

Implementing employment intensive road works

A **cidb** practice manual

Contributing to contractor development in
job creation

MANUAL 5

Concrete and masonry drainage works and structures

Published by the Construction Industry Development Board (cidb)
Private Bag X14, Brooklyn Square, 0075

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ISBN: 978-0-620-38198-7

MARCH 2007

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cidb is a public entity established in terms of the CIDB Act, 2000 to provide strategic direction for sustainable growth, reform and improvement of the construction sector and its enhanced role in the country's economy. In pursuit of this aim cidb partners with stakeholders and regulates the construction industry around a common development agenda underpinned by best practice procurement and project processes.

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Constructing shared growth

This set of practice manuals for employment intensive road construction, draws on the experience of the South African Construction Industry in the development of road building contractors, supervisors and designers, in implementing road works and creating jobs; and builds upon the labour-based best practice guidelines that have been published by the Construction Industry Development Board. (cidb) (see www.cidb.org.za):

“.....with the right construction technology, South Africa can successfully address infrastructural backlogs in a cost-efficient way and to acceptable engineering standards. We are saying we can do this while maximising job opportunities....”

(Ms Thoko Didiza, Minister of Public Works. Vuk'uphile learners welcoming ceremony, Nkangala, Mpumalanga, 29 June 2006.)

In assembling this publication, the cidb has collaborated with the Council for Scientific and Industrial Research (CSIR), and the International Labour Organisation (ILO) in fulfilment of the cidb's mandate to promote “national social and economic objectives, including the labour absorption in the construction industry”. (CIDB Act 38 of 2000). The cidb is committed to further partnerships with industry and stakeholders, to promote the use of these manuals and the training of SME contractors within the framework of the National Contractor Development Programme and the Construction Charter.

These manuals are supported by the Expanded Public Works Programme (EPWP), which directs a significant and increasing proportion of South Africa's public investment towards a labour intensive programme of construction, drawing the unemployed into productive work and providing access to skills development.

Implementing employment intensive road works

• **MANUAL 1: The fundamentals of road construction**

- Module 1: Basic mathematical concepts and calculations
- Module 2: Survey concepts
- Module 3: Material concepts
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- Module 1: Safety during construction
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• **WORKSHOP DRAWINGS**

Workshop drawings of selected items of specialised equipment



OVERVIEW of the practice manuals

The South African White Paper *Creating an Enabling Environment for Reconstruction, Growth and Development in the Construction Industry* (1999), expresses a vision for public-sector delivery aimed at optimising employment opportunities through labour-intensive construction. This can be realised in the delivery of infrastructure through the adoption, where technically and economically feasible, of

- labour-based methods of construction and manufacture where labour, utilising hand tools and light equipment, is preferred to the use of heavy equipment for specific activities.
- labour-based technologies where there is a shift in balance between labour and equipment, in the way the work is specified and executed for selected works components.

This **cidb** practice manual for *Implementing Employment Intensive Road Works* follows on from the **cidb**'s guide to best practice for *Labour-based Methods and Technologies for Employment-Intensive Construction Works*. The latter covers a broad spectrum of construction works. It establishes desirable and appropriate standards, processes, procedures and methods; relating to the design and implementation of labour-based construction technologies, methods for earthworks and for materials manufacture. This first set of guidelines provides sufficient technical information to enable those, responsible for the design of projects, to make confident and informed choices on their use in projects.

Implementing Employment Intensive Road Works aims to provide practical and technical guidance to small and medium sized (SME) contractors, supervisors and designers who are involved in the construction and upgrading of roads using labour and light plant. The need for these technical manuals was identified during the training of SME contractors, involved in the Gundo Lashu programme in Limpopo Province – a programme of labour-based upgrading of rural roads, promoted by the Department of Public Works, Roads and Transport in collaboration with the International Labour Organisation (ILO).

The development of this series of manuals is based on:

- experience gained in South Africa over the last ten years, including that of the Gundo Lashu project presently being implemented by the Road Agency Limpopo, with technical assistance from the ILO,
- best practices implemented by a number of Sub-Saharan countries,
- the relevant **cidb** best practice guidelines, in its series of *Labour-based Methods and Technologies for Employment-Intensive Construction Works*.

These manuals support the objectives of South Africa's Expanded Public Works Programme (EPWP), and are aligned with the *Guidelines for the Implementation of Labour-intensive Infrastructure Projects under the Expanded Public Works Programme (EPWP)* of the Department of Public Works, obtainable on www.epwp.gov.za.

Acknowledgements

These manuals were compiled by the CSIR in collaboration with, and funding from, the ILO and **cidb** to promote the implementation of employment intensive road works.

A **cidb** Focus Group of industry specialists and stakeholders has further reviewed and refined these manuals.

The contribution of these individuals whose passion, commitment and knowledge has enabled the development of this publication as a common resource in the fight against poverty and joblessness, both in South Africa and globally, is acknowledged. Special thanks to:

- Adrian Bergh and Alex McKay of the CSIR.
- Jon Hongve of the ILO.
- Rob Little, Bryan Westcott, Ian van Wyk and Ron Watermeyer of the **cidb** Focus Group.
- Maikel Lieuw Song, Basotho Seetsa and Mpayo Kasure of the Department of Public Works, as members of the **cidb** Focus Group.
- The many organisations and individuals referred to in the references quoted in these manuals.

MANUAL 5: Concrete and masonry drainage works and structures

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Introduction

1. Aim

The aim of this manual is to provide contractors, involved in the labour-based construction of concrete and masonry drainage works and structures, with a detailed description of the materials, plant and equipment and processes involved in the construction of concrete and masonry drainage works and structures.

The procedure followed is that of a systematic approach to the construction of concrete and masonry drainage works and structures.

2. Composition

The manual comprises the following modules:

- Module 1: Safety during construction
- Module 2: Concrete and mortar
- Module 3: Construction of lined channels and chutes
- Module 4: Construction of culverts/small bridges
- Module 5: Construction of drifts and causeways
- Module 6: Construction of erosion control structures
- Module 7: Process for placing pipes without the use of plant
- Module 8: Indicative production and task rates

3. Notes to designer/consultant

A set of 'Notes to designer/consultant' is included at the end of the modules comprising this manual, where applicable. These notes are provided to highlight important aspects applicable to that module which the designer/consultant should take into account.

4. Supplementary manuals

- Manual 1: The fundamentals of road construction
- Manual 2: Planning and contract management
- Manual 3: Gravel pavement layers
- Manual 4: Bituminous pavement seals

5. Bibliography

Labour Based Road Works Technical Manual – Volume 1. May 1997: Dar es Salaam: The United Republic of Tanzania; Ministry of Works.

Publications of the Cement and Concrete Institute. Midrand: South Africa:

1. *Guide to the safe use of Portland cements and concrete.*
2. *Concrete, mortar and plaster mixes for builders.*
3. *Concrete at home and on the farm.*
4. *Mortar mixes for masonry.*
5. *Lay a concrete driveway at home.*
6. *Concrete for precasting small items.*

Course material. Civil Engineering Industry Training Scheme (CELTS) - For more information on available CELTS training courses contact 011 455 1700.



MODULE 1: Safety during construction

1. General

A number of parties are involved with safety during construction, namely:

- The travelling public using the facility/road under construction.
- The contractor executing the work.
- The client/consulting engineer responsible for designing, specifying and supervising the contract.

The *Occupational Health and Safety Act – Act 85/1993* has important implications for the contracting parties. It is important that the parties are conversant with the act and its implications as it affects the execution of the work, and that the necessary Health and Safety Plan is in place in accordance with the client's Health and Safety Specifications. Refer also to Manual 2: Module 4: Health and safety issues.

Main objectives of this act are:

- To provide for the health and safety of persons at work, and for the health and safety of persons in connection with the use of plant and machinery.
- The protection of persons, other than persons at work, against hazards to health and safety arising out of, or in connection with, the activities of persons at work.

As part of the general safety management effort at a road works site, the site engineer and the contractor's representative dealing with safety should institute a regular programme of checking the site for compliance with specifications. The appointment of a nominated site safety officer is recommended. The inspection programme should occur as frequently as necessary and may need several inspections a day.

The inspection programme should pay particular attention to the effectiveness of the signs, delineation, and driver and public obedience under adverse weather conditions, at dusk and at night. In extreme cases, the illumination of critical signs may be justified by a combination of such conditions and high user volumes.

The ultimate goal is to provide a safe and efficient system for all vehicles, pedestrians and workmen. Implementing such a system is not only to aid the contractor; it's a legal obligation which benefits all parties concerned.

When developing/planning a safety control system, knowledge of the contract specification is needed. The contractor must work in agreement with the site engineer and be fully familiar with the *Occupational Health and Safety Act*, as well as with signing techniques that are stipulated in the relevant specifications referred to in the scope of work in the contract document.

2. Traffic management

An efficient traffic management system must be implemented at road works sites, whether the site operation is a small task or large scale construction. A high standard of traffic management and supervision must be well planned, implemented and overseen at all times throughout the contract duration.

In the planning process, those responsible for designing the traffic layout at a road works site must use common sense, think practically and make use of the site documentation which includes access to the *South African Road Traffic Signs Manual*.



It is impractical for this manual to try to present an ideal site situation for traffic management, as the considerations and practicalities obviously differ from site to site. Figure 5.1 is an example of traffic management where work is being executed on a drainage structure e.g. wing walls on one side of the road.

However, particular attention should be given to the manner in which each roadway may be affected by construction or maintenance operations. As mentioned above, complete standardisation of traffic management and practices of such sites is impractical. It is important, however, that both designers and site staff adopt a disciplined approach to the traffic management of road works sites.

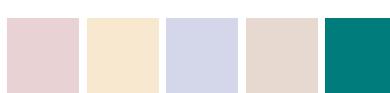
A systemised approach should be used to present the driver (whether he is a site operator or member of the public) with changes in conditions, one change at a time, by the use of standardised sub-components (i.e. signage). In this way the action or reaction of the driver can be anticipated and provided for with an acceptable degree of certainty and effectiveness.

Ideally it should be possible for almost any site condition to be simplified to a number of standard treatments and therefore traffic should be accommodated within the range of available signs. According to this principle, the motorist should then have to deal with only familiar situations and preferably one at a time.

In certain situations it will be necessary to create conditions where traffic is reduced to one-way operation within sections of a road works site. In this event the passage of traffic will have to be controlled manually or automatically.

Three methods of traffic control

- Flagmen
- STOP/GO signs
- Temporary signs



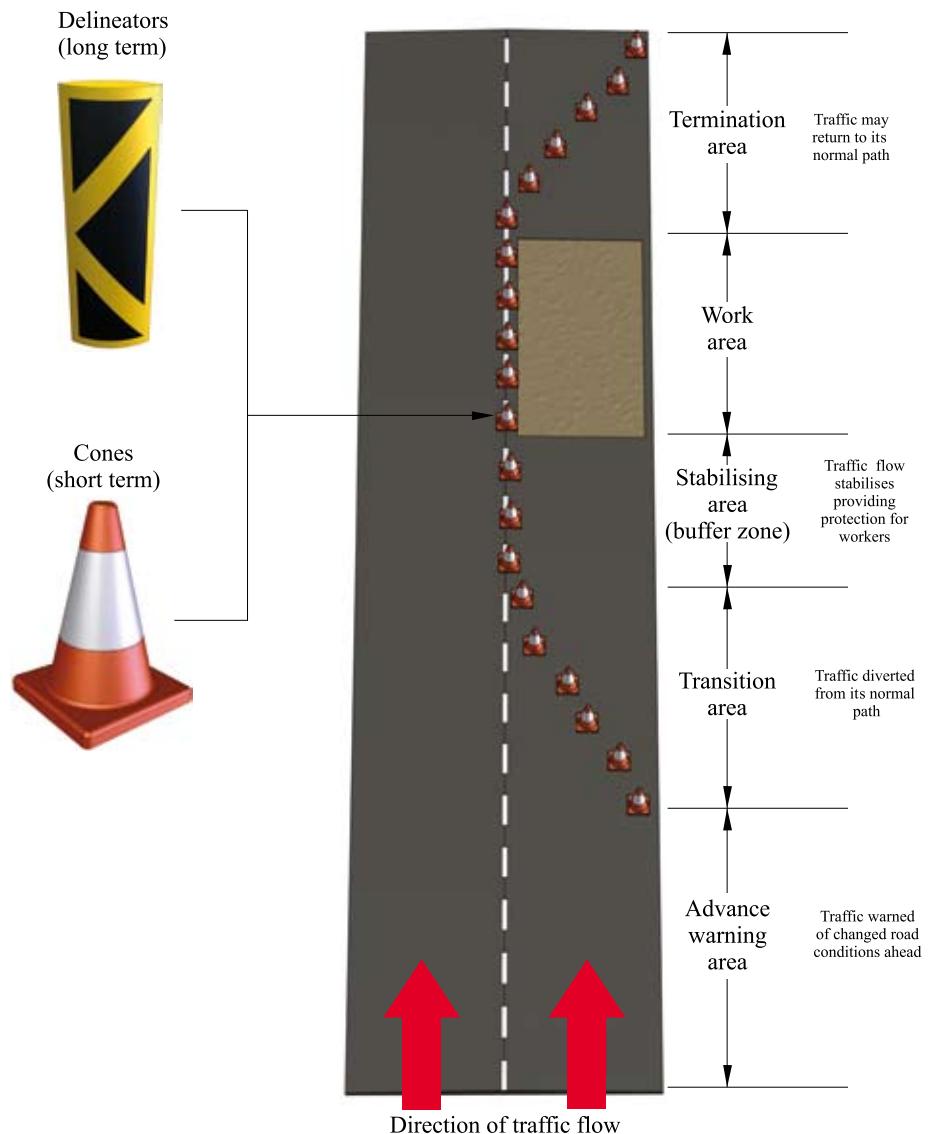


Figure 5.1: Example of traffic management at work site

3. Safety of workers and the public

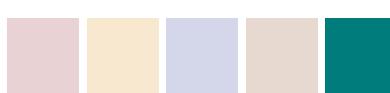
Many road rehabilitation operations are potentially dangerous, both to the workers and to the road users.

The risks are minimised by ensuring the following:

- The necessary temporary traffic signs and protection are provided and correctly located on site for the duration of the works. Where necessary, traffic should be stopped during placement or removal of temporary signs.
- Safety vests and helmets are worn in appropriate circumstances, e.g. when working on the carriageways or shoulders with traffic using the road, or on bridges.
- That all equipment and vehicles are parked off the carriageway or behind protective barriers signs, when not in use.



- That no materials are left in a dangerous location and that the road adjacent to the worksite is kept clean and swept of any debris arising from the road works.
- That proper precautions are taken and protective clothing is provided.
- That all operators are trained in the use of their equipment. If they are not adequately trained when they are assigned to the engineer or supervisor, he should provide, or arrange for, the necessary instruction. Both operators and labourers must be informed of the potential risks of, and procedures for, working with or close to machinery.
- That traffic control operations are properly carried out and road users are not unnecessarily delayed.
- All ladders, scaffolding and safety rails used in bridge works are securely fixed.
- That, where work on the carriageway or shoulder remains unfinished overnight, proper warning signs/lights are arranged and, if necessary, protected.
- That all sites are left tidy and cleared of debris when the work is completed.
- That a First Aid Kit is available at each work site.



MODULE 2: Concrete, mortar and plaster

1. Concrete

Concrete is made by mixing common cement, sand, stone and water. The potential strength of concrete depends largely on the proportion of each ingredient in the mix. Concrete hardens as a result of the chemical reaction between the cement and water; if concrete is allowed to dry out too rapidly it will not develop its full strength. This is why concrete should be cured, i.e. protected from drying out.

1.1 Materials

1.1.1 Cement

When water is added to cement, a chemical reaction is started which is known as hydration. The water and cement forms the glue or paste holding the sand and stone particles together which, on hardening, gives concrete its strength.

Thus the strength of properly compacted concrete depends primarily on its water:cement (w:c) ratio and moist curing. If additional water is added to a concrete mix, the glue will be diluted thus reducing the strength. The consistency of the glue or paste will also determine the resistance of the concrete to aggressive conditions, thus affecting its durability.

Common cement types

Common types of cement for concrete available in South Africa are covered by the *South African National Standards (SANS) 50197-1 – Cement – Part 1: Composition, specifications and conformity criteria for common cements*.

The products produced by the four major cement producers in South Africa for use in general concrete work and mortar are listed in Table 5.1.

Cement producer	Product	Strength class
Holcim	All Purpose cement	32,5N
Lafarge	Buildcrete	42,5N
NPC	NPC plus	42,5N
PPC	Surebuild	32,5N 42,5N (Western Cape and parts of Northern Cape)

Table 5.1: Cement products for general use

The numbers such as 32,5 and 42,5 indicate the minimum strength of the cement in MPa (megapascals).

The letter N indicates the rate of gain of strength of the cement. N is for normal strength and R is normally used for rapid strength gain.

Other types and blends are available but are less commonly used.

Unless the concrete is designed for specific purposes or the designer/engineer specifies a type of cement, the criteria for selecting cement is determined by availability and cost in the area.



Storage of cement

Cement should be carefully handled and stored to prevent breakage of the bags and spillage. Cement must be stored on a wooden floor, off the ground or on plastic sheets and protected from rain.

If stored for any length of time, the use of tarpaulins or plastic sheeting for covering the cement is not recommended as they allow moisture to collect on the underside.

Cement should be stored in such a manner that the bags that arrived first are used first.

1.1.2 Water

Water lubricates the mix and provides workability, by coating each particle with a thin film which assists the particles to slide over each other. Workability describes the ease with which concrete can be placed and consolidated and is measured in a number of ways but particularly by the slump test because of its simplicity.

Excessive water in a mix can cause the paste to become too thin and lose its buoyancy, thus being unable to hold the heavy particles of aggregate in suspension. This can lead to segregation which will create problems during placing and compacting, such as honeycombing of the concrete.

The usual criterion which must be considered for water in concrete is that it must be fit to drink, otherwise the final quality can be affected. Other sources would have to be passed to suit the particular job requirements.

1.1.3 Stone

Stone provides bulk in the mix and is therefore present for economic reasons. Stone also provides stability to hardened concrete. A mix containing only c:w paste would suffer from high shrinkage and creep. Therefore, as much stone as possible is used as it is compatible with the required workability.

Furthermore, the most economical mix is the one with the highest proportion of aggregate to paste, and yet retains the required degree of workability.

The quantity of stone which can be accommodated in a mix depends on a number of factors such as method of compaction (vibration, etc.), method of placing (pumping, etc.), as well as certain physical characteristics of the aggregates.

Stone size may be 26,5 mm, 19 mm, 13,2 mm or 9,5 mm. Concrete made with smaller stone such as 13,2 mm or 9,5 mm is easier to work with than concrete made with larger stone but requires more cement for the same amount of concrete.

1.1.4 Sand

Sand is used as void filler in the mix and also to reduce friction (harshness) between the stone particles. If the sand consists of round or cubical particles (like potatoes) that are smooth, the mix will flow easily and have good workability. If, however, the particles are flat and elongated (like potato chips or crisps), as well as rough textured, the mix will be harsh and the workability poor.

To improve workability, more lubrication is required but more water means more cement if the strength is to be maintained. This means increased cost.

The sand must be free of leaves, grass, compost, clay lumps, etc. Sand should be fairly coarse, with particles ranging from about 5 mm to dust.

Note

Fertilizer, sugar, oil, etc. are harmful to fresh concrete.



1.2 Mix proportions

The strength of the concrete depends on mix proportions and should suit the work being done.

Low-strength concrete is suitable for un-reinforced foundations (single storey only); mass fill, infill concrete in masonry (only with 13,2-mm stone) – approximates to a Grade (or Class) 20 concrete.

Medium-strength concrete is suitable for un-reinforced slabs, reinforced slabs and foundations, infill concrete in masonry (only with 13,2 mm stone) – approximates to a Grade (or Class) 25 concrete.

High-strength concrete is suitable for reinforced concrete members and precast items such as concrete flagstones – approximates to a Grade (or Class) 30 concrete.

1.3 Batching the materials

A builders' (concrete) wheelbarrow is a convenient measure for large batches; the capacity can be taken as 65 litres. (Figure 5.2)

Low-strength concrete

Cement	Concrete sand	Stone
		
1 bag	2 wheelbarrows	2 wheelbarrows

To make 1 cubic metre of concrete you will need:

5½ bags of cement + 0,75 cubic metres of sand + 0,75 cubic metres of stone

Medium-strength concrete

Cement	Concrete sand	Stone
		
1 bag	1½ wheelbarrows	1½ wheelbarrows

To make 1 cubic metre of concrete you will need:

7 bags of cement + 0,70 cubic metres of sand + 0,70 cubic metres of stone

High-strength concrete

Cement	Concrete sand	Stone
		
1 bag	1 wheelbarrow	1 wheelbarrow

To make 1 cubic metre of concrete you will need:

10 bags of cement + 0,65 cubic metres of sand + 0,65 cubic metres of stone

Figure 5.2 a: Batching large batches

Steel drums (20 l or 25 l capacity) and buckets are useful for small batches. Fill the amounts accurately each time so that the quality of concrete does not vary from one batch to the next. Check that the container is clean before you start. (Figure 5.2 b)



Note: Use containers such as buckets, drums or tins.
Use the same size container for measuring all the materials in a batch.

	Cement	Concrete sand	Stone
Low-strength concrete			
Medium-strength concrete			
High-strength concrete			

Figure 5.2 b: Batching small batches

1.4 Mixing concrete

Concrete can be mixed by hand if quantities are small or in a concrete mixer.

1.4.1 Mixing by hand

Very small batches of up to about 25 litres of mixed concrete can be mixed in a wheelbarrow.

Bigger batches should be mixed on a concrete slab or steel plate. Do not mix directly on the ground as water may be drawn out of the concrete or soil mixed into it.

Measure and mix batches of a convenient size. Spread the sand in a layer about 100 mm thick. Spread the cement on top of this and mix the two thoroughly. Now make a heap with the mix and make a hollow in the middle. Add water in small quantities and mix it in. Keep on adding and mixing in water until the consistency of the mix is rather like that of thin porridge.

Next, measure the correct amount of stone and mix this well into the mortar (sand-cement paste) until each particle of stone is well coated with mortar. If the mix is too stiff to be placed easily, add a little more water and mix it in thoroughly. If too much water is added, the mix will be slushy and the concrete will be weak.

If not enough water has been added, the concrete will be difficult to place and compact which will also reduce its strength.

The correct amount of water to the amount of cement used in the mix is known as the water:cement ratio. The water:cement ratio for the type of concrete required for the work covered in these manuals will be in the vicinity of 0,55 – 0,70 by mass.

1.4.2 Using a concrete mixer

The batch size should suit the mixer – under filling the mixer wastes time while overfilling results in spillage and poor mixing.

Measured quantities of materials are added in the following order: first the stone and about half a measure of water, then the cement, then the sand, and finally more water until the right consistency is reached.

When all the materials have been added, continue to mix until colour and consistency are uniform. Discharge each batch completely.

1.5 Transporting concrete

Concrete can be moved in buckets or wheelbarrows on site. If it is jolted too much the stone will settle at the bottom. If this happens, remix the concrete before placing it.

Don't let the concrete stand for so long that it stiffens before it is placed. Cover concrete with plastic sheets or wet sacking. This will ensure that it does not dry out in the sun or wind when there is a delay in placing the concrete.

1.6 Compacting concrete

This is the process of intentionally expelling air from the fresh concrete once it has been placed. Compaction is an important step in producing good concrete because voids in hardened concrete markedly reduce strength and potential durability. Compaction may be achieved by mechanically vibrating the concrete or by rodding or hand tamping.

Dump the concrete as close to its final position as possible. When concrete is placed on the ground, the soil should be thoroughly damp but without any standing water.

To compact concrete slabs, use a wooden beam that spans the slab. First use a chopping action and then a sawing action. Next, wood-float the concrete to obtain an even but rough surface.

