SKAT

Handbook for Instruction Courses

Road Projects Manggarai

Labour-based Road Construction

P. Hartmann

SKAT - Swiss Center for Appropriate Technology

Intercooperation - Swiss Organization for Development and Cooperation

Handbook for Instruction Courses

Road Projects Manggarai

Labour-based Road Construction

Remarks:

The pages of this publication are not numbered but arranged in tables. Each double page is a teaching-module and can be copied on a A3 sheet for visual aids.

The modules can be ordered at SKAT in loose-leaf-form.

First edition: 1991 by
SKAT, Swiss Center for Appropriate Technology and
INTERCOOPERATION, Swiss Organization for
Development and Cooperation

Author: Peter Hartmann

Published by: SKAT, Swiss Center for Appropriate Technology,
St.Gallen, Switzerland

Layout Peter Hartmann

Cover: SKAT

Comments: Please send any comments concerning this publication to:
SKAT
Tigerbergstrasse 2
CH-9000 St. Gallen, Switzerland

Printed by: Niedermann AG, St.Gallen, Switzerland

ISBN: 3-908001-35-8

Preface

This publication is a compilation of teaching modules, which was developed for training courses in the construction of rural access roads in Indonesia. The English version of this training handbook is meant to introduce the chosen construction standards and production proceedings of labour-based road construction to a broader circle of interested institutions and persons.

For clarity the Indonesian version was complemented with an introduction to the project background and concept, as well as with some detailed technical comments and references to the different work activities (see annex to the teaching modules).

Construction together with water supply, hand pumps and energy sources, are the four focal points of SKAT (Schweizerische Kontaktstelle für Angepasste Technik). In addition to its consultancy activities, SKAT tries to process and disseminate the experience of the Swiss development work to interested circles through publications. As with this publication field experiences can be made available and be useful beyond the project situation or geographic boundaries.

St. Gallen, March 1991

Werner Fuchs
Publications Department SKAT

Introduction

1. Road Projects in Indonesia

The Swiss Development Cooperation (SDC) has been supporting a programme for the construction of rural access roads in the Manggarai district on the island of Flores in Indonesia since 1985. With this programme SDC aims at benefiting the rural population in one of the poorest and least developed regions of Indonesia. In particular, road construction has the following objectives:

- To open up a region with good agricultural potential, to improve the marketing of agricultural produce and to improve services (inputs, extension, health, etc.), thus leading to a sustained improvement of income and of the socio-economic condition among a major part of the rural road population.
- To use and mobilise locally available resources and to build up local know-how in labour-based road construction with a demonstration effect to other road projects.

Swiss support is channeled through the Diocese of Ruteng via two priests of the Steyler-Mission who are the operational managers in charge. On the Swiss side, Intercooperation is the agency responsible for project implementation. The Engineering and Planning Office of Peter Hartmann, Trimmis, provides expertise and technical back-up in road construction during regular visits to the project.

2. Project History

The first road construction began in 1985. This road is approximately 50km long and runs from Pela on the Transflores road (about 1,100 metres above sea level) to Ramut, a small fishing village on the south coast of the island. The Polish missionary Stanis Ograbek of the Diocese Ruteng is the project leader who originally initiated the programme. The completion of the Pela - Ramut road is scheduled for 1991. In 1988 the construction of 6 additional roads began under the direction of father Stanis and another priest, Ernst Waser from Switzerland. It is planned to expand the project over the next few years and to construct additional roads.

3. Construction Standards

The roads are basically earth roads and only have a stabilised roadway where necessary because of geographical reasons and/or because of poor soil conditions. The roads are designed for one lane only with a width of 3.0 metres. The shoulders on both sides allow vehicles to pass one another. The drainage is designed to cope with the intensive rainfalls. The roof-shaped camber of the road allows the water to drain off on both sides. The side drains are supported with scour checks and sufficient culverts. In addition all necessary retaining walls, drifts and structures are part of the road construction. The design is further adapted to the low traffic density of maximum 40 to 50 vehicles per day. With regard to the construction costs the total expenses of US$ 25,000 to US$ 30,000 per km compare very favourably with low cost roads according to the World Bank standard.

4. Work Organisation

Important factors for the effectiveness of the project are:

- utilisation of locally available resources,
- technology and know-how transfer,
- promotion of the population's own initiative,
- identification of the population with the project and
- creation of employment and income opportunities.

All the work is carried out using labour-based methods. The excavation to road bed level is carried out by the local population in the traditional way using voluntary community labour. The organisation of the site operations for the construction of the roads is subdivided into technically logical sequences. They are as follows:

- setting out of the road alignment (routing), bush clearing and tree removal
- excavation to road bed level and removal of boulders
- construction of dry stone retaining walls, drifts, bridges and culverts
- reshaping and correction of slopes
- camber formation and construction of shoulders
- excavation of ditches and building of scour checks
- laying of stone paving (soling)
- sealing of stone paving
- grass planting for erosion protection on slopes and shoulders
- routine maintenance

5. Training

The organisation of the site activities in clearly defined sequences requires the work of specialised work gangs under the direction of capable foremen. The foremen have to be trained and prepared for their assignment together with the project leaders. This is carried out in two ways:

- on-the-job training throughout the project duration by the two priests, and

- special short courses, mainly during the project visits of the road construction consultant.

These courses usually last one or two days and are divided into theoretical and practical training sessions. Supporting teaching modules, which explain the most important activities with drawings, pictures and texts, are presented in a handbook. These modules are also printed on flip charts for practical training sessions in the field.

The teaching modules in this handbook are explicitly not a manual of labour-based road construction methods with detailed technical instructions. They are meant as course notes to support theoretical and practical training.

Peter Hartmann

Technical advise and translation by:

- A. Beusch, CH-7000 Chur
- D. Ikin, CH-3036 Detligen

0

Contents

1.1 Objectives of the programme

The aim of village roads is to provide access to isolated areas in the Manggarai District.

Village roads provide new connections between remote villages and the nearest main road.

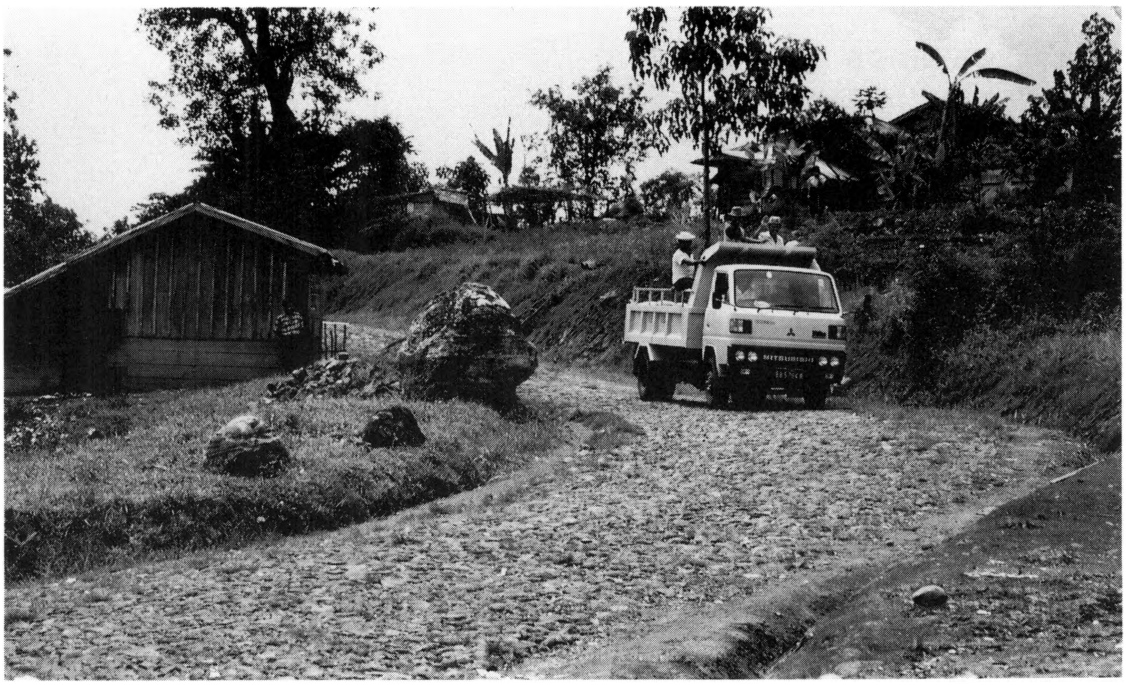
Village roads make it possible to travel to the nearest market, to the capital Ruteng, to medical clinics and to schools.

Village roads enable the transport of agricultural produce such as rice, coffee or coconuts, building material for the construction of houses, consumer goods, etc.

The construction of village roads creates employment and income opportunities for the rural population.

Technical knowledge and skills are learnt during the construction of village roads.

The construction of village roads promotes the villagers' own initiative and leads to the construction of roads through a self-help approach.



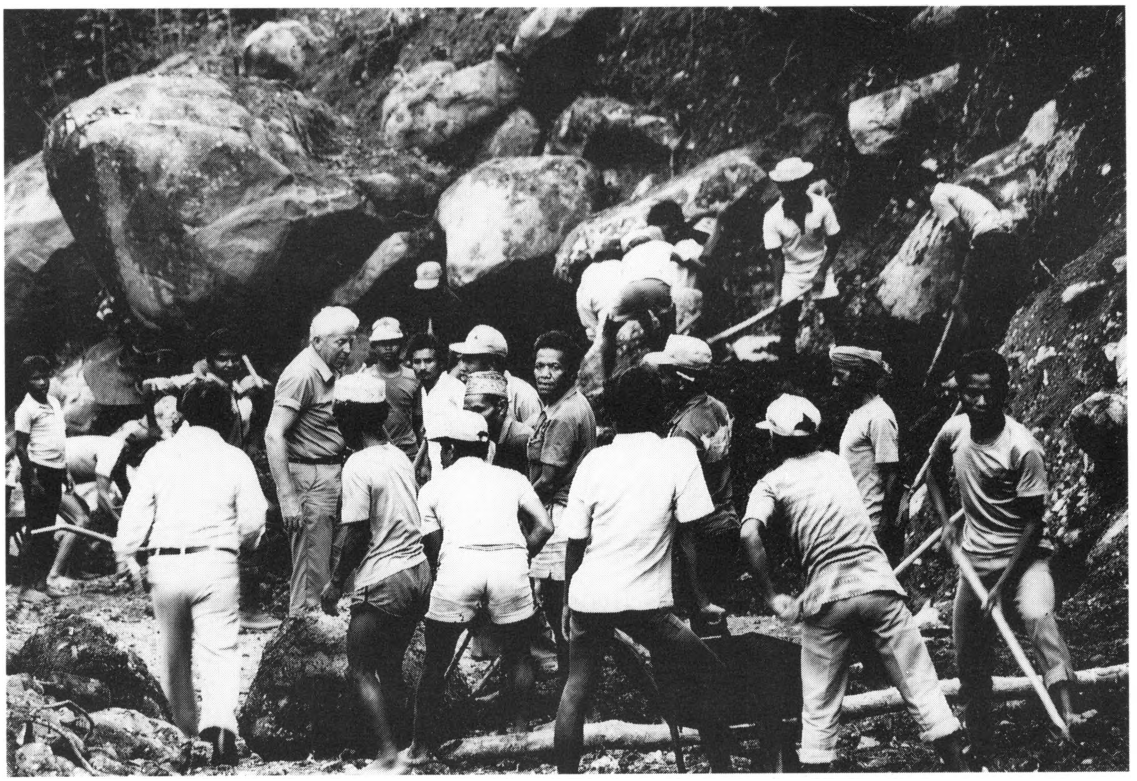
1

The most important requirements for the construction of village roads are:

The village roads need to be robust and durable so that they can be used throughout the year, that means during the dry and rainy seasons.

The costs for the construction of village roads have to be kept to a minimum in order to build as many roads as possible with the available funds.

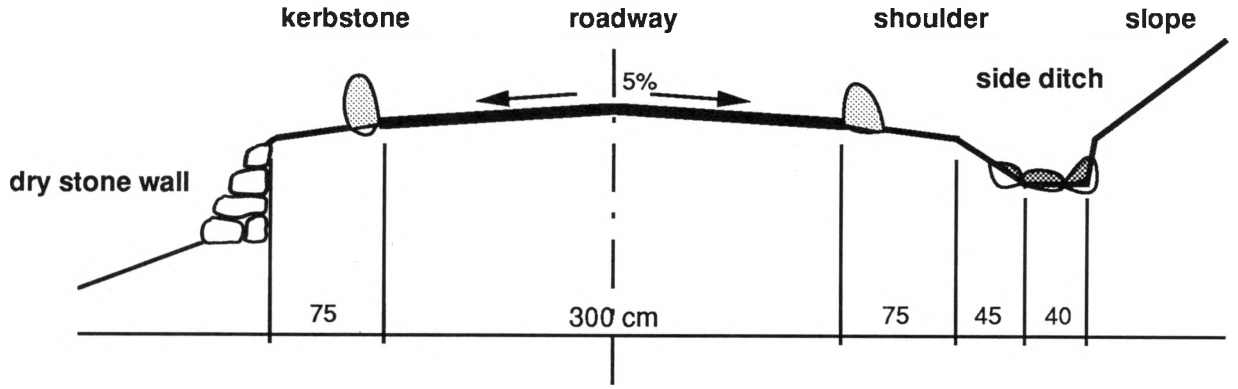
In order to build village roads at minimum cost they have to be constructed using labour instead of equipment and the minimum of expensive building materials such as cement.



