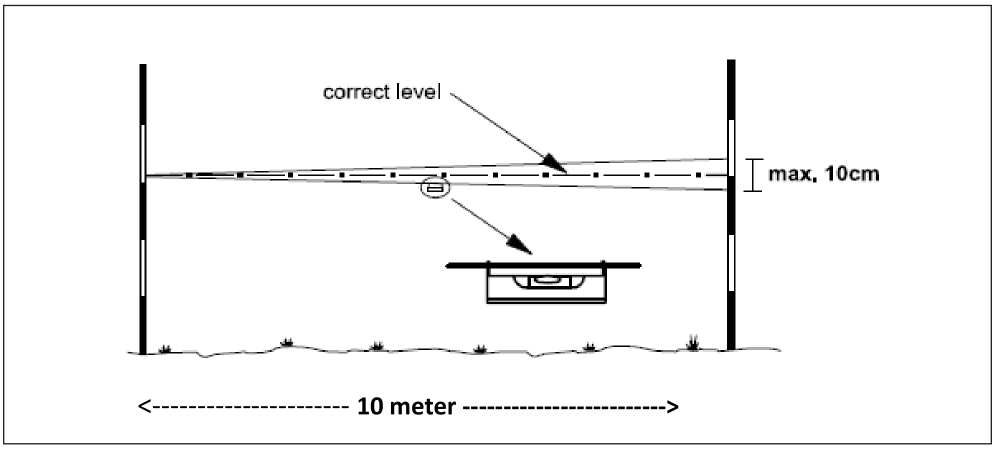


Procedure for checking the accuracy of a spirit level

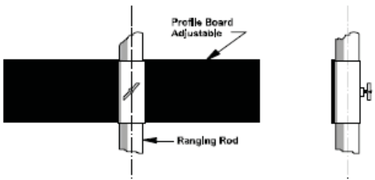
How to check the accuracy of the spirit level:

1. Place two ranging rods 10m apart and fix a line on one rod;
2. Transfer the level to the other rod and mark this level;
3. Keep the line in place and turn the level;
4. Adjust the line again and mark the new level;
5. Measure the different between the two levels;
6. If the difference is less than 10cm, the level works correct, if not replace the level

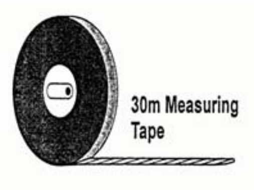
Figure 5: **Procedure to Check the Accuracy of the Spirit Level**



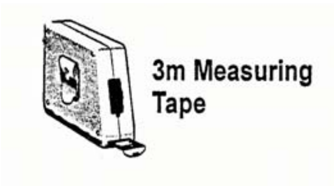
Ranging Rods and profile boards are used to set out works and to calculate volumes of earthworks. Ranging rods are made of hollow metal tube (20 – 25mm diameter galvanized water pipes) with a pointed end of reinforcement steel. Standard they are 2 meters long and painted alternately red and white to make them easy to see during setting out. The length of red and white sections is 250mm.



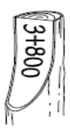
Profile boards are used to set out the road profile. A profile board can slide up and down a ranging rod and can be fixed to it at any point with a screw. A profile board is usually made from thin steel plate welded to a short length of metal tube that can slide up and down and clamped to the ranging rod. A useful size for a profile board is 40 x 12cm, painted red.



Measuring tapes of 30 meter and 3m or 5m are used for setting out. The tapes are made of steel or linen. Keep the tapes clean and avoid dirt from entering the housing.



Pointed Chisels or Metal Spikes are octagonal or round steel rods with one pointed end. The minimum diameter is 20mm and the length should be 30 – 40cm. They should be very strong. They are used with hammers to make holes for ranging rods or pegs in hard/compact soils.



Pegs are made of wood or bamboo and are ≈ 40cm long. The chainage of the road where the peg is put, is marked on the peg with waterproof marker.

4.2 Equipment

Commonly used equipment

Commonly used equipment:

- Tractors and trailers;
- smooth-wheeled pedestrian or sit-on vibratory rollers of 0.8 – 1.7 ton;
- Water bowsers;
- Tractor-towed graders;
- Concrete mixers;
- Bitumen sprayers.

Maintain equipment

Equipment needs to be regularly inspected and maintained. Operators need to know maintenance and service requirements of the equipment. Typical daily checking, cleaning and maintenance activities for equipment are listed in table 6.

Picture 1: cleaning of emulsion sprayer after use

Table 6: Daily Maintenance Activities to be Carried-out for Equipment

Daily Checks for Equipment
☑ Oil levels lubrication, hydraulics and transmission
☑ Brake and clutch fluid level
☑ Hydraulic hoses and couplings
☑ Radiator water level
☑ Grease nipples/tracks
☑ Battery connections and battery water
☑ Connections from alternator
☑ All V-belts and their tension
☑ Tire pressure
☑ Nuts and bolts

Construction Materials

Chapter

5

Sufficient construction materials should be available on site before starting the works. When receiving the materials on site, inspect the quantity, verify the quality and store them properly. Record received quantities in the stores ledger. Also record quantities used in the construction works.

5.1 Cement

Cement is very expensive and must be handled and stored with care. Always stack the cement bags off the floor and use the oldest cement first. Cement is used for concrete structures. The section below explains how to prepare concrete.

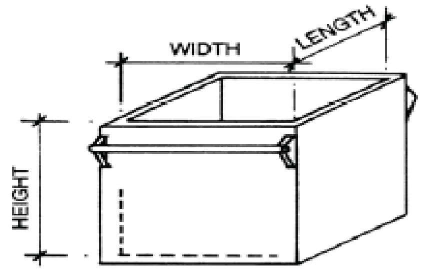
Concrete should be prepared according to prescribed procedures to make sure that it reaches it required strength. Avoid under-design or over-design. An under-designed structure is weaker than desirable and is likely to fail (leading to extra costs). Over-designed structures are too strong and this results in unnecessary costs.

Mixing of concrete is called batching. Usually batching is done very close to the structure to be constructed. The site should be cleared of all vegetation and humus, and leveled out to prevent water running off during mixing.

The batching site should hold stockpiles of materials and part of the site has to be kept for concrete mixing. A batching site should be at least 4 x 6m and needs to be well compacted. If concrete is to be mixed by hand, apply a layer of cement mortar on the section set aside for mixing and leave it to harden for about 2 days before mixing begins. For batching it is very practical to use a gauge box with internal dimension of 400 mm x 300 mm x 300 mm. The volume of the box is 0.036 m3 or 36 liters, which is equivalent to the volume of one (50 kg) bag of cement (see figure 6).

Figure 6: **Gauge box to control mix proportions**

Concrete can be batched by volume.
Gauge Boxes made from steel, wood or plywood are used for this.



Box dimensions

Inside measurements

Length	Width	Height
400mm	300mm	300mm

Volume

0.036m³ or 36 litres.

36 litres are equal to 1 (50 kg) bag of cement.

The volume of the other materials is calculated proportionally for one bag of cement. One batch of concrete is a mixture of one bag of cement and the required quantities of sand and aggregate. These ratios depend on the approved mix designs. If the mix design is 1:2:4, then one bag of cement is mixed with 2 gauge boxes of sand and four gauge boxes of aggregate. This is called on one batch of concrete.

On most labour-based projects concrete for small structures is mixed by hand because the volumes of concrete involved are appropriate for hand-mixing. If large volumes of concrete need to be mixed, concrete mixers should be used.

Procedure for mixing of concrete by hand:

❶ Place the materials in layers, starting with sand at the bottom followed by cement and then concrete stone. If more than one batch has to be mixed at a time, the same order of layers of materials shall be placed on top of the previous batch and so on.

❷ Mix thoroughly and then add water and continue to mix until all the aggregate is coated with cement paste and the mix looks consistent. A well mixed concrete has a consistent colour and looks greasy. Make sure that the mixing process takes no more than 15 minutes from the time water is added.

Procedure for mixing concrete with concrete mixer:

❶ Proportion the different materials using gauge boxes according to the required mix design;

❷ Feed the materials into the concrete mixer starting with concrete stone followed by sand and cement and, finally, water;

❸ Mix the concrete thoroughly for about 90 seconds.

Clean water needs to be used

Water is an important ingredient in concrete works. If the water is dirty, it results in weaker concrete. In general, there is no need to test the water if it looks clean. Water that looks dirty should be checked. If the intended concrete structure is no larger than a small box culvert, a trial concrete mix is sufficient to check whether the water is suitable. For larger structures the water should be tested in laboratories.

After mixing, the concrete needs to be placed within 30 minutes. Often wheelbarrows are used to transport the concrete. They should be clean and without holes. Pouring of concrete should be done in layers. Concrete needs to be compacted otherwise the concrete will not reach its required strength. Compaction should be carried out until there are no air bubbles popping out on the surface of the concrete. Over-compaction should be avoided as segregation may occur. If compaction is done by hand rammers, a layer should not be thicker than 300mm. If poke vibrators are used a layer should be at most 600mm thick.

To prevent segregation, concrete should not be poured over a height of more than 1.5m under freefall. Where the depth of free fall exceeds 1.5m wooden or steel funnel chutes should be used. Concrete on all slabs or horizontal structural members should be placed in a continuous pour in order to avoid construction joints. For vertical members, construction joints should be roughened or grooved to ensure bonding between two separate pours. The top of the concrete should be floated to level with a trowel or metal or wooden float.

Following pouring and compaction, and after the concrete has set and under-gone initial hardening, the concrete needs to be cured. Water for curing can be applied by flooding, wet dressing or wet sand cover or any other method as long as the concrete surfaces are kept moist Curing is very important as it will ensure that the concrete gains strength and hardness. If curing is not carried out properly then the concrete close to the surface of the structure will not harden properly. Curing should normally be carried out for at least 7 days.

For non-flexural members, formwork may be removed after 2 days. On short span flexural members, side shuttering may be removed after 3 days but the propping should be left in place for at least 7 days. On long span flexural members propping should be left in place for 28 days, otherwise wide cracks may develop that will weaken the structure or the structure may actually collapse. Expansion joints in concrete slabs are required for approximately every 10 to 15 meters.

5.2 Aggregate

Aggregate is used in concrete works, in sealing the road surface, in gravel roads and as sub-base material. Fine aggregate includes pit-sand, river-sand and other similar fine aggregate that could be used in concrete mixes. Coarse aggregate can be crushed stone from quarries, hand-crushed stone or natural aggregate. Natural rounded river aggregate is weak if exposed to weathering. If particular aggregate size specifications are required, aggregate from natural gravels normally needs to be sieved. Aggregate from river gravel can be used in small to medium concrete works (i.e. those smaller than bridges).

How to check whether aggregate is clean

If aggregate contains mud or organic materials, it should be washed as the strength of concrete is much less if dirty aggregate is used. To check the contamination of an aggregate, half-fill fill a transparent container (of a small diameter and with straight vertical walls) with a sample of the aggregate. Pour water into the container until it is full. Shake the contents for 5 minutes and place the container on a flat surface. Let it stand for at least 3 hours. If the water is then still dirty, there is clay in the aggregate. In that case let the clay sediment settle for another 12 hours.