1.7 Curing concrete

Curing is achieved by keeping the concrete damp. Once it has stiffened, either cover it with plastic sheeting which is held down firmly along its edges, or cover it with hessian or sacking that is kept wet. Curing should continue for a minimum of seven days and up to a maximum of 28 days (when it is fully cured). Good curing also helps to limit cracking of the concrete.

1.8 Bleeding

After compaction, it is normal for some of the water in a concrete mix to rise to the surface. We call this phenomenon bleeding. Bleeding occurs because the solid material in the mix settles due to gravity. If excessive bleeding occurs, the top portion of the concrete can become too wet. This produces a layer of weak, porous concrete which can disintegrate by freezing. Bleed water can also be trapped under particles of aggregate and when this water evaporates, a void is formed. The result is a loss in strength of the concrete.

In addition, the rising bleed water can carry with it fine particles of cement and sand to form a layer of laitance. If this is at the top of a slab, a porous surface will result, with the surface being permanently dusty. Bleed water should not be trowelled back into a surface slab as it results in a weak surface finish.

Bleeding of concrete can be reduced by taking one or more of the following steps:

- Reduce the water content.
- Increase the cement content.
- Increase the fines content of the sand.

When concreting in high temperatures, the concrete stiffens quickly, so the time in which bleeding can occur is limited but in cold weather, bleeding may continue over a longer period.



Where excessive bleeding has occurred, the detrimental effects can be overcome by re-compacting the concrete as long as possible after the initial compaction, but while the concrete is still workable to respond to the additional compaction. (This should only be done on the instruction, and under the supervision, of the engineer.)

1.9 Joints and panel sizes

Concrete slabs should be divided into panels to limit random cracking. The distance between joints should be about 2,5 metres in concrete which is 80 mm thick and 3,5 metres in concrete 100 mm thick.

Panels should be more or less square and each panel must be completed in one operation.

2. Mortar

Mortar consists of cement, sand and water. It binds stone masonry, bricks, blocks and stone pitching together to give strength and stability to a wall or slab. Freshly mixed mortar must be soft and plastic so that it spreads easily and makes good contact without becoming too strong. Mortar which is too strong may crack and is wasteful as it is more expensive.

2.1 Materials

2.1.1 Cement

Refer to Section 1 for information relating to 'Common cement types' and 'Storage of cement'.

2.1.2 Lime

Use only bedding lime which complies with SANS 523:2002. Do not use quick-lime or agricultural lime. Lime is usually sold in 40 kg bags and should be used if the sand lacks fine material or is single sized; such sands tend to produce mortar with poor workability unless lime is included in the mix. Lime also increases the water retention of fresh mortar when it is placed against dry bricks or blocks and helps to prevent cracking of the hardened mortar. A maximum of 40 l of lime is permitted per 50 kg of cement. Do not use lime with masonry cement.

2.1.3 Sand

The sand should be clean (grass, leaves, roots, etc. are harmful) and it should not contain too much clay. It should consist of hard particles which range in size, from dust up to about 2 mm. Pit sands generally have these characteristics. River, dune and beach sands are often too uniform in size (single sized) to give good results.

2.2 Mix proportions

The proportion of each material in the mix should suit the type of work being done. Strength requirements and mix proportions, recommended by C&CI, are given in Table 5.3 a and 5.3 b. In general terms the classes of mortar may be used as follows:

Class I

Highly stressed masonry incorporating high-strength structural units might be used in multi-storey load-bearing buildings; reinforced masonry.

Class II

Normal load-bearing applications, as well as parapets, balustrades, retaining structures, and freestanding and garden walls, and other walls exposed to possible severe dampness.



In practice, Class II mortars are used for most applications.

Other proportions may be used if these can be shown by test to be satisfactory.

Mortar must not be used after it has started to set, which usually occurs about two hours after it has been mixed (or one hour in hot weather $\pm 32^{\circ}\text{C}$). One man can probably lay a little more than 60 bricks an hour. If you are working on your own or with one assistant, it is better to mix a number of small batches as required, rather than mix a one-bag batch.

Do not use too thick a bedding layer of mortar between bricks or blocks; this is wasteful and may lead to cracking.

2.3 Batching the materials

A builders' wheelbarrow is a convenient measure for large batches; the capacity can be taken as 65 litres. (Figure 5.3 a)

Suitable for laying bricks and blocks in normal applications (SANS Class II)

Cement	Building sand
	
1 bag	3 wheelbarrows

To lay 1 000 bricks you will need:
3 bags of cement + 0,6 cubic metres of sand

Figure 5.3 a: Batching large mixes (SANS Class II)

Steel drums (20 l or 25 l capacity) and buckets are useful for small batches (Figure 2 a). Check the capacity of drums and buckets when filled to the brim, as this is often more than the nominal capacity. To batch, shovel material into the measure and then strike off level with the brim.

Cement	Building sand
	
1	5

Figure 5.3 b: Batching small mixes (SANS Class II)

2.4 Mixing

Mixing should be done on a clean hard surface such as a smooth concrete floor or a steel sheet. Small batches may be mixed in a wheelbarrow provided the volume of the batch is not more than half the capacity of the barrow. Sand and cement, and lime if used, should be mixed until the colour of the mix is uniform. Then add water in small quantities, mixing after each addition, until the mix is soft and plastic.

2.5 Handling

If mortar is to be left in the sun before being used, it should be covered with plastic sheeting or a wet sack. Discard mortar that has stiffened so much that it is impossible to restore workability without adding more water.

3. Notes to consultants

Specifications for concrete and mortar work should cover the following aspects: selection of materials, mix proportions, application, finish and tolerances.

The following should be noted:

1. Specifications to include: Concrete bricks and blocks must be laid dry and should not be wetted before being laid. Burnt clay bricks should be wetted but surface dry before being laid.
2. Limes used in South Africa do not have cementing properties. Therefore, they cannot be used to replace cement but are used in addition to common cement.
3. Builders' lime and mortar plasticizers (normally containing an air entraining agent) should not be used with masonry cement.
4. Safety.

Concrete is the world's most widely used building material and workers in every sector of the construction industry handle common cement and wet concrete every day. As with most materials, there are potential risks involved in handling or working with common cement, or mixes made using common cement. This section is intended to inform users of these risks, provide guidance on how to avoid the effects of unprotected exposure and outline basic first aid procedures.

Safety measures when handling concrete

- The composition of common cement is such that, when dry cement is exposed to water, a chemical reaction called hydration takes place which releases a very strong alkaline (and caustic) fluid. This can cause alkali burns and safety measures should be observed.
- Appropriate precautions are advised to prevent tissue damage when handling fresh mixes containing water and common cement.
- Working with cement and concrete usually involves manual labour and lifting heavy loads. Care must be taken to avoid back strain and other kinds of strain, due to unaccustomed physical labour.
- Cement dust, dusts from handling aggregates and from cutting concrete are easily inhaled. Prolonged or regular exposure to these dusts should be avoided.

3.1 Recommended precautionary measures

3.1.1 Physical strain

Bagged cement is usually packaged in 50 kg units. Handling and moving cement bags should be undertaken with due regard for the possibility of back and other physical strains. Similar caution should be exercised when mixing, transporting, placing and finishing concrete, as many of these operations may involve unaccustomed physical effort, or working in awkward or uncomfortable positions for long periods.

3.1.2 Dust

- Cement is an abrasive fine powder and when handled, some dust may become suspended in the air in the working area. Users should avoid inhaling cement dust as this may cause irritation of the nose, throat and eyes. Every attempt should be made to keep cement dust to a minimum to avoid these problems. Should this be impractical, the use of goggles and dust masks is strongly recommended.
- Silica dust. Many of the aggregates used in concrete have high silica contents. The fine silica dusts created when crushing or handling these aggregates could cause lung problems. Similar precautions should be observed to avoid breathing in such dusts.
- Dust from demolishing or cutting hardened concrete. This may contain unhydrated cement and could cause respiratory problems similar to those outlined above. In addition, if the coarse or fine aggregate used in making the concrete contains crystalline silica, then inhalation of the fine silica particles could expose workers to the risk of developing silicosis. A concerted effort should be made to avoid generating such dusts. If this is not possible, the use of suitable respiratory protective equipment is recommended.

3.1.3 Alkaline fluid

The product of the hydration reaction between common cement and water is a very alkaline fluid which has the potential to attack any exposed organic tissue. When fresh concrete or its fluid comes into contact with human tissue, the alkalis react with the tissue's oils, fats and proteins, causing damage. To safeguard against accidental exposure, appropriate protective equipment is strongly recommended.

- Wear impermeable gauntlet type rubber gloves and high length rubber boots to prevent direct contact with skin. Trousers should overlap the boots rather than be tucked into them.
- Apply hydrophobic alkali-resistant barrier creams to hands and any areas of skin likely to be in contact with fresh concrete. Ordinary barrier creams are likely to be inadequate. These precautions may be ineffective if the skin itself is not clean and free of concrete residue. Even a tiny trace of cement dust remaining in contact with wet skin will raise the pH significantly. For this reason, some authorities recommend the use of disposable gloves and discourage reusable gloves.
- Regularly wash (at least daily) protective clothing and keep it clean and free of concrete.
- Wash any areas that have been accidentally splashed with wet concrete as soon as possible with large quantities of clean water. Particular care should be taken to ensure that:
 - Normal and protective clothing do not become soaked with wet concrete or concrete fluids. This could result in exposure over an extended period, resulting



in tissue damage that can be particularly severe and even disfiguring.

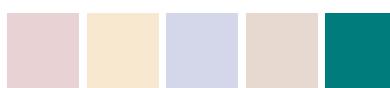
- Workers do not kneel on fresh concrete during placing, compacting and finishing operations. If kneeling is unavoidable, thick waterproof kneepads should be worn and a kneeling board used to prevent the pads sinking into the fresh concrete. In severe cases of alkali burns, a medical practitioner should be consulted as soon as possible.

3.1.4 First aid and remedial treatment

1. Carefully remove any wet concrete-soiled clothing.
2. Rinse the affected skin as soon as possible with cool, clean water. If the skin is treated soon enough (before ulceration), vinegar can be added to the rinse water to neutralise the alkalis (half a bottle of vinegar to a bucket of water). Thereafter, milk (which is a good natural buffer) can be applied to the skin with a pad to neutralise any further traces of alkalis without risk of acid burning the skin. The skin should then be dried by gently dabbing with a towel, and lanolin may be applied to replace lost fats and oils and to restore suppleness.
3. If ulceration has already set in, do not attempt to treat the wound with anything other than clean water without first seeking expert medical advice. The risk of spreading infection to the wound at this stage is severe.
4. A sterile burn dressing can be applied over the wound and bandaged. An ice pack can be applied afterwards above the dressing but not directly to the skin.
5. Do not delay getting medical treatment as the alkalis will continue to destroy tissue.

Important

It is advisable to notify any medical authorities that the victim should be treated for alkali burns.



MODULE 3: Construction of lined channels and chutes

1. General preparatory work

1.1 Prepare ground to given levels

For road-drainage systems to work effectively, the pipes or in the case of V- or flat-bottom drain construction, channels must be laid with a fall. This fall encourages the water which collects in the drain to flow in the required direction.

The levels of the fall are obtained from site drawings and are transferred onto the actual job by site-supervisory staff, competent in the use of survey equipment such as boning rods, ranging rods, spirit level and possibly the automatic or dumpy level, etc.

These levels are usually indicated on profile boards or steel pegs, along with other details such as the exact position of the drain. The pegs/profile boards may indicate the centre line of the drain or the outside measurements – the more common being the centre line indication.

1.2 Construction plant, tools and equipment

The following plant, tools and equipment are recommended to promote the construction of the lined channels by labour-intensive methods:

- Steel pegs
- Hammer
- Bedding line
- Pre-made drain former/template
- Pick and shovel
- Wheelbarrows
- Pedestrian vibratory roller (alternative – hand tamper)
- Straight edge and gauge block (timber) of required depth
- Boning rods
- Spirit level
- Hand tape – 3 m or 5 m
- Side-formers/formwork
- Concrete mixer for mixing concrete and mortar (hand mixing is also acceptable)
- Concrete shovels

Note

The pre-made drain formers (steel templates) are made to the correct shape and size of the drain specification and act as a profile. The side-formers are used as a mould/formwork to hold the concrete in place while it sets.

- Containers for batching of aggregate, sand and cement (see Module 2)
- 210 litre drums for storing water
- Scree
- Wooden float
- Equipment for tamping/compacting concrete

The templates (Figure 5.4 and 5.5) must be used and placed with aid of spirit level.

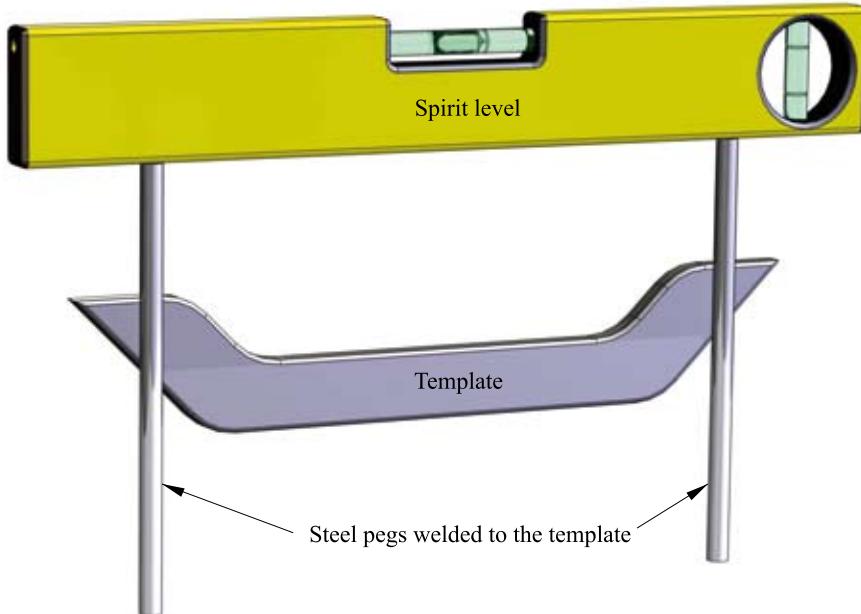


Figure 5.4: Typical flat-bottom drain steel template

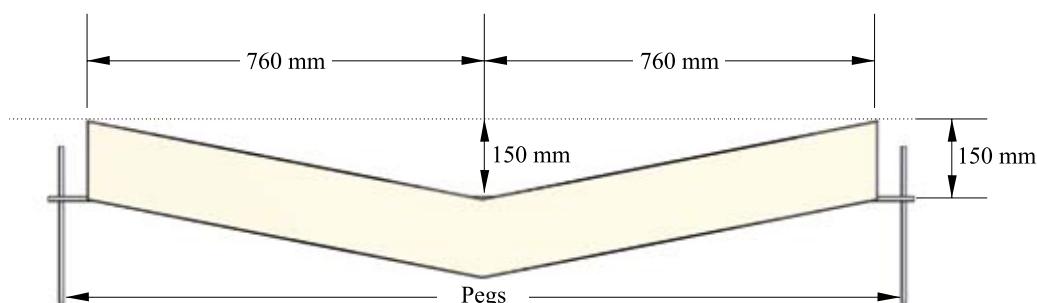


Figure 5.5: Typical V-drain template

Not all jobs will require side-formers. Often by neat excavation and trimming, the concrete can be contained by the ground itself. Remember you must be able to adapt to various site situations and make use of what resources you have available, to your advantage.

2. Construction

2.1 Construction plant and equipment

The selection of the construction plant tools and equipment needed for channel linings, listed in Section 1.2, will depend on the type of lining.

2.2 Stone pitching

There are various methods of pitching. These methods are determined by the degree of damage expected from the water flow.

2.2.1 Materials

Materials required for the construction of stone pitching, include:

- Selected stones.
- Cement and sand for mortar (Module 2).
- 150 mm mesh for netting (metal or plastic or both).

The materials required for a specific stone pitching will depend on the method of holding the stones together.

2.2.2 Prepare ground to given levels

No pitching shall be placed on any fill or surface which has not been trimmed, prepared and compacted. The density of compaction must be so that it produces a surface which is equal to that of the surrounding material. Where shown in drawings, or as directed by a supervisor, free-draining stony material may be required to be laid on the prepared surface. The ground below these layers still has to be prepared as follows:

The area shall be marked out under supervision according to drawing details. Levels shall then be placed in and around this working area at various points. This allows you to make full use of them by stringing lines or with the use of straight edges.

Usually, these levels will be wooden or steel pegs. The height of the pegs will be placed by a site supervisor and will either give the height of the finished stone surface, or the height to which the ground area is to be excavated.

To ensure a uniform surface area, it is recommended that you make use of a rigid straight edge. By using a sawing action and drawing the straight edge towards you, you will level the area. Make sure you work to the given levels and check the area for a uniform fall as work progresses. Remove any timber, rocks, roots, etc. that interfere with obtaining levels.



Figure 5.6: Fill loose pockets and holes

As small pockets or low areas appear behind the screeding action of the straight edge, they should be filled with additional material (Figure 5.6) and rescreeded.

Once the area has been levelled and checked, it is necessary to compact the area to prevent any further soil settlement. This is done by using a heavy metal hand rammer. By lifting the rammer and thumping it down, the loose excavated area can be compacted. (Figure 5.7)



Figure 5.7: Compact the area

This compacting action may be assisted by lightly sprinkling the area with water. Ensure the whole area is evenly compacted.

2.2.3 Edge restraint

A trench shall be excavated as instructed by the site supervisor, along the toe (bottom) of any slopes (Figure 5.8). This acts as an anchor and will prevent the finished stonework from sliding at a later stage.

The trench width is usually about 200 mm wide and 300 mm deep unless you are otherwise instructed. Again the bottom of any trench dug for pitching must be well compacted, using a hand rammer.

Figure 5.8 is an example of finished stone pitching. This will give you a good idea of what is expected in the ground preparation.

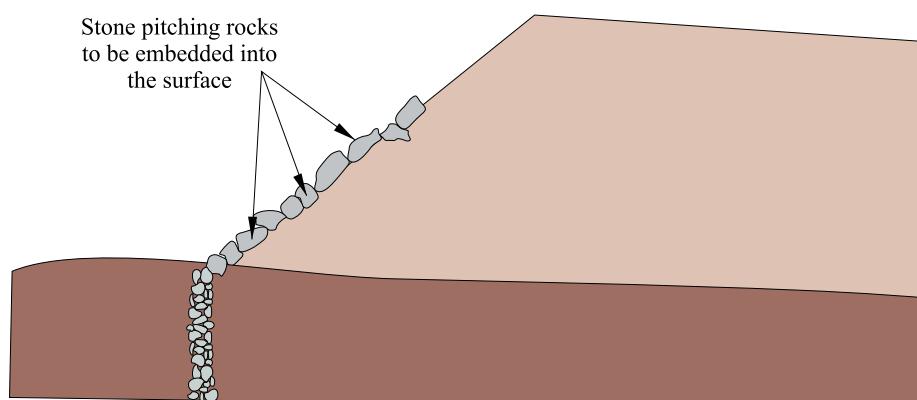


Figure 5.8: Trench at bottom of slope



Important

- It must be stressed that care should be taken not to disturb any peg levels during the excavation and compacting operation.
- The finished ground level after compaction should be ± 10 mm from the given levels.
- All excavated material shall be placed neatly to one side, close to the work area.
- While working through this procedure you are expected to practice a policy of good housekeeping and safe working practice.
- If you have any doubts or misunderstanding of the instructions given by your facilitator/supervisor about the work to be done, sort these out before you begin the work task. Ensure that you know exactly what is expected of you during any work situation.

2.2.4 Lay plain pitching

Plain stone pitching can take the form of two methods. Both must be fully understood and practiced.

Use the work area that has been prepared.

Stone to be used for pitching shall be sound, tough and durable. The size of stone used shall not have a dimension of less than 200 mm, except those smaller pieces (called spalls) which are used for filling spaces between the larger stones.

The shape of the stones or rocks used form a stable protective layer of the required thickness. Rounded boulders shall not be used on slopes steeper than 2:1, unless grouted.

The choice of the type of stone must be decided and approved by the site engineer.

Ensure you have a ready supply of stone to be used close to the work area to avoid standing time. Get stones tipped as close to the work area as possible, this will save time, labour and avoids double handling of material.

Method 1

1. Starting at the bottom of the trench and lay the stones firmly against each other; the stones must be rammed into the soil below, giving a firm bed. Care must be taken not to damage or crack the stones during this process.
2. Complete the filling of the trench up to the required finish height of the stone surface.
3. Working up the slope, the stones shall be placed firmly. Embed each stone into the underlying material and against adjoining stones.
4. Each stone shall be placed with its largest dimension at right angles to the slope and in close contact with previously placed stones.
5. Stone should be placed in a random pattern and care must be taken to avoid running joints. Do not lay these so straight that joint lines can be noticed. This will also apply to any joints which may run up the slope. The pattern formed must be random, i.e. similar to that of a jigsaw puzzle.
6. The stones will be rammed into the bank/slope surface as work proceeds. Spaces



between the larger slopes shall be filled with spalls (smaller stones). These spalls are to be rammed securely in place.

7. Stones shall be placed individually. Dumping is not allowed.

Method 2

The method and procedures laid down in Method 1 shall also apply to Method 2, except in the following points:

1. No small stones or spalls shall be used to fill the spaces between the larger stones.
2. As the larger stones are placed, topsoil shall be packed between individual stones and sufficiently rammed (use a wooden peg) to provide a firm bonded structure. The topsoil shall be provided to the full depth of the stone pitching at any point.
3. Rooted grass or tufts shall then be planted in the topsoil between the stones. This must be watered immediately on completion of the work area for that day. Further watering will be required at later stages until the grass has established itself. Use a sprinkling action when applying the water to avoid washing away the topsoil.

Using either method, work up the slope and cover the required area. Remove level pegs as you come to them. The finished surface of the stone pitching must be even, tight and have a neat appearance with no stones varying by more than 25 mm from the specified surface levels.

The material that was excavated and placed to one side must now be backfilled against the toe pitching and any exposed sides. Compact the backfill using a hand rammer.

Any remaining soil should be removed or neatly spread over the surrounding area.

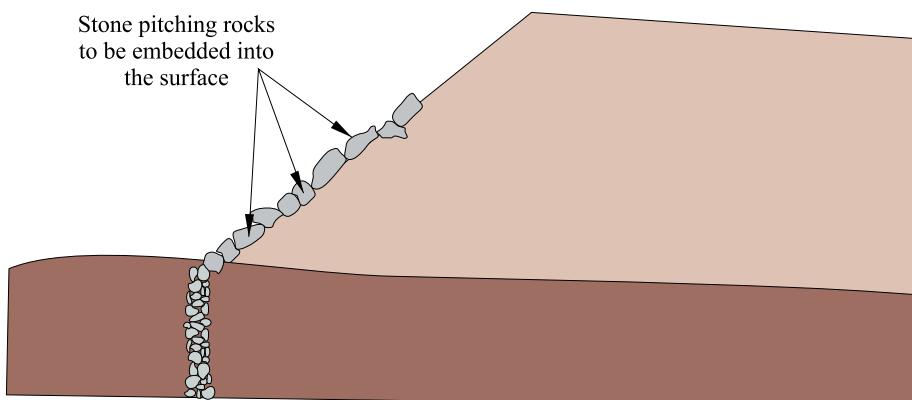


Figure 5.9: Completed stone pitching on slope

2.2.5 Grouted stone pitching

Grouted stone pitching is used where the erosion damage will be severe. Such areas may be drainage pipe discharge points where running water is constant or where the water leaves the pipe at high speed.