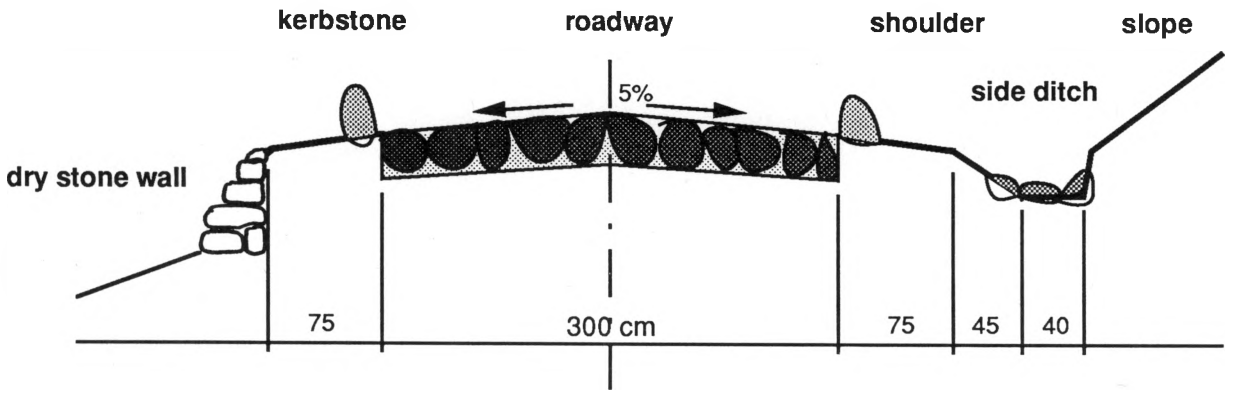
Even if village roads are constructed using labour-based methods they have to be technically sound in order to make sure that they have a long life span, are easy to maintain and require as little repair work as possible.

1.2 Construction standards

Construction standards for an earthroad



Construction standards for stone paved roads



2

The village roads are basically earthroads. Stone paving is layed in mountainous areas and soft ground stretches.

Example of an earthroad

Example of a stone paved road

1.3 Step-by-step organisation of the construction activities

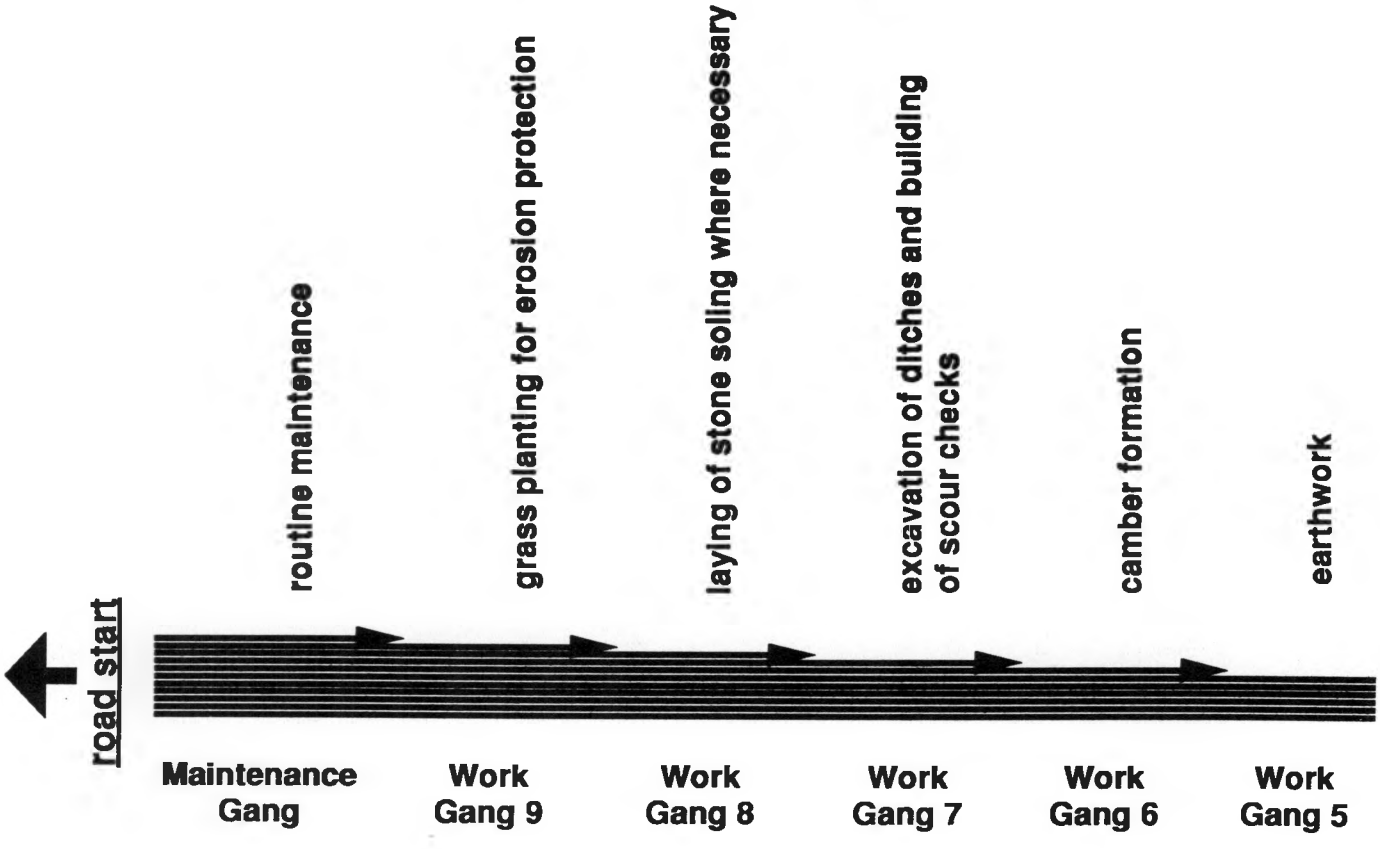
In order to build village roads that are technically sound and to ensure easy supervision it is necessary to divide the construction work into various stages.

The different stages are carried out by specialized work gangs who are controlled by a foreman.

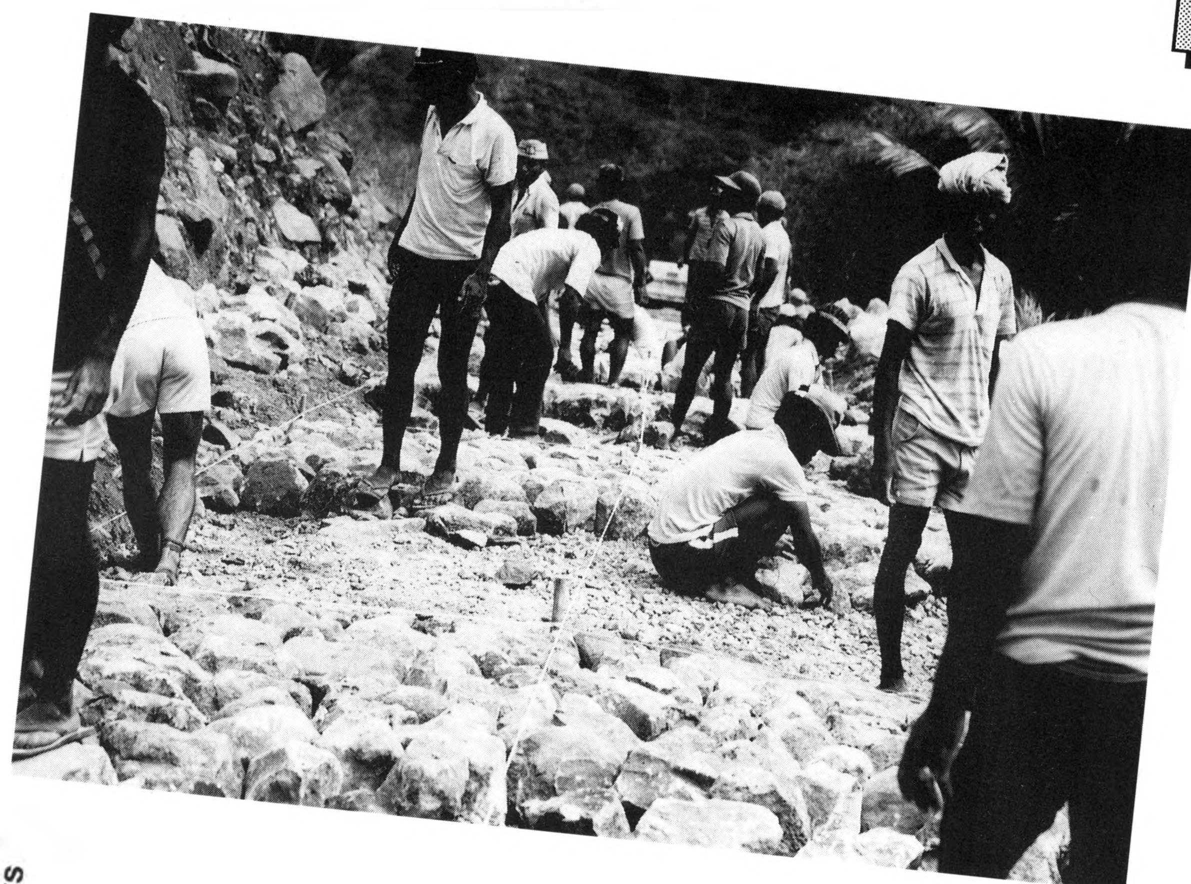
Different work gangs on the village roads carry out their activities in sequence. The activities follow one another but are spaced at short intervals along the road from beginning to end so that the road can be continuously completed.

Routine maintenance work should start as soon as a section of the road is completed.

Stages for the construction of village roads

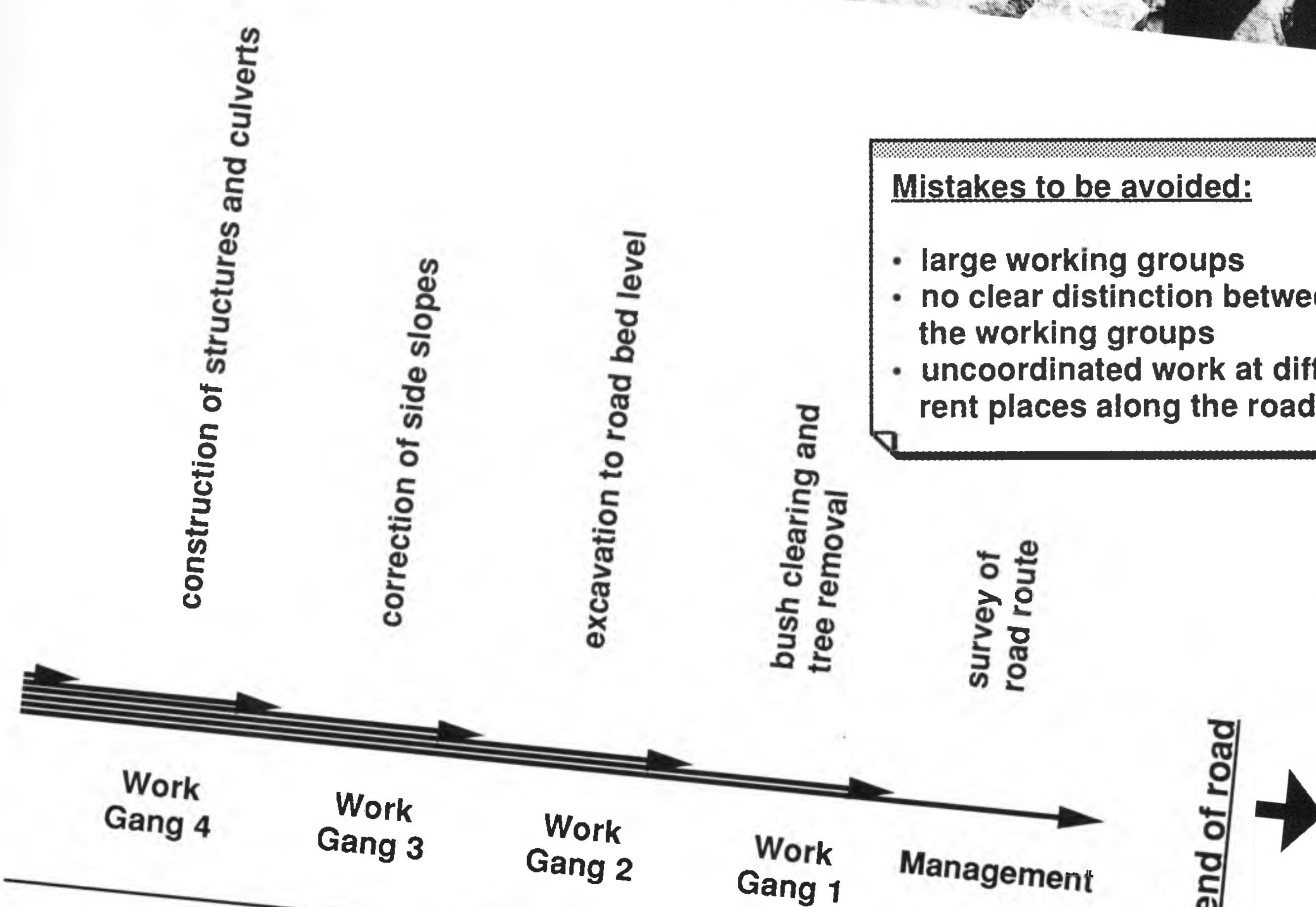


Well-organised stone paving work



Mistakes to be avoided:

- large working groups
- no clear distinction between the working groups
- uncoordinated work at different places along the road