Aggregate with more than 5% undesirable material should be rejected

The next step is to measure the thickness of the top layers with undesirable material. Do this without disturbing the container. The thickness of the undesirable material (t) should be not more than 5% of the total thickness of the sediment (T). If for example the total thickness of a sample is 60cm and the thickness of the fine layers is 6cm, the undesirable material constitutes = (6:60) x 100% = 10% and the aggregate should be rejected.

Checking the strength of aggregate for small structures

To check the strength of the aggregate take about 200 representative aggregate particles and place them on a hard surface. Each stone is then hammered once with an ordinary claw hammer. If more than 10% of the stones crumble to fine particles or pulverize then the aggregate should be rejected. This method is only applicable for aggregate proposed in the construction of small structures.

Sand for construction works

River-sand is usually the best sand for use in concrete because it generally meets the grading requirements and it is usually clean. Pit-sand is often mixed with organic materials and if this is the case, it needs to be washed. Take care when using pit-sand instead of river-sand for concrete works. Where river-sand is too coarse, pit-sand can be mixed with river-sand.

5.3 Fuel, Oil, Lubricants and Bitumen

Fuel, oil, lubricants and bitumen should be stored separately, away from other supplies. Make sure that there are no open fires nearby the store. Store fuel, oil, lubricants and bitumen in good drums that do not leak.

Planning and Organization of Works

Chapter

6

6.1 Planning of Works

Before you can start with the construction activities, a planning of the work is required. This includes a plan for the required labour inputs, the procurement of construction materials and securing the necessary equipment. A normal sequence of activities that have to be carried out and for which a planning needs to be made is as follows:

Work operations that need to be planned

❶ Setting out of works;

❷ Clearing of shrubs, trees, grass cover, debris, humus etc;

❸ Excavation to level, i.e. make a level X-section on which to form the road;

❹ Construct retaining walls;

❺ Construct structures like culverts, bridges, drifts;

❻ Construct drains, like side, mitre and cut-off drains, scour checks, etc;

❼ Formation of the camber or cross-fall of the road;

❽ Construction of the pavement, including the base and the surface;

❾ Finishing activities like erosion protection measures, final clearing, etc.

Before you can make a work plan, you need to have certain information. Without it, it will not be possible to make a realistic work plan. It is important to remember that a good and realistic work plan is always required. Without it, you will not be able to estimate how much inputs (including labour) are required and when these inputs are needed.. The absence of work plan will result in a disorganized (and unhappy) workforce and it will prevent you from achieving your targets (both in terms of quality and quantity). Information that you need to have in order to be able make a work plan includes the following:

Information required for preparing a site work plan

- Expected starting date and completion date of the works;
- volumes and locations of the different types of work to be undertaken;
- Input requirements for labour, construction materials, equipment, tools;
- Availability of labour, equipment, tools and construction materials;
- Information about the usual start and end of the rainy season.

Table 7 presents an illustrative example of how a work plan could look like. In this example we have assumed that a section of 1 kilometer of a road will be sealed using a Double Bituminous Surface Treatment (DBST). The information about the required inputs for this work is obtained from the example presented in table 3. Suppose that the work as shown in table 3 has to be completed in 6 months and that per month 20 days are worked. Table 7 shows the monthly planning for the required labour, material and equipment inputs. It may be necessary to break-down the planning into a weekly plan as well. The same approach can be used for making a weekly plan as for the monthly plan shown in table 7.

In making the illustrative plan as shown in table 7, the purpose was follow a logical sequence of activities and to try to balance the total required number of worker-days of inputs equally over the 6 months. Table 7 shows that every month about 10-12 workers would be required, assuming that each worker works 20 days per month (take for example month 1: row 13 shows that 230 work-days are required and if a worker works 20 days per month that means that for month 1 230/20=11.5 workers are required. This number is rounded to 12).

Table 7 also shows when the tools, materials and equipment need to be secured or procured, in line with the work plan. The preparation of a work plan like presented in table 7 will require some trying before you will get a balanced and logical work plan. The technical officer or engineer may assist in the preparation of the work plan.

Table 7: Illustrative example of a monthly work plan for the construction of 1 km of DBST

		Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Total
		Labour input requirements						
	Activity							
1	Setting out	120						120
2	Site clearing	50						50
3	Preparing sub-grade		27					27
4	Cutting boxes		107					107
5	Spreading sub-base		16	80				96
6	Spreading shoulder			65				65
7	Spreading base course				140	115		255
8	Spreading chips						20	20
9	Applying coat						80	80
10	Roller operator						37	37
11	Transport material			20	40	40		100
12	Labour support	60	60	60	60	60	60	360
13	Total worker days	230	210	225	240	215	197	1,317
14	Total workers	12	11	11	12	11	10	
15	Engineer-days	5	5	5	5	5	5	30
16	Technical Officer -days	10	10	10	10	10	10	60
17	Supervisor-days	20	20	20	20	20	20	120
		Tools, equipment and material requirement schedule						
	Secure tools							
	Rent roller 1 ton							
	Rent roller 3 tone							
	Hire tractor + trailer							
	Hire waterbowser							
	Procure material base							
	Procure sand							
	Procure bitumen							
	Procure chips							

Once the overall work plan has been made, the preparation for the start of the works can begin. This also includes the preparation of a more detailed site work plan that gives information on how the labourers should be organized on the site. How such a plan can be prepared, in particular regarding the organization of the labour, is explained in paragraph 6.3.

6.2 Labour Incentives

A well motivated workforce is very important for the successful implementation of the construction works. The role of the supervisor is very important in motivating the labourers. He/she can help to motivate the labourers in various ways:

Motivating labourers has a positive effect on the work

- Creating a feeling of achievement and showing appreciation of the work done by the labourers;
- Delegating responsibilities to the labourers and instructing and training the labourers so that they can do their work well;
- Organizing and managing the work in an efficient and effective way and communicating and behaving correctly with the labourers;
- Ensuring good and decent working conditions at work sites.

6.3 Organization of the Labour

The organization of the workforce at the site is very important when construction activities are being implemented using labour-based work methods. There are a number of attentions points that must be kept in mind when organizing the labour at the worksite:

Attention points in organizing the workforce

- **Mobilization of labour**: Make sure that sufficient labourers are available for the planned works for a particular day or week. Try to mobilize labourers within the vicinity of the work sites. Plan the work well in advance so that local villagers now well in time what inputs are expected;
- **Establishing labour gangs**: Labour gangs have to be set-up to implement the works. Depending on the type and volume of work, a gang consist of 10 – 25 workers. Each gang should have a gang leader.;
- **Spacing of labour gangs**: Labour gangs should not be working too close to each other, otherwise they may disturb each others work. If they work too far apart, this will complicate supervision. The distance between the work location of the different gangs should be not more than 2 kilometer;
- **Assigning activities to labour gangs**: To make optimum use of gained experiences and skills, try to let a gang continue to work on the same operations and activities throughout the construction period;
- **Gang balancing**: Make sure that the work load is equally divided between the different gangs. Also make sure that there is a good balance of the division of tasks between labourers within a particular gang;

- **Set out daily tasks** that allow the average worker to finish a day's work in approximately 75% of the normal working hours. Table 6 shows some average task rates. These should only be used in an initial phase, before more appropriate quantities have been determined through site trials.

An example on how to organize the labouers in labour-gangs

An illustrative example is given here to show how the labourers involved in road construction activities can be organized on-site. Assume that over a section of 0.4 kilometer earthwork excavation activities have to be carried out that include excavation, haulage and spreading (including leveling). The work has to be finished in 10 days. From the survey information you know how much and what type of works have to be done for every 100 meters of the road section. Table 8 shows how the labour can be organized for this example.

Table 8: Example of organizing the work along a road section in labour-gangs

		Volume of work (m^3)	Productivity (volume per labour-day	0-100m	100-200m	200-300m	300-400m
I				Volume of work (m^3 per section)			
1	Excavation	500		200	50	100	150
2	Haulage (10 m)	250		100	0	100	50
3	Spreading	500		200	50	100	150
II				Labour - days needed			
4	Excavation		1 m^3/ld	200	50	100	150
5	Haulage (10 m)		5 m^3/ld	20	0	20	10
6	Spreading		2.5 m^3/ld	80	20	40	60
III				No. of labourers needed			
	Excavation			20	5	10	15
	Haulage (10 m)			2	0	2	1
	Spreading			8	2	4	6
	Total			30	7	16	22
IV							
10 excavate, 1 haulage, 4 spreading: total 15 workers				gang 1			
10 excavate, 1 haulage, 4 spreading: total 15 workers				gang 2			
15 excavate, 2 haulage, 6 spreading: total 23 workers					gang 3		
15 excavate, 1 haulage, 6 spreading: total 22 workers							gang 4

The first step is to show how much work for each of the activities needs to be done at every section. This is shown under (I) in the table . Once this is done and with information about labour-productivity the required number of labour-days for the different activities and for the distinguished sections can be calculated. This is done under II. The labour-productivity rates shown in the table are for illustrative purposes only. Actual labour productivity norms need to be obtained locally. Either from the Department of Public Works or based on local experience. Steps II shows for example that with a labour productivity of 5 m^3 per labour-day for haulage and a volume of haulage in the section 200-300m of 100 m^3, the number of labour-days required for haulage in the 200-300m section is 20. As the work needs to be completed in 10 days in this example, this means that 20 / 10 = 2 labourers will be required for haulage in the section 200-300m. Step III in the table shows the number of labourers required for the different activities in the distinguished sections.

In step IV the organization of the work in labour gangs is prepared. As a workable gang size is up to 25 labourers it has been decided in the example to split the required workforce of 30 people for the section 0-100m into two gangs of 15 people each. In the sections 100-200m and 200-300m relatively less labour inputs are required and the labour requirements for these sections can be handled by one gang for these sections together (the size of this gang is 7 + 16 = 23 people). The work in the section 300-400m can be done by one gang of 22 people.

Under step IV it is also shown how many in each of the gang have to excavate, do the haulage and carry out the spreading to achieve an n efficient gang-balance, based on the work requirements. This information has been taken from step III where the number of labourers required for the various activities has been determined.

6.4 Safety on Site and Working Conditions

To minimize the risk of accidents and the exposure of workers to dangerous working conditions, the supervisor has to ensure that measures are taken to minimize such hazards and exposure to hazardous conditions. Dangerous conditions and situations could be created for example if no proper safety measures are being taken during the felling of trees, the removal of boulders, blasting, working with bitumen, cement and other chemical materials.

Other possible dangerous situations could be created for example when excavating unstable soils in sloping terrain or when working on narrow ridges,. Working with mechanical equipment could also pose a potential hazard especially when the operators are not sufficiently skilled or when no proper measures are taken to keep worker and bye passers away from such equipment. These are just a few examples of possible risks involved in construction activities. There are many more of such risks and the supervisor should be aware of such potential risks and take the appropriate measures. This may also include ensuring that adequate protective gear is available.

As part of the prevention measures, the supervisors should brief the workers and operators about potentials safety and health risks involved with the different construction activities and inform them how to deal with them. In case accidents happen, the supervisor should know what to do in particular cases. He/she should at least have a well stocked first aid kit on the site and somebody should always be around who knows how to give first aid. The supervisors should also have contact details and phone numbers of health clinics or hospitals at hand in case of a serious injury. For serious accidents there should also be provisions in place regarding the organization of the transport of the injured person.

Workers have to carry out physically hard work and drinking water therefore needs to be available on the site. A minimum of 3 liters per person per day should be provided.