Grouted stone pitching shall be laid as described in Method 1 except in the following points:

1. No spalls or topsoil shall be placed between the larger stones.
2. Once the larger stones have been laid, they must be cleaned of any dirt, soil or clay.
3. The stones shall then be moistened with water.
4. The space between the larger stones is now ready to be filled with grout.
5. The grout mix shall be one part cement, six parts of sand by volume. The amount of water added to form the grout should be just enough to form a consistency similar to a thick soup. It should pour easily from a suitable container.
6. Grout which is mixed more than half an hour before the time should not be used.
7. Grouting should be done at the end of each day's work. Do not leave an area of stone pitching for grouting to the following day.
8. The space between larger stones shall be filled by pouring the grout and then working it into the space by rodding or trowelling. This ensures that all spaces between the stones will be completely filled with grout.
9. The grout shall be filled to within 50 mm of the finished stone surface unless otherwise instructed.
10. After the grout has been placed, the surface of the stones should be thoroughly brushed to ensure the top surface is exposed. A quick wipe of the stone surface using a cloth or cement bag will give a neat finish to the surface of the stone pitching.
11. After the grouting has been completed, it is important that the finished surface is protected from drying out too fast, as this will result in cracks forming in the grout. Cover the completed stone pitching with damp sacking or other approved methods for a minimum period of four days after grouting. No loading or walking on the pitching is allowed during this time.

The final surface must conform to the same standards as set for plain pitching – neat, even and tight appearance, with a surface that does not vary more than 25 mm from the given final surface levels.

2.2.6 Wire-and-grouted stone pitching

A variation of grouted stone pitching is referred to as wire-and-grouted stone pitching.

The basic principles are as follows:

- The pitching shall be held in position at the bottom and top with 150 mm mesh wire nets. The bottom net shall first be placed over the prepared surface to be pitched, with wire ties fastened to it at 600 mm spacing and projecting upwards.
- The stone shall then be laid on this net in a similar fashion to the method described for plain pitching.
- After the stones have been laid, the top wire net shall be drawn tightly over the stone surface. Securely fasten this to the wire ties passing from the bottom net through the pitching. After tying, the ends must be turned down into the pitching. The entire area of wire pitching shall then be grouted as described for grouted stone pitching.

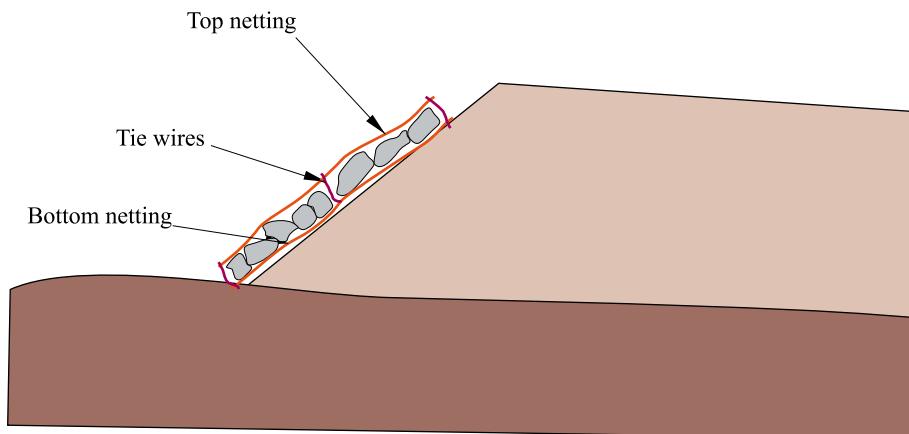


Figure 5.10: Wire-and-grouted stone pitching

2.3 Concrete lined drain construction

2.3.1 Materials

Materials required for the construction of lined concrete drains include:

- Cement, aggregate and sand for concrete (Module 2).
- Mesh reinforcing to specification, if required.
- Joint material to specification, if required.

2.3.2 Typical working example based on V-drain

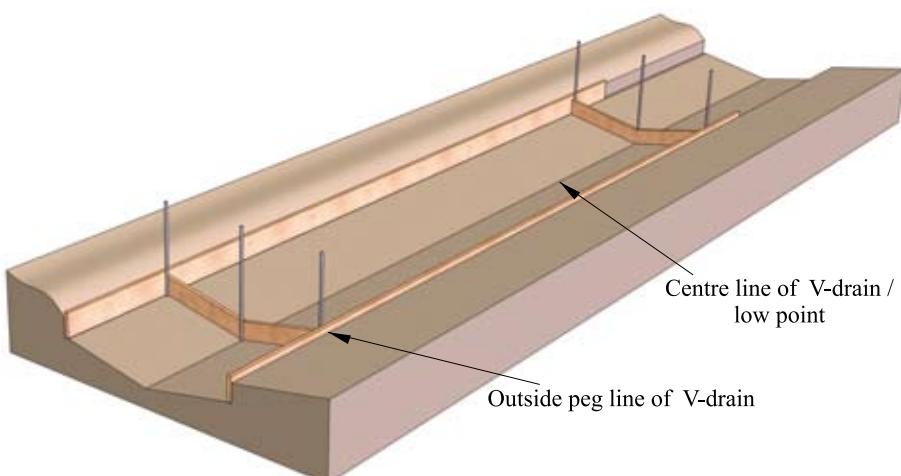


Figure 5.11: Setting out of V-drain

Steps to follow:

1. From the given pegs you should see the path the V-drain is to follow. Working levels are usually placed on these pegs.
2. String the building line on the outside pegs, making sure the pegs are not disturbed.
3. Position the drain formers at the given pegs to the given levels. Slight excavation may be required at this stage and formers are to be secured (make use of reinforcing off-cuts).

4. Set further drain formers at 1 m intervals (can vary on site), using the building lines as a guide.
5. Excavate all unwanted material to the depth required between the building lines. Use the straight edge as a guide between the formers (a gauge block used below straight edge can help). At this stage the excavation should take on the shape of the required V-drain, as you will be using the drain formers as a profile. Trim sides neatly.
6. Compact the ground using the tamper or punner. Adjust the excavation levels of cut and fill to a uniform depth of drain thickness. At this stage, remove all unwanted material such as rocks, timber and clay, and form the excavation into a well-compacted V-shaped shallow trench to the bottom depth of the drain. This will now act as a mould to receive the concrete that forms the channel of the drain. (Refer to Section 2.2.2.)

If the local soil cannot be used to contain the concrete that will form the drain, side-formers must be used. Align these, using the building line pulled between the outside pegs. If the drain needs a clean, definite edge, side-formers may also be required.

The side-formers may be suitable standard steel formwork or timber such as scaffold boards on edge. Both are capable of providing a neat finish. Care must always be taken to keep the forms true to line and given levels.

2.3.3 Batching and mixing of concrete

This aspect is dealt with in detail in Module 2 of this Manual.

2.3.4 Place concrete and complete project

Prior to placing concrete to form the V-drain channel, you must undertake the following:

1. Are all drain formers set at the required spacings and secured? The method of placing the concrete will be by pouring alternate bays. Secure all drain formers at required level and height.
2. If using side-formers (height-formers), check they are firmly in position to the line and height you have been given.
3. Has ground base been properly excavated and compacted? Get your supervisor to check if needed.
4. Has the ground been dampened prior to concreting?
5. Do you have all necessary tools at hand?

Important

- Concrete lined open drains only. Has polythene sheeting been placed over compacted material?
- If steel reinforcing is required, it will be specified. You must check the work prior to concreting. It is expensive in time and material if any mistakes are made when dealing with concrete.
- These items do not fall directly under the basic construction of V-drains, but under site supervision you will be able to combine these situations into the basic construction of cast-in-situ concrete V-drains.



After the check has been done, start placing the concrete using the alternate bay method. (You will be informed of bay lengths.)

Day 1	Bay 1	Bay 2	Bay 3	Bay 4	Bay 5
-------	-------	-------	-------	-------	-------

Day 2	Bay 1	Bay 2	Bay 3	Bay 4	Bay 5
-------	-------	-------	-------	-------	-------

Day 1: Cast bay 1; 3 and 5

Day 2: Cast bay 2 and 4

Figure 5.12: Casting of bays/panels

- Place the concrete by shovel and work it in well to the forms. It must be tamped and screeded to the levels of the forms and entirely cover all exposed surfaces.
- The concrete should then be evened off with a wooden float, leaving the channel shape of the V-drain. The concrete should be allowed to stand for a short time to allow initial setting.
- Leave the concrete until just dry enough to make a slight footprint in it. When in this condition, the final float finish should be done.
- Forms shall not be removed from the concrete for 24 hours after placing, otherwise damage may occur. Minor defects may be repaired with a 2:1 sand:cement mortar (plastering is not permitted).
- After the concrete in the alternate bays has set and the formwork removed to allow the casting of intermediate bays, the exposed contact surface of the old and new bays shall be painted with an approved bituminous paint, prior to pouring concrete. (Note: movement (expansion) joints are to be placed according to drawing specification.)
- Curing of the concrete shall commence as soon as the concrete has hardened sufficiently to ensure that the surface will not be marked or stained in any way. Curing may be done by covering the exposed surface with sand or fabric mats. Either must be kept continuously damp. The period of curing will be stated by your supervisor. An alternative curing method is the use of a curing compound.

2.3.5 Transition sections

Where the drain construction meets with existing work or enters into inlet/outlet areas of the total drainage system, they must tie in neatly. They must be constructed to the same standards as far as practical and using the same construction methods as specified in this Module.

2.3.6 Backfill to sides

After the pitching or concrete work has been completed and the initial curing has taken place, you may be required to backfill the channel, i.e. build up the surrounding area to the upper levels of the channel. Such backfill shall be placed in layers not exceeding 150 mm and each layer should be watered and thoroughly compacted. The backfill should be sloped towards the channel encouraging water to enter it. Care must be taken not to damage the construction of the drain at this stage.

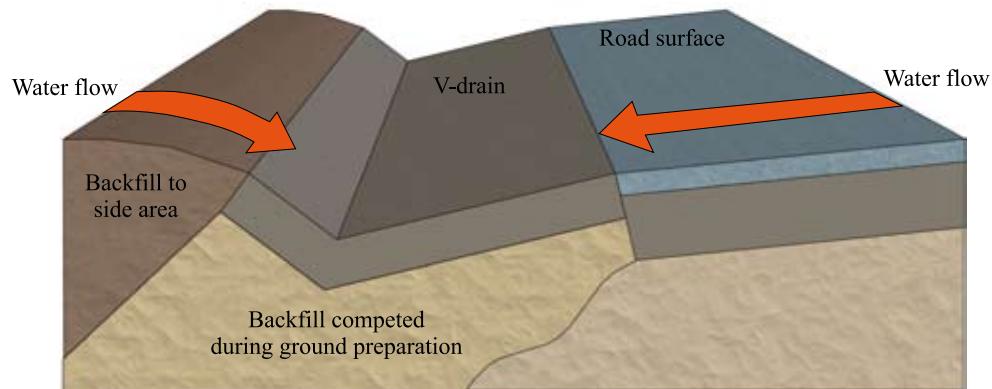


Figure 5.13: Example of backfilling V-drains

The cross-sectional sketch (Figure 5.13) shows a completed V-drain which has one side against a road surface and the other with backfill material. As you can see, surface water is encouraged to flow into the V-drain channel.

The material used for backfilling will be specified.

3. General notes

The final product must comply with the shape of the pre-made drain formers. The final surface must be uniform and true to shape.

Movement (expansion) joints may be cut at a later stage or constructed between alternate bays at a pre-designed measurement, according to the details supplied by the designer/engineer.

The completed project must be able to do the job intended i.e. collect and carry surface water away from the road structure and surrounding area. The project must be left clean and tidy and pleasing to look at.

Open channels are readily constructed by hand as the requirements for accuracy and quality are generally not onerous. The essential elements in the construction of open channels are the following:

- Commence work at the lower end so that any water flowing into the channel will drain away immediately and not accumulate to saturate the soil.
- Approach the final excavation level with caution so as not to over excavate. (Over break requires costly backfilling that seldom matches the strength and stability of undisturbed soil, especially in the case of unlined earth channels.)
- The use of templates is encouraged, as unskilled labour will quickly learn how to use them to ensure correct shape and side-slope of the channel excavation. Boning rods, used in conjunction with profiles, will ensure correct longitudinal gradients.
- When linings are to be constructed, the channel bottom and sides must be compacted to at least 90% of Mod AASHTO maximum density. Poor soils exposed during excavations should be removed and replaced with better quality gravel soils. Considerable effort is required to ensure good preparation before lining, as uneven settlement may destroy the lining and negate its purpose. (Remedial work is more costly than doing the job properly in the first place.)



- Stone pitching and block-laying is always started at the low end and worked upstream. The units should be tightly packed.
- Grouting of stone pitching should be undertaken as the job progresses. If grouting is delayed, storm flows carrying sediments can fill the voids in the pitching. Should this happen, the pitching will have to be taken up, the sediments cleaned out and the stone re-laid.
- Attention must be given to the surface finish of linings in order to fulfil the design requirements. If the design relies on a rough finished surface to control the flow velocity, then a steel-trowelled finish is not desired.
- Drainage of the space behind the lining may be crucial and attention must be focused on getting the details to work. Filter layers and the installation of flap-valves to relieve groundwater pressures may require the input of a specialist.
- Concrete work must be properly cured for at least four days. Poorly cured concrete will not have the abrasion resistance needed to withstand high velocity, debris-laden flows.
- Careful backfilling of spaces along and behind structures is essential for the drain to function correctly. Adequate quality control measures must be in place.

4. Notes to consultants/designers

4.1 General

To overcome flooding, storm water drainage was introduced to minimise the inconvenience and disruption of activity caused by the runoff from frequent or minor storms. It also minimises the danger to life and property by controlling the runoff from infrequent or major storms.

This can be achieved by the use of two separate but inter-related systems: the minor and major drainage systems.

The minor system forms the conventional urban drainage system which collects runoff from storms of up to 10 year return periods. As the minor system is designed in conjunction with a major system, less reliance need be placed on its function and it can be designed for smaller storms, thus saving on construction costs. Open channels are the preferred conduits for the conveyance of storm runoff for several reasons.

Flow velocities in open channels will dictate the type of channel or channel-lining required. Sensible limits to the flow velocity must be applied in order to limit erosion damage.

The chosen lining should be labour-friendly i.e. it should be amenable to construction by labour. For open channels, virtually all lining materials can be laid by hand, so this requirement is hardly a restriction. However, for economic reasons, the chosen channel lining should make maximum use of local materials.

Flow velocities

The approximate, maximum flow velocity which can be withstood by various soil types and ditch linings is as follows:

- Fine sandy soil: 0,6 m/s
- Gravel soil and stiff clays: 1,2 m/s
- Cement grouted rock lining: 3,0 m/s
- Concrete over: 5,0 m/s

Further guidance, as well as the typical roughness coefficients for various channel materials and linings can be found in the *Road Drainage Manual* (Rooseboom, 1993).



4.2 Treatment of drains

4.2.1 Flat terrain

The side drain channel is a flat bottom drain construction, together with top soil and encouragement of vegetation i.e. either grass planting or seeding, together with artificial fertilisers.

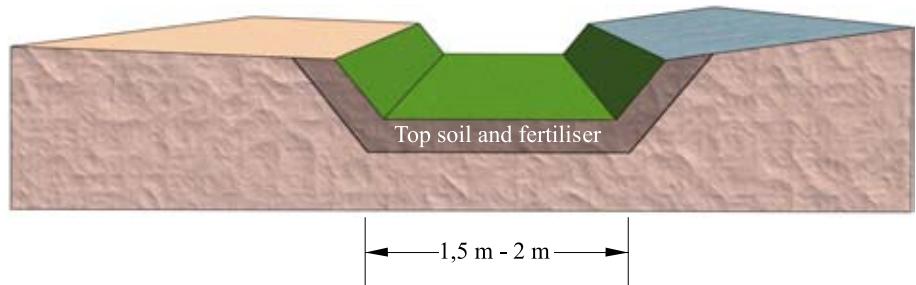


Figure 5.14: Drain lined with vegetation

4.2.2 Steep terrain

Lining of side drains is necessary where the slope of the drain is excessive and the speed/rate of flow is $> \pm 0,6 \text{ m/sec}$.

The lining of drains is always an expensive exercise but the cost of repairing an erosion problem is often more expensive. There are several methods which can be used to save the cost of constructing the lining of the side drain. Concrete (Figure 5.15) and stone pitched (Figure 5.16) are common examples.

Note the following:

- Use river gravel or river sand. Concrete mix = 1 cement to 6 sand or river gravel (screened).
- Use stabilised gravel – must be compacted to at least 95% Mod. AASHO density – there are problems compacting the side walls. It is therefore more practical to use a V-drain for this type of lining.
- Stabilised gravel can be CTB, ETB or LTB i.e. cement, emulsion or lime treated gravel, depending on what material is readily available. Templates and steel shuttering is required.
- Line only the inverts of the drain with cement/sand concrete/stone, as the erosion normally occurs on the invert area i.e. the bottom of the drain and not the sides.

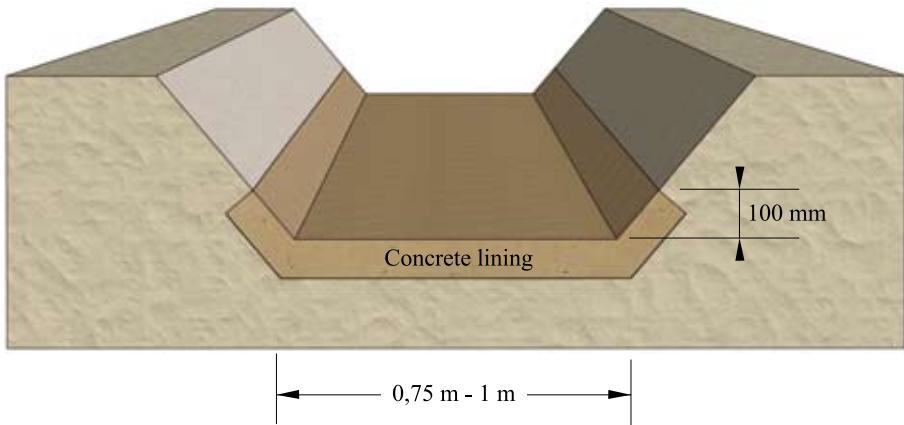


Figure 5.15: Concrete lined

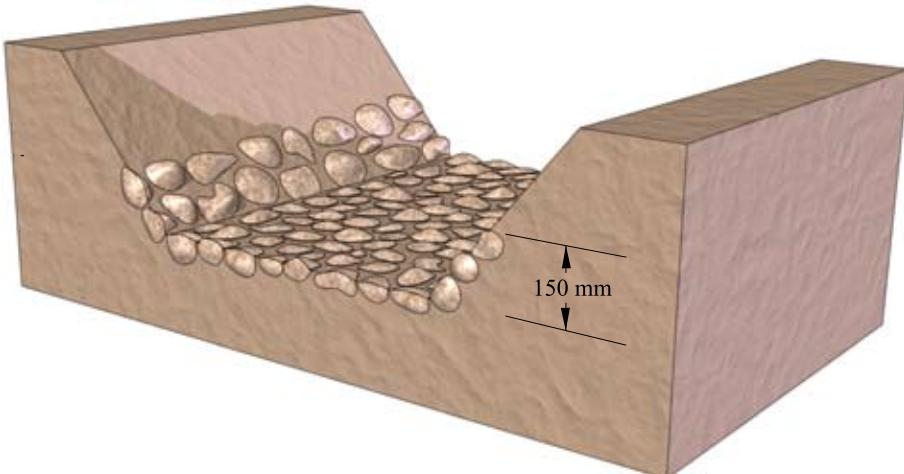


Figure 5.16: Stone lined

Encourage vegetation on side slopes. The invert/bottom of drain must be properly compacted. Using a 1,5 bulking factor ensures that the required compaction is achieved. If ETB is selected, there is an advantage of minimum cracking of the material occurring.



Steel templates (Figure 5.17 and 5.18) must be used and placed with aid of spirit level.

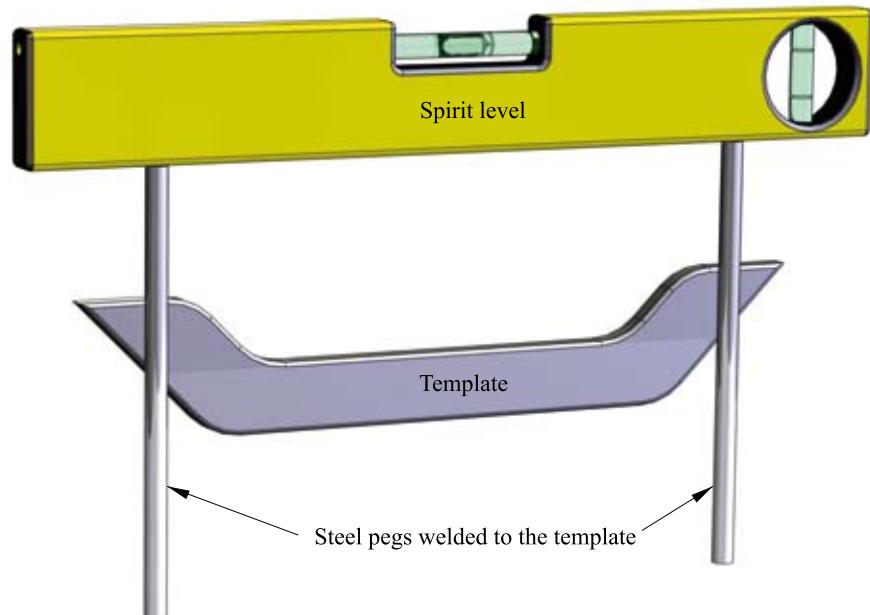


Figure 5.17: Typical flat bottom drain steel template

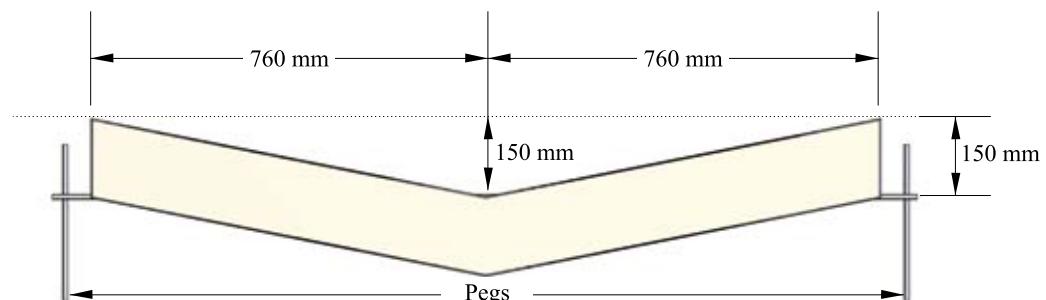


Figure 5.18: Typical V-drain template

4.3 Materials

Open channel drains may comprise lined or unlined channels, depending on the ground conditions and the flows to be carried. Linings are costly and should only be used after the conditions for a channel have been properly assessed. Scour checks can control flow velocities to a limited extent and are usually cheaper than lining.

Typical channel lining materials include:

- Vegetation: low-growing vegetation like grass is suitable for channel linings. Kikuyu grass should be avoided as it needs fairly large quantities of water for its establishment and continued growth in arid climates; in wetter climates kikuyu grows too vigorously and chokes the waterway, requiring regular cutting. It is advisable to consult a local extension officer of the Agricultural Department for advice on the most suitable grasses to plant.