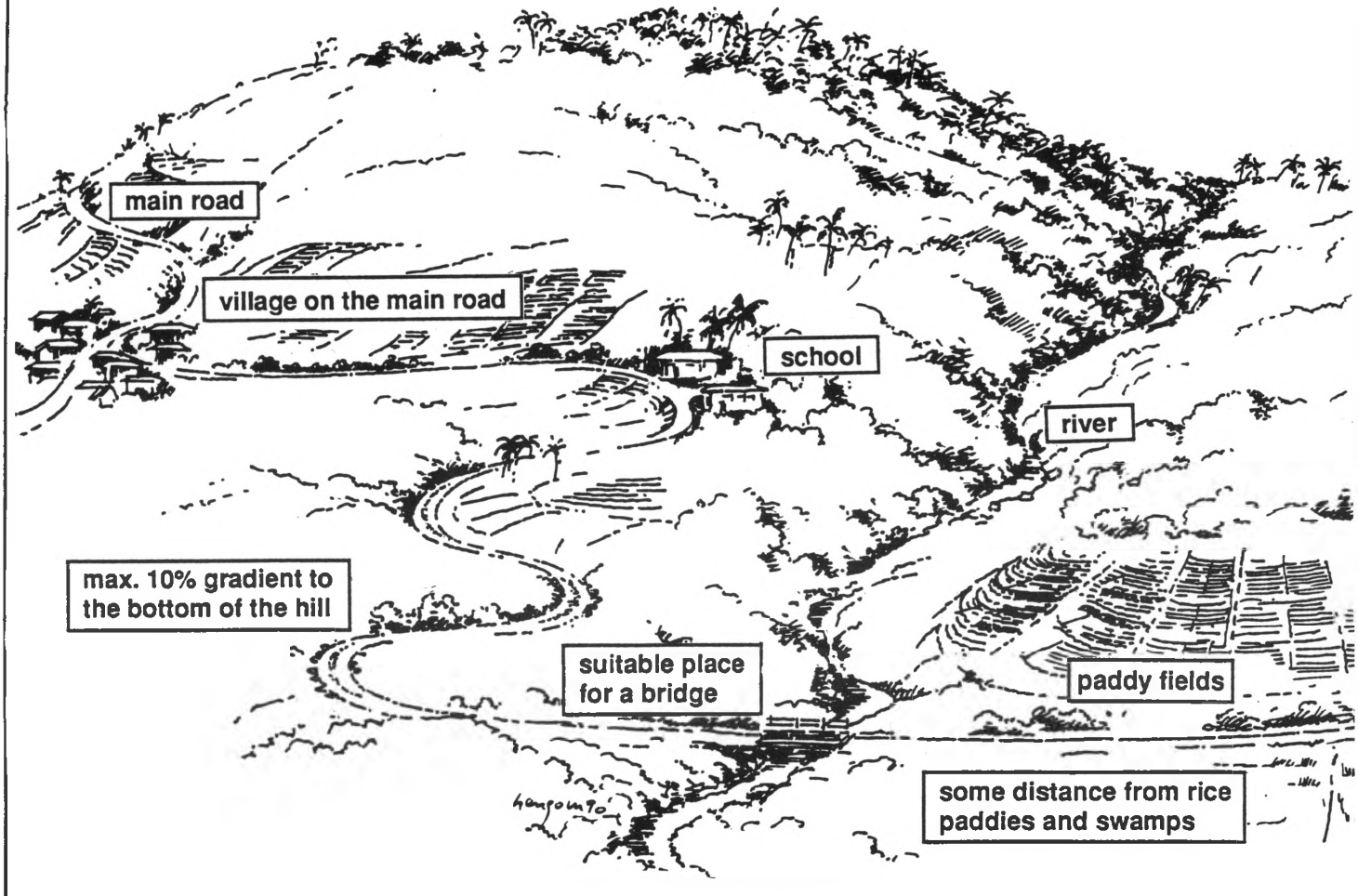


2.1 General road routing

Attention has to be paid to the choice of the general road alignment (route) so as to make sure that the road can be constructed at a low cost while remaining technically sound. The route has to be set out by the project leader together with representatives of the villages concerned.

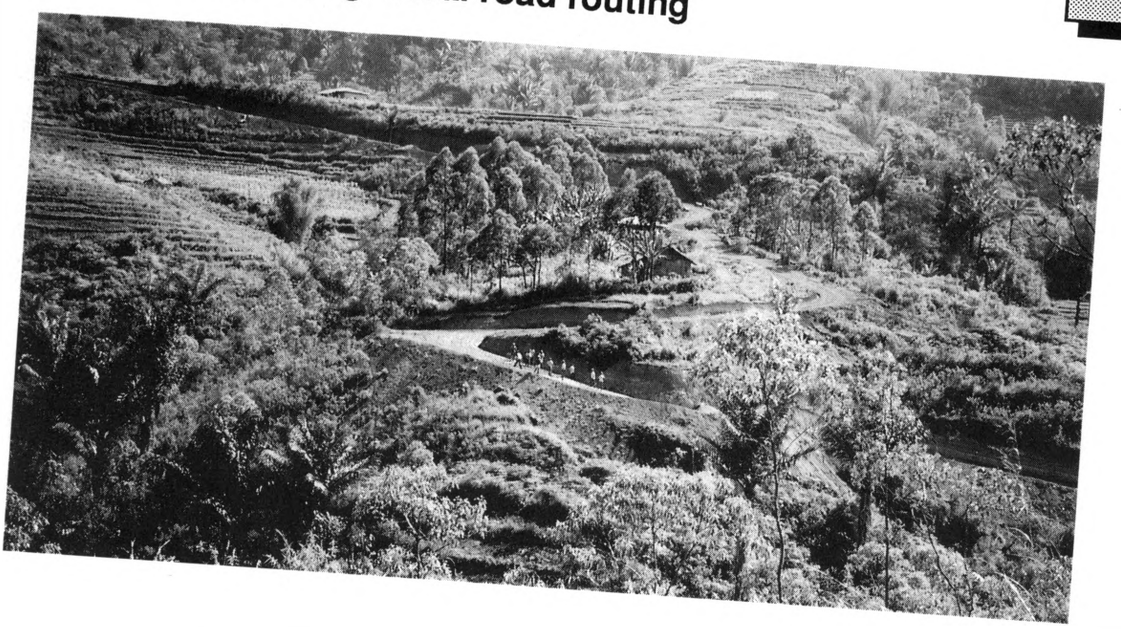
Example in the choice of a general road route

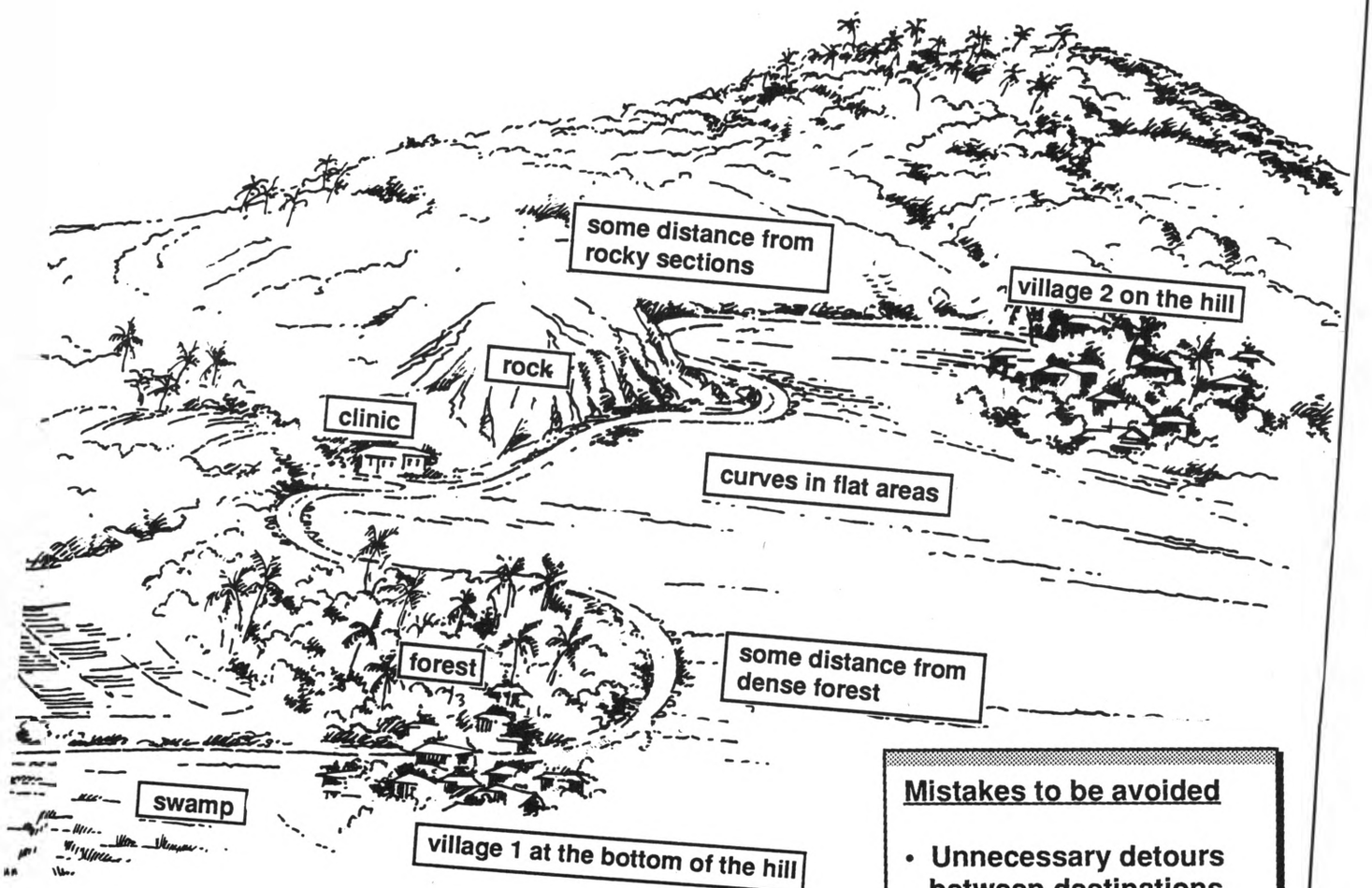
From the village on the main road along the existing slightly sloping footpath to the school. From the school with a continuous gradient of about 10% downhill to the bridge. After the bridge along the bottom of the hill with a slight gradient up to the village 1 below the hill. From village 1 passing the dense forest with a big curve up the hill to village 2.



Good example of general road routing

4





Mistakes to be avoided

- **Unnecessary detours between destinations.**
- **Crossing of unsuitable areas.**

2.2 Setting out of road centre line

For the setting out of the centre line in the field two elements are very important: the longitudinal gradient and the geometry of curves.

In order to reduce the velocity of the water in the ditch and to minimise erosion, the road should on the one hand not be too steep.

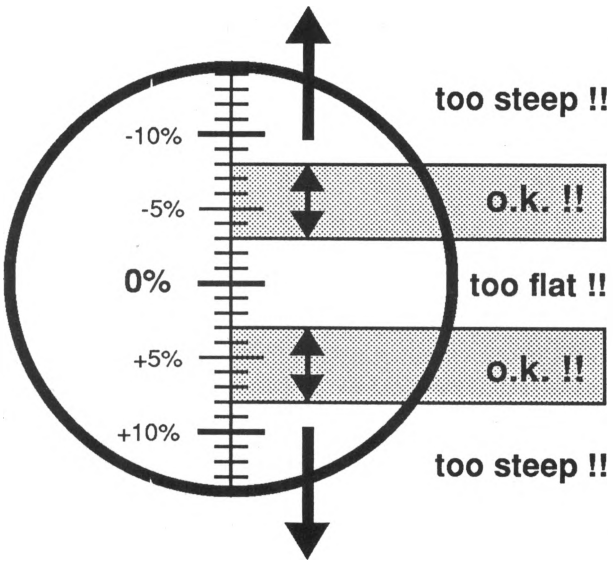
On the other hand, the road should not be too flat otherwise water will collect in the side ditches, silting them up and resulting in a wet, damp road.

As a rule, it is recommended that if possible the gradient be not steeper than 10% and not less than 3%. The ideal gradient of a road is between 3% to 8%.

The setting out of the road centre line is done using a levelling instrument (clinometer). The centre pegs are set out at regular intervals.

The setting out of the centre line is carried out by the project leader.

View through the levelling instrument

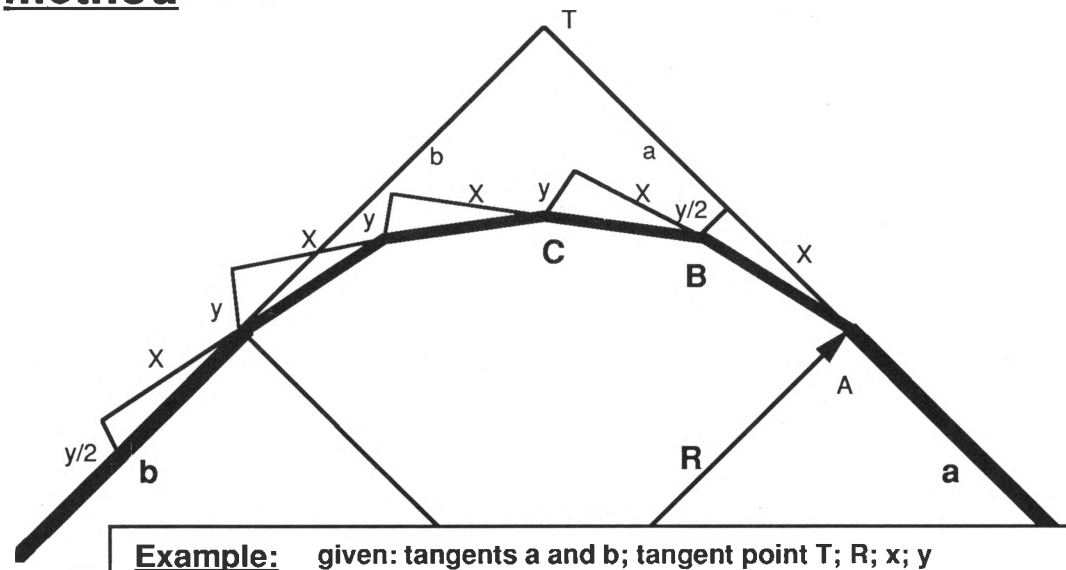


Mistakes to be avoided:

- longitudinal gradient below 2%
- longitudinal gradient above 15%
- hairpin bends steeper than 5%

The setting out of curves using the offset method

5



Example: given: tangents a and b; tangent point T; R; x; y

1. Choose the beginning of the curve on one tangent (point A)
2. Set out point B using x and y/2
3. Set out point C using x and y
4. Set out the other points as described above

If it is not possible to reach b, you may have to repeat the setting out with another offset y or choose the beginning of the curve differently (y = x2 : R)

Examples of curves:
R = 100 m; x = 10 m; y = 1.00 m
R = 40 m; x = 10 m; y = 2.50 m
R = 40 m; x = 5 m; y = 0.60 m
R = 15 m; x = 5 m; y = 1.65 m

Where hairpin bends on steep slopes have to be built it is important to reduce the longitudinal gradient before and after the curve. The curve as such should not have a gradient of more than 5%.

after the curve: steep!