6.5 Supervision

The quality of supervision determines the quality of work

The quality of the supervision is the most important factor that determines the quality of the work. The role of the site supervisor is therefore crucial. **Supervisors need to know What, How, Where, When and by Whom** works needs to be done.

Direct instructions work best

Direct instructions to all concerned workers, including their gang-leader, work best. Also ask questions to check that the instructions have been understood. It is useful if the supervisor actually demonstrates how work activities have to be carried out.

Check the work of the labour-gang every day

Supervisors need to inspect and approve the work before the workers are released for the day. They have to check: the following:

- ☑ Have Set-out measurements been followed correctly?;
- ☑ Are Edges of earthwork straight and well trimmed?;
- ☑ Is Soil placed correctly?;
- ☑ Is All the work completed correctly as per the given daily task?

Reasons for failure to complete daily tasks

If a daily task has not been completed at the end of the day, find out the cause of the delay. If the reason for not finishing is related to unforeseen difficulties, incorrect setting out or calculation of the task, a shortage of labour or bad weather, the workers can go home. of the following, the workers or gangs can be released. If the reason for non-completion lies with the workers, the supervisor needs to discuss with the labourers a way to complete the task without falling behind the work plan. If this is not possible, the work plan needs to be adjusted.

Construction

Chapter

7

7.1 Setting Out

Calculating areas, volumes and slopes

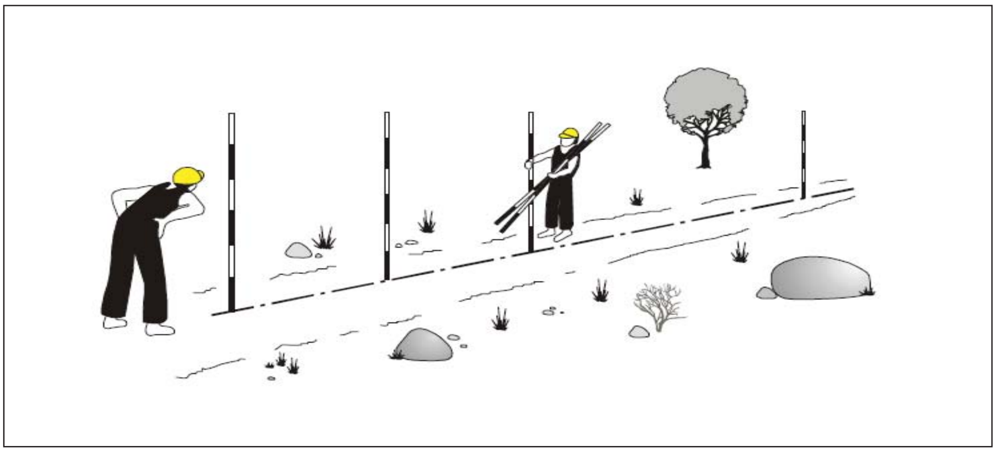
This chapter describes how to survey roads and how to set out works for road construction activities. Setting out works and surveying are of key importance in the design and construction of road works. Setting out also enables the calculation of quantities of work to be done and different slopes and gradients of the road and associated structures. Annex 2 provides information on how to calculate the area and the volume of basic shapes. Basic information on how to set out or calculate slopes and gradients is given in Annex 3.

7.1.1 Horizontal Alignments

Setting out straight lines

Straight lines are set out by marking points every 50m to 100m with ranging rods (see also figure 7 and picture 2). 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. This method is also being used to set out the "Center Line" of a road.

Figure 7: **Setting out Straight Center Lines**



Picture 2: Setting out straight lines and gradients

Mark the center line by placing off-set pegs

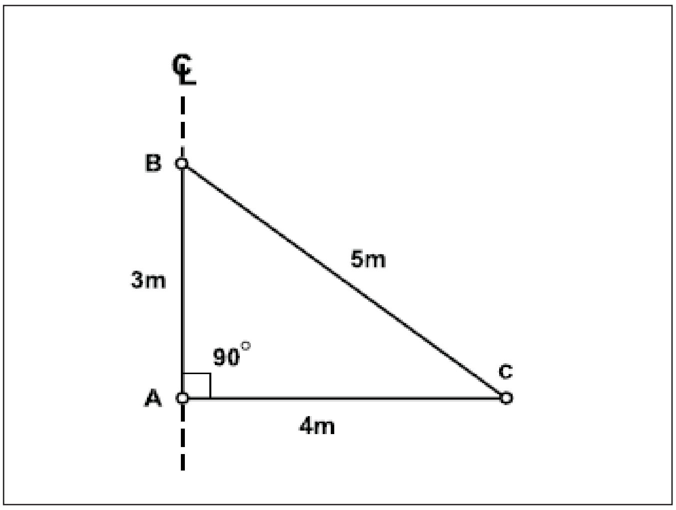
After the center line has been set out, mark this line by setting out solid off-set pegs at 90^0 to the side of the pegs that indicate the center line. In the case of embankment, place the off-set pegs on each side at the foot of the planned embankment, at 10m intervals along the road line. Place the off-set pegs at each side of the road at equal distance from the peg placed at the center line.

Use the 3-4-5 method to set out 90^o angles from the center line

To set out the off-set pegs, construct a 90° angle from the center line, using the 30m tape. Measure 3m from ranging rod (A) along the center 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). Position a ranging rod at the 8m mark on the tape, creating a line between A and C, 90° to the center line (see also figure 8 and picture 3). Repeat this exercise on the opposite side of the center line and check that the three ranging rods are on line. Measure out the position of the off-set pegs by sighting along the three ranging rods. An alternative method for setting out 90 degree angles is to use a template with 3:4:5 proportions.

Picture 3: Setting out 90^o angle from centre line

Figure 8: **Setting Out 90° Angle from Centre Line**



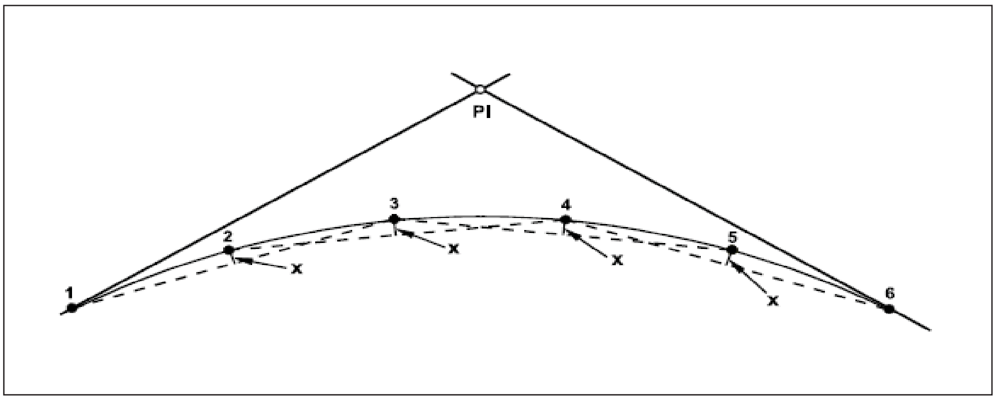
7.1.2 Curves

After the center lines have been set out by straight lines that meet at intersection points (like P1 in figure 9), curves need to be set out. Do this by placing pegs in the curve "by eye" until they appear to follow a smooth curve. Check whether the curve is smooth by lining up the 1st and 3rd peg and measure the off-set of the 2nd peg to this line (this is the distance "x" in figure 7).

Repeat this exercise by lining up the 2nd and 4th pegs and measure the off-set to the 3rd peg to this line. Repeat this for all sets of pegs. Check and adjust all these off-sets until they are nearly equal.

Setting out smooth curves by using the "by Eye" method

Figure 9: **Setting Out Curves "By Eye"**

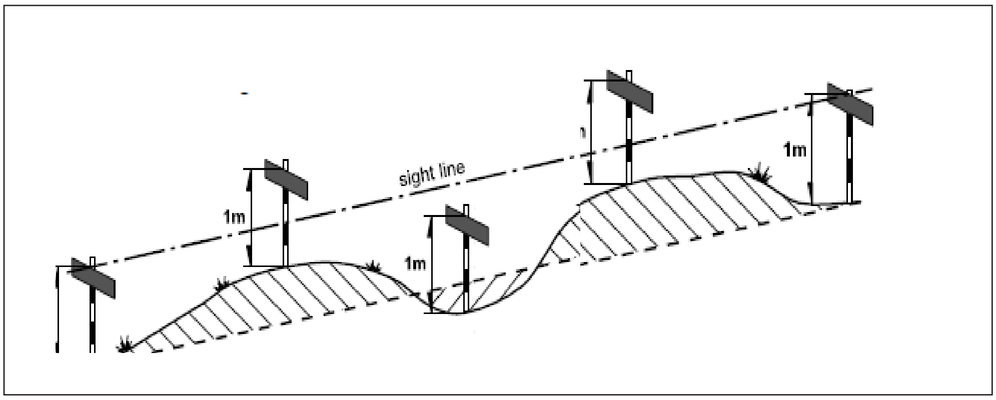


7.1.3 Vertical Alignments

❶ Fix profile boards on the ranging rods along the center line at a fixed level, say 1 meter above the ground level (figure 10).

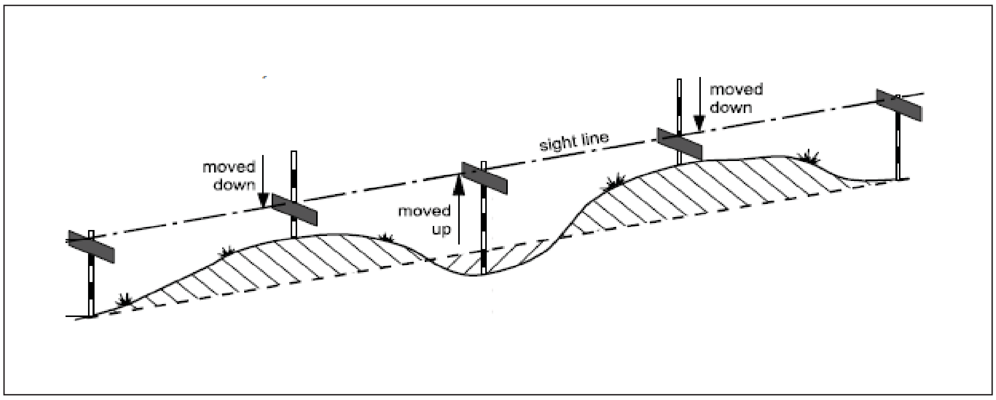
4 steps for setting out vertical alignments using profile boards

Figure 10: Fix profile boards on ranging roads along center line



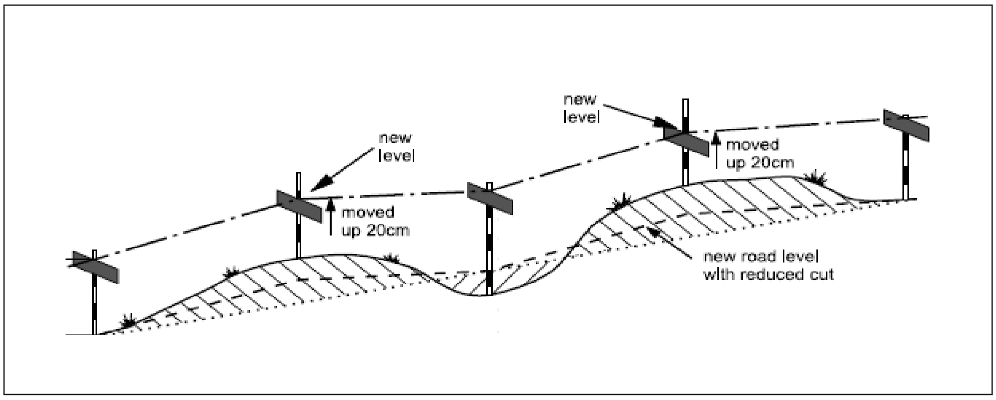
❷ Sight along the profile boards (figure 11). Let an assistant adjust the level of each intermediate profile board so they are all on line with the first and last profile. All profile boards will then be 1m above the level of the center line of the new road (before designing the camber).