- Masonry linings are rarely appropriate for large channels carrying high flows. However, for small channels brick linings are technically adequate and can have positive aesthetic qualities that are difficult to match in other materials.
- Precast concrete units are available in many shapes and sizes and provide a lining with many desirable properties. Paving units are suitable for small channels and have positive aesthetic qualities. Vertically interlocking units are resistant to higher flow velocities and by alternating blocks of different thickness, provide greater roughness. Wired interlocking units are suitable for high flow velocities and the openings between the blocks encourage the establishment of vegetation. Grass blocks (precast concrete units with openings) are often suitable for lining channel bottoms and allow the establishment of vegetation. They combine well with loeffel blocks used to support the channel sides. With all such linings, care must be taken that turbulent flow does not erode the soil behind the lining or through gaps in the lining and cause the lining to collapse. Geofabrics are generally used to counter erosion behind the lining, while allowing free drainage of groundwater. Abrasion of debris-laden water requires high unit strength.
- In-situ concrete is costly, but used in the right circumstances, it can be cost-effective. It can resist high flow velocities when carefully detailed and properly constructed. Drainage behind the lining must receive attention, as high ground water levels after storm runoff has passed can cause the lining to be lifted. The surface can be made very smooth, to reduce sedimentation at low flow velocities but it is more difficult to make the surface sufficiently rough to control high flow velocities. High flow velocities are perhaps better controlled by means of a series of steps or stepped pools, which induce a hydraulic jump at every step (Rooseboom, 1993). Abrasion of debris-laden water requires high concrete strength.
- In-situ concrete cast into Hyson Cells combines the advantages of in-situ concrete with the flexibility of discrete blocks. (Reference should be made to the literature from the supplier.)
- Rock is an excellent channel lining material and can often be obtained locally. Rock can be used in many forms:
 - Plain stone pitching comprises hand laying stone onto a compacted area. The stones are driven into the earth and the gaps between the stones are filled with spalls or topsoil and rooted grass shoots.
 - Grouted stone pitching comprises plain stone pitching with the interstices filled with a 1:6 cement:sand grout instead of spalls or topsoil.
 - Wired and grouted stone pitching comprises a wire net of 150 mm mesh beneath and above the stone pitching, with vertical wire ties at 600 mm centres. When laid and tied together, the area is grouted with a 1:6 cement:sand mortar. (Quality of stone required must be sound, tough and durable, generally with a minimum dimension of 200 mm – some specifications permit stone with a maximum size of up to 600 mm to be used. Wire should be 4 mm galvanised wire.)
 - Various membranes are in use for channel linings, generally for waterproofing to cut infiltration into the ground. However, none are robust enough for township or rural settlement use.

MODULE 4: Construction of culverts/small bridges

1. Construction plant equipment and tools

The following plant, tools and equipment are recommended to promote the construction of culverts/small bridges by labour-intensive methods:

- Steel pegs
- Hammer
- Building line
- Pre-made drain former/template
- Pick and shovel
- Wheelbarrows
- Pedestrian vibratory roller (alternative – hand tamper)
- Pump and/or buckets for dewatering
- Bags for filling with sand for deviation of stream
- Straight edge
- Boning rods
- Spirit level
- Hand tape – 3 m or 5 m
- Steel and/or timber shutters/formwork
- Concrete mixer for mixing concrete and mortar (hand mixing is also acceptable)
- Concrete shovels
- Containers for batching of aggregate, sand and cement (see Module 2)
- 210 litre drums for storing water
- Screed
- Wooden float
- Trowels

2. Preparatory work

2.1 Positioning of a culvert

The placing of a culvert is critical. It is recommended that the culvert is positioned as close as possible to the direction of the natural flow of the stream. This may initially involve extra cost.

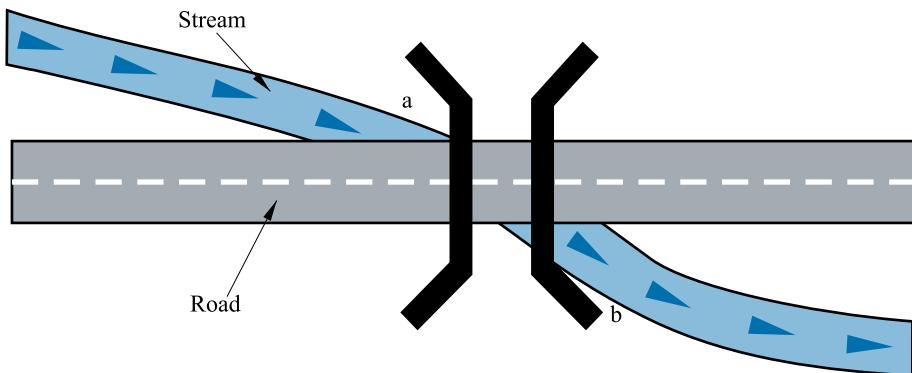


Figure 5.19: Incorrect positioning of culvert

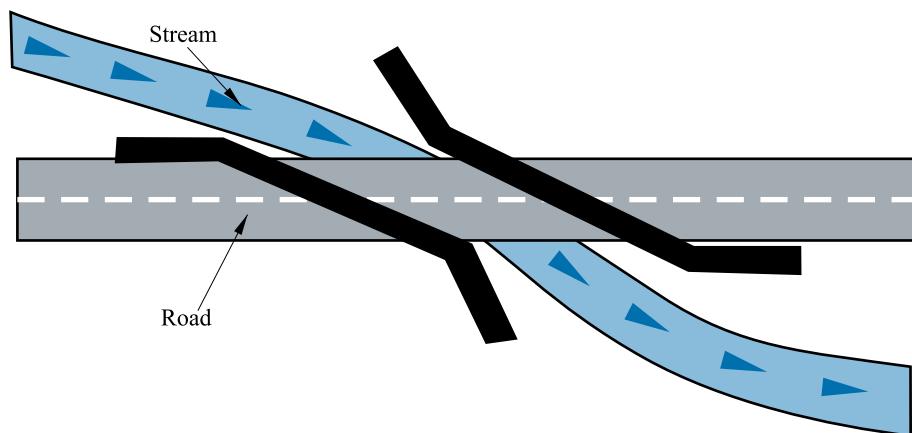


Figure 5.20: Correct positioning of culvert

The positioning of the culvert as shown in Figure 5.19 would require river training, either at the inlet at a or outlet at b or both a and b. This is not advisable as in most cases this results in catastrophic erosion problems. The ideal placing of the culvert is shown in Figure 5.20. Interfering with the direction of the flow of the stream is not recommended.

2.2 Culvert setting out and preparation

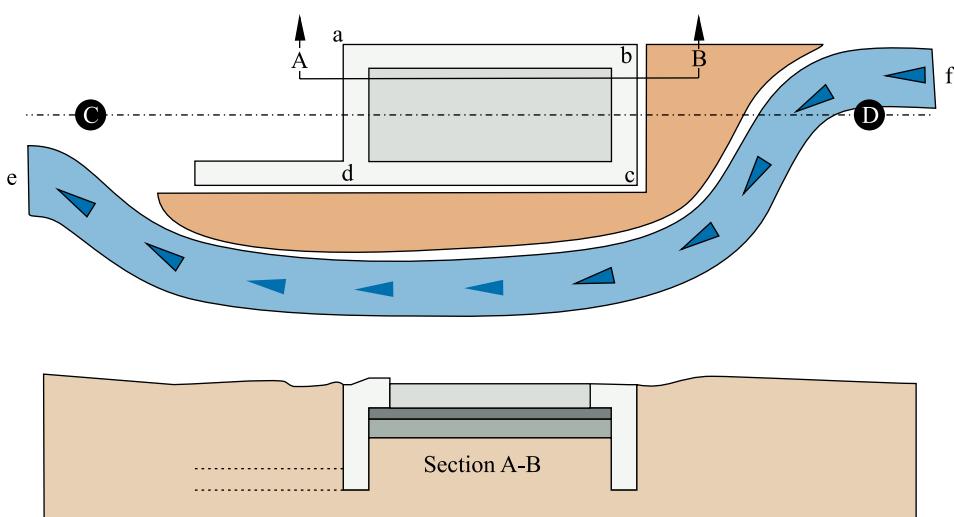


Figure 5.21: Culvert setting out and preparation

- Establish the centre line of the culvert and place the concrete at the reference points at C and D.
- Set out a, b, c and d (with stakes) $\pm 0,5$ m wider than foundation slab on all sides of slab.
- Excavate a drainage channel ± 300 mm wide to drain the area so that the water exits along de.
- If water is flowing in the streambed, divert the water in a separate channel fe in addition to channel abcde.
- Allow the drainage to function for a couple of days until the area can be accessed.
- Remove ± 100 to 150 mm of the mud/clay and vegetation.
- Replace with suitable gravel or (stabilised gravel) and compact with plate vibrator or hand tamp to specified levels and slope. Normally 1:50.
- Add 25 – 37 mm sand concrete screed (sacrificial) for working platform ± 200 mm wider than concrete slab.

2.3 Diversion of small streams

The diversion of small streams (Figure 5.22) is relatively easily achieved by using sandbags if excavations are not feasible.

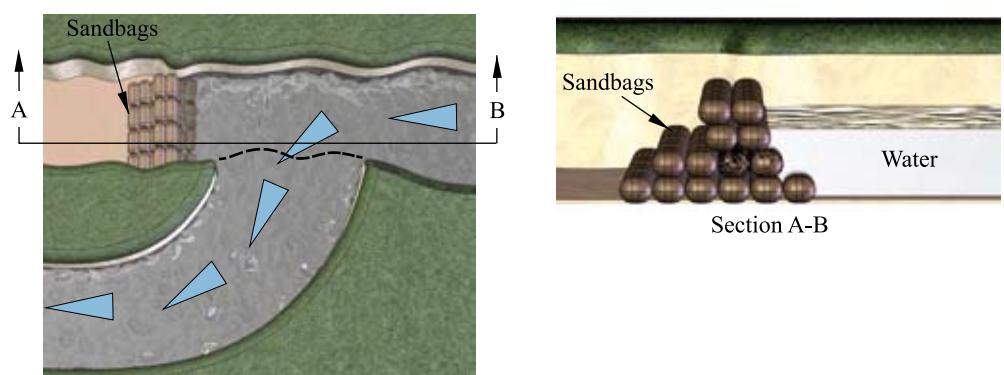


Figure 5.22: Stream deviation

It must be noted that the area in which the work is to be executed must be dry – in a practical/acceptable condition to allow efficient workmanship.

2.4 Setting out of lines parallel to centre line of road

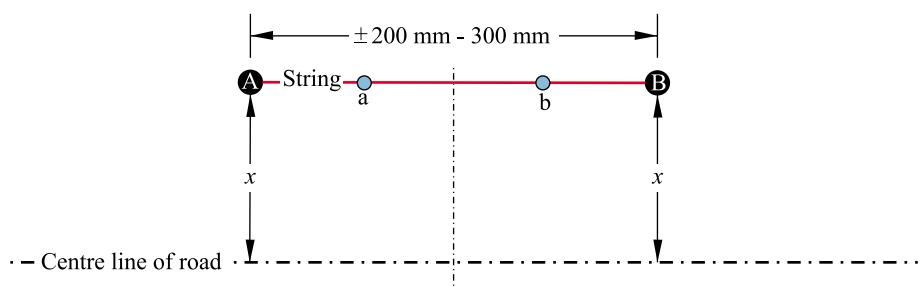


Figure 5.23: Setting out parallel lines

It often happens that a reference line or pegs are required for constructing the head wall of a culvert, kerbs and gutters, lining of side drains or even widening of the surface or repairing edge breaks of the surface.

Unsightly mistakes can be made by not establishing the reference line meticulously. On the principle of working from the greater to the lesser (Figure 5.23), establish two ranging rods A and B $\pm 200 - 300$ m apart, x metres from the centre line of the road. From this line AB, two reference pegs a and b can be placed and, depending on the type of repair/construction, the distance between a and b can be calculated.

If difficulty is experienced in lining up a and b with A and B, stretch a string line between A and B and accurately establish a and b.

2.5 Setting out of outfall exit drain from culverts

The most useful tools on construction are suitable pegs, string line, ranging rods, tapes and spirit level or string-line levels and boning rods.

For neat, professional work, it is advisable to carefully set out the work required before physical work is attempted.

- Step 1: Check the grade/slope of the outfall drain. Using the method in Figure 5.24 and selecting the direction of the drain that gives the best slope, place a reference peg 4.
- Step 2: Bone in the levels of intermediate pegs (1a), (2a) and (3a) along the centre line of selected direction, using reference peg in (4) above and centre of culvert a (Figure 5.25).
- Step 3: Measure $\frac{1}{2}$ width of culvert and place (1b) + (1c), (2b) + (2c) and (3b) + (3c).
- Step 4: Excavate trench to level (1a), (2a) and (3a) with vertical walls to width of culvert.
- Step 5: Trim sides of trench to 1:1½ slope using 1:1½ template and spirit level.
- Step 6: The excavated material must be removed from the open trench by a wheelbarrow.

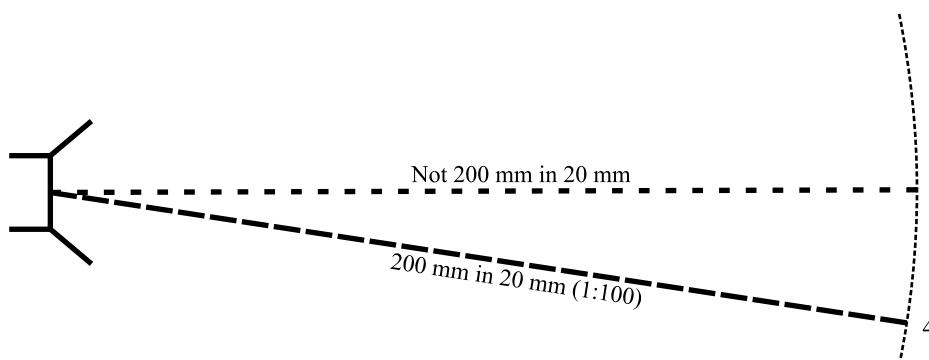


Figure 5.24: Checking the slope of the outfall drain

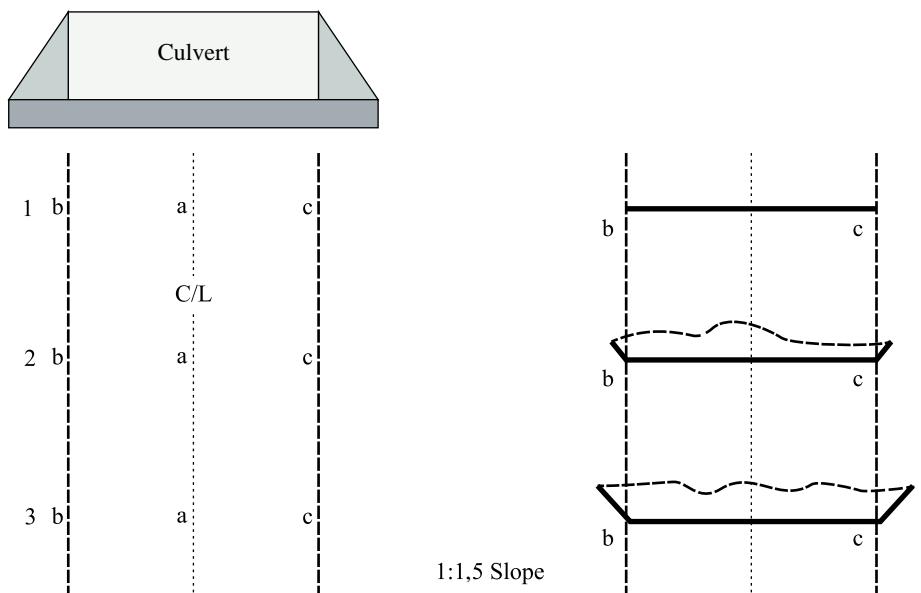
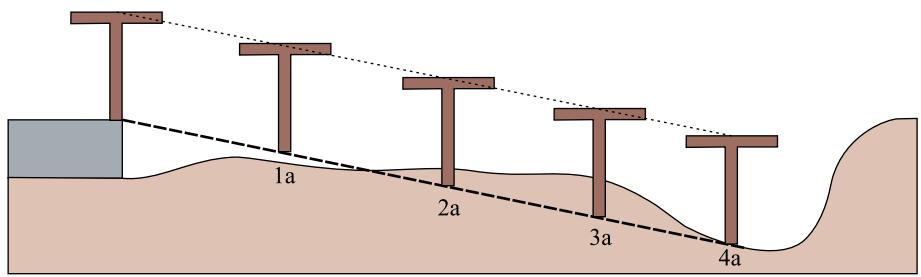


Figure 5.25: Levels

The outfall/exit drain from any culvert should have a minimum slope of 1:100 for efficient free flow of the water, i.e. 200 mm in 20 m or 100 mm in 10 m.

i.e. 200 mm in 20 m or 100 mm in 10 m

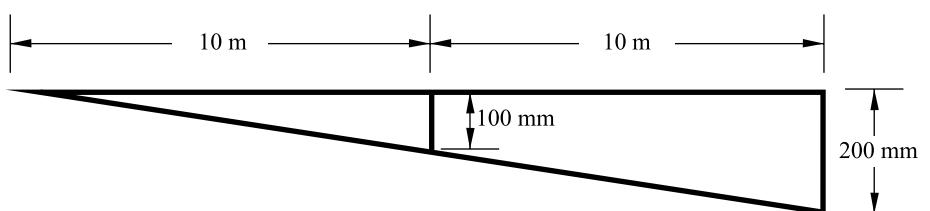


Figure 5.26: Slope of outfall/exit drain

3. Construction plant and equipment

The selection of the construction plant equipment and tools (listed in Section 1) needed for construction, will depend on the type of material being used in the construction and foundation conditions.



4. Construction materials

Construction materials will depend on the material used for the construction of the various elements of the culvert but the main materials will include:

- Cement, sand and aggregate for concrete and mortar (Module 2).
- Bricks to specification.
- Concrete blocks to specification.
- Stones to specification for stone masonry work.
- Gabion baskets and stone for filling baskets.
- Steel reinforcement and/or mesh.
- Sand for filling sandbags.

5. Construction

5.1 Head and wing walls

5.1.1 Interpret drawings and setting out

Head and wing walls are constructed at the inlet and outlet ends of culverts. Their purpose is to prevent soil erosion which occurs as water enters or exits the culvert chamber.

Depending on the site specifications, head and wing walls may be constructed from concrete, brickwork, block work or stone masonry and gabions which are usually associated with minor works.

The drawings give the information required for the construction details and setting out requirements.

Head walls are constructed flush and in line with the chamber face, (including culvert face) according to drawing detail. Wing walls are constructed at angles off the head wall according to drawing detail. (Figure 5.27)

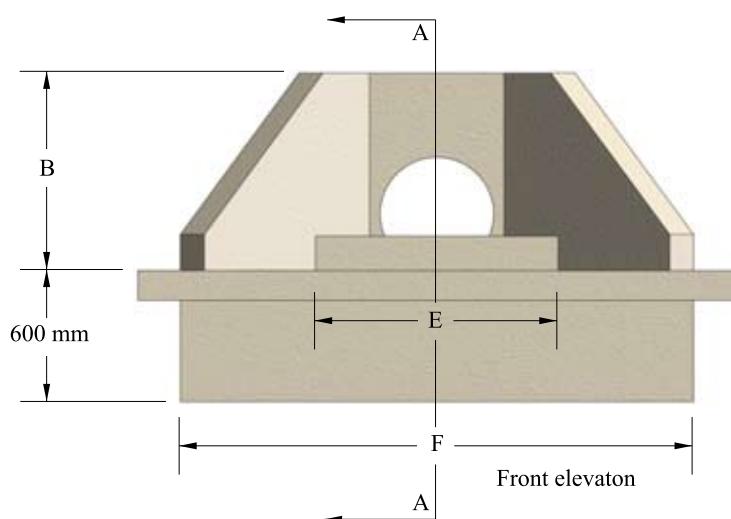
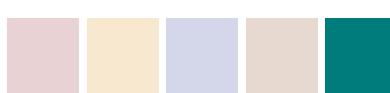


Figure 5.27: Typical head wall/wing wall drawings (continued overleaf)



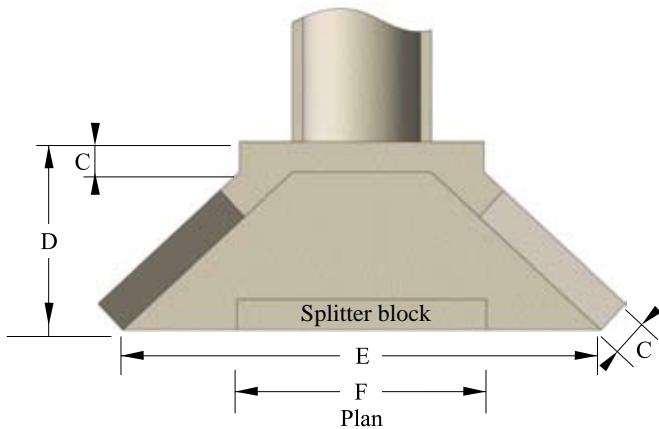


Figure 5.27: Typical head wall/wing wall drawings

The following drawings (Figure 5.28) show typical construction detail required for the setting out and construction of head and wing walls to pipe culverts. (The same basics apply to box sections.)

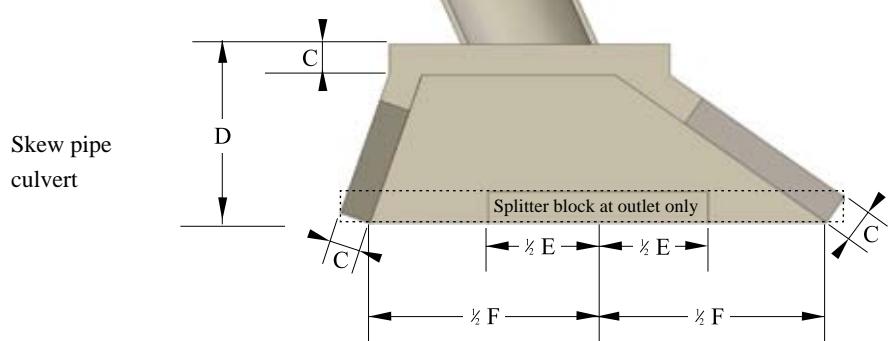
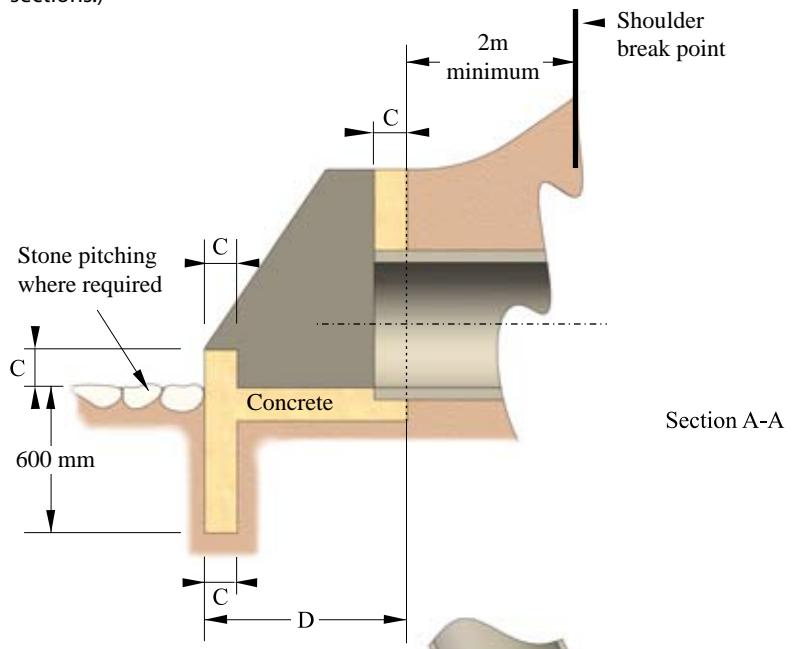


Figure 5.28: Typical construction detail



The concrete base slab, known as the apron, would be cast in situ prior to the brick/block/masonry work being constructed. It would further act as a foundation for such brickwork. The splitter block (as indicated in Figure 5.28) helps to slow the rush of water leaving the pipe outlet.

Procedures

Principle setting out procedures for head and wing wall construction:

- Head and wing wall setting out/construction takes place once the culvert has been laid.
- The apron slab is then cast to specifications according to the drawing details.
- The setting out of the head and wing wall will then take place on top of the apron slab.

STEP 1

By squaring off from the culvert centre line, a line can be drawn or scribed onto the apron surface; this is the construction line for the brickwork.