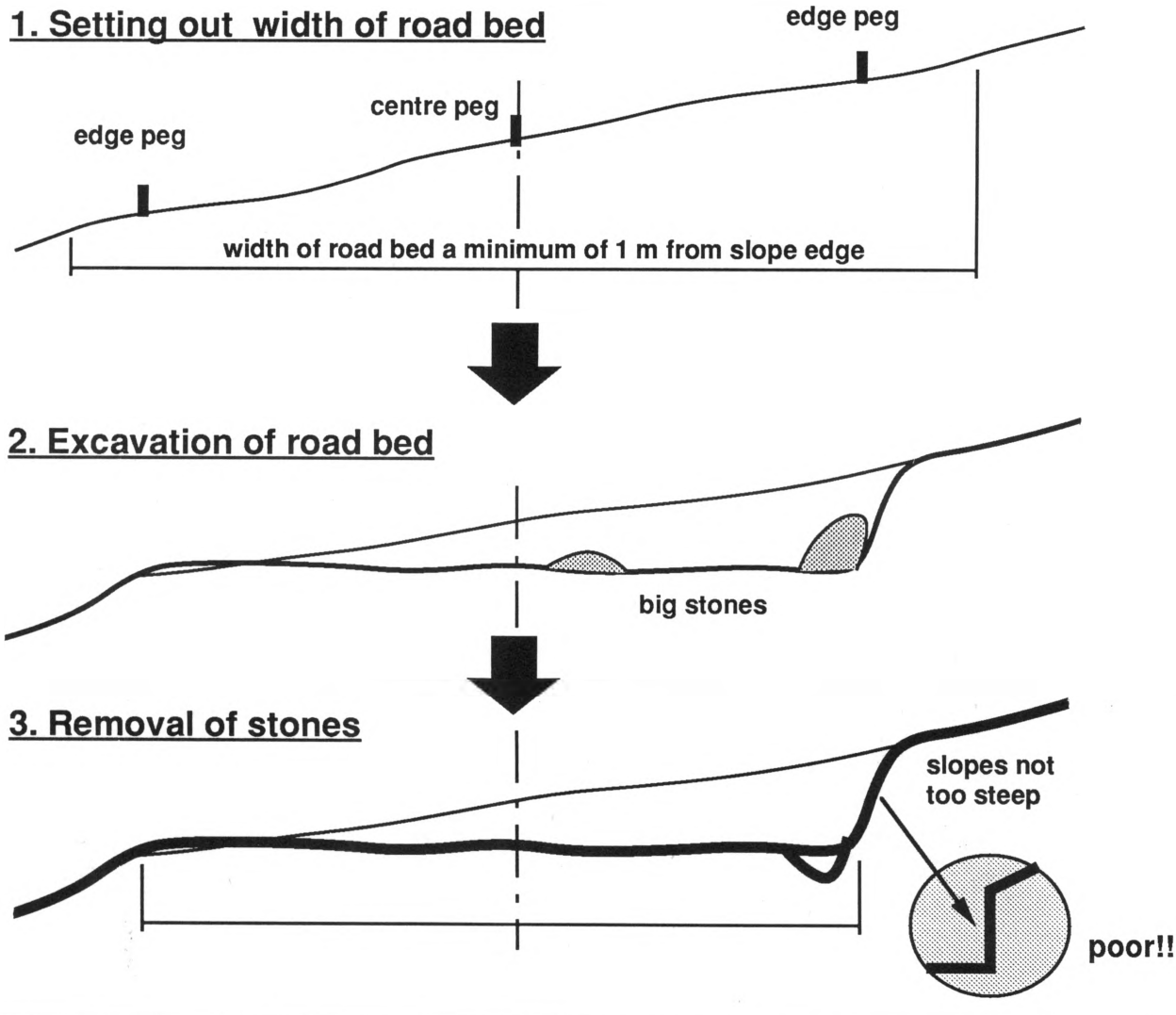
in the curve: flat!

before the curve: steep!

3.1 Construction of the road bed

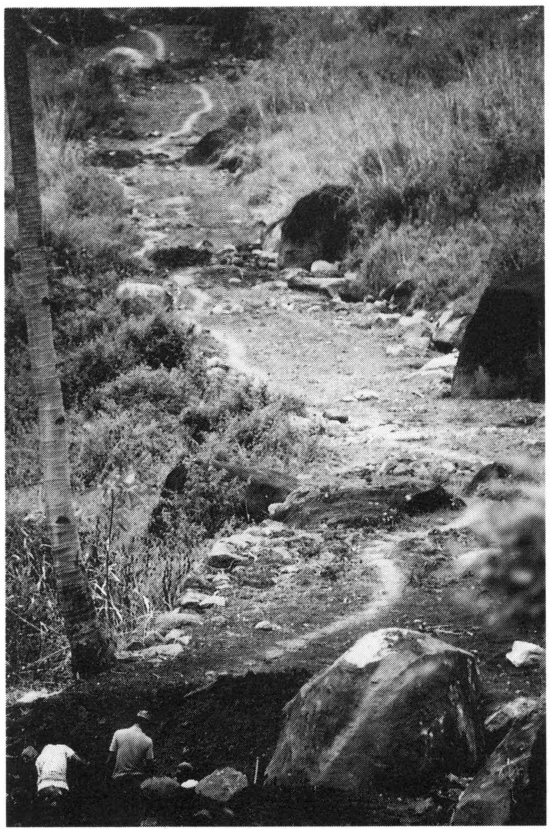
Preparatory work: Before the construction of the sroad bedcan start bushes and trees have to be cleared. The width of the cleared area depends on the size of the slopes. In steep places the clearing has to be wider than in flat areas. The standard width for clearing bushes and trees is a minimum of 100 cm or more from the edge of the slope. In some cases a valuable tree can be left on a slope as long as the road drainage is not endangered.

The population living near the village road constructs the road bed with voluntary community labour. After excavation the road bed has to be at least 500 cm wide and as level as possible. The slopes on the hill side must have a gradient which does not allow rock or earth slides onto the road. Big stones must be removed when preparing the road bed. These stones can be dug out, buried, cracked and removed using fire, water and chisels. Below the slope on the hillward side a temporary drainage ditch has to be dug.



Road bed before removing stones

6



Possibilities for the removal of stones:

- **dug out and rolled away**
- **buried below the road bed**
- **split with fire and water**
- **broken up using chisels and crowbars**

When this work is completed the road bed should be usable for motor vehicles, at least in the dry season and where there are no river crossings.

Good example of a completed road bed

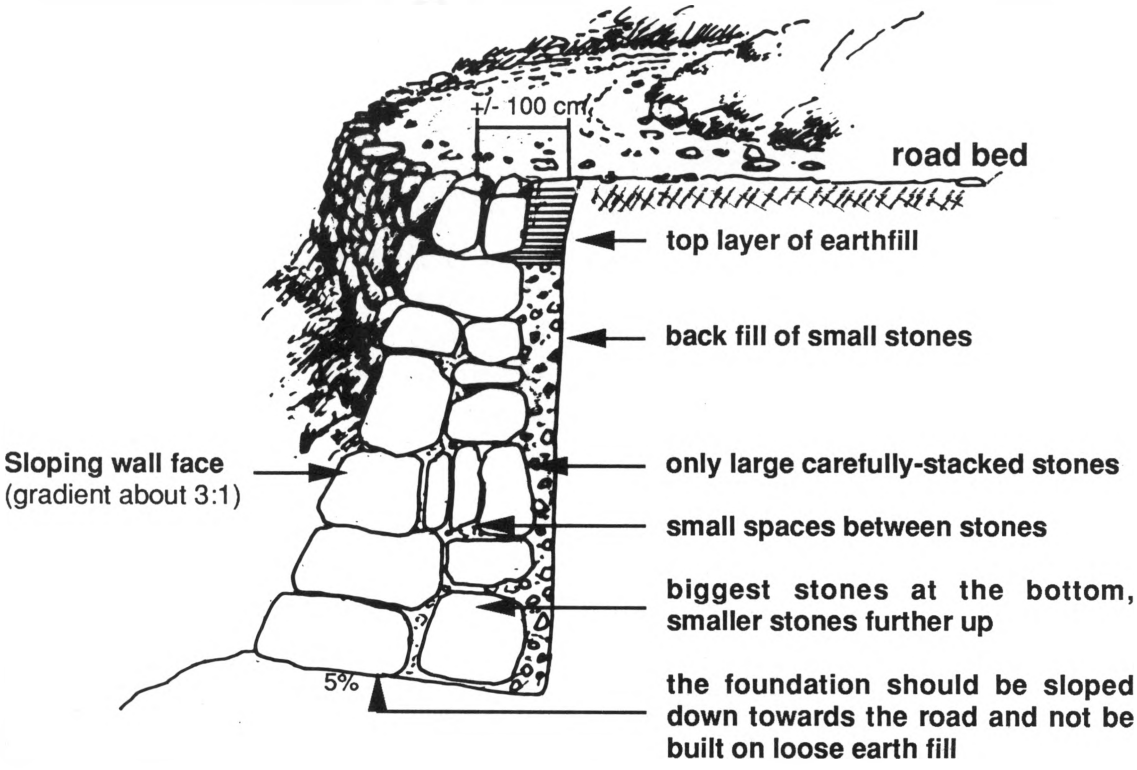
Mistakes to be avoided:

- **road bed too narrow**
- **slopes too steep**
- **big stones left behind**

3.2 Structures and culverts

The most important structures to be constructed along the village roads are: dry stone retaining walls above and sometimes below the road, culverts at regular distances, drifts on small water courses and bridges on larger rivers. The larger structures are constructed by contractors.

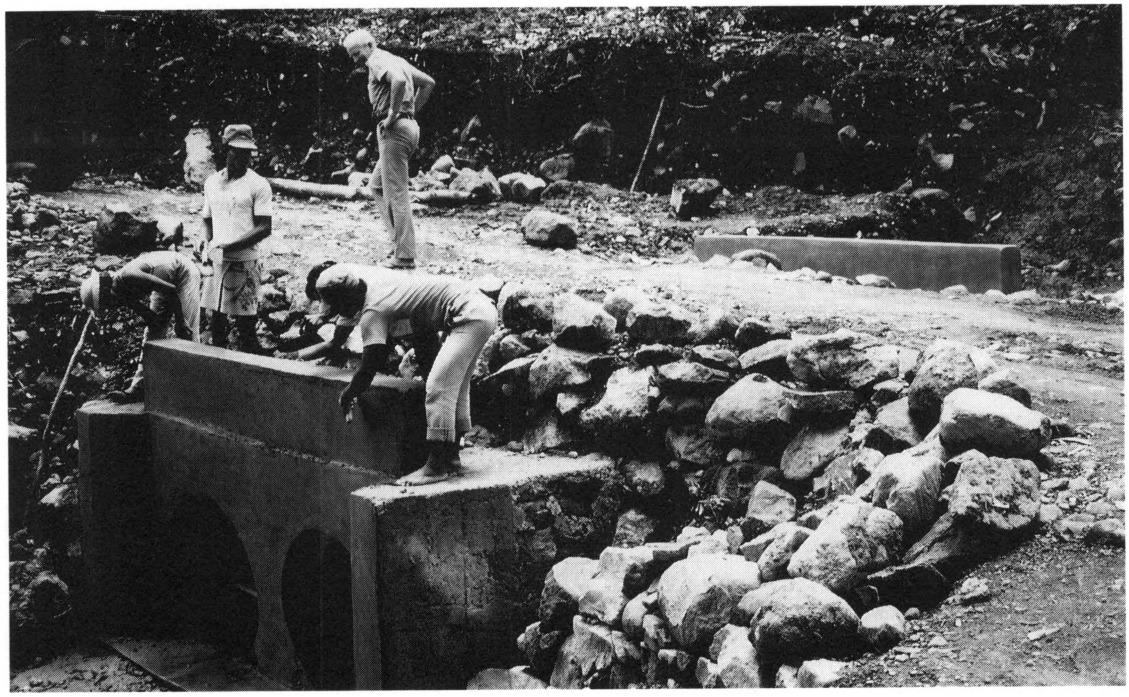
Dry stone retaining walls



Example of a dry stone wall

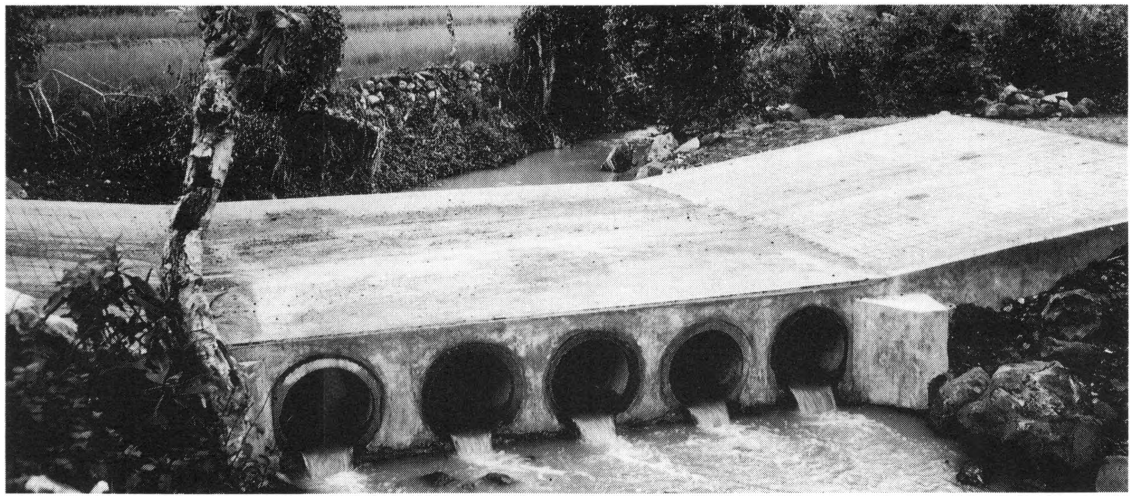
Culverts

Culverts allow water from the hillward side ditch to pass under the road out to the valley side. Culverts have to be positioned in accordance with the expected flood water volume. The culverts are constructed by specialized work gangs or contractors.



Drifts

Drifts are river crossings or fords consisting of a row of culverts and a concrete apron with ramps at both ends. The normal dry season water flows through the culverts while in flood conditions the water flows over the apron.



4.1 Correction of steep slopes

The most important activities are: the correction of steep slopes above the road, the camber formation, the digging of ditches and the construction of scour checks. The various earthwork activities are carried out by different gangs.