Figure 11: Sighting of the profile boards



❸ If the level of the center line is too deep into the terrain, i.e. needs too much excavation, move the profile boards up or down to reduce the leveling works, see figure 12.

Figure 12: Adjust profile boards to reduce amount of leveling work



❹ Ensure that the profile boards along the center line are correctly placed. All other levels for the road structure will be set out based on the profiles along the center line.

Picture 4: Checking gradient along center line

Check that the gradient along the road is not too steep

When your set out the center line, check the gradients along the road profiles. If the road gradient is too steep, change the road levels. When selecting the road center line also check the gradient of the existing terrain to ensure it is not too steep. If you have to calculate the vertical gradient along an existing road, transfer the level of one profile board to the next ranging rod and measure the difference.

The gradient of a road is defined by the following formulae:

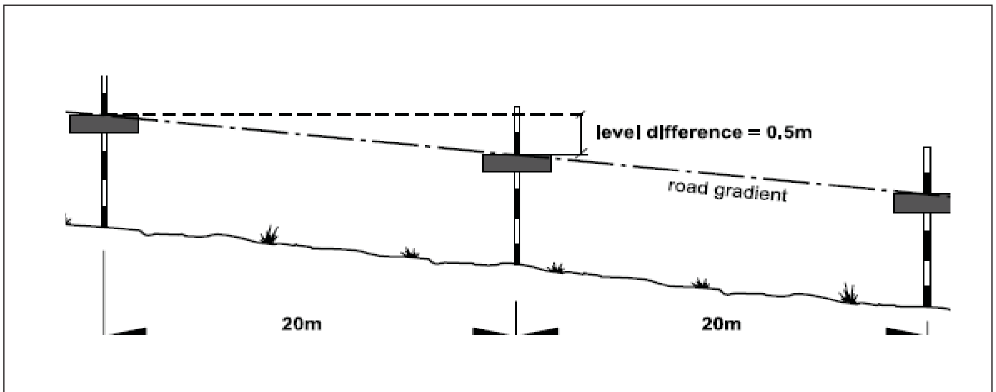
Level difference / length) x 100% = slope (%)

Example of calculating the vertical gradient along an existing road

If the difference in level between two profile boards (set 20m apart) is 0.5m, you can calculate the gradient to be (see also figure 13):

Gradient = (0.5/20) x 100 = 2.5%

Figure 13: Example of Calculating the Vertical Gradient Along a Road



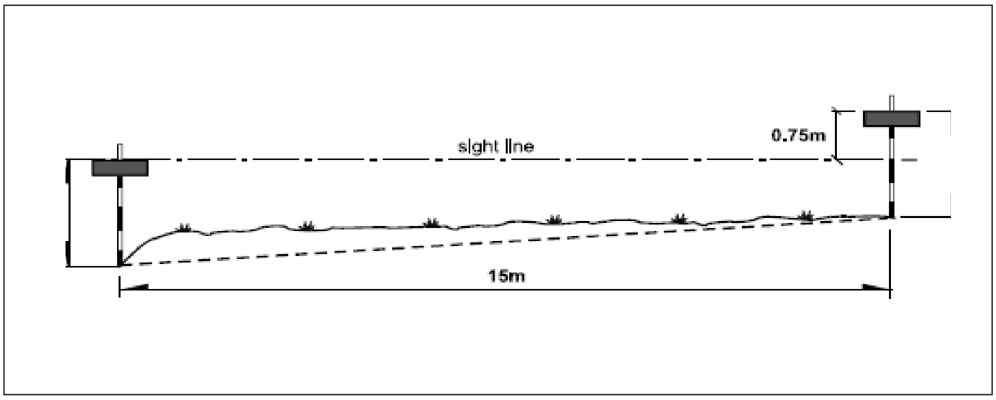
Example of setting out a vertical gradient

An example of setting out a vertical gradient with profile boards is shown in figure 14. If you have to set out a vertical gradient of 5% over a horizontal length of 15 meters, you can calculate the required height difference:

Height difference = 5% x 15m = (5/100) x 15m = 0.75m

Next, transfer the level of one profile to the ranging rod 15m away and set the profile board 0.75 m above this mark. The two boards are then set at a slope of 5%.

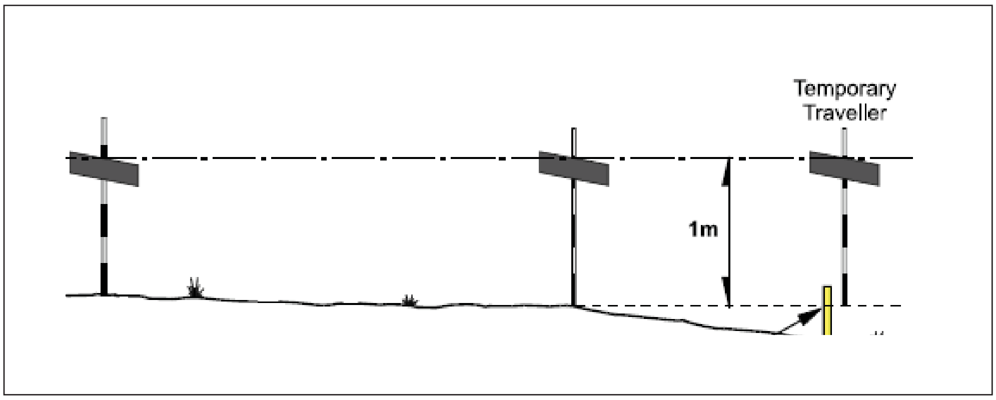
Figure 14: Setting Out a Vertical Gradient



In those cases where levels have to be set out below the line of sight, a temporary traveler needs to be used, as is shown in figure 15.

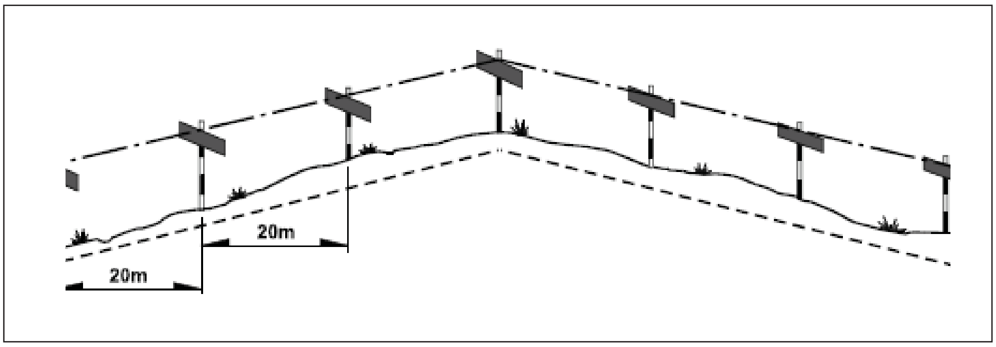
Example of setting out a level below the line of sight

Figure 15: Setting Out Levels Below the Line of Sight



If you have to set out a vertical curve over a hill or through a sag 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 (see also figure 16).

Figure 16: Setting Out Vertical Curves



Example of setting out a vertical curve over a hill

For setting out a vertical curve though a valley or a dip, in principle the same principle is applied as when setting out a vertical curve over a hill. But now you can use a nylon string line to set out a smooth “sag vertical curve”.

Example of setting out a vertical curve through a valley or a dip

To minimize quantities of earthwork it may be possible to vary the vertical gradient. If the height of the profile boards above the ground level is more than 10cm +/- the 1m level, inspect the gradient and adjust it as shown in figures 17 and 18. When doing this, keep in mind that the vertical gradient should not exceed the maximum allowable vertical gradient of 12%.

Example of minimizing earthwork by varying the vertical gradient

Figure 17: Excessive Cut When Applying a Straight Gradient

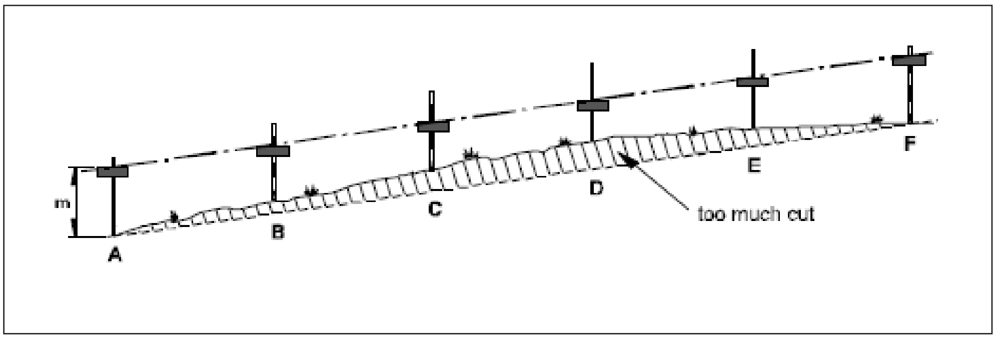
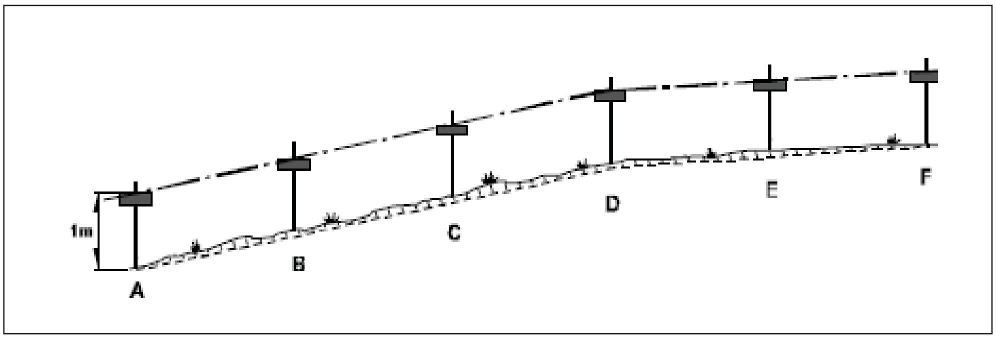


Figure 18: Minimizing Cut by Applying Two Different Gradients



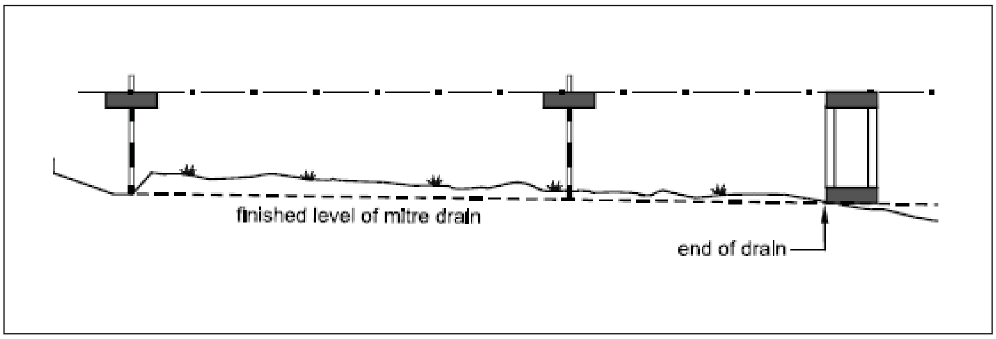
Example of setting out the length of a mitre drain

7.1.4 Mitre Drains

A mitre drain is a drain that empties the side drain at regular intervals before the volume of water builds up in the side drain and causes erosion.