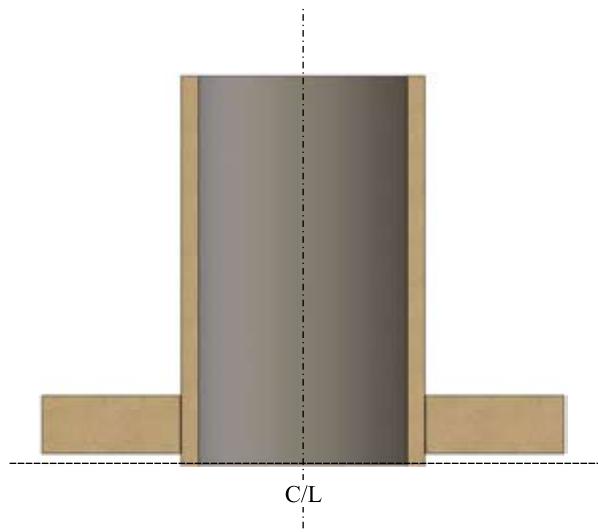


Figure 5.29: Allowance for plaster

If the brick/block work is to be plastered, measure the plaster thickness from this line and scribe the construction line for the brick/block work. (Figure 5.29)

The length of the head wall can also be marked out according to drawing detail.

STEP 2

As before, using the culvert centre line as a control line, set the brick/block/masonry work outline for the wing walls. (Figure 5.30)

Take note of the typical dimensions required and always make sure you allow for plaster thickness (if required), which will be stipulated in the drawing details.

Also be aware of smaller details such as the 25 mm allowance gap shown in Figure 5.30 i.e. the wing walls. Do not butt up directly against the culvert wall.



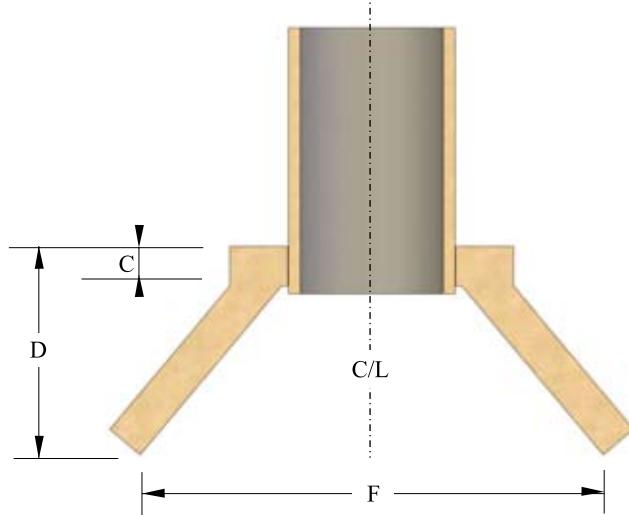


Figure 5.30: Setting out wing walls

On completion of the setting out, always check the dimensions before proceeding to the actual construction.

5.1.2 Construct head and wing walls in brickwork

Brickwork used in this type of construction must conform to the requirements of the contract documents.

Typical requirements that usually apply are as follows:

Clay bricks used shall be engineering bricks. Concrete bricks shall be 14 MPa minimum strength. All brickwork shall be built in English bond, in a mortar mix consisting of one part cement and six parts sand (50 kg cement:200 l sand), or in stretcher bond where its thickness does not exceed 115 mm.

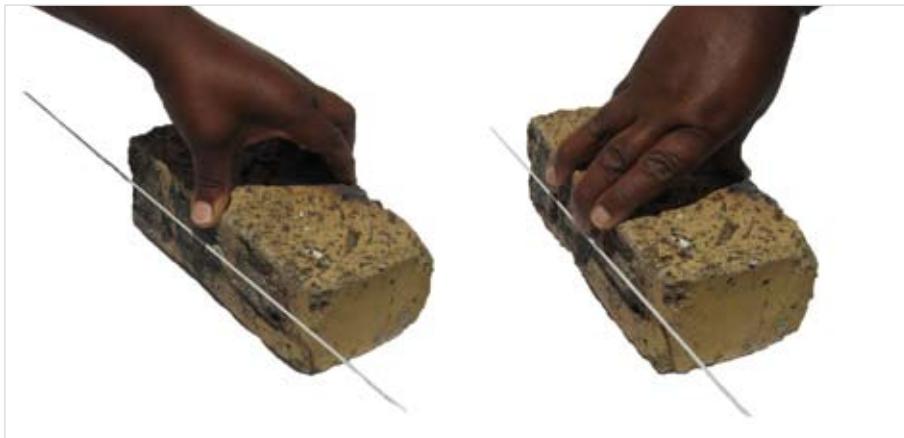
All bricks shall be unbroken, except where required as closers, etc. Clay bricks shall be well wetted but surface dry and concrete bricks dry before laying. Each brick shall be pressed into its bed so as to leave a finished joint not exceeding 10 mm in thickness. All joints shall be filled solid with mortar, and joints for exposed surfaces shall be jointed as work proceeds.

Where culverts enter brickwork, the surrounding joint shall be thoroughly filled all round.

5.1.3 General technique of laying bricks



This is the best way of holding a brick. Let your fingers curl at the tips round the edges of the brick.



The reason for holding the brick in this way is that your finger won't disturb the building line. Just lift the fingers or thumb on the side of the building line.



Lay the bed by depositing mortar firmly into position.



Slightly furrow the bed with the trowel by making a ditch in the middle of the bed. This will make the laying of the brick easier. If the furrow is too big, the bedding mortar does not cover the whole brick surface when the brick is laid.





Take up a brick firmly in one hand while still holding the trowel with your other hand.



Take up mortar with the trowel but this time much less than for the bed. Take up just enough to butter the perps of the brick. The perp or perpend is the perpendicular joint side of the brick.



Hold the brick forward so that you can still see the perps. Smear some of the mortar onto the perp closest to your index finger.



In the same motion, move the trowel back and smear the remaining mortar onto the perp end closest to your thumb.

The brick is now buttered.

Note

If protection against rain or moisture penetration through the wall is required, the perp joints must be completely filled with mortar and not merely buttered.

This method is applied when laying a stretcher course. When laying a header course, butter the long sides of the edge of the brick which have to slot in with the laid bricks. Always butter the connecting side of the brick.



Place the buttered brick into position so that it joins in with the laid bricks. Remember to leave ± 10 mm jointing space between adjoining bricks.





After placing the brick in the correct position, press it down with the fingers and manipulate it to lay flush with the building line. If the brick touches the building line it might move the line out of position. Remember to also leave ± 10 mm jointing space between the brick and the bricks below it.



Remove excess mortar on the sides by cutting it off with the blade of the trowel.

If only the edges of the bricks are buttered, excess mortar can be added in with the perp joints to ensure a solid watertight bond or can be placed between bricks if it is a double wall.

Remaining mortar can be flicked back onto the heap of mortar.

Pointers

In order to build in straight lines, set up a building line and a gauge rod. The building line can be held in position by using line blocks.

Use a spirit level to level your corner bricks. Corner bricks can be placed first on each course. Adjust their height according to the gauge rod, before levelling for plumb in two directions on top of the brick. Line blocks and line can then be set up on the corner bricks to get a straight building line. Check line position with the gauge rod.

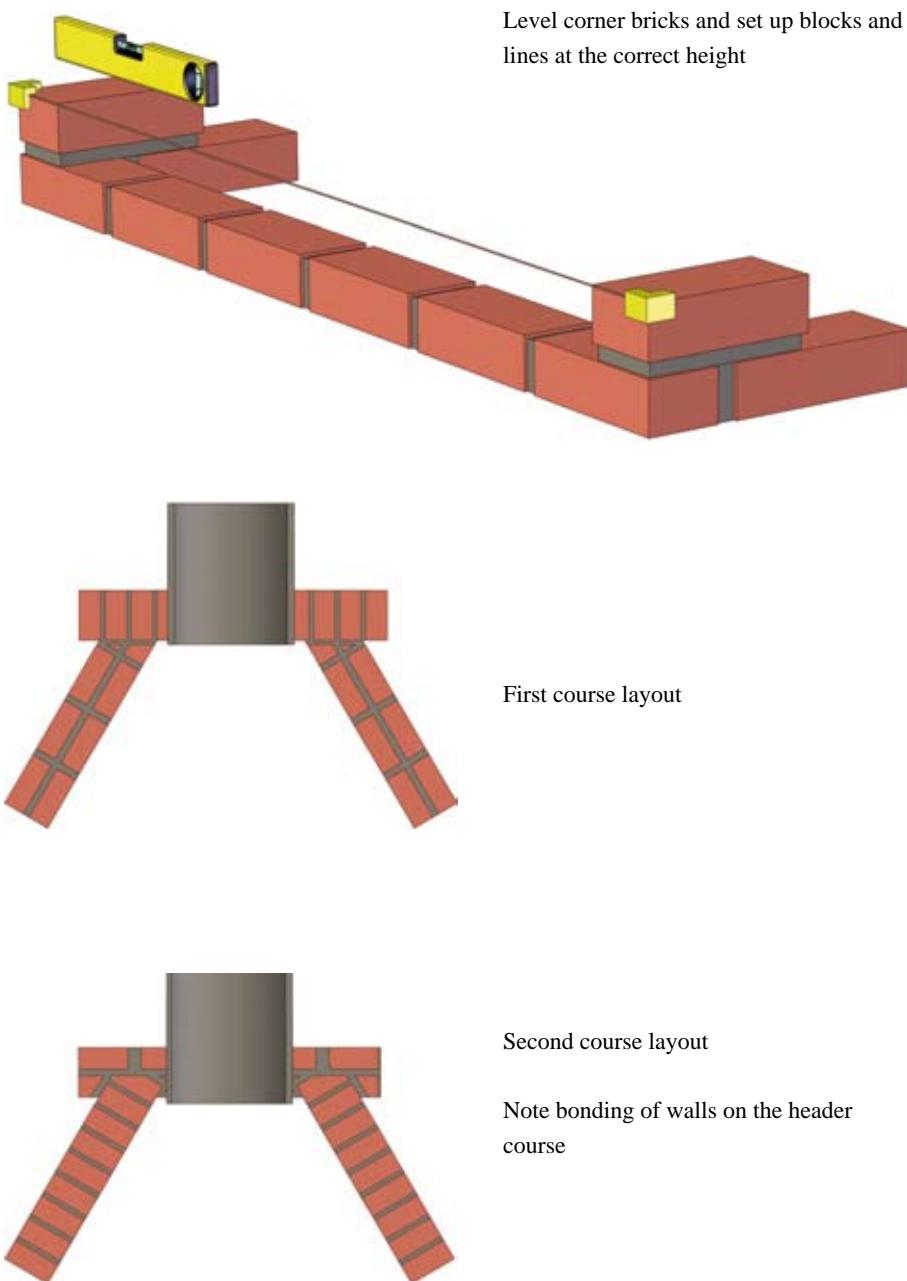


Figure 5.31: Typical bonding pattern in English bond

Tip for bonding

Before you start laying, position the bricks dry (no mortar) within the setting out lines to give you an idea as to how the bonding will proceed.

Check that the dimensions of the bricks are suitable for English bond patterns, i.e. the length of the brick is double the brick width plus 10 mm (for the mortar joint).



General points for setting out brickwork

1. Place the spirit level on the concrete apron slab to check if the surface is level or sloping.
2. On sloping slabs, always start the brickwork from the highest point and level the first course through from there. The first joint thickness should not exceed 15 mm. If the foundation surface is not level, add a concrete screed to the top of the footing to obtain a level surface. Stack bricks and obtain mortar for easy working.
3. The face side of the brickwork must be kept in line with the mark indicated on the slab surface and plumbed up from that point.
4. Ensure all joints are full of mortar, and bring brickwork up at equal course level on both sides of the pipe and over its top.
5. On longer lengths of brickwork use a building line/blocks to maintain face alignment.
6. If plastering is required, make use of straight edges secured and plumbed into position. Screed off the straight edge face after the plaster has been applied. Ask your facilitator to give guidance if you are unsure.

5.1.4 General technique for stone masonry work

The following techniques and guidelines apply for construction of minor works such as culvert head walls, wing walls and piers.

Materials: *Cement* – refer to Section 1.1.1 for information relating to common types of cement and storage of cement.

Sand – clean building sand free of organic particles and clay. (Section 1.1.4)

Stones – clean hard rubble stones of similar size (cracked or weathered stones should not be used). Wash dusty or dirty stones before use. Some porous stones need to be slightly dampened before use to reduce excessive suction of moisture from the mortar. (Section 1.1.3)

Quantities: For 1 m³ of finished masonry (approximately):

Stone : 1,2 m³

Sand : 0,36 – 0,4 m³

Cement : 2 × 50 kg bags (1:6 mix)
3 × 50 kg bags (1:4 mix)

Mortar mix: The mixture of mortar for masonry which is structural or which will frequently be in contact with water is 1:4 (cement:sand by volume), otherwise 1:6 should be used.

Thoroughly mix the sand and cement before adding water. Only a little water should be used for a good quality mixture.

The quantity of mortar to be mixed should not be more than a mason can use within one hour.



Joints and bond: Joints should be between 10 mm and 40 mm thick. The bond should allow a minimum overlap of $\frac{1}{4}$ length of the smaller stone (Figure 5.32). Mortar joints on the face of the masonry should be compacted smooth to produce a durable finish.

No stone should touch another but should be laid into mortar. Most of the stones should be laid as stretchers (i.e. along the face of the wall). However, headers or through stones should be laid at regular intervals to bond the two faces of the wall together.

Loose stone next to the weep hole for drainage of the fill protected with geo fabric.

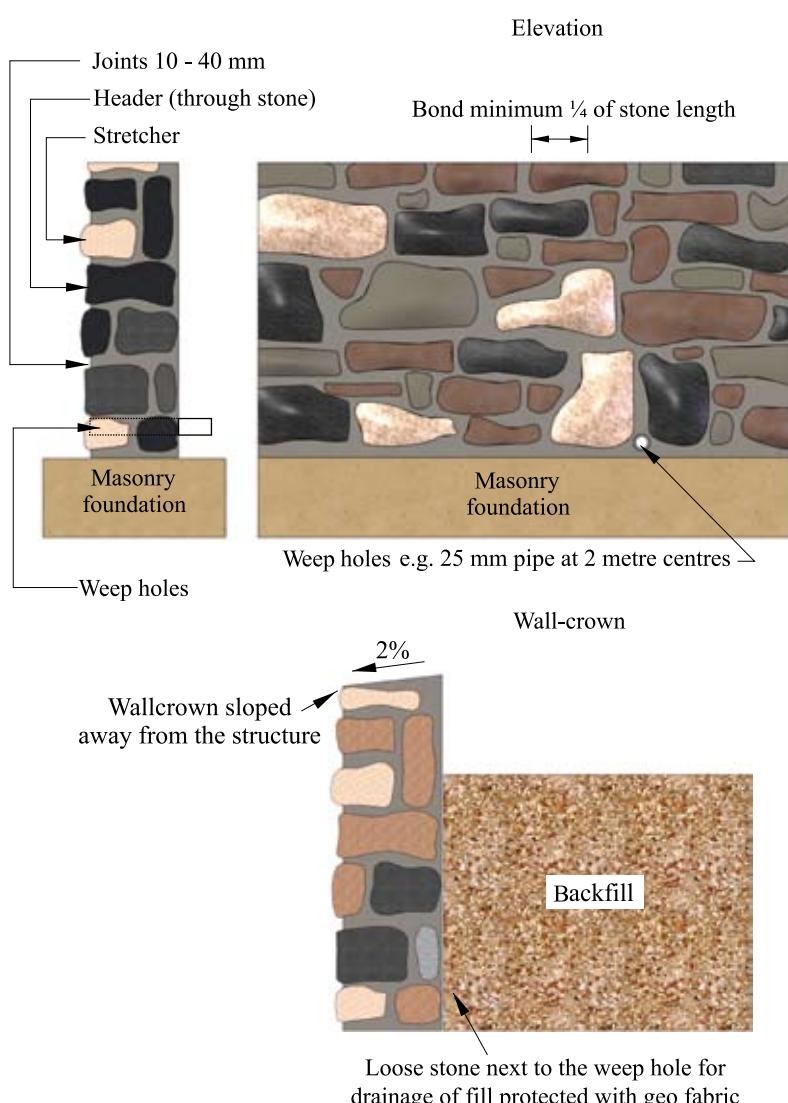


Figure 5.32: Stone masonry requirements

Curing:

Mortar needs to be cured to achieve satisfactory strength. After the mortar has set, the masonry work should be covered with sacking and kept damp for at least four days.



5.1.5 General technique for gabion work

Foundations should be excavated level and cleaned as for a conventional structure, with any unsuitable material removed and replaced with good soil, stone or gravel and then compacted. The baskets should be erected in their final position. Cages should be woven together using 3 mm binding wire, securing all edges every 150 mm with a double loop. The binding wire should be drawn tight with a pair of heavy duty pliers and secured with multiple twists. The connected baskets should be stretched and staked with wires and pegs to achieve the required shape.

Filling should be carried out by hand, using hard durable stones not larger than 250 mm and not smaller than the size of the mesh. The best size range is 125 – 200 mm. The stones should be individually and tightly packed with a minimum of voids. They must not be tipped into the baskets.

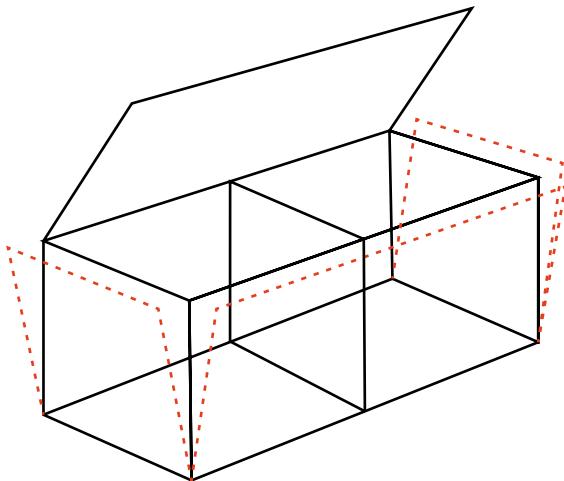
Boxes of 1 metre height should be filled to $\frac{1}{3}$ height. Horizontal bracing wires should then be fitted and tensioned with a windlass, to keep the vertical faces even and free of bulges. Further bracing should be fixed after filling to $\frac{2}{3}$ height. 500 mm height boxes should be braced at mid-height only. $250/330$ mm height gabions do not require internal bracing.

Where water falls directly onto the top of the gabion, vertical bracing wire should also be fitted to secure the gabion lid when closed. The stones should be carefully packed to about 30 – 50 mm above the top of the box walls to allow for settlement. Smaller material can be used to fill the voids on the top face, but excessive use of small stones should be avoided.

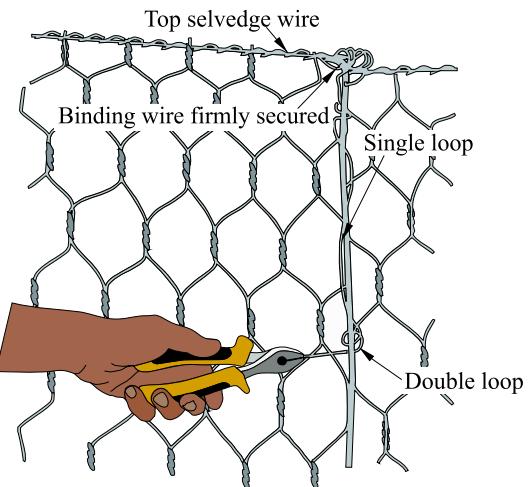
The lids are then closed and stretched tightly over the stones. Carefully use crowbars if necessary. The corners should be temporarily secured to ensure that the mesh covers the whole area of the box. The lid should then be securely woven to the tops of the walls. If necessary, remove stones to prevent the lid from being overstretched.



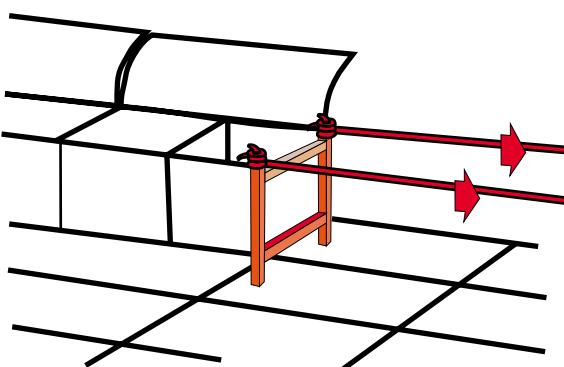
1. Assemble cage



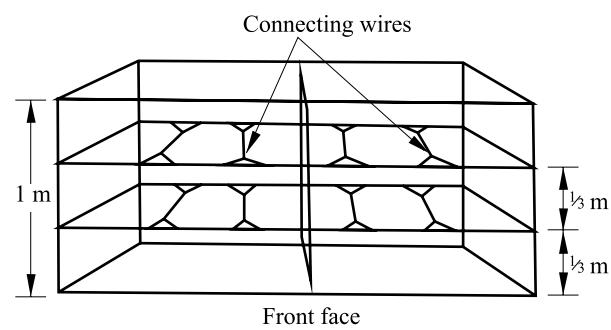
2. Weave boxes securely together



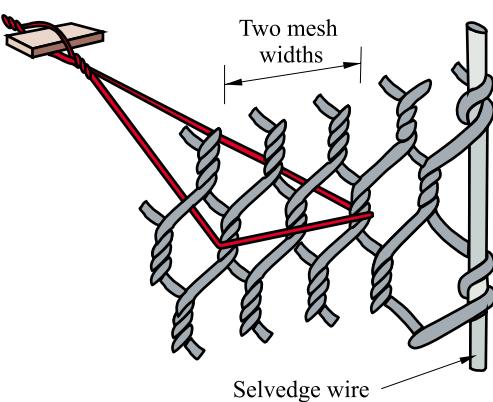
3. Stake and stretch cages to required shape



4. intermediate bracing



5. Windlass bracing



6. Close and secure lid

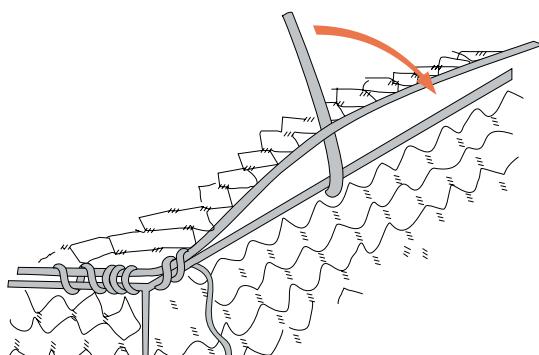


Figure 5.33: Gabion construction



6. Notes to consultant/designer

6.1 General

The culvert is a cross drain built under the road and its function is to lead water from the upper or uphill side of the road to the lower. (Figure 5.34)

Normally, about three to four crossings per kilometre will be required on unpaved rural roads.

In addition to permanent water crossing points, a culvert will be required at every low point in the vertical alignment and at intermediate points to relieve the uphill side drain. Normally side drains should not carry water for more than 200 m without a discharge point, culvert or erosion-control measures.

It is important to install the culvert at the correct level and gradient while considering the existing ground level and watercourse. As a general rule, the alignment of the culvert should take precedence over the vertical alignment of the road i.e. invert levels of the culverts are to be determined before the road level is fixed.