1. Earthwork activity: correction of steep slopes

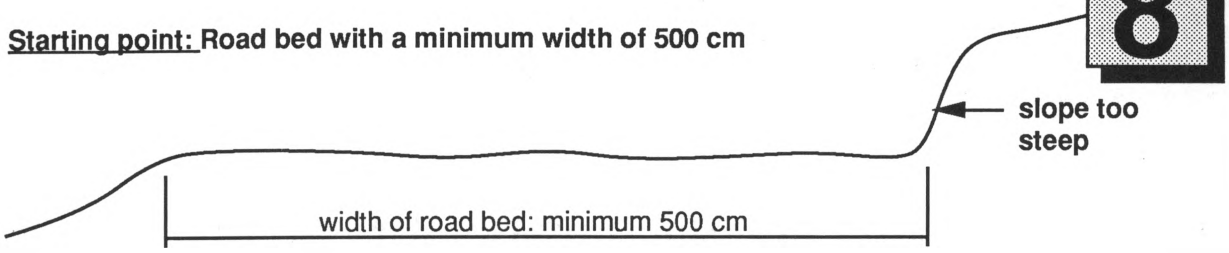
After the road bed preparation by voluntary community labour the hill side slopes will in many places be too steep and earth could slide onto the road.

Example of slopes which are too steep

These steep slopes can be improved by correcting their gradient. The rule is: the softer the soil the flatter the slope. Where the incline is very high, retaining walls should be built on the hillward side of the road.

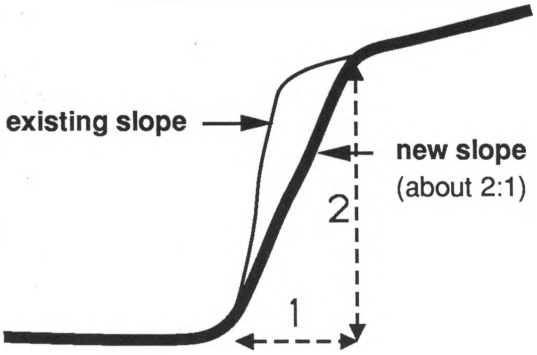
8

Starting point: **Road bed with a minimum width of 500 cm**

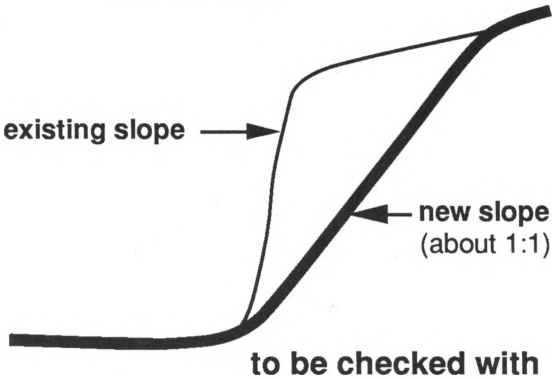


Reduction of steep gradient

in hard soil



in soft soil



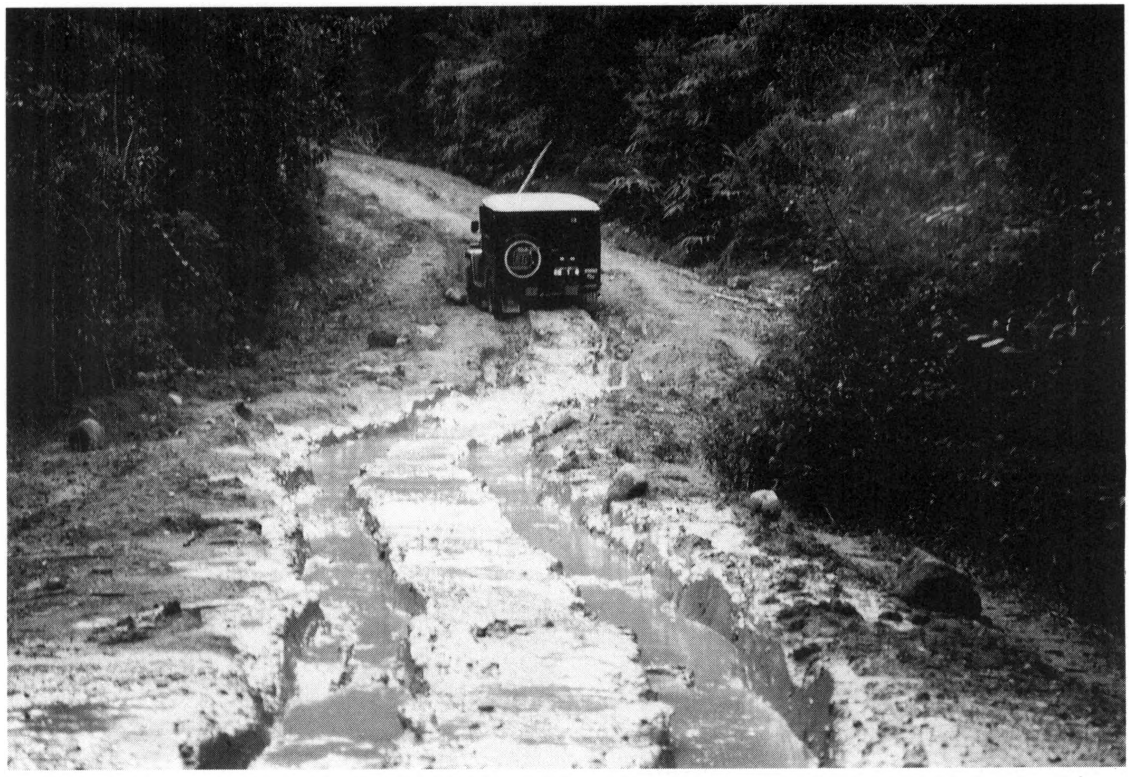
to be checked with slope template

Example of a slope in soft ground

4.2 Camber formation

2. Earthwork activity: camber formation

Rainwater cannot drain off if the camber is too flat. The water collects on the road surface, softening and weakening it. Vehicle wheels will then cut deep ruts into the road and more water will collect during the next rainfall. The ruts become deeper and deeper.

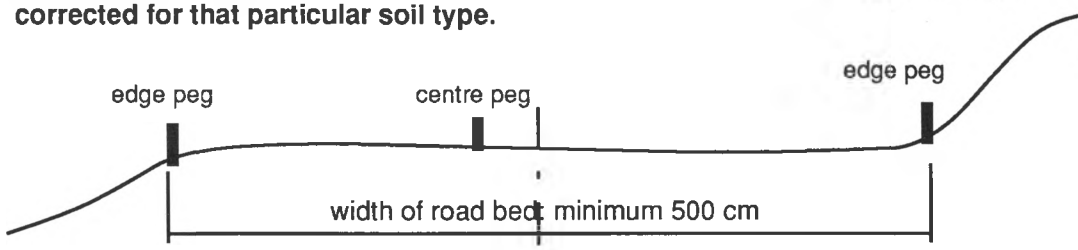


So that rainwater can drain away at all times the surface of the road has to be roof-shaped. The camber of the road should be about 5% on both sides.

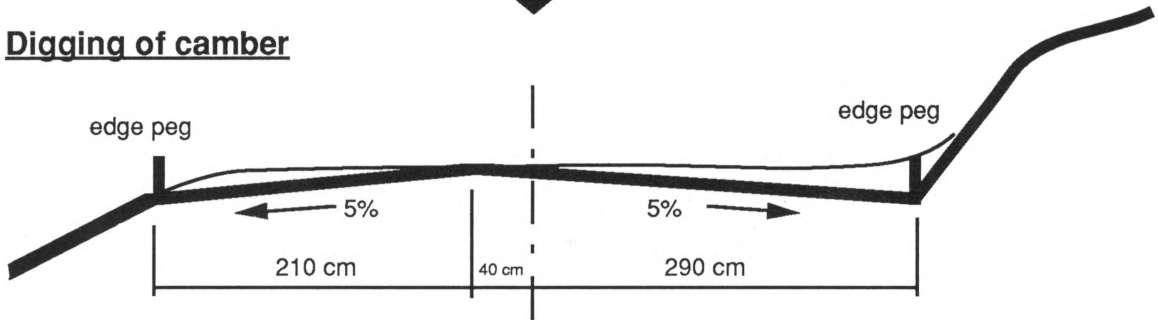
The camber is dug in the road bed starting from the centre line towards both sides. Therefore it is important to set out the centre line first using pegs with a spacing of 500 cm. The centre line of the road bed has to be moved 40 cm away from the hillward side, thus allowing space for the upper drainage ditch.

Starting point: **Road bed with a minimum width of 500 cm and a hillward slope corrected for that particular soil type.**

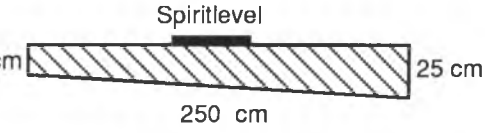
9



Digging of camber



to be checked with template:



Example of camber formation

Mistakes to be avoided:

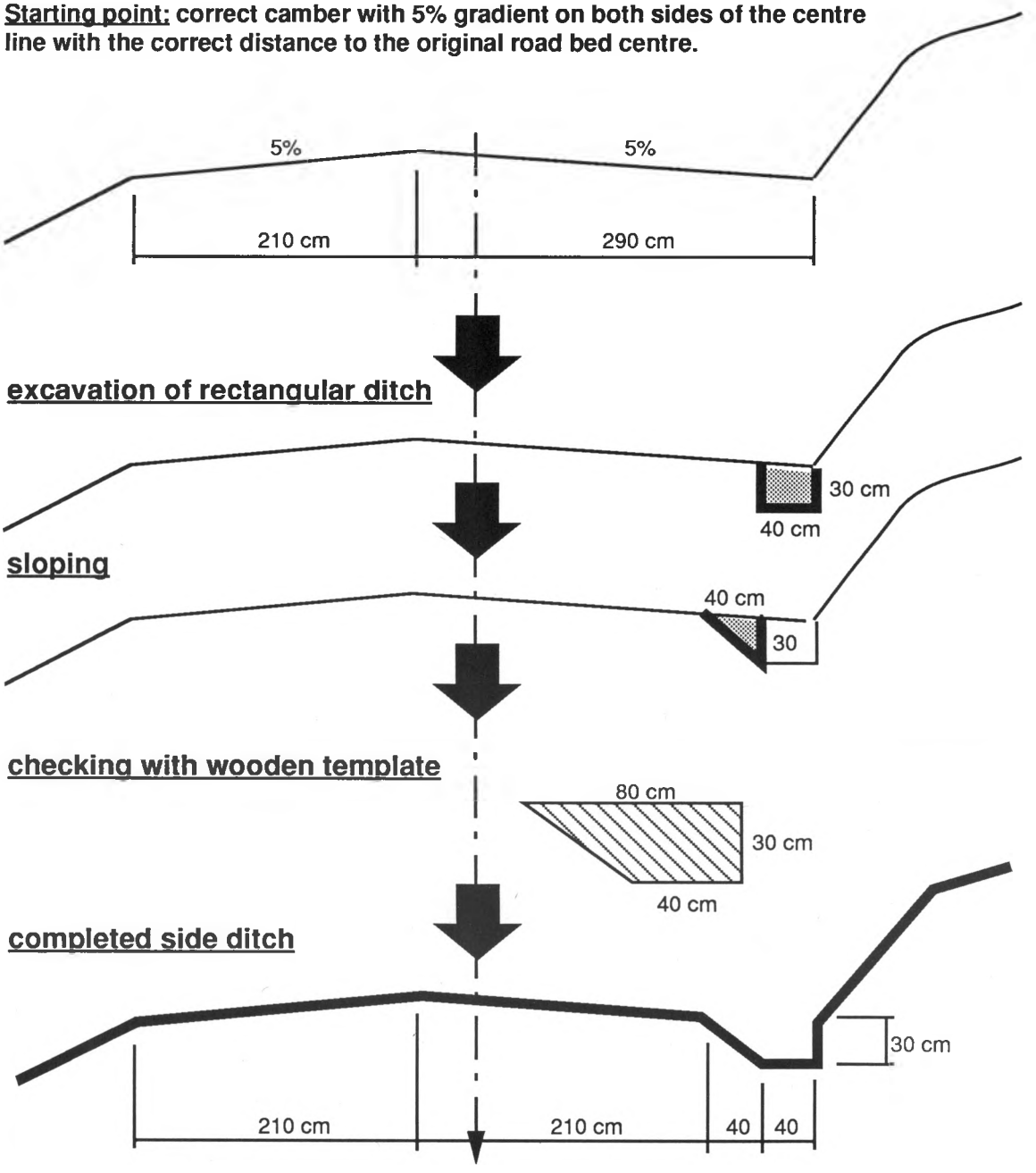
- **camber too flat**
- **camber too steep**
- **camber formation using loose soil**

4.3 Excavation of drainage ditches

3. Earthwork activity: excavation of ditch

A hillward drainage ditch is required so that water flowing from both the road surface and the hill slope can drain away and out through the next culvert.