After your have determined the gradient of the mitre drain, set out this gradient with profile boards (figure 19). Then use a **Temporary Traveler** to see how far your have to go to get the three profiles to line up. The position where the **Temporary Traveler** rests on the ground and lines up with the two fixed profile boards shows where no excavation is needed and is therefore the end of the drain.

Figure 19: Setting Out the Length of a Mitre Drain

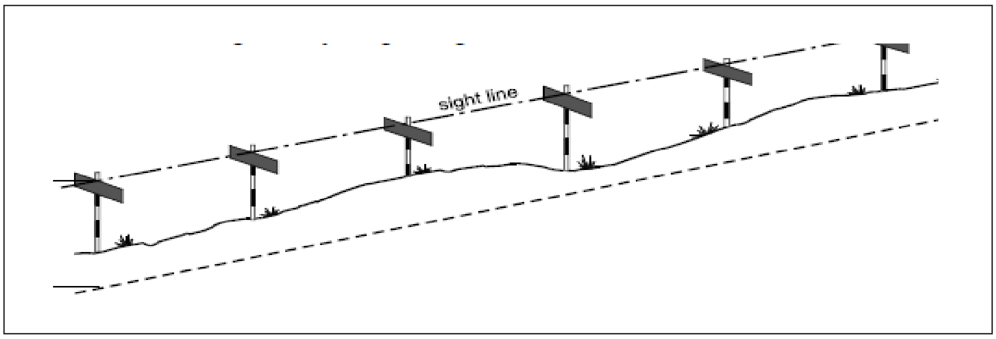


Example of setting out a side drain with a straight gradient

7.1.5 Side Drains

Figure 20 shows how to set out a side drain with a straight gradient by using profile board, even though the depth of the excavation will vary along its length.

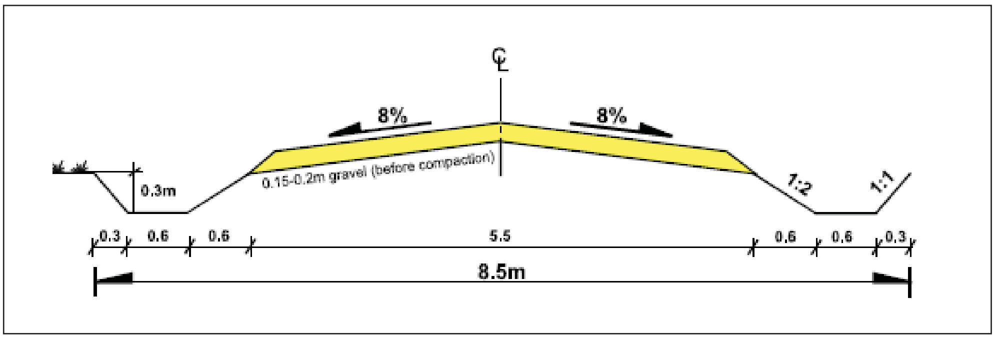
Figure 20: Setting Out Side Drains



7.1.6 Cross Sections

Once the position and levels of the center line have been determined, it is possible to set-out the side drains and the camber. Cross sections should be set out at right angles to the center line of the road by using the 3-4-5 method. An example of a cross-section is presented in figure 21. Dimensions may vary, based on the actual design specifications. The road camber is set out together with the side drains.

Figure 21: **Example of a Cross-Section of a Gravel Road**



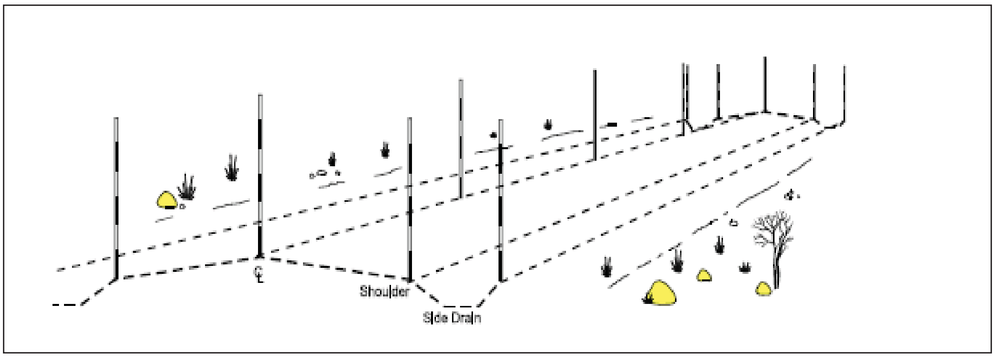
Procedure for setting out cross sections that minimize earthwork:

10 steps for setting out cross sections

❶ On the center line, set out ranging rods at 10m intervals over a section of 50 to 100 meters. At the start of the section, set out the position of the road shoulders and the outer end of the side drains. Repeat this at the other end of the section. Place a wooden peg next to each of the ranging rods.

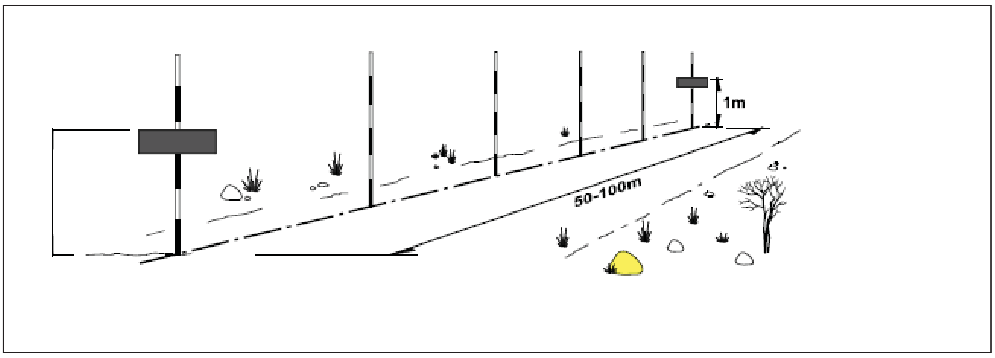
❷ Sight in intermediate rods at every 10m along the road shoulders and side drains (figure 22). Place pegs next to each of the intermediate ranging rods.

Figure 22: **Setting out ranging rods and pegs to mark center line, shoulders and side drains**



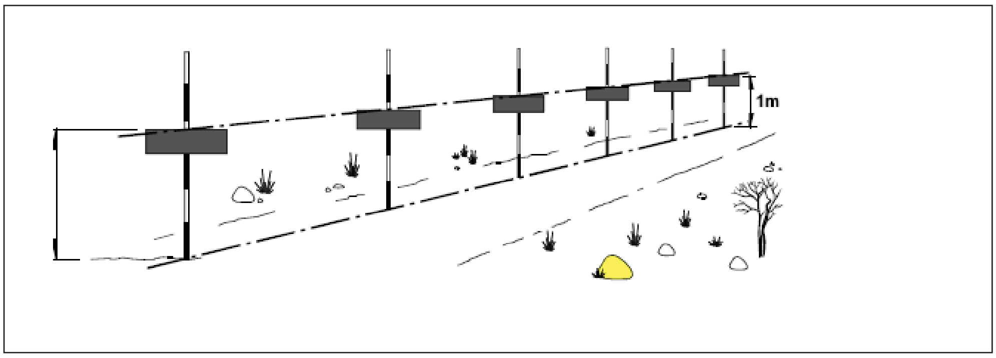
❸ On the center line, fix profile boards at the start and end of the section (figure 23).

Figure 23: **Set up profile boards at the start and end of the section**



❹ Sight in the intermediate profiles from one end and fix profile boards on the intermediate ranging rods along the center line so that they are all at the same level (figure 24).

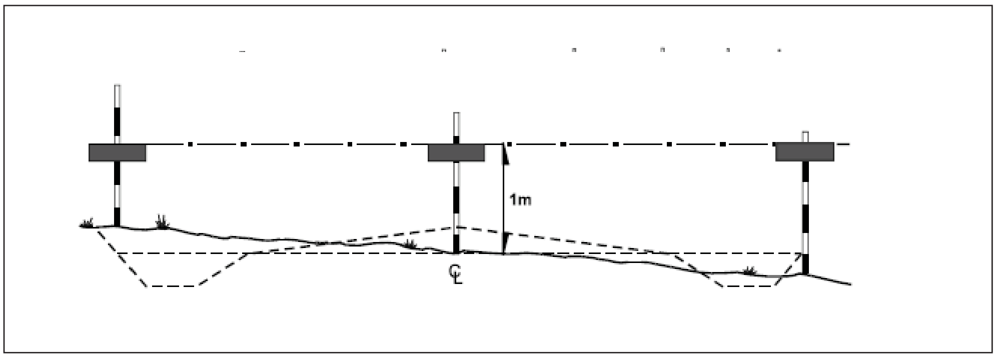
Figure 24: Sighting of profiles on intermediate ranging rods



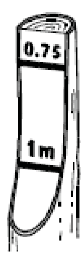
❺ Check the height of each profile board. If the height of the profile boards differs more than 10cm from 1m, inspect the line. It may be that the set out line is over a hill or a dip in the terrain. Then, you have to adjust the profiles to avoid too much excavation.

❻ Transfer the levels to the ranging rods at the outer end of the side drains (figure 25). Start at the beginning of the road section. Use a string and line level to transfer the level of the profile board at the center line to the side drains. Set out the levels with profile boards and mark them 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 also for the intermediate profiles. Then, sight in the intermediate side drain levels.

Figure 25: Transfer levels of center line to the outer side of the drains



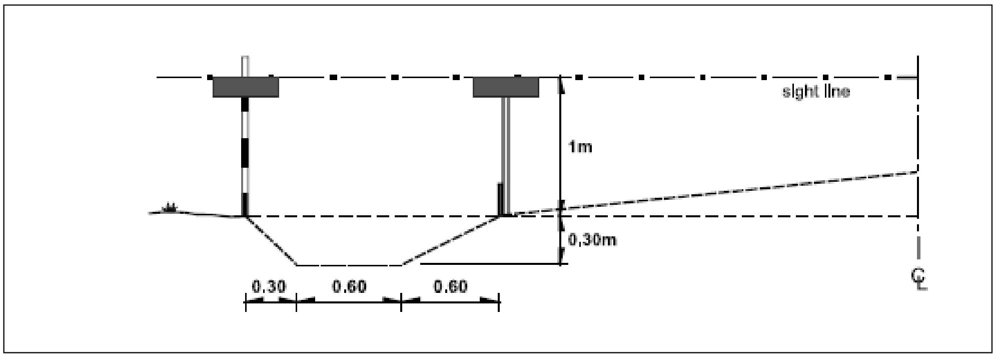
Usually the height of the drain profile on the low side of the center line is more than 1m. This is because you have started from higher grounds, and since the road is level, the lower side drains will be less deep.