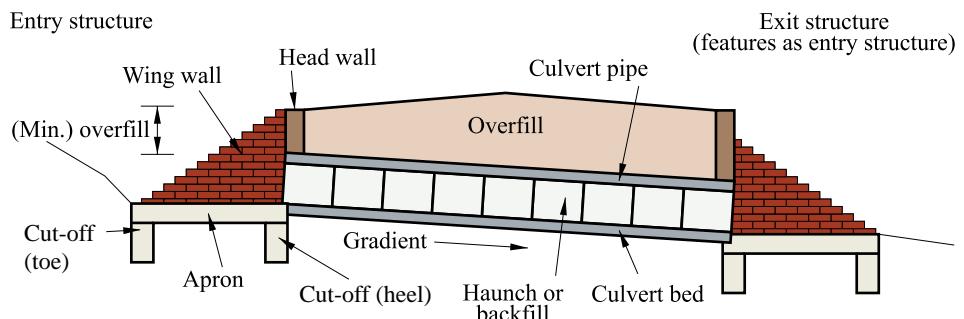


Figure 5.34: Culvert features

6.2 Final size and placing of culverts

To make a final decision as to the size and placing of culverts, the longitudinal section of the road must be available or prepared, along with cross sections of the road in question, as well as a long section of the streambed.

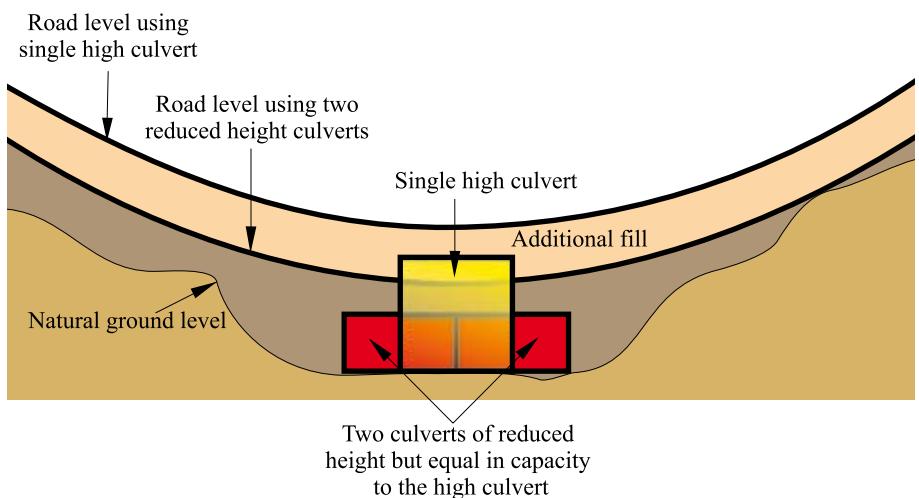


Figure 5.35: Effect of culvert height on fill



By reducing the height, extending the width and maintaining the area of the opening of the culvert, the following improvements have been achieved:

- Reduction of extra earthworks/fill.
- Reduction of extra base gravel.
- Reduction of erosion on the outfall side of the culvert.

6.3 Foundation aspects

6.3.1 Sandy riverbed

When constructing a causeway/or series of culverts across a sandy riverbed, the following precautions are advisable/essential.

- Adequate drop walls/cut-off walls must be constructed at both inlet and outlet ends of culvert. (Figure 5.36)

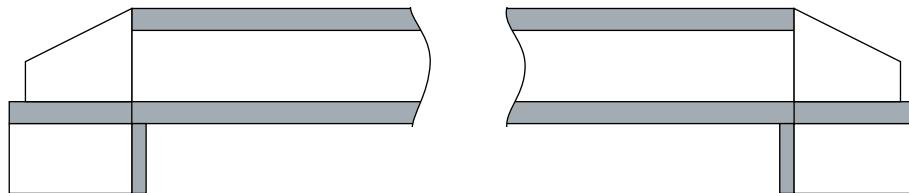


Figure 5.36: Drop walls/cut-off walls at inlet and outlet

- If there is any rock formation near the surface the foundations must be tied into the rock with tie bars – even large boulders tied to foundations.
- The concrete slab on the causeway must be extended up the slope on either side of the river/streambed.
- Depending on the site conditions, a causeway will also require drop walls or stone pitching for protection against erosion/undercutting and lifting of the slab by the force of water.
- Causeways are particularly effective when crossing dongas, which are often subjected to flash floods – cheaper/more economical than large box culvert with its concomitant earthworks and fill/gravel.

6.3.2 Solid rock

Often the streambed passes over solid rock. In this case foundation slabs for the full width of the culvert are not required. (Figure 5.37)

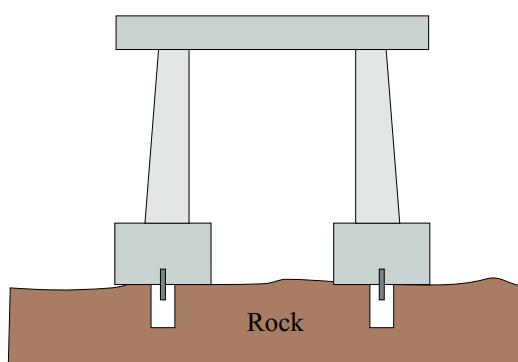


Figure 5.37: Founding on rock bed



6.3.3 Poor foundations of expansive clays

The placing of culverts on black turf/red clay with high plasticity indices (PIs) can create problems, especially on surfaced roads. When these clays are subjected to standing water they absorb the water and expand.

The expansion generates forces, resulting in the movement of the foundation/system, known as the potential vertical rise. This problem can be overcome by superimposing a large load on the clay to overcome the vertical movement/upward thrust of the clay. Ponding in and about the culvert must be rectified by ensuring efficient drainage measures in and about the entrance and exit of the culvert.

To overcome the upward thrust of the clay, extend the foundation slab by half the width of the culvert on either side of the piers, i.e. by $L/2$ where L is the width of the culvert. The slab must be reinforced on the top and bottom.

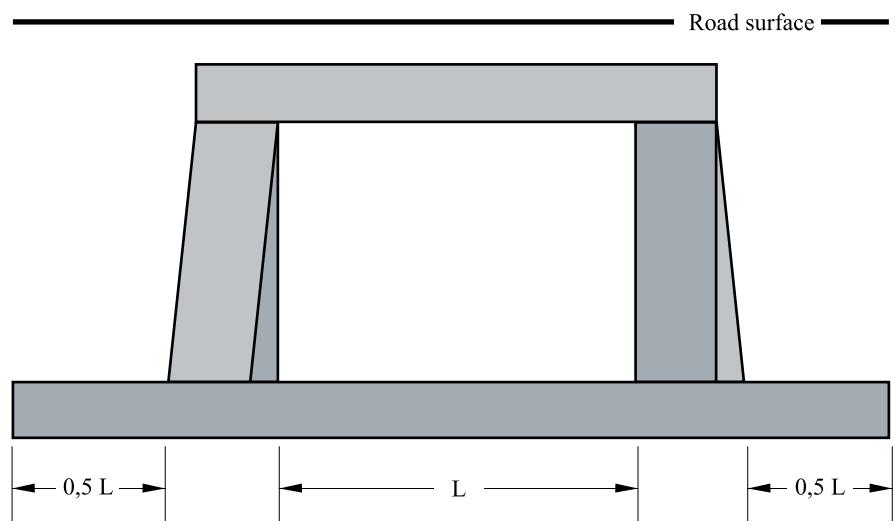


Figure 5.38: Box culvert base on expansive clays (slab reinforced top and bottom)

Where more than one culvert opening is required, the culverts must be separated to accommodate the extra slab width for each culvert. Where pipe culverts are used in expansive clay terrain, the same principle as above applies.

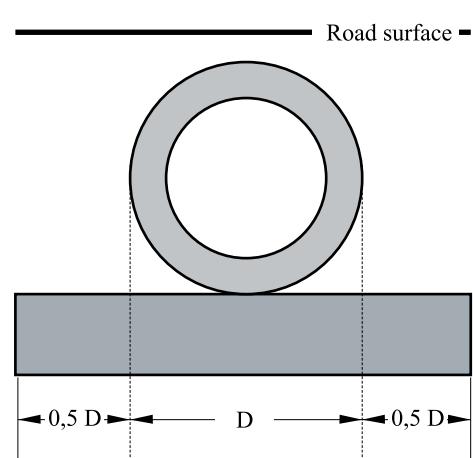


Figure 5.38: Pipe culvert (slab reinforced top and bottom)



6.3.4 Invert level problems

The following conditions could occur:

- The invert of the culvert is lower than the invert of the centre line of the streambed – resulting in the silting of the barrel of the culvert. (Figure 5.39)
- The invert of the culvert is higher than the invert of the outfall/centre line of the streambed – resulting in erosion on the outfall. (Figure 5.40)

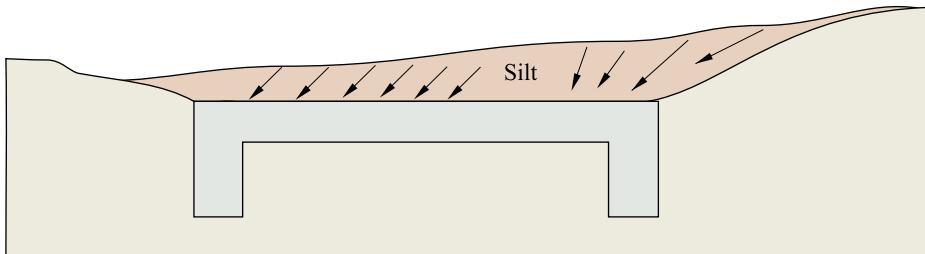


Figure 5.39: Invert too low

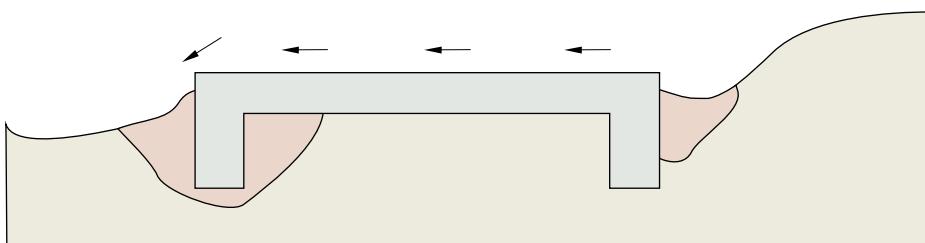


Figure 5.40: Invert too high

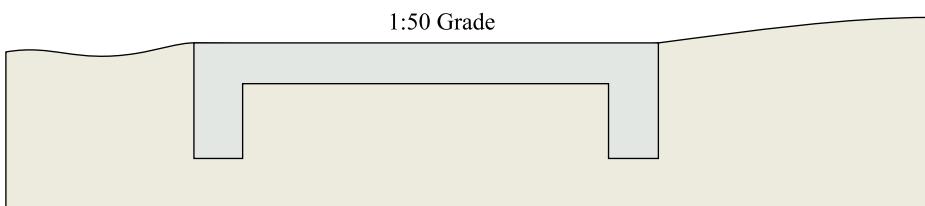


Figure 5.41: Correct invert

6.4 Constructing in-situ culverts

The choice between using precast concrete culverts and constructing the culverts on site is easy: the latter is more economical and in many cases more practical for the following reasons:

- Normally the minimum size culvert is a 600 mm^Ø pipe. The effective area = 0,283 m². The reason being the practicalities of cleaning a smaller pipe.
- A 900 mm × 400 mm box = 0,36 m² is much easier to clean and the level of the road does not have to be raised to accommodate a 600 mm^Ø pipe plus the cover required.
- The capacity of the box section is some 27% greater than the pipe section (diam²).
- The transport of precast concrete sections to remote areas is expensive when compared with cartage of bricks and precast slabs.
- Backfill of box culverts is more efficient.



It is recommended that:

- Box culverts are constructed on site using cast in-situ concrete slabs for foundations, engineering bricks (blue bricks or fair face) or concrete bricks for the piers head walls and wing walls, or stone masonry if rock is readily available.
- Precast concrete designed slabs are used for the deck.

Dimension	Max for 225 mm brick pier (mm)	Max for 113 mm brick pier (mm)
Height of wall	600 – 1 500	400; 500; 600
Span	1 000 – 3 000	600 – 1 000

Note:

- All brickwork must be reinforced with brick force.
- All slabs are to be structurally designed.
 - Suggest/recommend standard lengths be established, i.e. $w = 600$ mm, 1 m, 2 m, 3 m
- If stone masonry piers are to be used, they must be designed appropriately.
- If the piers are to be built of concrete block, the strength of the block is important and blocks should be purchased from reputable suppliers. If manufactured on site they must be subject to strict quality control. Hollow blocks must be filled with a suitable concrete.

6.5 Drop inlets to culverts

Drop inlets (Figure 5.42) can be constructed to assist in overcoming the following:

- Erosion on inlet side of culvert.
- Excessive silting in sandy/non-plastic soil condition.

Drop inlets act as a sand/debris trap and reduce the velocity of the water; dropping the sand in the sand trap and then regaining speed through the culvert.

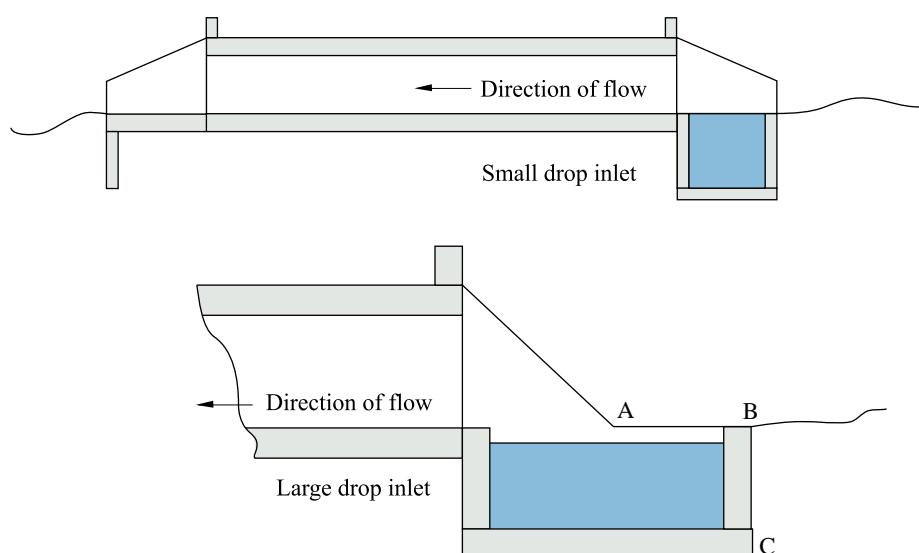


Figure 5.42: Drop inlets



Constructing a drop wall at AB across the side drain of the road, above the invert of the drain, will result in silt being trapped/caught behind the wall. Vegetation, an efficient silt trap, will eventually be established. The drop wall BC will equally encourage vegetation – trapping silt.

6.6 Cover and compaction over culverts

Culverts must be handled and installed with due care, as described in the following publications of the Pipe and Infrastructural Products (P & IP) Division of the Concrete Manufacturers' Association (CMA):

- *Concrete Pipe and Portals Installation Manuals.*
- *Concrete Pipe Handbook.*

6.6.1 Precast box (portal) culvert

The use of precast box culverts must be avoided. If for some reason it is necessary to use precast box culverts, they must be manufactured in accordance with SANS 986 (latest revision).

The culverts design must be in accordance with the *Technical Methods for Highways Code TMH7 – Code of Practice for the Design of Highway Bridges and Culverts in South Africa*.

There are certain restraining conditions regarding:

- The foundation conditions on which the culverts are constructed.
- The placement conditions (trench or embankment).
- The limiting/permissible heights of fill that are applicable.
- The class of the culvert (S-load class).

6.6.2 Pipe culverts

Concrete pipe culverts must be manufactured in accordance with SANS 676 and 677 (latest revision).

The culverts design must be in accordance with the *SANS 10102 Parts 1 and 2 – Standard for the Selection of Pipes for Buried Pipelines*.

There are certain restraining conditions regarding:

- The bedding conditions of the pipe culvert.
- The placement conditions (trench or embankment).
- The limiting/permissible heights of fill which are applicable.
- The class of the pipe culvert (D-load class).

6.6.3 Backfilling of culverts

The material used for backfilling those sections of culverts, subject to traffic loads, shall consist of selected material of at least sub-base quality.

In the case of concrete pipes, the backfill material shall be thoroughly tamped in under the flanks of the pipes to provide uniform bedding.

Backfilling alongside and over all culverts shall be placed at optimum moisture content and compacted in layers, not exceeding 150 mm thick after compaction of at least the density required for the adjoining layers of fill, sub grade and sub-base.

Backfilling shall be carried out simultaneously and equally on both sides of a culvert to prevent unequal lateral forces.

Consideration should also be given to use a lean concrete or a wet or stiff mixture of soil cement as backfilling between the side of the culvert and the excavation up to the top of the culvert.

6.7 Masonry arch culverts

Masonry arch culverts (Figure 5.43) may be more economical than pipe or box culverts in areas where stone is cheaply available close to the culvert site. Arch spans of 0,6 – 2,0 m may be easily constructed by a skilled mason and assistants. Strip foundations of concrete 500 mm wide and 200 mm deep should be laid on firm ground. Temporary formwork for the arch may be made from corrugated roof sheets, bent to the required shape and supported on timber formwork, or solely from timber. Formwork should be supported on wedges or a similar system to facilitate subsequent removal.

Alternatively the lost-earth method may be used, where the finished shape of the arch invert is formed in compacted soil after the side walls have been built up to springing level. This will adequately support the freshly laid masonry arch. The arch is constructed and after seven days the support can be removed. The masonry arch should be constructed in a thickness of 400 – 500 mm with individual stones of the same dimensions as the arch thickens.

The invert of the culvert should be constructed of masonry and must be concave to direct the water to the centre at low flows. All other features of culvert silting and construction as described for pipe or box culverts apply.

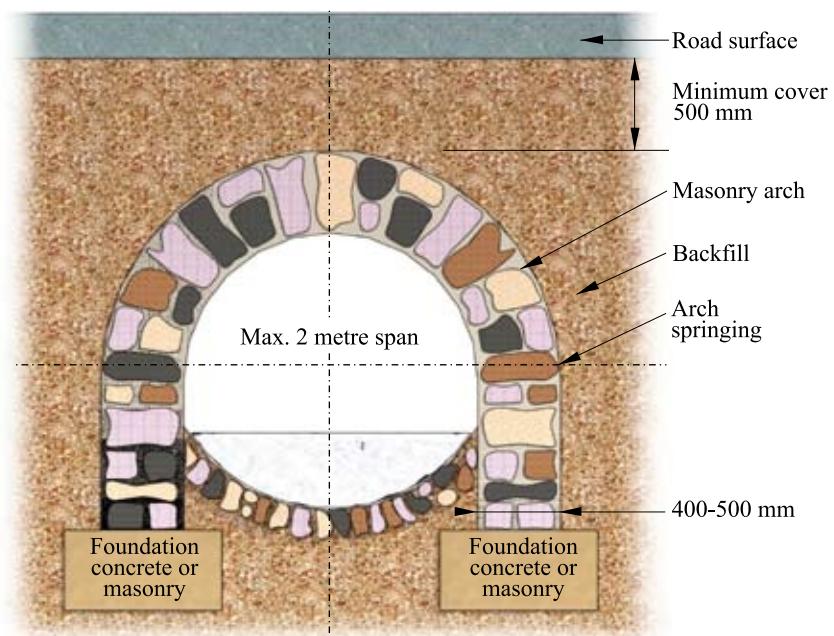


Figure 5.43: Masonry arch culvert



6.8 Head walls and wing walls

6.8.1 Concrete and masonry work

The head walls are the retaining walls (masonry, concrete) at the entry and/or exit of the culvert. They retain and protect the embankment. Head walls are always built parallel to the road centre line.

Wing walls are the retaining walls (masonry, concrete at the side of the culvert). Their purpose is to protect the embankment and channel water through the culvert. Wing walls are usually sited at an angle of 45° to 75° to the road centre line.

As a guide, the thickness of a gravity retaining wall at any point should be at least $\frac{1}{3}$ of the retained height. For high walls, the front face may be sloped outwards towards the base and the thickness may be increased gradually or in steps towards the base to achieve the desired thickness.

The minimum width of a masonry wall should be 400 mm. This thickness is normally adequate for culvert head walls, wing walls and other retaining walls up to 1,2 m height. More substantial walls need to be individually designed.

Retaining walls should be provided with regular weep holes, just above the ground level on the outer face. These prevent water pressure from building up behind the wall. The weep holes should allow water to seep through but retain all material. A filter of uncompacted lean concrete or other porous material or geofabric should be placed at the back of the weep hole to achieve this aim.

6.8.2 Gabions

Gabions can be used as a substitute for concrete or masonry structures and should be built with the same principles of good foundation, stability and quality control. The advantages of gabions are their simplicity of construction (Figure 5.33 – Section 5.1.5) requiring low levels of skill, use of local materials (stone), ability to let moisture pass through, avoiding the build-up of water pressure and flexibility (should minor settlement occur).

Advantages of gabions

1. Simple to construct.
2. Require low levels of skill.
3. Local materials (stone) can be used.
4. Allow moisture to pass through, avoiding the build-up of water pressure.
5. Flexible.

6.9 Materials

Culverts can be concrete pipe or box culvert sections. Stone masonry structures are also viable. As previously stated the head walls, wing walls and drop inlet features may be concrete, masonry, stone or gabion structures.



MODULE 5: Construction of drifts and causeways

1. General

This module should be read in conjunction with Module 4: Construction of culverts/small bridges – as many of the construction techniques and materials dealt with in Module 4 are applicable to this module.

2. Construction plant, equipment and tools

The following plant, tools and equipment are recommended to promote the construction of drifts and causeways by labour-intensive methods:

- Steel pegs
- Hammer
- Building line
- Pre-made drain former/template
- Pick and shovel
- Wheelbarrows
- Pedestrian vibratory roller
- Hand tampers
- Jackhammers and/or drills for fixing dowels in rock
- Pump and or buckets for dewatering
- Bags for filling with sand for deviation of stream
- Straight edge
- Boning rods
- Spirit level
- Hand tape – 3 m or 5 m
- Steel moulds for arch construction
- Steel and/or timber shutters/formwork
- Concrete mixer for mixing concrete and mortar (hand mixing is also acceptable)
- Concrete shovels
- Containers for batching of aggregate, sand and cement (see Module 2)
- 210 litre drums for storing water
- Screed
- Wooden float
- Trowels



3. Construction materials

Construction materials will depend on the material used for the construction of the various elements of the drift or causeway but the main materials will/can include:

- Cement, sand and aggregate for concrete and mortar (Module 2).
- Bricks to specification.
- Concrete blocks to specification.
- Stones to specification for stone masonry work.
- Geocell fabric and/or other geofabrics.
- Gabion baskets and stone for filling baskets.
- Steel reinforcement and/or mesh.
- Steel dowels.
- Sand for filling sandbags.