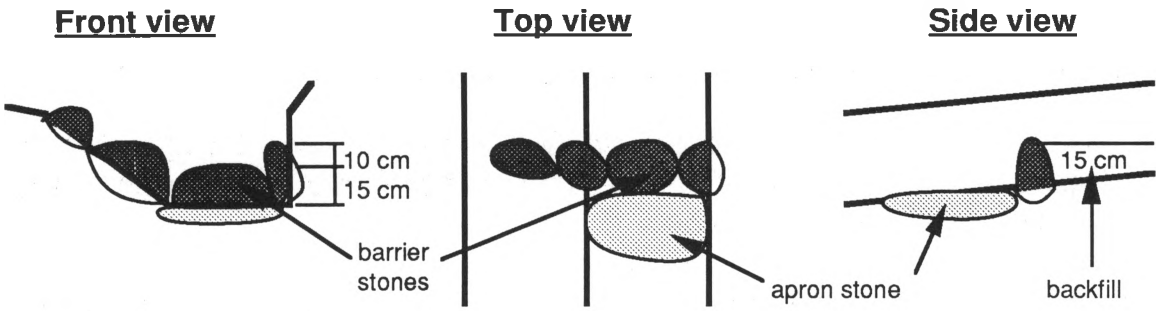
<u>Starting point:</u> **correct camber with 5% gradient on both sides of the centre line with the correct distance to the original road bed centre.**



10

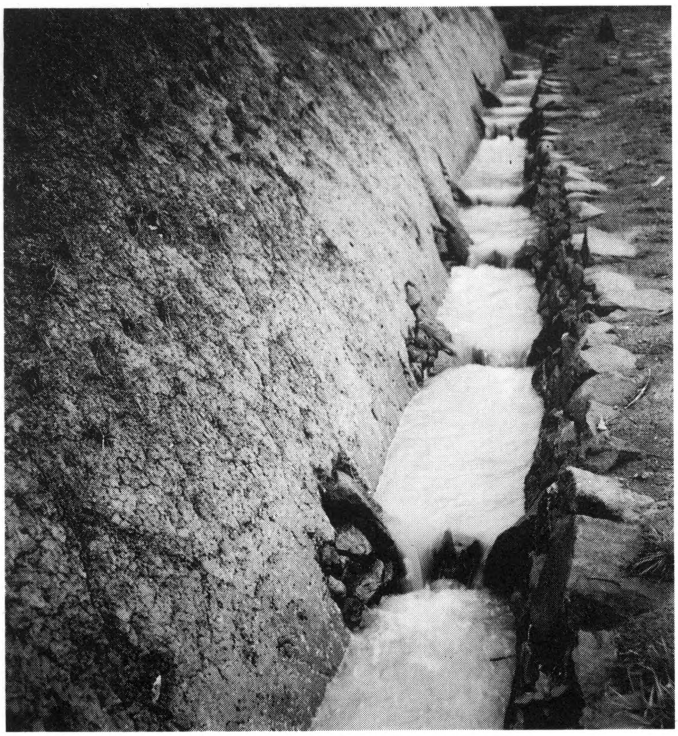
In order to prevent drainage ditch erosion on steep road sections, the velocity of the water flow has to be checked by stone scour checks at regular intervals. The following rule applies: the steeper the road the smaller the distance between scour checks.

Correctly constructed scour checks in ditch:



The scour check consists of 4 barrier stones placed upright and slightly buried into the slope and ground. Below the barrier stones a flat apron stone is placed to prevent the scour check from being washed away. The earth collected from burying the stones is used to backfill the scour check

Example of well-functioning scour checks



Mistakes to be avoided:

- **too narrow or not deep enough ditches**
- **not enough scour checks**
- **no apron stone below the scour checks**

4.4 Completion of the earthroad

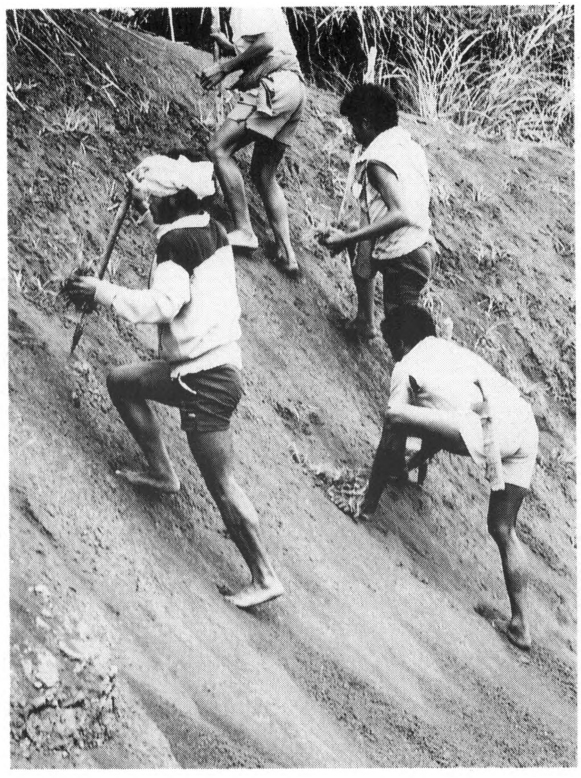
The most important finishing work in earthroad construction is grass planting on shoulders and slopes and placing of kerb stones.

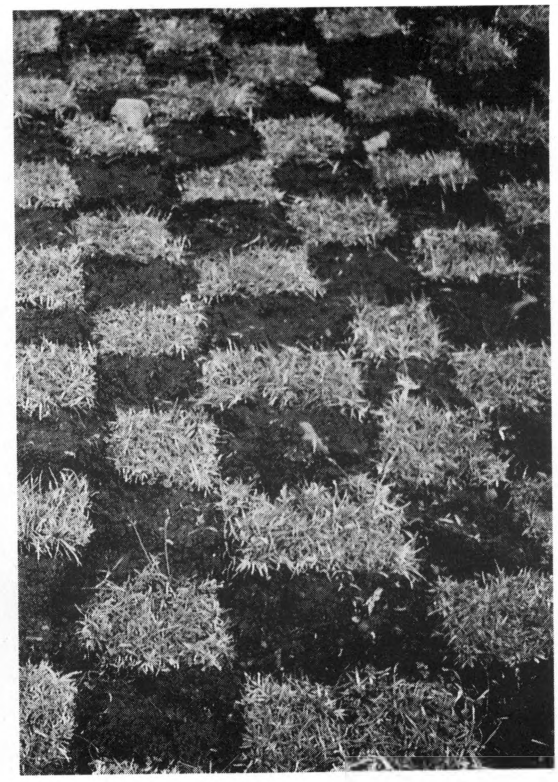
Planting of grass for erosion protection

The roots of the grass retain the soil and hold together the slopes and shoulders, thus preventing the soil from being swept away into the ditches.

Depending on the soil type grass can be planted on the shoulders and slopes in tufts or blocks of turf. During maintenance of the road it is important that the grass is kept short enough to allow the water to flow unhindered into the ditches.

Planting of grass as erosion protection

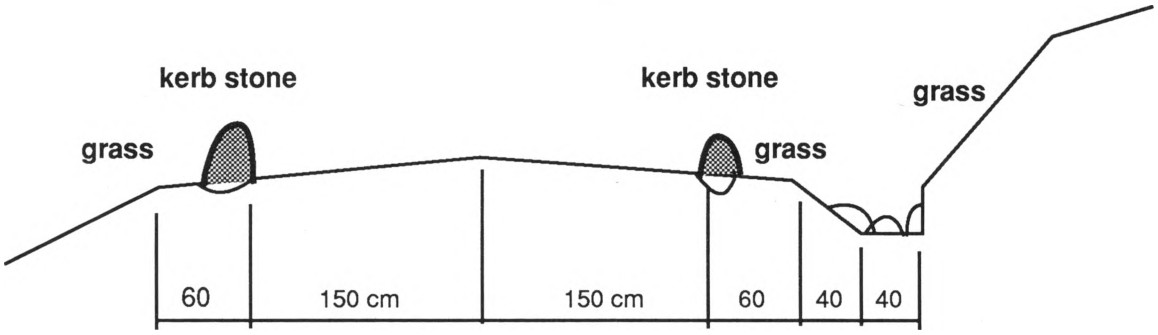




Placing of kerb stones

11

In order to keep vehicles driving on the 300 cm wide roadway and thus preventing damage to the road shoulders kerb stones are placed at regular intervals of about 15 meters.



After completing these activities the village road can be immediately handed over for routine maintenance. The necessary maintenance activities are described in the second part of this handbook.

Example of a completed earthwork

5.1 Excavation of foundation

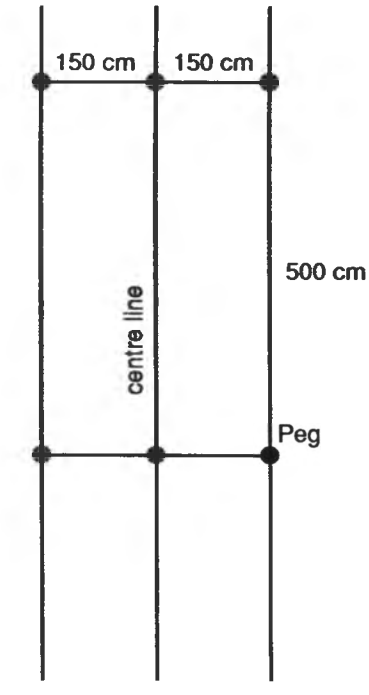
Stone paving is only done where an earthroad is not suitable e.g. on steep sections and/or where there is soft soil. The most important activities are: excavation of foundation, placing of stones and sealing of the stone paving. Various activities are carried out by different work gangs.

1. Stone paving: excavation of foundation

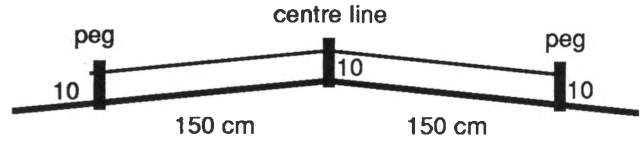
The foundation is directly cut out of the road bed or at a later stage out of the camber surface of the completed earthroad. The foundation is 300 cm wide and 20 cm deep.

In order to maintain the correct width and depth for the stone paving it is necessary to set out the measurements with pegs and string lines before the work starts. The road is divided into 500 cm sections. The pegs have to be about 10 cm higher than the existing road surface so that the stone paving will be approximately 30 cm high.

Peg and string line setting from above



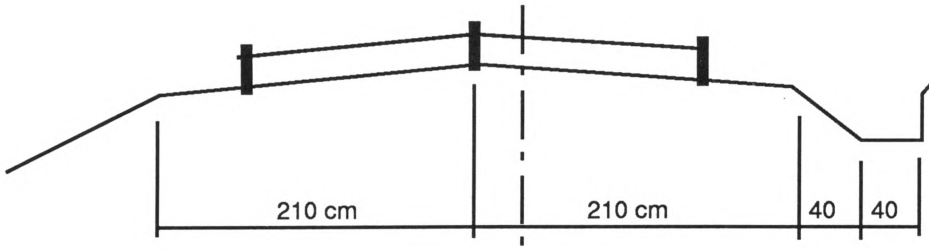
Side view



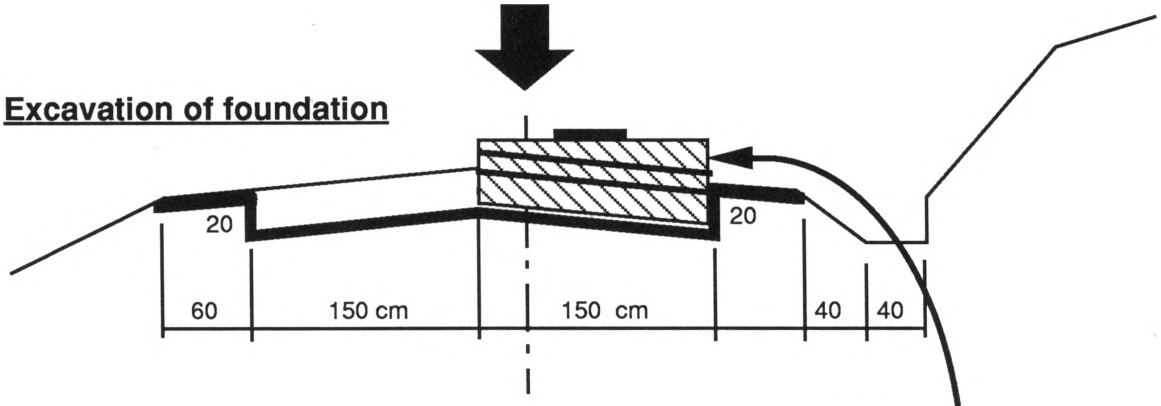
The excavation can be started only when the setting out has been completed and checked.

12

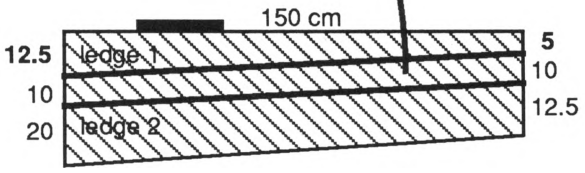
Starting point: 500 cm wide road bed or completed, staked out earthroad



Excavation of foundation



Template for checking the foundation (ledge 2) and the stone paving (ledge 1)



Example of a well-excavated foundation

Mistakes to be avoided:

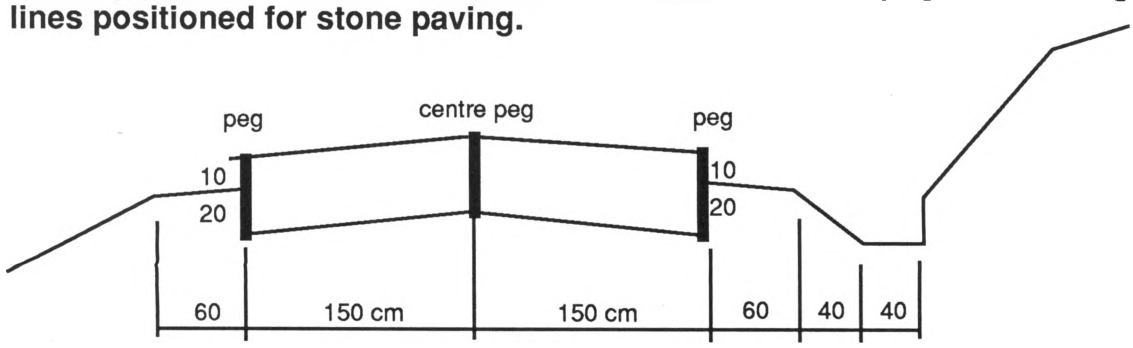
- working without setting out string lines
- damaging of shoulders

5.2 Laying of stone paving

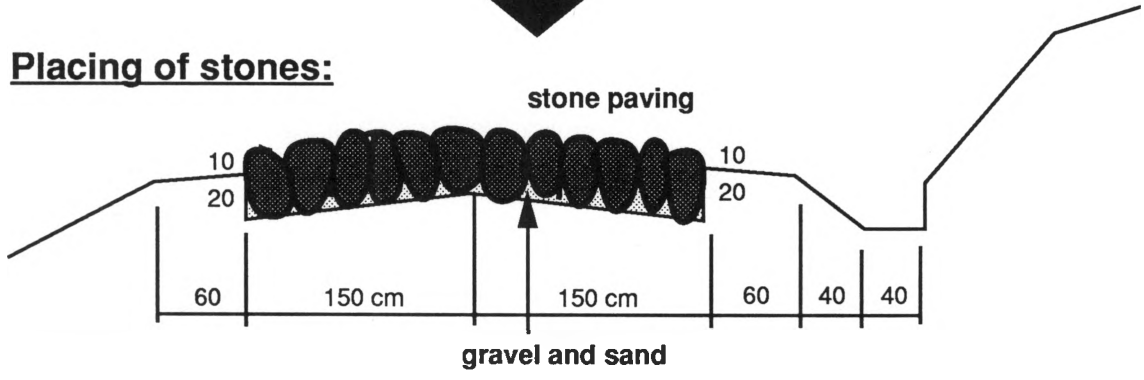
2. Stone paving: laying of stones

Before the stones are laid, a 5 cm layer of sand and gravel is spread onto the excavated camber. This layer acts both as a base for the stones and as a filter. The stones are then placed upright and as close together as possible so that the spaces between the stones are as small as possible. The surface of the stone paving has to be as smooth as possible and must have a uniform final gradient of 5% as set out with the pegs and string lines. In order to drain the stone paving French drains have to be constructed at regular intervals.