❼ Mark the levels for the center line on pegs placed next to the ranging rods along the center line. Then use the center line profile boards to set out intermediate pegs every 5m along the center line. This is can be done with a 1m temporary traveler. Mark these pegs at the point where the bottom of the traveler touches the peg, when lined up with the profiles. On all the center line pegs, mark the level of the crest of the camber 0.25m above the 1meter level on the pegs. You have now set out profiles for the leveling of this road section.

❽ For setting out the levels of the shoulders use a traveler of 1m high. When you line up the traveler along the line between the two side drain profiles, the bottom of the traveler will show the correct shoulder level (figure 26).

Figure 26: Set out the level of the shoulders



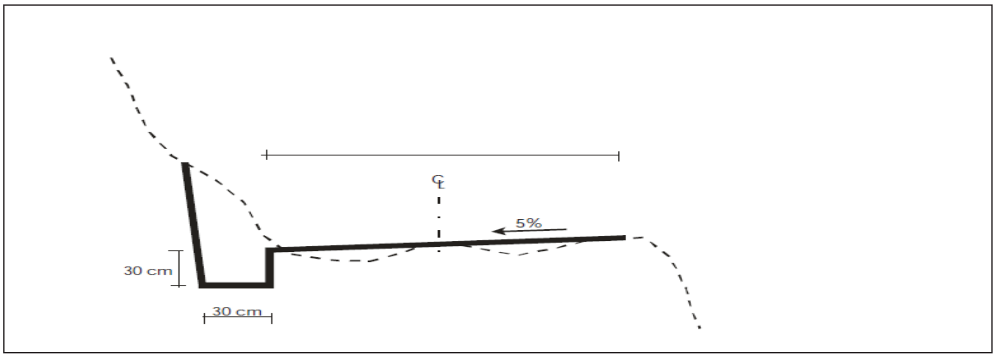
Place pegs every 5m along the edge of the shoulder and, using the traveler, mark these pegs at the point where the bottom of the traveler ends when it lines up with the profiles.

❾ Locate and set out the mitre drains. This should be done before the excavation works for the side drains and camber start.

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

Normally, sections of not more than 50 to 100m are set out at the time in flat terrain. In mountainous terrain, sections of less than 20m may be chosen. A typical cross-section in mountainous terrain with a cross-fall of 5% is shown in figure 27.

Figure 27: Example of Cross-Section in Mountainous Terrain



Example of typical cross section in mountainous terrain

7.2 Clearing

Clearing of bush, trees and grasses

Clearing involves cutting down and removing trees, clearing of bush and digging up and removing root systems. Avoid heavy bush clearing and unnecessary cutting down of trees wherever possible by careful selection of the center line. When you cannot avoid cutting trees, dig up and remove the roots as well to a depth of more than 200mm below ground level. Fill holes caused by extracting roots and compact these filled holes properly using hand rammers. Heavy grass cover should be cleared. Light grass cover can usually be used in construction earthworks without too much of a problem. Afterwards it re-grows, forming protection against erosion on the shoulders. Heavy grass tufts can be used to protect side slopes in.

Removing boulders

Try to avoid the need for removing big boulders as this work is often time consuming and expensive. Where there are many big boulders in the soil, which creates problems in excavating the drains, consider the possibility of raising the road level.

Removal of top soil

Topsoil usually only needs to be removed when it is deep (more than 10-15cm), very organic and has much less strength than the soil below. 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 remaining, which can be mixed in with the earthworks for the road construction.

7.3 Earth Works

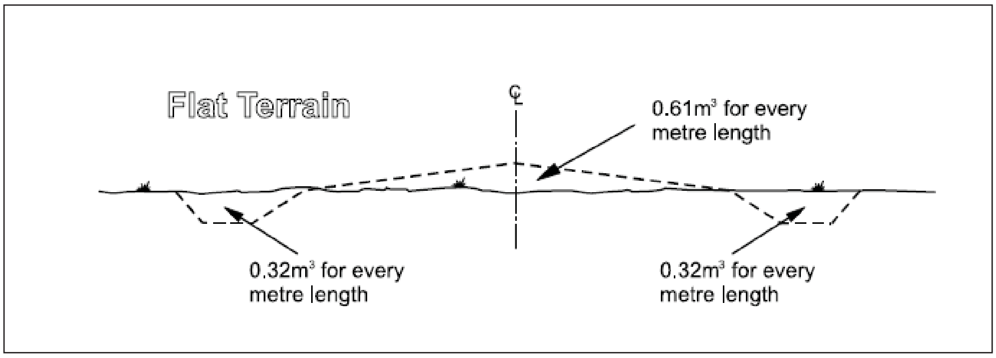
Always try to minimize earthworks

Earthworks includes digging drains and building up the road formation and the camber (or cross-fall). When setting out alignments, always try to do this in such a way that it minimizes earthwork. This is the case for both new road construction and the rehabilitation or upgrading of existing roads.

Earthwork in flat terrain

Figure 28 gives and example of excavation works in flat terrain (i.e. with very little cross slope). Because there are usually low spots in the ground, use slightly more materials from the side drain to form the camber than what is actually required.

Figure 28: Example of Earthwork in Flat Terrain



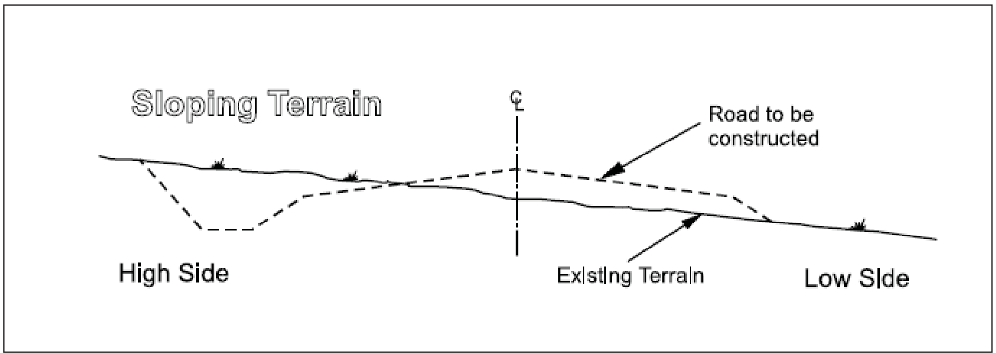
Excavation of drains and formation of camber

To form the road excavate material from the drains and place it on top of the road-bed to form the sub-grade layer. The excavated material should be of sub-grade quality. Remove stones, boulders and organic soil. Make sure that the camber and drains are formed as per design specifications. Annex 5 provides an overview of the different types of soils that can be distinguished, their key characteristics and an explanation of the terminology used in describing soils.

In sloping terrain (figure 29) try to reduce earthwork. Locate the road on ridges where possible - this will reduce earthwork and drainage works. The high side drain normally has to be dug deep whereas normally no low side drain is needed. On the low side of the cross slope the road usually has to be build on a fill.

In sloping terrain minimize earthwork and balance cut and fill

Figure 29: Example of Earthwork in Sloping Terrain

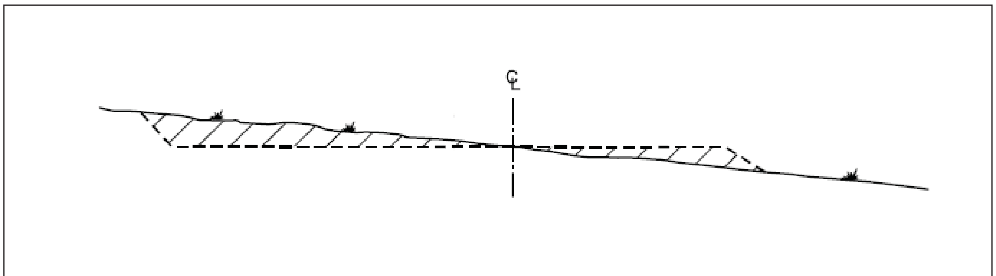


In sloping terrain build the road in two stages. Using this method you can keep the earthwork to a minimum as cut and fill are balanced and it will usually avoid the need for a side drain on the low side.

2 stages in constructing a road in sloping terrain

Stage 1: Excavate the high side and build up the low side and form the side slope on the low side (figure 30).

Figure 30: Stage 1 in constructing a road in sloping terrain



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

Figure 31: Stage 2 in constructing a road in sloping terrain

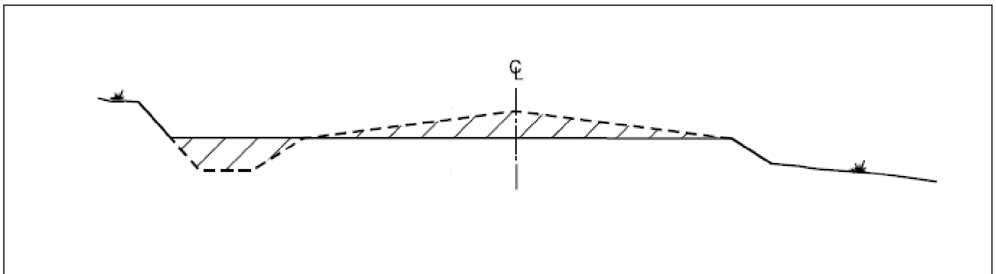
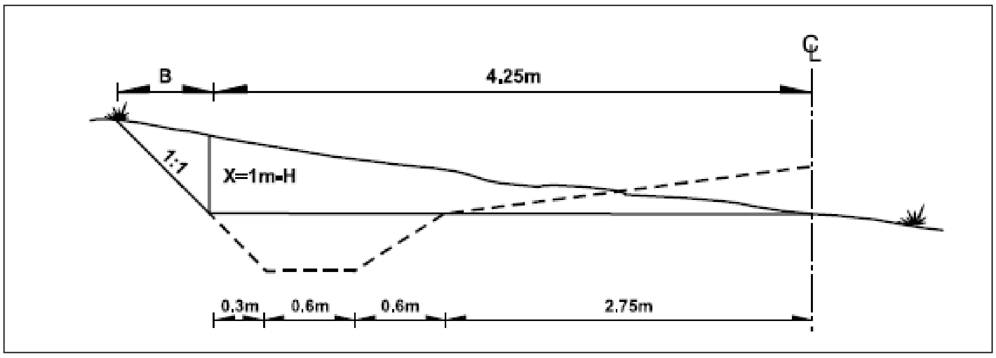


Figure 32 shows how to balance the earthwork cut and fill using this method. When you balance cut and fill, make sure to leave sufficient space for the side drain on the high side. In the example of figure 32 the ground needs to be leveled to 4.25m back from the center line to provide enough room to dig and back slope the side drain. The width of the back slope to the excavation should be sufficient to achieve a slope of 1:1, similar to the back slope of the side drain.