4. Construction

4.1 Drifts

4.1.1 General

Drifts are normally formed during the construction of the road formation and comprise the following elements to the engineer's design and specification. (Figure 5.44)

Running surface and approaches of:

- Concrete
- Grouted stone pitching
- Plain stone pitching

Cut-off walls of:

- Concrete
- Stone masonry
- Gabions

Aprons of:

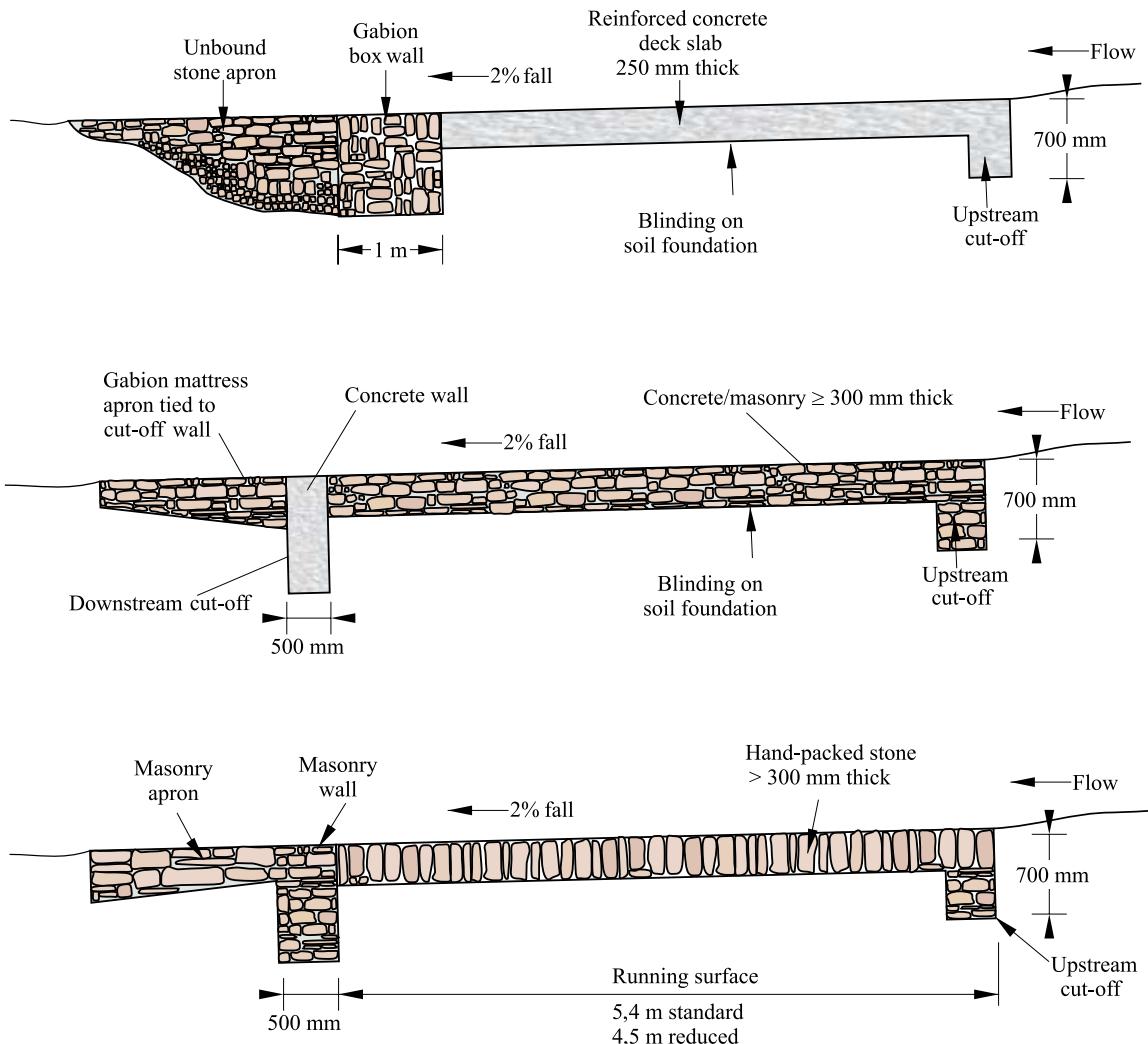
- Grouted pitching
- Gabion mattress
- Plain (unbound) stone pitching

Additional erosion protection if required of:

- Grouted pitching
- Gabion mattress
- Plain (unbound) stone pitching
- Other



Note: Surfacing, wall and apron types may be interchanged in the following sections.



Downstream cut-offs should extend 1 - 1,5 metres below bed level.

Figure 5.44: Drift construction alternatives

4.1.2 Notes on construction

Preparation

- Set out alignment from drawings and levels provided by the engineer.
- Divert river, using sandbags to create clear and dry working area.
- Set out final levels from drawings issued by engineer.
- Shape the drift and dig the trenches for the cut-off walls.

Construction of cut-off walls

There are two techniques for constructing the cut-off walls and these are described below:

Stone masonry and gabions

General technique for stone masonry work

Materials: Cement – refer to Section 1.1.1 in Module 2 for information relating to the common types of cement and storage of cement.

Sand – clean building sand free of organic particles and clay (Section 1.1.4 in Module 2).

Stones – clean hard rubble stones of similar size (cracked or weathered stones should not be used). Wash dusty or dirty stones before use. Some porous stones need to be slightly dampened before use to reduce excessive suction of moisture from the mortar (Section 1.1.3 in Module 2).

Quantities: For 1 m³ of finished masonry (approximately):

Stone : 1,2 m³

Sand : 0,36 m³

Cement : 2 × 50 kg bags (1:6 mix)
3 × 50 kg bags (1:4 mix)

Mortar mix: The mixture of mortar for masonry which is structural or which will frequently be in contact with water is 1:4 (cement:sand by volume), otherwise 1:6 should be used.

Thoroughly mix the sand and cement before adding water. Only a little water should be used for a good quality mixture.

The quantity of mortar to be mixed should not be more than a mason can use within one hour.

Joints and bond: Joints should be between 10 mm and 40 mm thick. The bond should allow a minimum overlap of $\frac{1}{4}$ length of the smaller stone (Figure 5.45). Mortar joints on the face of the masonry should be pointed and raked to produce a durable finish.

No stone should touch another but should be laid into mortar. Most of the stones should be laid as stretchers (i.e. along the face of the wall). However, headers or through stones should be laid at regular intervals to bond the two faces of the wall together.

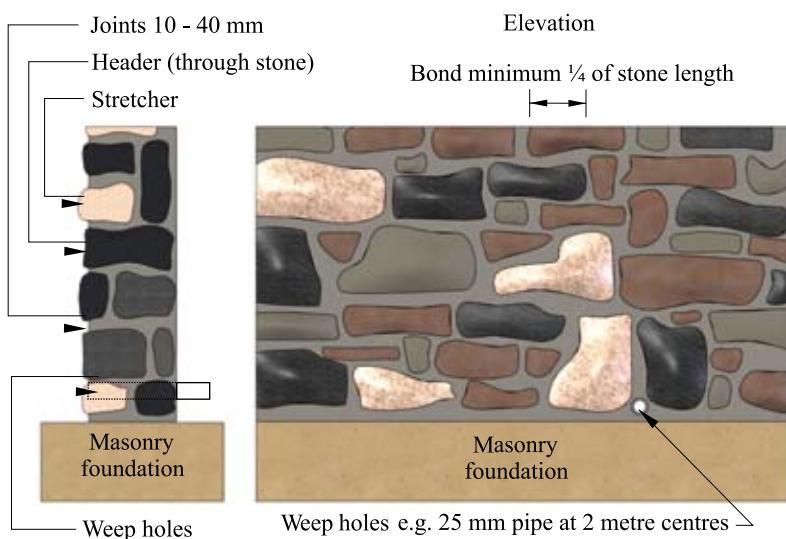


Figure 5.45: Stone masonry requirements (continued overleaf)

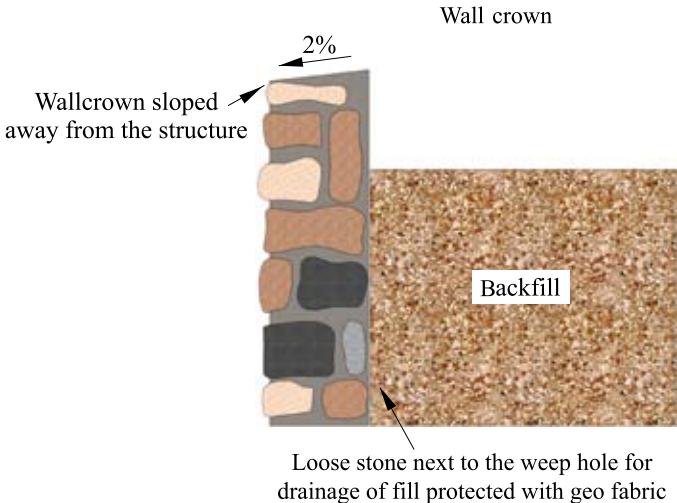


Figure 5.45: Stone masonry requirements

Curing: Mortar needs to be cured to achieve satisfactory strength. After the mortar has set, the masonry work should be covered with sacking and kept damp for at least four days.

General technique for gabion work

Foundations should be excavated level and cleaned as for a conventional structure, with any unsuitable material removed and replaced with good soil, stone or gravel and then compacted. The baskets should be erected in their final position. Cages should be woven together using 3 mm binding wire, securing all edges every 150 mm with a double loop. The binding wire should be drawn tight with a pair of heavy duty pliers and secured with multiple twists. The connected baskets should be stretched and staked with wires and pegs to achieve the required shape.

Filling should be carried out by hand, using hard durable stones not larger than 250 mm and not smaller than the size of the mesh. The best size range is 125 – 200 mm. The stones should be individually and tightly packed with a minimum of voids. They must not be tipped into the baskets.

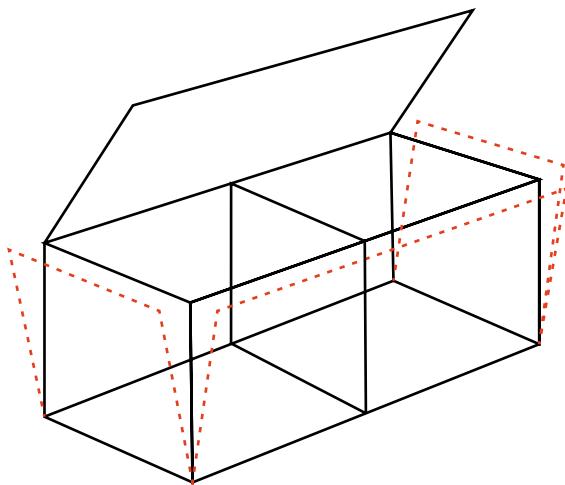
Boxes of 1 metre height should be filled to $\frac{1}{3}$ height. Horizontal bracing wires should then be fitted and tensioned with a windlass to keep the vertical faces even and free of bulges. Further bracing should be fixed after filling to $\frac{2}{3}$ height. 500 mm height boxes should be braced at mid-height only. $\frac{250}{330}$ mm height gabions do not require internal bracing.

Where water falls directly onto the top of the gabion, vertical bracing wire should also be fitted to secure the gabion lid when closed. The stones should be carefully packed to about 30 – 50 mm above the top of the box walls to allow for settlement. Smaller material can be used to fill the voids on the top face, but excessive use of small stones should be avoided.

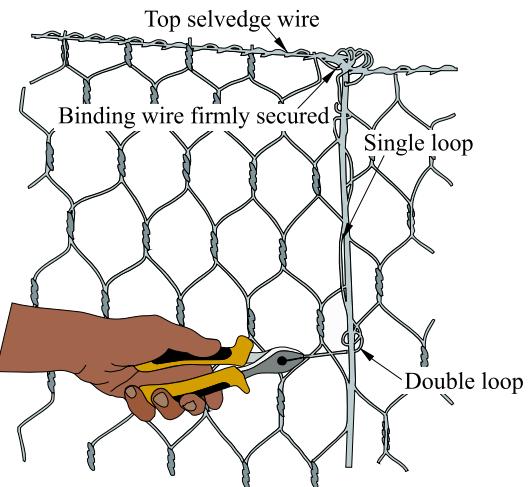
The lids are then closed and stretched tightly over the stones. Carefully use crowbars if necessary. The corners should be temporarily secured to ensure that the mesh covers the whole area of the box. The lid should then be securely woven to the top of the walls. If necessary, remove stones to prevent the lid from being overstretched.



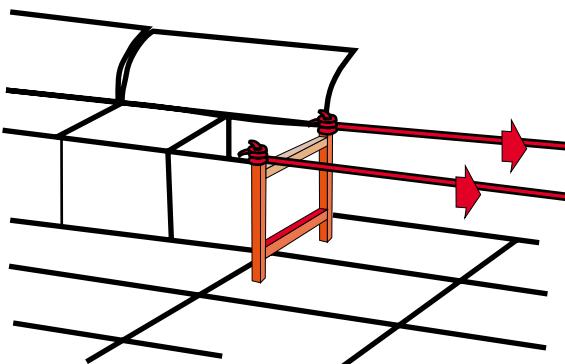
1. Assemble cage



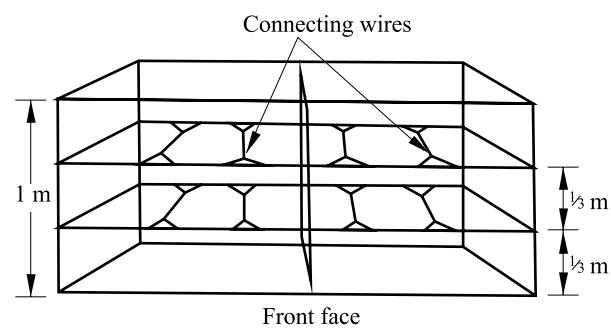
2. Weave boxes securely together



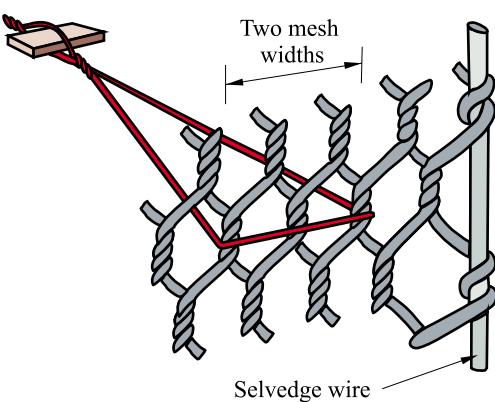
3. Stake and stretch cages to required shape



4. intermediate bracing



5. Windlass bracing



6. Close and secure lid

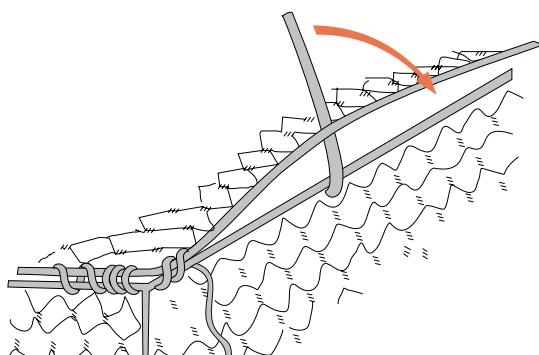


Figure 5.46: Gabion construction



4.1.3 Construction of running surface and approach

The running surface and pavement layers will be constructed as per the engineer's design in accordance with the techniques and methods described in:

- Manual 3: Gravel pavement layers
- Manual 5: Module 2: Concrete and mortars.

A typical working example based on the concrete running surface:

Steps to follow:

1. Check the levels and finish on the prepared pavement layer (Manual 3).
2. Position and fix shutters for the casting of the concrete work and fix reinforcement as shown on the drawings.
3. Batch and mix concrete as described in Module 2 of this manual.
4. Place the concrete.

Prior to placing concrete to form the running surface you must undertake the following:

- Are all shutters set at the required spacings and levels and are they secured?
- Has the pavement base been properly constructed and compacted to the correct levels?
- Has the layer been dampened prior to concreting?
- Are all necessary tools, plant and equipment at hand?

After the check has been done, start placing the concrete in accordance with Module 2 using the specified method.

Curing of the concrete shall commence as soon as the concrete has hardened sufficiently to ensure that the surface will not be marked or stained in any way. Curing may be done by covering the exposed surface with sand or fabric mats. Both should be kept continuously damp or use a curing compound.

4.1.4 Apron and erosion protection

The apron and other erosion protection, in the vicinity of the drift and on the approaches, will be constructed as per the engineer's design in accordance with the techniques and methods described in the following modules of this manual:

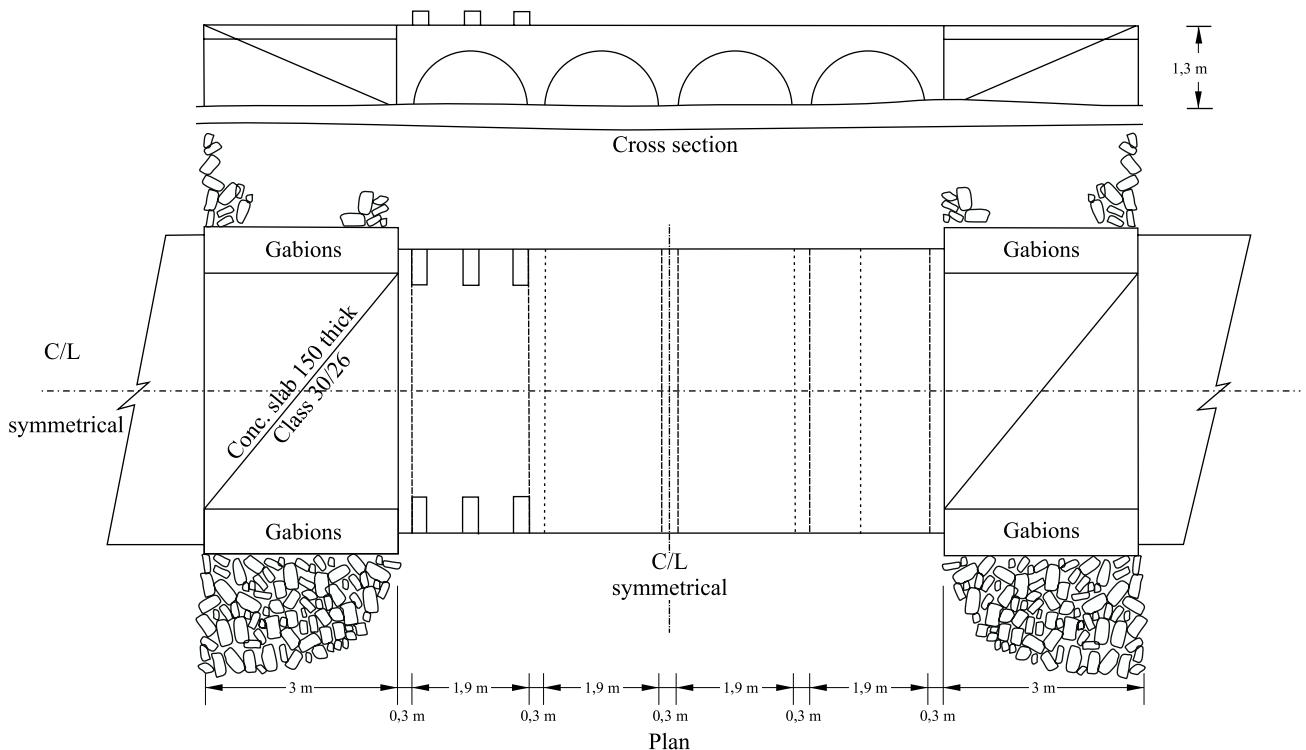
- Module 2: Concrete and mortars
- Module 3: Construction of lined channels and chutes.



4.2 Low level arch causeway

4.2.1 Construction process

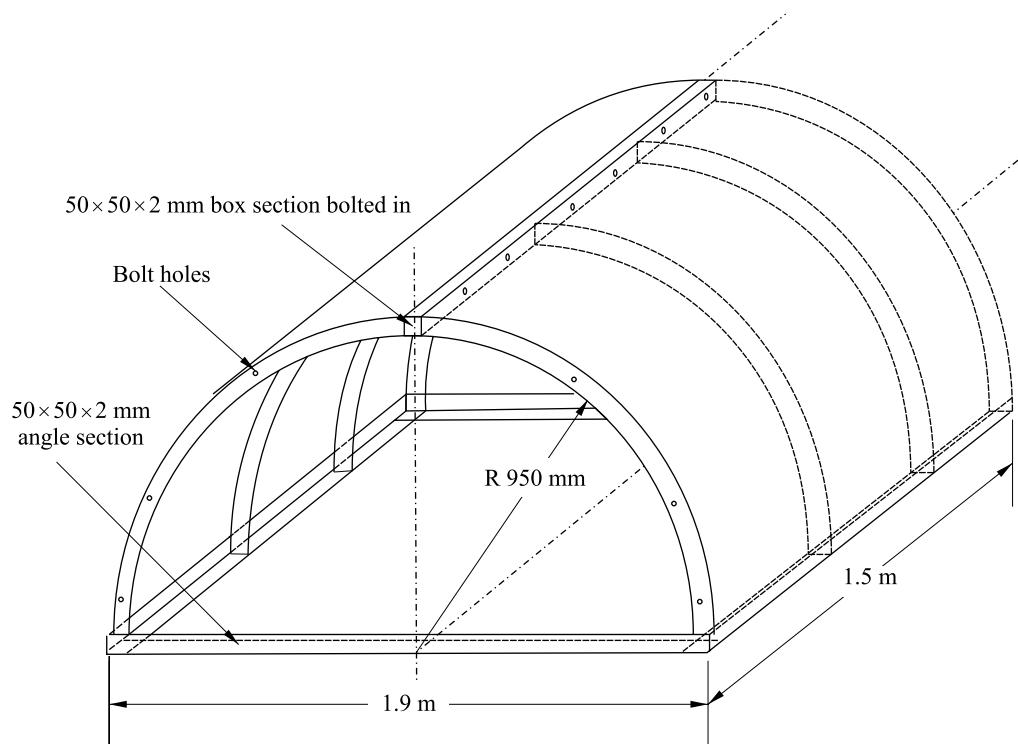
The construction process described consists of in-situ, reinforced concrete arches (Figures 5.47 and 5.48). (These have an estimated flow capacity three times greater than 600 mm diameter pipes.)



Causeway detail	
Notes:	
1. Mass concrete base to be class 20/26 reinforced with mesh Ref. #311, 50 mm below top. 2. Edge blocks: $2 \times 3 = 6$ no. per arch = 24 no. total. 3. Fill to be wrapped in bidim and securely fastened. 4. Arch concrete to be class 30/26. 5. Minimum cover to steel = 50 mm.	

Figure 5.47: Typical drawing of 4-arch causeway





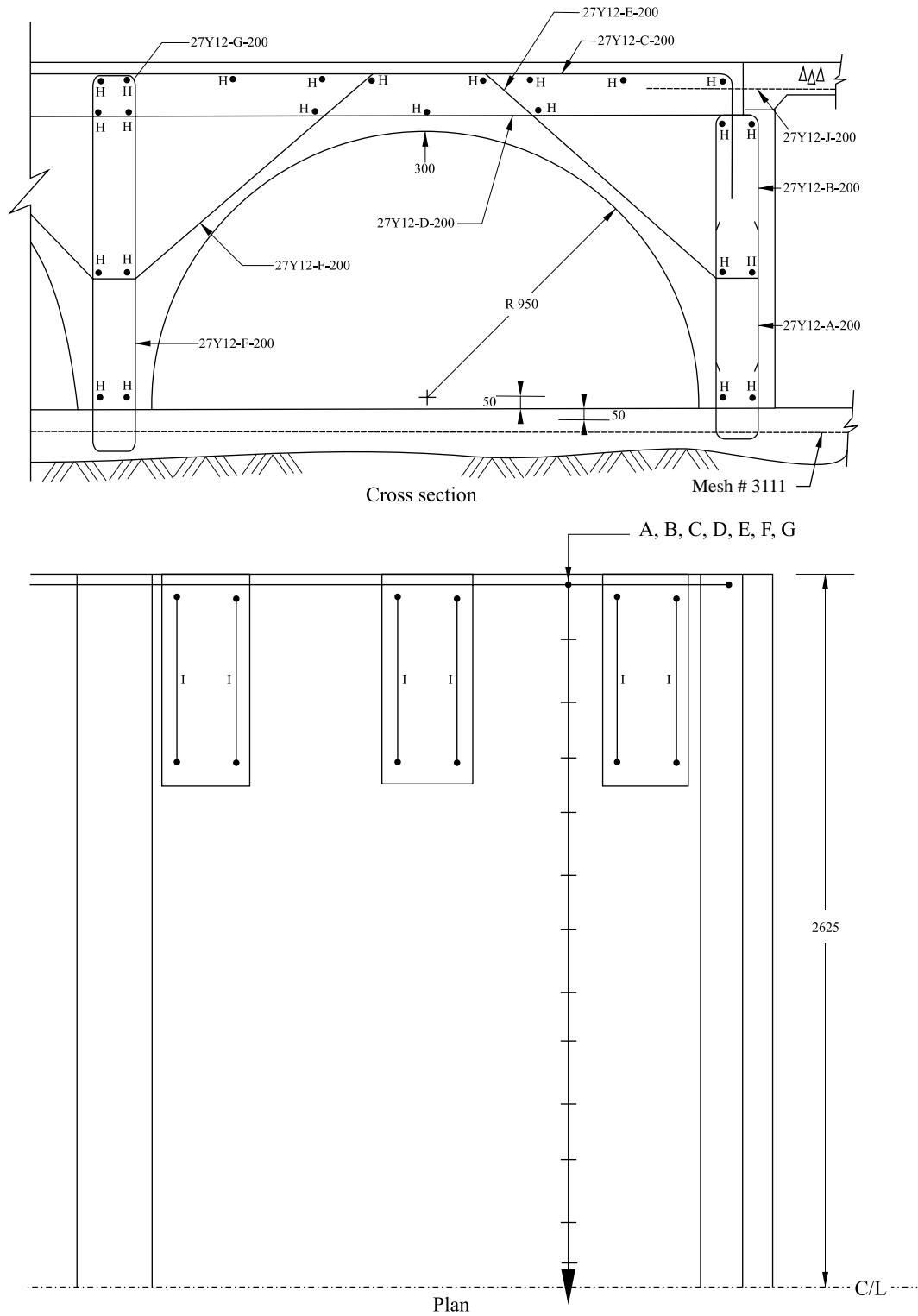
Causeway detail	
Notes:	
1.	Main shell rolled from 5 mm mild steel.
2.	Arch length of 5,25 m made up of 3 no. sections of 1,5 m each and 1 no. section of 0,75 m.
3.	Bolt holes provided to bolt sections together.
4.	Each mould made in two halves with removable box section to allow easy collapse.