Starting point: Dug out cambered earth road bed with pegs and string lines positioned for stone paving.



Placing of stones:



It is important that each stone is properly placed into the gravel / sand layer. After the stones have been placed they have to be tightly wedged using stone chips which are hammered in-between the stones.

Example of stone paving using pegs and string lines and well-organised work gangs.

Completed stone paving before wedging

Wedging of stone paving

Mistakes to be avoided:

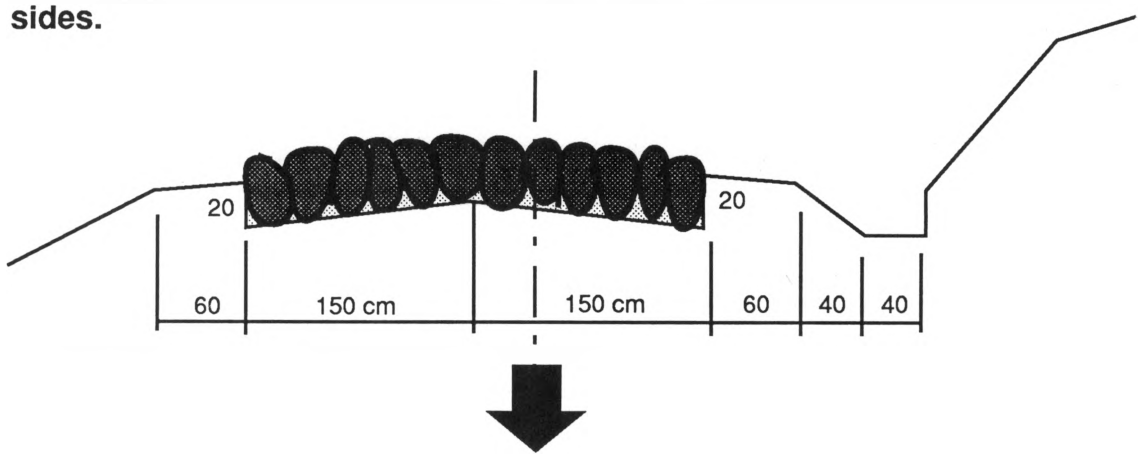
- road work without properly set out pegs and string lines
- stones laid flat instead of upright
- using small stones in layers

5.3 Sealing of stone paving

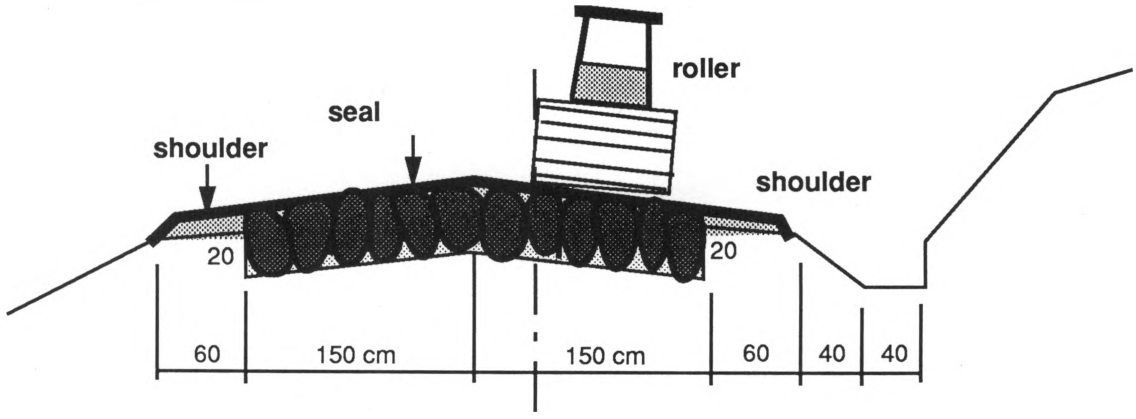
3. Stone paving: sealing the stone paving

In order to prevent water from penetrating the stone paving and to provide a smoother surface for vehicles the stone paving has to be sealed with a mixture of gravel. sand and clay. This mixture is spread onto the stone paving The gaps between the stones are rammed full using sticks. At the same time soil is spread onto the shoulders and together with the mixture of sand, gravel and clay compacted onto the top of the stone paving using a roller or compactor.

Starting point: 300 cm wide stone paving with shoulders lower on both sides.



Sealing and compacting the stone paving and shoulders



Applying the gravel, sand and clay sealant

After the shoulders have been completed they have to be protected from erosion by planting grass. Every 15 metres kerb stones are placed on the edges of the road way to prevent vehicles from damaging the shoulders. The road is now completed and can be handed over for routine maintenance. The most important maintenance activities are described in the second part of this handbook.

Example of a completed stone paved road

Completed road carrying traffic

15

Pela-Ramut Road

6.1 Definition of road components

16

The roadway is that part of the road on which vehicles travel. It is made either of earth or of stone paving sealed with a layer of gravel, sand and clay.

On either side of the roadway there is a shoulder of compacted earth, enabling vehicles to pass one another.

Kerb stones are placed at regular intervals along the edge of the roadway. They mark the edge and prevent vehicles from driving on the shoulders and damaging them.

The drainage slope is the slope between the road shoulder and the bottom of the drainage ditch.

Flood and rain water from the road surface flows into the drainage ditches and out through the next culvert.

Culverts carry off the water from the drainage ditch alongside the road and thus prevent regular flooding of the road.

Scour checks are erosion controls each consisting of five stones. They are constructed on steep sections of the road to reduce the velocity of the water and thus prevent the ditch from eroding.

Hillward and valleyward banks separate the edge of the road from the surrounding areas, but are still part of the road and therefore need to be maintained.

Other building structures are dry stone or cement retaining walls, multiple culverts, drifts, concrete ditches and bridges. They secure the road at critical places.

6.2 Objectives of road maintenance

The road serves everybody. Driving on the road should be possible throughout the year, in the dry as well as in the rainy season. The road has to be protected from being damaged and must therefore be continuously maintained.

The biggest enemy of the road is water. Rainwater can erode slopes and create ruts on the roadway. It can also erode ditches, and block and silt up culverts. Too much water can cause slides which damage slopes, retaining walls and other structures.

Traffic, too, can affect the road. Vehicle wheels can cause potholes and ruts. Where vehicles pass one another ruts are created on the shoulders and kerb stones are dislodged. Heavy lorries can even break culverts or damage retaining walls or drifts.

Too much vegetation can damage the road, although roots retain soil and prevent erosion. Bushes and long grass can block ditches and culverts. Roots of bushes and trees can damage structures.

Road maintenance provides a serviceable road at all times. It is important to make sure that water can always flow freely off the road and into the drainage system. It is also important to constantly repair damage caused by traffic and to keep vegetation short and under control. Efficient road maintenance allows the road users to utilise the road throughout the year, in the dry as well as in the rainy season.

Roads are progressively destroyed by water, traffic and vegetation if insufficient or no maintenance is done.

6.3 Maintenance of drainage ditches 18

Maintenance of drainage ditches is the most important routine maintenance activity for roads. If the water velocity or volume is too great in a drainage ditch the bottom of the ditch is washed away and the ditch becomes deeper and deeper. If the water flow is too slow, the ditch can silt up until it is practically non-existent. The most important activities for maintaining ditches are:

1. Grass in the ditch and on the slopes is allowed to remain, but must be cut short to allow the water to flow over it. Bushes and obstacles have to be removed.

2. Silted ditches have to be cleaned and eroded sections have to be filled with soil in order to retain the original form.The ditch measurements must be checked with a template.

3. Scour checks which have been damaged or swept away must be repaired or replaced. It is important to construct them according to the standards provided in chapter 4.3, table 10 of this handbook.

6.4 Maintenance of the roadway

Maintenance of the roadway is the second most important maintenance activity. During heavy rains water flow can form ruts in the road surface or where there is stone paving it can wash away the sand and gravel sealant from between the stones. Traffic can loosen and dislodge stones from the stone paving. The most important activities for roadway maintenance are:

1. The grass which grows on the roadway has to be carefully removed so that the roadway is not damaged. Ruts and potholes on the roadway have to be filled with a mixture of gravel, sand and clay. This filling has to be compacted.

2. Loose stones in the stone paving must be wedged in again in order to tighten them. Dislodged stones have to be replaced. It is important to make sure that new stones are of the correct size and are properly wedged between the existing stones. Repaired sections have to be sealed again as described in chapter 5.3, table 14.

3. The edges between the stone paving and the shoulders have to be shaped in such a way so as to allow the water from the road surface to flow over the shoulders down into the ditch and not along the edge of the roadway.

6.5 Maintenance of shoulders

If there is no grass on the road shoulders the water draining from the roadway can wash out deep gullies. After heavy rains vehicles passing one another can cut deep tracks into the wet and soft shoulders. The most important activities for maintaining the shoulders are:

1. **The grass on the shoulders can be left but must be cut short in order to allow the water to flow from the roadway over the shoulders into the ditch. Where there is no grass or where grass has been removed new grass must be planted.**

2. **Potholes and ruts on the shoulders have to be filled with soil. This filling has to be compacted and regrassed.**

3. **Loose or dislodged kerb stones have to be repositioned or where necessary replaced. The kerb stones should be large enough so as to be visible to drivers and not be easily removable.**

4. **The road edges between the shoulders and the stone paving have to be shaped in such a way so as to allow water from the road surface to flow over the shoulders into the drainage ditch and not along the road edge.**

6.6 Maintenance of slopes

During and after heavy rains water flowing from the surrounding areas over the hillward slopes into the drainage ditch can erode these slopes. The valley side slopes can also be eroded by heavy water flow from the roadway itself. These gullies become deeper with every rainfall until the whole slope is damaged. The most important activities for maintaining the slopes are:

1. During road construction grass is planted on the slopes to provide erosion protection. Existing grass and bushes are left on the slopes and grass and bushes should be planted where there is no vegetation.

2. Bushes and shrubs on slopes should be kept short in order to reduce shade on the road, thereby allowing the road to dry more quickly after rain.

3. Bushes and shrubs should also be kept low in places where they could hinder the drivers' view. This applies particularly to the inside of sharp curves.

4. Any loose soil and stones on the hillward slopes should be removed to prevent them being washed into the ditches and culverts, and blocking them.

6.7 Other maintenance activities

As already mentioned, the most important maintenance activities are the maintenance of the drainage ditches, the roadway, the shoulders and the slopes. Further maintenance activities need to be done on culverts, building structures and on the stone paving.

1. The culverts have to be checked regularly. Blocked culverts have to be cleaned immediately. If a culvert is cracked or broken in any way, this should be reported to the supervisor.

2. Structures such as dry stone walls, drifts and bridges must also be checked. Small grass tufts or bushes on dry stone walls can be left as they assist in keeping the wall together. Actual damage has to be immediately reported to the supervisor.

3. The gravel, sand and clay mixture on the stone paving will be washed away by rain and dispersed by traffic. Therefore where ruts appear, a new layer of this mixture has to be added.

Comments and Technical References

Table 1: Objectives of the village roads programme

Communication between people and institutions is one of the basic human needs, like food, clean water, acceptable shelter, and basic hygiene and sanitary provisions. It is considered that the construction and maintenance of rural roads constitutes a correct measure to promote communication as part of rural development.

A large percentage of the funds for the construction of roads using labour based methods is used directly to pay the labourers' salaries (70% to 80% in the Manggarai District, West Flores).

Table 2: Construction standards for village roads

The commonly found red clay soil (laterite) of the Manggarai District allows the construction of simple earth roads which are basically motorable throughout the year, provided these roads are well maintained. Stone paving is usually required for steep sections with a longitudinal gradient above 10%, for hairpin curves and for sections with poor soil (e.g. soil with a high organic component, swampy areas, etc.).

Table 3: The organisation of the construction activities

The size of the work gangs for the different activities depends on:

- the planned time schedule
- the type of activities required
- the number of trained supervisory staff (foremen)
- the available labour force within the area of influence of the road.

A capable foreman can control work gangs of the following sizes:

- bush clearing and tree removal: 10 to 20 labourers
- excavation to roadbed level and removal of boulders: 50 to 100 labourers
- construction of dry stone retaining walls: 10 to 20 labourers
- construction of culverts: approximately 5 labourers
- reshaping and correction of slopes: 20 to 30 labourers
- camber formation and construction of shoulders: 20 to 30 labourers
- excavation of ditches and building of scour checks: 20 to 30 labourers
- laying of stone paving : 10 to 20 labourers
- sealing of stone paving: 10 to 20 labourers
- erosion prevention on slopes and shoulders: 10 to 20 labourers
- routine maintenance: 5 to 10 labourers

The different work gangs follow one another in short distances but have to be kept well separated from each other. With an optimal labour force and good construction weather the following construction programme should be achievable:

- bush clearing and tree removal: at most a few hundred metres ahead of the excavation of the road bed level,
- excavation to road bed level and removal of boulders: both activities at the same time,
- construction of structures (retaining walls, drifts, bridges, etc.) and culverts: as soon as the relevant equipment can be brought to the site by lorry.