Picture 5: Cutting and leveling

Minimize earthwork by balancing cut and fill in construction of road

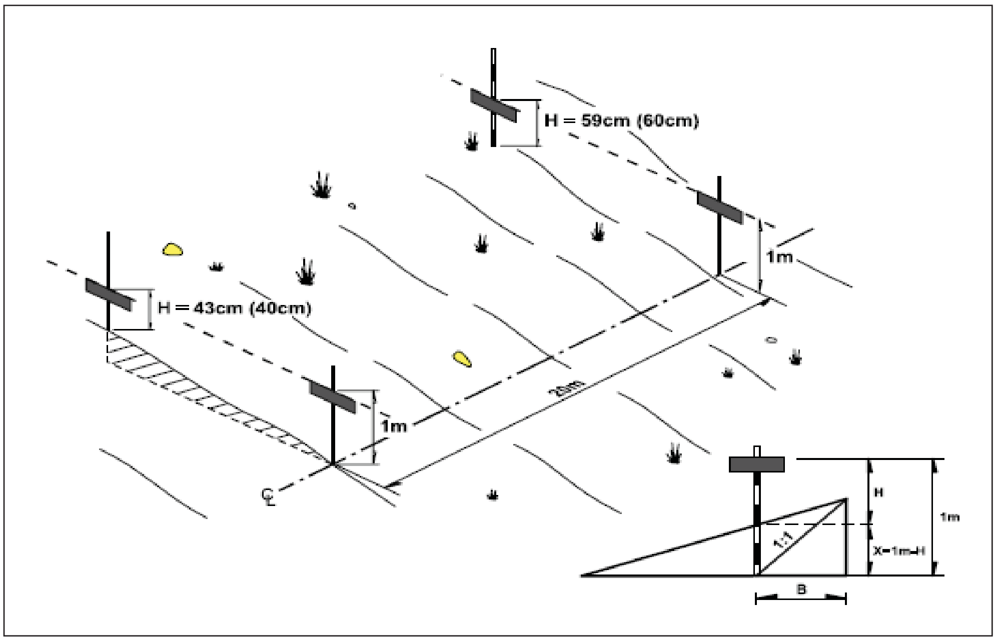
Figure 32: Example of Balancing Cut and Fill in Earthworks



Calculating the quantities of earthwork to be excavated

If there is too much excavation work for a gang to finish in one day, the work needs to be divided over several days. In the example of figure 33 the height at the beginning of a 20m long section is 43cm at the end the height is 59cm, so the average height H = (43 + 59)/2 = 51cm.

Figure 33: Example for Calculating Earthwork Excavation Works



The length along the cross-section to be excavated is 4.25 meters (see figure 33). This excludes the excavation of the back slope. For back slopes with a gradient of 1:1 figure 35 shows how this area of excavation can be calculated. In this example H = 0.51 meter, so X = 1 – H = 0.49 meter. D = 4.25 meter and L = 20 meter.

Example of calculating the quantity of earthwork to be excavated

Using the formulae in figure 34, the volume V of earthwork to excavate is:

V = ((D2 x X) / (2 x (D-X)) x L, so

V = ((4.252 x 0.49) / (2 x (4.25-(4.25-0.49)) x 20 = 23.5 m^3

If for example one labourer can excavate 1.45 m^3 earth per day, the number of labour-days to excavate **23.5m^3 = 23.5 / 1.45 ≈ 16 labour-days**.

Suppose a gang consists of 8 labourers, this means **16 labour-days / 8 labourers = 2 days** are required to complete the work. On each of the 2 days the volume of earthwork to be excavated is **23.5 / 2 = 11.75 m^3**. Figure 35 shows how this can be set out for this example.

Formulae used to calculate quantity of earthwork in excavation

Figure 34: Formulae to Calculate Area of Excavation

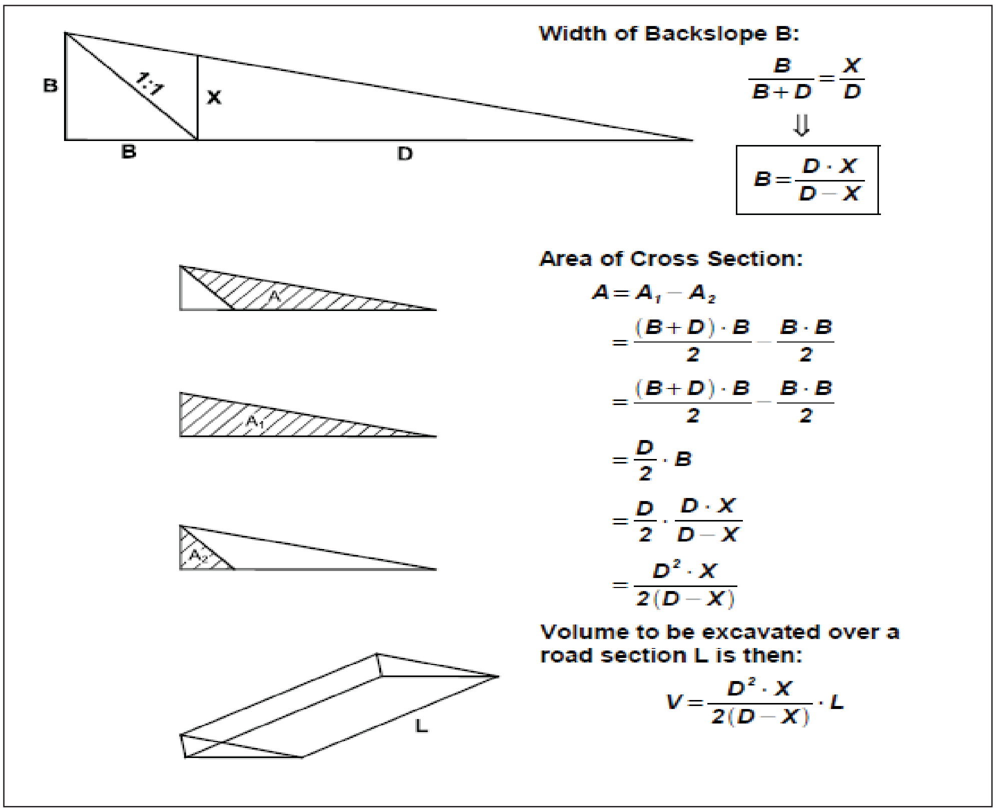
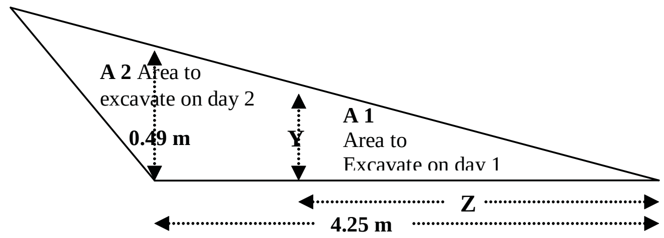


Figure 35: Example of Calculating the Daily Area to be Excavated



The area to be excavated during day 1 = **11.75m3 = 20 x A1.**

A1 = (Y x Z) / 2 so : 11.75 m3 = 20 x ((Y x Z) / 2). We need to know how much Z is.

This we can do as follows:

Y / Z = 0.49 / 4.25 or 4.25 x Y = 0.49 x Z or Y = (0.49 x Z) / 4.25 or Y = 0.1153 x Z

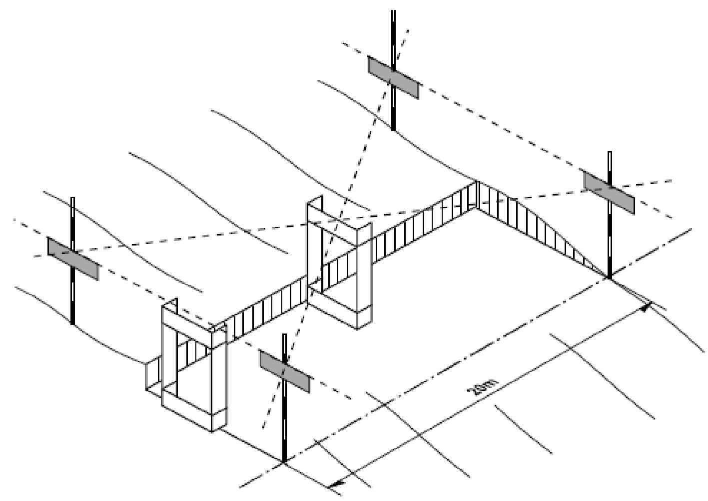
Then fill in Y = 0.1153 x Z in 11.75 m3 = 20 x ((Y x Z) / 2). This gives:

11.75 = 20 x (0.1153 x Z x Z) / 2 or 20 x (0.1153 x Z2) / 2 = 1.153 x Z2. or 11.75 m3 = 1.153 x Z2. or Z2 = 11.75 / 1.153 = 10.19. So Z = (10.19)1/2 = 3.19 meter.

A horizontal distance of 3.19 meter thus needs to be excavated during day 1. The remaining volume of the cross-section (area A2) needs to be excavated during day 2.

To ensure that the cut is fully excavated for a day of work, a temporary traveler can be used as shown in figure 36.

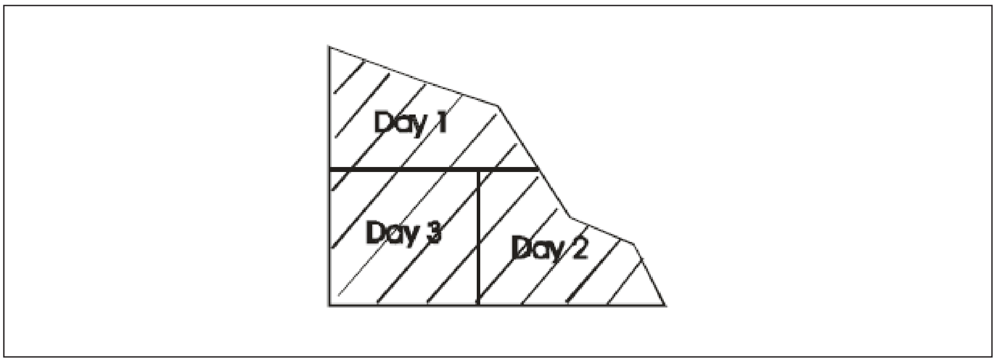
Figure 36: Using Traveler to Check that Earthwork Excavation is done as Required



Use a traveler to check that earthwork excavation is done as per requirements

If the area to excavated is very high, the top section is usually excavated first. Figure 37 shows an example of how the work could be organized on such a section. In this example 3 days will be required for the excavation works.

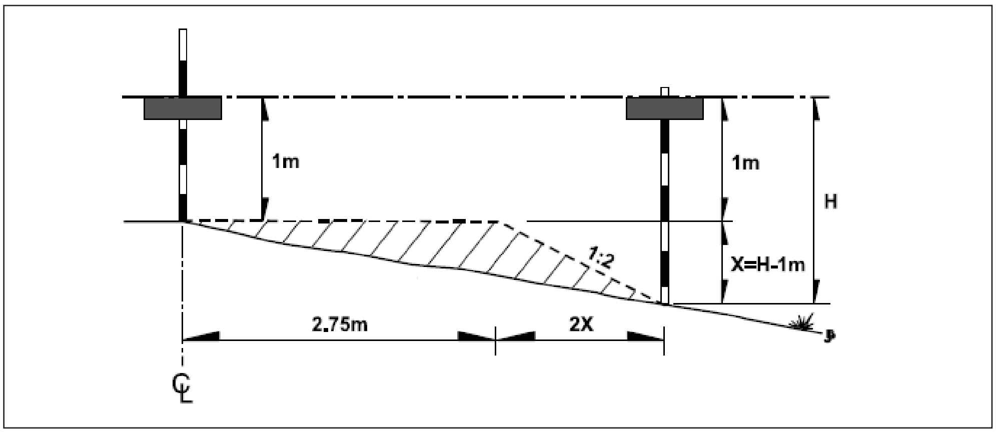
Figure 37: Example of setting out excavation works over a period of 3 days



The excavated soil is used to form the fill side. If the haulage distance from the excavation site to the fill site is small, you will usually need twice as many labourers for the excavation (cut) works than for the fill works.