After these activities have been completed the road is ideally left for natural compression by rains and local traffic for a duration of at least one rainy season, before the remaining activities are carried out:

- reshaping and correction of slopes: a few hundred metres ahead of the camber formation and construction of shoulders,
- camber formation and construction of shoulders: a few hundred metres ahead of excavation of ditches and construction of scour checks,
- excavation of drainage ditches and building of scour checks: a few hundred metres ahead of laying of stone paving,
- laying of stone paving: immediately before the paving is sealed,
- grass planting to prevent erosion, on slopes and shoulders: at the same time or just after stone paving,
- routine maintenance: ideally routine maintenance should commence during the last construction activities or immediately after the completion of the construction activities.

Simple measuring aids have been developed and introduced to measure, set out and control the different activities. The most important are:

- levelling instrument: to set out the longitudinal gradients,
- level pegs: to mark the longitudinal levels of the road bed at intervals of 5 metres,
- wooden templates: to set out and control the correct sloping of retaining walls and the back slopes in different types of soils,
- pegs and string lines: to mark the centre line and the edges of the shoulders and their levels (cross-fall),
- wooden templates, pegs and string lines: to mark and check the construction of drainage ditches,
- wooden templates, pegs and string lines: to mark the centre line and the edges of the stone paving and the levels thus required in order to control the camber and the thickness of the stone paving,
- wooden templates: to check the correct sizes of the stones to be used for stone paving.

Table 4: General road routing

During the process of establishing the general road alignment (routing) the most important reference points for a particular road have to first be identified:

- the beginning and the end of the road (e.g. market place, village, etc.),
- existing roads connecting the planned new road,
- other important places which will be connected by the new road (e.g. other villages, schools, clinics, etc.),
- additional important features of the area which may be of importance for the construction of the new road (e.g. possible water crossings, rocky or swampy areas, steep sections, etc.).

The exact alignment between the chosen reference points is then established in a second step. Specific attention is paid to the technical feasibility and the possible interference with the use of land (agricultural situation along the planned route).

For the technical feasibility the following aspects are important:

- geometric standards, e.g. maximum and minimum longitudinal gradients, minimum radius for curves, cross-sections, etc.,
- crossing of difficult areas such as swamps, rocky sections, steep hills, etc.

Where possible the road should not be taken through forests and intensively cultivated land such as paddy fields, coffee plantations etc.

Table 5: Setting out of centre line

The main characteristic of setting out the centre line for a road which will be constructed using labour-based methods is to avoid any longitudinal balancing of soil unless absolutely necessary (such as in the construction of short embankments). This can be achieved by following the existing contours as much as possible. The road is basically cut out of the hill. This results in most cases in a road with plenty of curves and therefore also in a reduced vehicle operating speed (30km/hr).

To set out most curves the offset method has proved to be the most appropriate. For this method only ranging rods, a tape measure, pegs and string lines are required.

The reduced longitudinal gradient in hairpin bends is necessary to avoid steep gradients of the camber on the inner side of the curve (less erosion of the roadway). It also ensures that vehicles operate at low speed around the curves and therefore minimises damage to the road. Ideally the reduction of the longitudinal gradient (max. 5%) should start at least 20 metres before the curve and end about 20 metres after the curve.

To reduce high velocity drain water in the ditches and on the roadway and to allow the water to drain off efficiently, the maximum gradient should not be greater than 10% and not less than 2%.

Table 6: Construction of the road bed

The inhabitants living along the village roads construct the road bed with voluntary community labour. This is in line with the institutionalised voluntary community participation "Gotong Royong" of Indonesia and is seen as a project-related contribution by the population which will profit most from the new road. However, this incentive does not sufficiently motivate the labourers and therefore the achieved quality of the work is not always of a very high standard.

Since there is enough labour and no compacting equipment is available, no balancing of soil (cut and fill) is carried out. The road bed is fully cut out of the existing slope and is at least 500 cm wide. Exceptions are made only in steep sections where dry stone retaining walls on the valley side have to be erected.

The longitudinal balancing of the road bed is achieved by constructing 'slots' (horizontal trenches of 60 cm which are set at a right angle to the centre line). Slots define the exact level of the road bed and are dug every 5 to 10 metres prior to excavation. Slots also assist in calculating the exact quantity of soil which has to be excavated for the construction of the road bed.

Table 7: Structures and culverts

Culverts are constructed at regular intervals. The distance between the culverts depends on the expected volume of rainwater and the chosen diameter of the culvert rings. The inner diameter of culverts for the roads programme in the Manggarai District is 900 mm and the culverts are laid at intervals of approximately 250 metres. Additional culverts have to be placed in dips in order to stop water, which flows in from both sides, remaining in the ditch.

The diameter of the culverts has to be such as to allow a labourer to crawl into the culvert to clean it. The minimum inner diameter is therefore 600 mm. In order that culverts are not damaged by passing traffic they have to to be sufficiently covered. For an earth road the cover should be at least 2/3 of the culvert's diameter but not less than 500 mm. Where stone paving is applied the earth cover between the culvert and the stone paving has to be at least 300 mm thick. The backfill and the culvert cover has to be of pure earth and no stone should come into contact with the culvert rings. The earth has to be backfilled in regular layers of not more than 100 mm and has to be properly compacted using earth rammers.

Culverts for earth roads have to be laid with a gradient of 3% to 4% in order to avoid silting up. The outlet of the culvert should have the same gradient as the culvert itself. Special attention has to be given to the exact setting out of the outlet where the existing slope of the area is minimal.

A masonry headwall and apron are provided at the culvert inlet. The inlet apron is 200 mm lower than the actual culvert inlet. This allows silt to be retained on the apron and to protect it from stones which are swept in by the drain water. The outlet is also provided with a masonry apron to prevent erosion.

Drifts are constructed on small seasonal rivers. Bridges are provided over bigger rivers with a regular and permanent water flow.

Table 8: Correction of steep slopes

The permissible gradient of the valley side slope depends mainly on the existing soil conditions, which can vary from 2:1 in hard soil to 1:1 in soft soil. The choice of the correct gradient requires some relevant experience on the part of the project supervisors. If earth slides occur on the hillward side after construction is completed, then not only does the soil have to be removed from the roadway and ditch, but the whole slope has to be graded to the correct gradient.

On very steep sections the height of the hillward side slope can be reduced by constructing a dry stone retaining wall along the outer side of the ditch. The decision to construct a retaining wall in any case must be taken by the project management. Such a decision depends on the general danger of erosion in that particular area, the use of land above the road and the availability of stones for the construction of the retaining wall. A retaining wall on

the hillward side should only be constructed if it proves to be the most economical and appropriate solution for that particular road section.

Table 9: Camber formation

The maximum resulting gradient from the longitudinal gradient and the camber of about 5% increases with increasing road steepness. For example, with a longitudinal gradient of 5%, 10% and 15%, the maximum resulting gradient is about 7.1%, 12% and 15.8%. To drain the surface water in the shortest possible way it would be necessary to increase the camber on steep sections. Such changes in the camber are deliberately not introduced in order to keep the construction methods simple and uniform

Since the camber is basically cut out of the road bed and not formed by excavated material from the ditches and slopes, possible differences in the longitudinal section cannot be balanced by adding more excavated material. Large differences can be regulated by correcting the road bed (balancing of slots during the setting out activity). Small differences in the longitudinal section are not corrected since the traffic operating speed and riding comfort are not major design criteria for these roads.

Table 10: Construction of side drainage ditch

In accordance with the standard construction the outer side of the ditch, and therefore also the relevant ditch template, is vertical. This reduces the width of the road bed by 20 cm.

The distance between the scour checks depends on the gradient and the soil condition of the road. The steeper the road or the softer the soil, the closer the scour checks have to be to each other. Usually scour checks are provided where the longitudinal gradient of the road is equal to or greater than 4%. In order to achieve the desired reduction of the gradient the distance between the scour checks is 15 metres at 4%, 10 metres at 6% and 5 metres at 8% or more. The soil which is excavated when laying the stones is usually not enough to backfill the scour checks sufficiently. The required material is usually washed down from the slopes after one or two rainfalls.

Should there be no stones available to construct scour checks, alternative building material can be used, e.g. bamboo pegs or wooden pegs which are supported by planting grass above and below the scour check. In special cases prefabricated concrete scour checks can be used (expensive).

Table 11: Completion of the earth road

Where grass is planted to prevent erosion, only species which can grow well in that particular soil should be used. In red clay soil, for instance, some top soil has to be added when planting the grass tufts.

The kerb stones are basically placed at regular intervals of about 15 metres on both sides of the roadway. Along the inner side of sharp curves the distance between the kerb stones should be smaller so as to avoid damage to the shoulders by vehicles. The kerb stones have to be at least 40 cm high and should be properly dug into the ground so that they cannot be damaged by vehicles.

Table 12: Excavation of foundation

Stone paving is required on steep road sections with a gradient above 10%, in hairpin bends and on sections with soft road bed material (e.g. soil with high organic components, in swampy areas, etc.).

It is important to ensure that the edges next to the shoulders are not damaged when excavating the foundation for the stone paving. These edges provide the necessary support for the outer stones of the paving and ensure that the stone paving remains in place, becoming a compact layer. The excavated earth is kept and later used to form the shoulders.

Table 13: Laying of stone paving

For the stone paving no weathered or cracked stones should be used. Ideally the stones should be square and 30 cm thick. Most stones have to be shaped to the right size with sledge hammers and chisels. The stones are placed upright and as close together as possible. Most stones are in the shape of a wedge and it is therefore necessary to place them in such a way that those with wider ends down alternate with those with wider ends up. When the stones are placed onto the sand and gravel layer it is important to make sure that some of the sand and gravel mixture is also distributed all around the stones and filled into the gaps. The laying of the stone paving is a demanding activity which requires good and exact workmanship.

In order to drain the stone paving French drains are provided at intervals of about 10 metres. The French drains are extended through the shoulders to the ditch and are filled with stones. Later they are covered with earth from the shoulder.

For the wedging of the stone paving, stone chips left over from shaping the stones can be used. These chips are hammered in between the stones of the paving in order to make sure that all stones are firmly held and that the whole stone soling becomes a compact layer.

Table 14: Sealing of stone paving

The ratio of the gravel, sand and clay mixture for the sealing of the stone paving depends on the type and quality of the different components. The aim is to create a mixture which is rough enough when it is wet and which has sufficient plasticity when it is dry. With well graded gravel, clean sand and pure earth a mixture of 1:1:1 has proved to be ideal for the road project in the Manggarai District.

The sealing mixture for the stone paving and the earth for the shoulders are added at the same time and in such a way that the stone paving is covered with a layer of about 5 cm. Afterwards the layer on top of the stone paving and the shoulder is compacted with a roller. For the roads programme in the Manggarai a self propelled vibrating roller and a vibrating plate are used. If there is no compacting equipment available the local traffic compresses the material, but this requires regular reshaping and intensive maintenance of the road during the first year.

Recommended Reference Books

1.) Labor-based Construction Programs, A Practical Guide for Planning and Management. A World Bank Publication.

2.) Guide to Tools and Equipment for Labour Road Construction and Maintenance.

3.) Guide to the Training of Supervisors for Labour-Based Construction and Maintenance, Vol. I + II: Trainees' Manual, Vol. III: Instructor's Manual. International Labour Office, by L.S. Karlsson and J.J. de Veen.

4.) Road Maintenance Handbook, Vol. I to III. United Nations, Economic Commission for Africa.

5.) The Application of Appropriate Technology in Road Construction and Maintenance; a learning methodology. International Labour Office, by G.A. Edmonds and J.J. de Veen, 1981.

6.) Roads and Resources, Appropriate Technology in Road Construction in Developing Countries. IT Publications, by G.A. Edmonds and J.D.F.G. Howe.

7.) Earth Roads, their Construction and Maintenance.

8.) Synthesis 1: Maintenance of Unpaved Roads; Synthesis 2; Stage Construction; Synthesis 3; Labour-based Construction and Maintenance of Low Volume Roads. Transportation Research Board, National Academy of Sciences, Washington D.C.

9.) The Road Maintenance Problem and International Assistance. A World Bank Publication, December 1981.

10.) The Selection of Geometric Design Standards for Rural Roads in Developing Countries. TRRL Supplementary Report 670, by R.Robinson.

11.) Some Manual Methods of Screening Aggregates for Labour-Intensive Road Construction. TRRL Supplementary Report 503, by R. Robinson.

12.) Road Maintenance, Planning and Management for Developing Countries. TRRL, by R. Robinson

13.) The Kenya Maintenance Study on Unpaved Roads: Optimum Maintenance Strategies. TRRL Laboratory Report 1112, by T.E. Jones.

14.) The Kenya Maintenance Study on Unpaved Roads: Research on Deterioration. TRRL Laboratory Report 1111; by T.E. Jones.

15) Overseas Road Note 1 to 3: Maintenance Management for District Engineers / Maintenance Techniques for District Engineers / A guide to surface dressing in tropical and subtropical countries. TRRL.

16) The Rural Access Roads Programme, Appropriate Technology in Kenya. International Labour Office, by J.J. de Veen.

17.) Road Maintenance: Options for Improvement. International Labour Office, by G.A. Edmonds and J.J. de Veen, 1982.

18.) Rural Access Roads Programme Kenya: An Analysis of Costs and Productivities. International Labour Office, by Steinar Hagen, 1985

19.) The Rational Utilisation of Available Resources for Road Improvement and Maintenance: Alternative Approaches to Road Maintenance. International Labour Office, by J.J. de Veen, 1988.

20.) International Course for Engineers and Managers of Labour-Based Road Construction and Maintenance Programmes, Course Notes Volume I and II. International Labour Office, by Jan de Veen and Andreas Beusch, 1991.

21.) Building Roads by Hand, an Introduction to Labour-Based Road Construction. International Labour Office, by J. Antoniou, P. Guthrie, J. de Veen, 1990.

22.) Road Construction in the Nepal Himalaya: the Experience from the Lamosangu-Jiri-Road Project. U. Schaffner.

Road Construction Manggarai is a compilation of teaching modules, developed for training courses in the construction of rural access roads in Indonesia.

This publication is meant to introduce the chosen construction standards and production proceedings of labour-based road construction to a broader circle of interested institutions and persons. The teaching modules are completed with an introduction to the project background and concept, as well as with detailed technical comments and references to the different work activities.

ISBN 3-908001-35-8