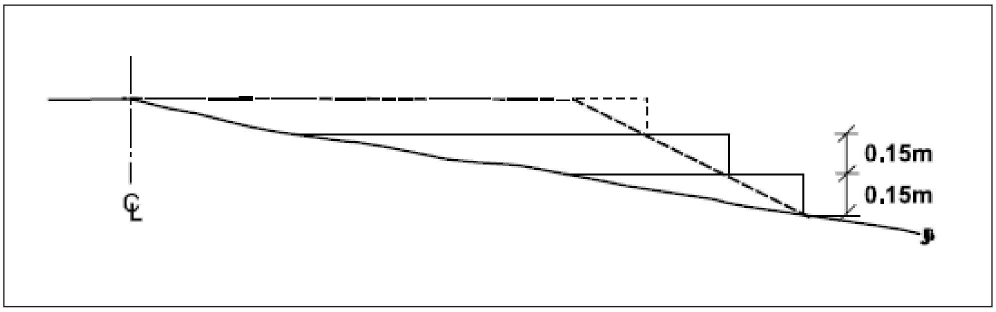
If the depth of the fill on the low side road shoulder is greater than 0.3m, there is usually no need for a side drain on the low side of the road. Make sure that the slope of the fill has a slope of 1:2 as shown in the figure below.

Figure 38: Setting out a slope of the fill of 1: 2



To get a good quality fill on the low side, make sure that the soils are properly compacted. The fill needs to be built up in layers of 15cm, and each of these layers needs to be well compacted before a new layer is added (see figure 39). If the area is too small to use mechanical compaction equipment, use hand rammers for compaction.

Figure 39: building up fill through compacted layers



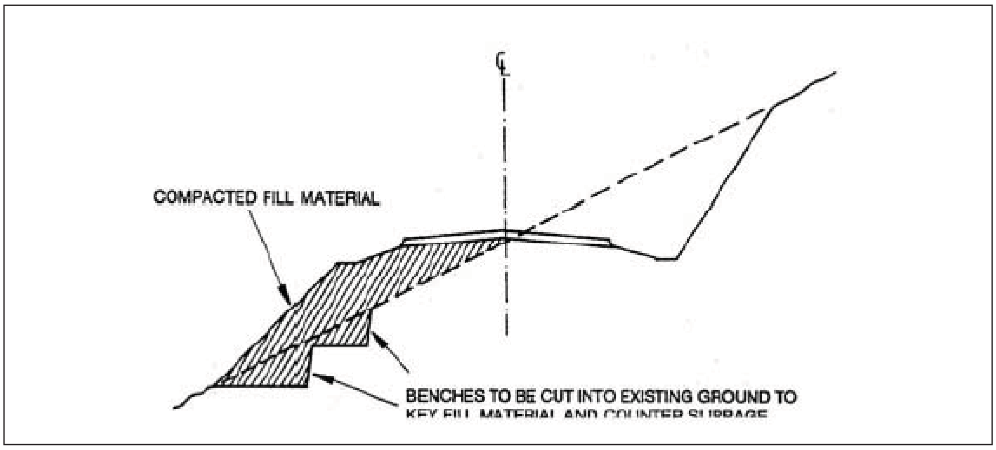
For excavation works usually twice as many labourers are needed as for fill works

The slope of the fill needs to be generally 1:2, depending on the soil type

Fill should be built up in layers and the layers need to be well

Benching of the fill side is also recommended as this will minimize the risk of slippage of the fill material over the existing ground. Figure 40 shows how to do this.

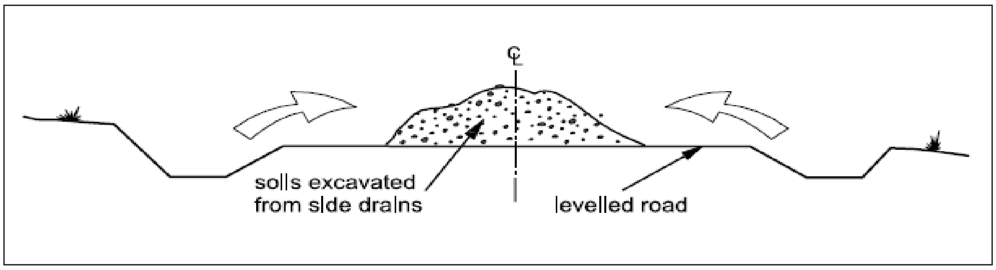
Figure 40: Keying of the fill material through benching



Constructing camber from soils from side drains and back slope

Once the excavation and fill have been completed, construct the road camber using soil from the side drains and back slope. Usually less labourers are needed for excavating the back slope than for excavating the drains. The excavated soils is thrown to the center of the road and from there it is leveled out towards each road shoulder to form the camber (see figure 41 and picture 6). Picture 7 shows a completed camber for a gravel road.

Figure 41: Constructing camber using soils from side drains and back slope



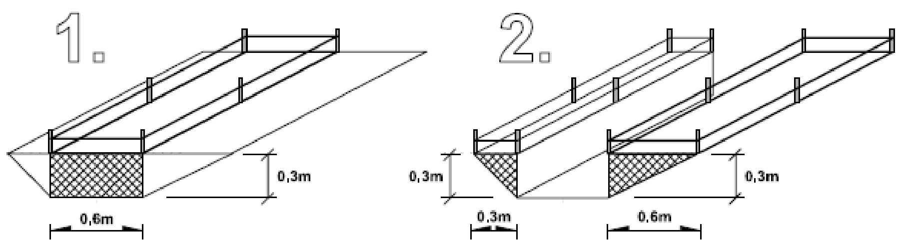
Picture 6 : Constructing camber with soils from side drains

Picture 7: Completed camber of gravel road

Side drain excavation is done by first excavating the ditch and then forming the side slopes of the ditch (figure 42). The side drain excavation is set out using string line and pegs, and controlled by using ditch templates.

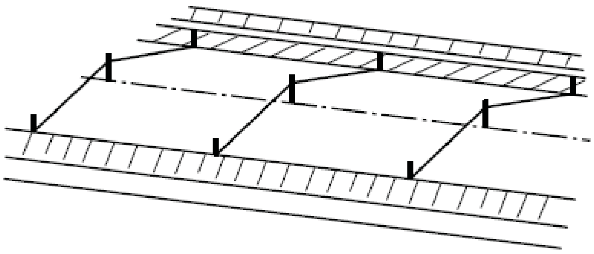
Side drains are excavated in two stages

Figure 42: Two-staged side drain excavation



To achieve an exact and properly leveled camber, the work is set out using pegs and strings (see figure 43). Once the soils for the camber has been leveled, the camber is properly compacted. Make sure that the soils contain optimal moisture content

Figure 43: Setting out camber by using pegs and strings

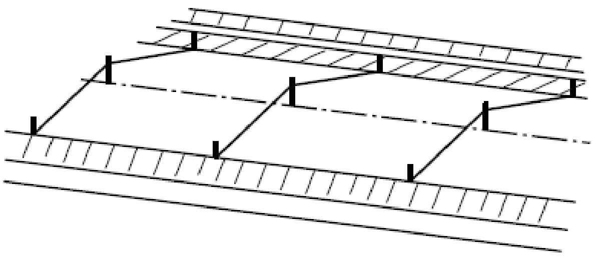


To check whether the achieved levels of the road camber are exact and to the prescribed standard and quality This can be done by setting out the profile boards and checking the level between the profiles with a traveler. A quicker but less accurate method is to use string lines (figure 44 and picture 9). If the levels are inaccurate, it should be corrected. If more filling is needed, make sure that these patches are properly compacted.

Picture 8: Compacting while maintaining camber

Check the camber using pegs and strings or with profile boards

Figure 44: Checking the camber using pegs and strings

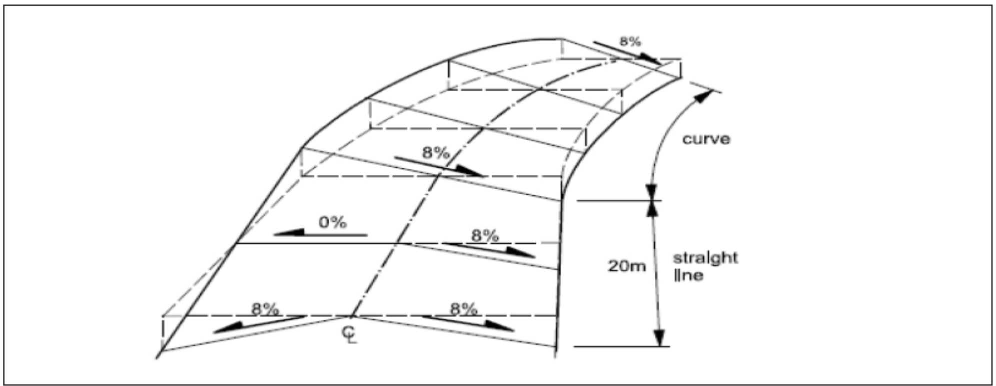


Picture 9: Checking the camber using pegs and strings

If there are sharp curves in the road where vehicles can maintain a high speed, invert the camber of the road (see also figure 43). This will reduce the risks of slipping vehicles. Inverting the camber is gradually built up over a 20m section before entering into the curve.

In sharp curved the camber of on the outer side needs to be inverted

Figure 45: Example of inverting the camber in a sharp curve



7.4 Graveling

Gravel surfaces have many limitations

In the past graveling of roads was considered an effective and cost-effective option for surfacing low-volume rural roads. Recent research however shows that gravel roads have serious limitations in many situations. Very often gravel surfaces are not appropriate, affordable or sustainable for rural roads. There are for example serious problems related to the maintenance and sustainability of gravel surfaces (or ordinary earth roads). Although the initial construction costs of gravel roads are low, the maintenance costs are very high.

The suitability of graveling roads depends on a range of factors. These include for example the road gradient, rainfall, material quality, haul distance and maintenance regime. Gravel should NOT be used if any of the following conditions, or a combination of them applies:

Situations where gravel is not suitable as surface option

- Gravel quality is poor;
- Compaction & thickness cannot be assured ;
- Haul distances are longer than 10km;
- Rainfall is very high – Gravel loss is related to rainfall;
- There are dry season dust problems;
- Traffic levels are high, i.e. more than 200 vehicle equivalents per day;
- Road gradients are more than 6% (with < 1,000mm rain per year) or more than 4% (with 1,000 – 2,000mm rain per year);
- If rainfall is more than 2,000mm/year;
- Adequate maintenance cannot be provided;
- Sub-grade is weak or soaked;
- Gravel deposits are limited or environmentally sensitive.