Figure 5.48: Typical arch mould detail

The arches are formed of prefabricated, reusable steel moulds (Figure 5.48). The superstructure is cast one arch at a time to the full width of the bridge.

High strength concrete, as described in Module 2 of this Manual, is used and can be mixed by hand on the bridge next to the box.

Steel reinforcement as detailed in Figures 5.49 and 5.50 is used to strengthen the structure. The causeway is anchored down to rock by means of dowel bars.



Causeway reinforcement

Figure 5.49: Typical causeway reinforcement drawing

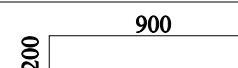
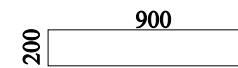
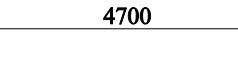
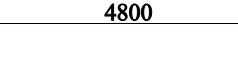
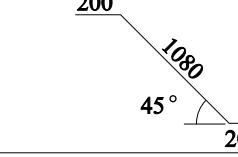
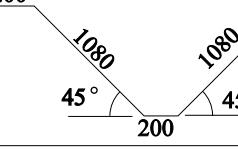
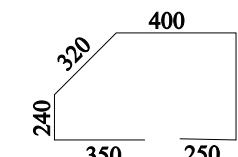
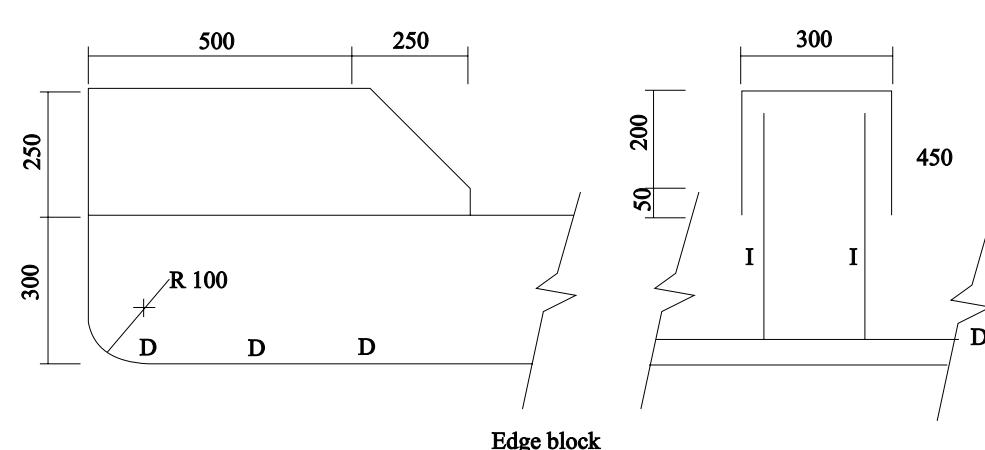
Mark	Diameter	Bending	Length	Total No
A	Y12		2 000	135
B	Y12		2 000	54
C	Y12		5 200	54
D	Y12		5 000	54
E	Y12		1 680	54
F	Y12		2 760	81
G	Y12		2 200	81
H	Y12	Straight	5 150	57
I	R10		2 000	48
Mesh # 311		Mesh # 311	Quantity (area)	
			70 m ²	
 <p>Edge block</p>				
Reinforcement bending schedule				

Figure 5.50: Typical causeway bending schedule



4.2.2 Construction sequence

- Set out bridge alignment from the drawings and levels provided by the engineer.
- Divert river, using sandbags, to create clear and dry working area.
- Set out final levels from drawings issued by engineer.
- Drill into rock and install dowels.
- Cast a blinding slab if specified.
- Install steel reinforcement according to engineer's drawing and bending schedule. The steel reinforcement must be checked by the engineer for correct fixing and placing before any concrete is cast.
- Erect arch moulds and shuttering – including shuttering for edge blocks.
- Mix, place, compact and cure concrete in accordance with Module 2: Concrete and mortar of this manual.
- Strip arch moulds and shuttering and prepare next section for construction.

4.2.3 Photographic record of construction of causeway



Photo 5.1: Initial construction showing the reinforcement and a cast arch

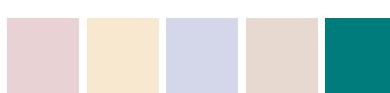




Photo 5.2: Construction in progress



Photo 5.3: The finished 16-arch causeway



Photo 5.4: The 4-arch causeway



5. Notes to consultants/designers

5.1 General

Drifts are low-cost structures which may be successfully installed as long as a few basic principles are followed. A drift allows water to cross the surface of the road. (Figure 5.51). A vented drift/causeway allows normal water flows to pass under the road, while overtopping is expected during storm conditions. (Figure 5.52)

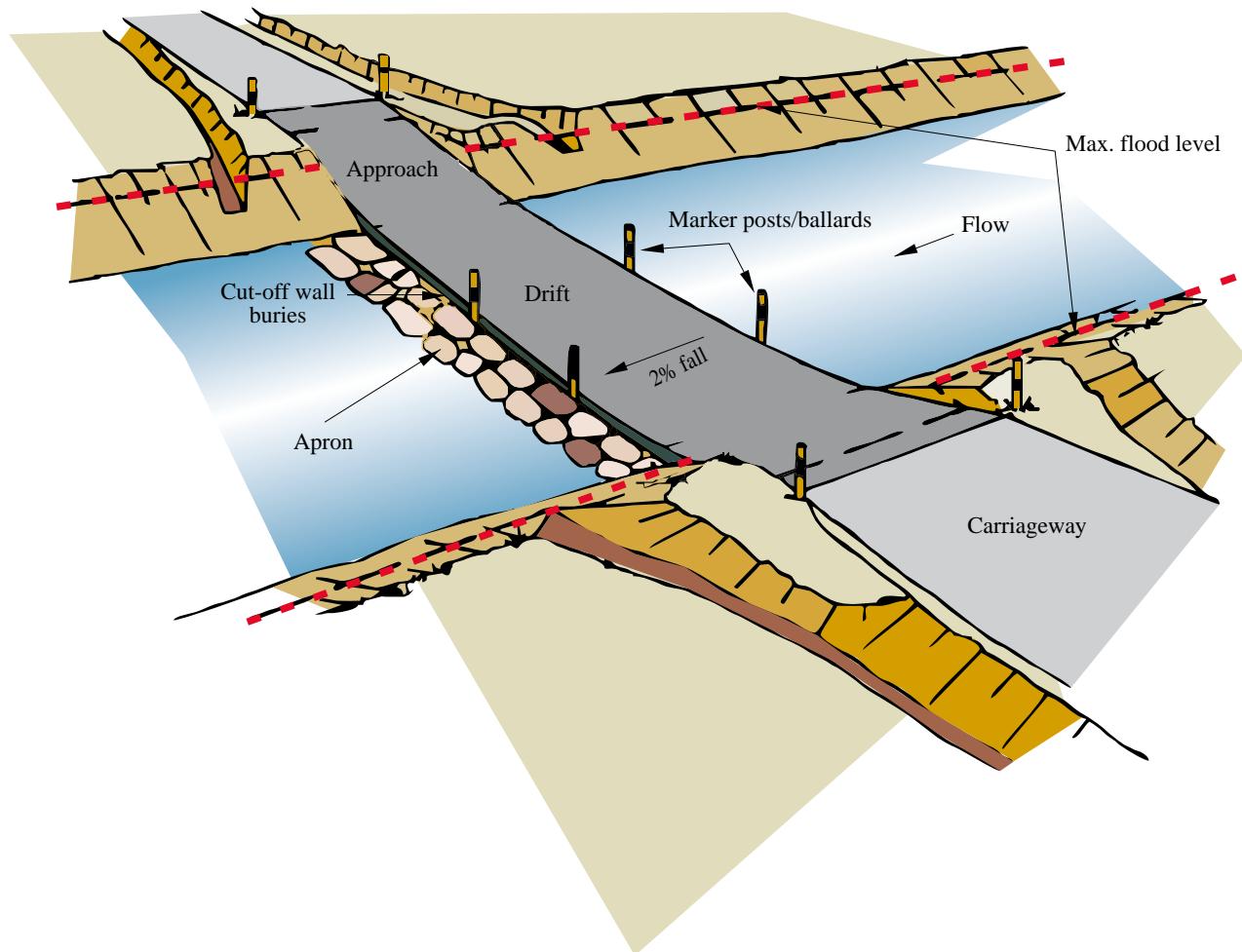


Figure 5.51: Drift features



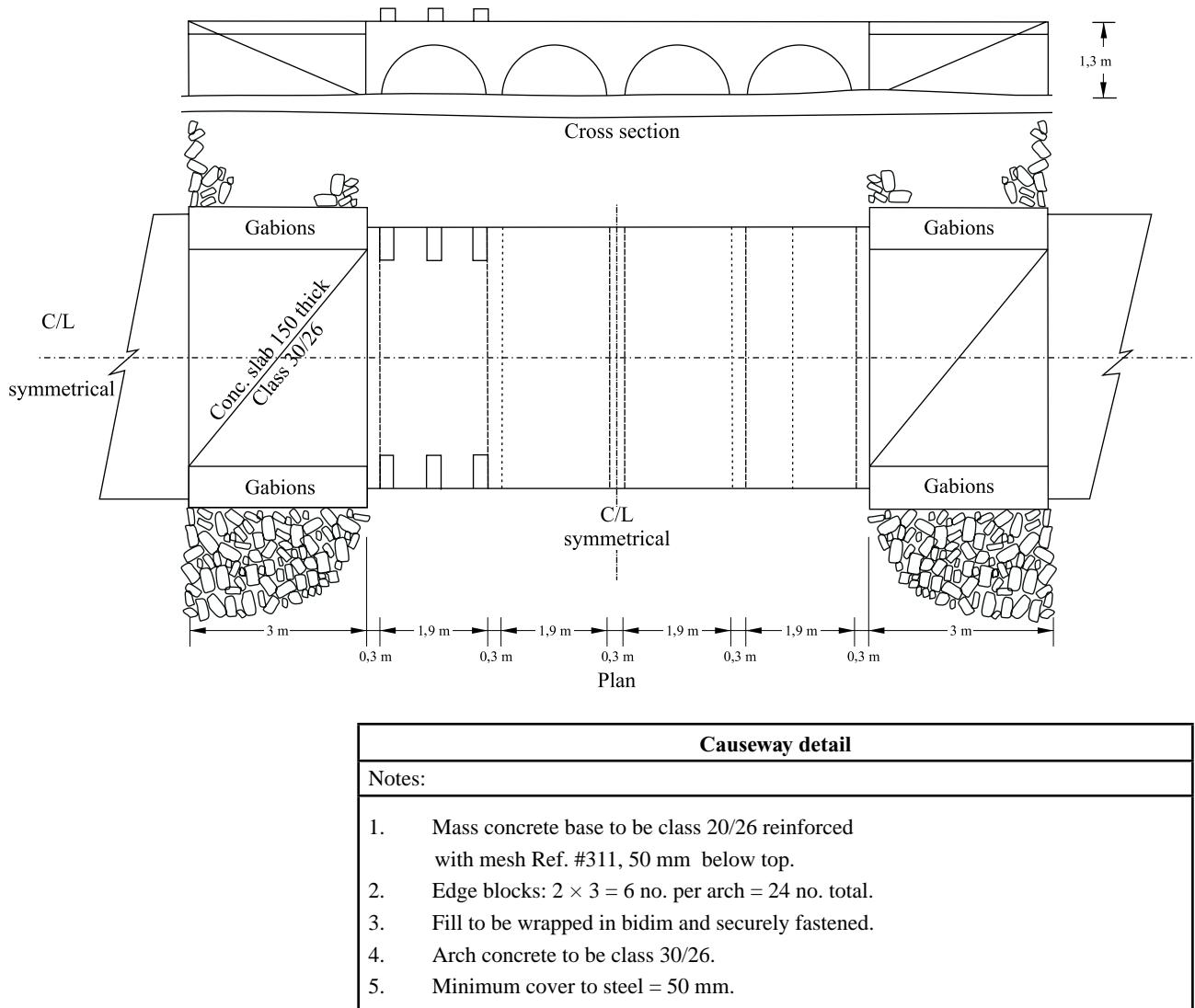


Figure 5.52: Causeway features

Drifts and causeways are normally used for seasonal water crossings although causeways can be successfully used on permanent watercourses.

Drifts and causeways are used in the following situations:

- Where rock exists at, or just below, the ground level and a culvert would be too costly or consume excessive resources.
- On a wide watercourse where the water flow (seasonal or permanent) can be spread across the structure so that vehicles and foot traffic can safely cross for most of the year.
- Where trees, branches or stones are brought down to the crossing site by flood water that would foul culverts or bridges.

They are not suitable where water is fast flowing or the volume of water would endanger the passage of vehicles, people or animals. Very careful consideration should be given to the type and cost of crossing on very wide seasonal rivers in semi-arid areas, particularly where traffic flows are low.

5.2 Design considerations – drifts and causeways (vented drifts)

5.2.1 General

As previously indicated the main difference between a drift and a causeway (vented drift) is that a drift allows water to flow across the surface of the road rather than below it; whereas in the case of a causeway normal water flows pass under the road and over the top during floods.

Although some of the points identified below are specific to drifts, the majority apply to both drifts and causeways.

5.2.2 Running surface

The running surface across the stream/riverbed should be almost flat and may be constructed out of natural hand-packed stone (slow flows only), masonry or concrete. The hand-packed stone surface will require more maintenance than the cement-bound surfaces. Gabions are not a suitable (surface) for foot or vehicle traffic.

The soil or rock foundation of the structure must be carefully prepared to ensure a good base for the construction. On a soil foundation any unsuitable material must be removed down to a firm base. If necessary, backfill will clean granular material, well compacted. A lean concrete blinding of 100 mm thickness should be laid on the prepared soil foundation and used as a clean working surface to lay the masonry or concrete slab.

The drift surface must be able to resist the plucking action and eroding power of the flood water. The extent of the running surface must be clearly shown by marker posts/bollards; visible even under flood conditions.

5.2.3 Approaches

The approaches must allow vehicles to descend to and leave the drift/causeway without grounding or loosing traction. On short structures (less than 10 m), the approaches should not be steeper than 5% (1 in 20). On longer structures the approaches can be steepened to 8% (1 in 12). Approaches should be surfaced in the same material as the main part of the structure.

Care must always be taken to ensure that the approaches to the drift/causeway are extended beyond the flood line. The surfacing must extend above the expected highest flood level.

The approach ramps should not be built into the watercourse so that the cross section of the watercourse is reduced. This would create additional turbulence and erosion immediately downstream of the structure. The approach ramps should be cut into the banks of the watercourse.

5.2.4 Cut-off walls

The structure normally incorporates a buried cut-off wall downstream which anchors it into the bed of the watercourse and prevents scour undermining the structure. An upstream cut-off wall reduces the seepage and lifting forces of water passing under the structure.

5.2.5 Apron

An apron is required immediately downstream of the buried wall to protect the structure from erosion by the turbulence that will be created by the structure.

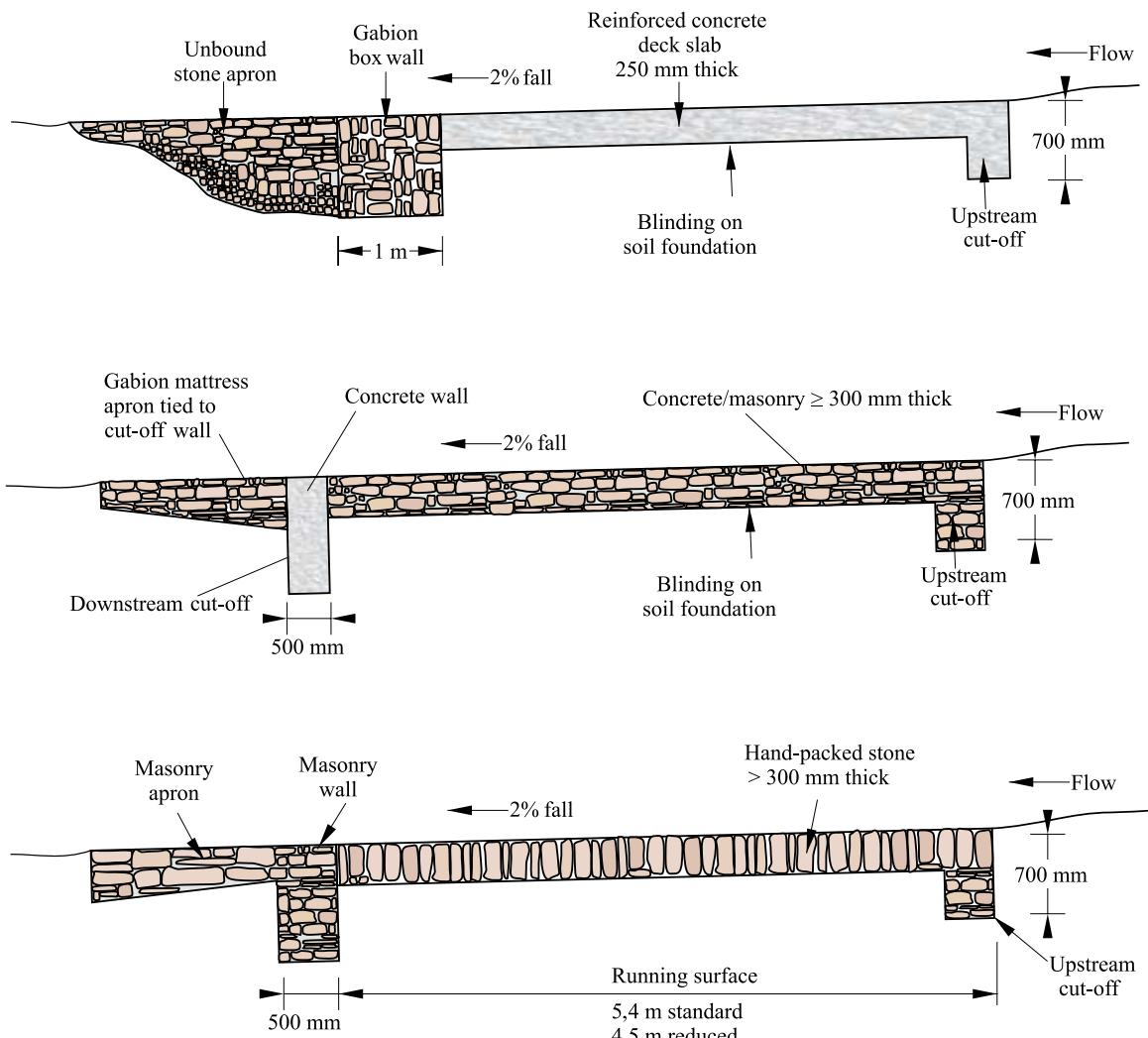
5.2.6 Other erosion protection

The structure may need further erosion protection on the approach ramps to protect them from damage in flood conditions.

5.3 Materials

Drifts may be constructed with natural stone, gabions, masonry or concrete. However, they will all require the features illustrated in Figure 5.53.

Note: Surfacing, wall and apron types may be interchanged in the following sections.



Downstream cut-offs should extend 1 – 1,5 metres below bed level.

Figure 5.53: Drift construction alternatives

5.4 Design

The aim in designing the structure should be to disturb the flow of water as little as possible. Any change in the cross section or longitudinal profile of the watercourse bed will cause turbulence and erosion potential in the flow, particularly under flood conditions.

If a change in level is required to keep the drift running surface clean or to accommodate a change in bed level, this should not occur at the intersection of the cut-off wall and apron. However, these two parts of the structure should be securely tied together to resist the inevitable erosion forces.



The downstream cut-off wall should normally extend about 1 m below bed level to act as a key, and water seepage cut off in the case of impervious masonry or concrete running surface slab construction. In conditions of expected severe erosion forces, the downstream cut-off wall should be even deeper. Impervious running surfaces (masonry and concrete) should have an upstream cut-off wall extending at least 700 mm below the riverbed to reduce seepage.

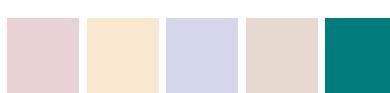
5.5 Siting

The drift or causeway should not be sited where the stream/river is likely to change its course. Therefore bends should be avoided. The structure should ideally be located on a straight section of watercourse, with a fairly even bed. Sites with severe scour or silting should be avoided. The approach ramps should not require large earthworks.

The level of the drifts should be set just slightly above the average existing streambed level. If it is set too high, the stream will silt up upstream of the drift and there will be an increased risk of erosion immediately downstream of the structure. If the level is set too low, the drift will silt over.

If there is a small step between the running surface and the apron (up to 300 mm), the drift should be self cleaning and silt will be discouraged from being deposited on the running surface.

Road users should be warned of the structure location with a sign placed approximately 50 m before the approach ramps. The signs should be clearly visible by the driver from a distance of 60 m.



MODULE 6: Construction of erosion control structures

1. General

This module deals with the construction of stone masonry and gabion construction for retaining structures associated with erosion control.

A number of alternatives for smaller structures and scour checks are dealt with under Section 5: Notes to consultants/designers of this Module.

2. Construction plant equipment and tools

The following plant, tools and equipment are recommended to promote the construction of stone masonry and gabion structures by labour-intensive methods:

- Steel pegs
- Hammer
- Building line
- Pick and shovel
- Wheelbarrows
- Pedestrian vibratory roller (alternative – hand tamper)
- Straight edge
- Boning rods
- Spirit level
- Hand tape – 3 m or 5 m
- Steel and/or timber shutters/formwork
- Concrete mixer for mixing concrete and mortar (hand mixing is also acceptable)
- Concrete shovels
- Containers for batching of aggregate, sand and cement (see Module 2)
- 210 litre drums for storing water
- Screed
- Wooden float
- Trowels

3. Construction materials

Construction materials will depend on the material used for the construction of the structure. However, the main materials will include:

- Cement, sand and aggregate for concrete and mortar (Module 2).
- Stones to specification for stone masonry work.
- Gabion baskets and stone for filling baskets.
- Steel reinforcement and/or mesh.



4. Construction

4.1 Preparation

Foundations should be excavated to the lines and levels on the engineer's drawings. Any unsuitable material shall be removed and replaced with approved soil, stone or gravel and compacted to the engineer's specifications.

4.2 General technique for stone masonry construction

The following technique and guidelines apply for construction of minor works. Major retaining walls may include further requirements.

Materials: *Cement* – refer to Section 1.1.1 in Module 2 for information relating to the common types of cement and storage of cement.

Sand – clean building sand free of organic particles and clay (Section 1.1.4 in Module 2).

Stones – clean hard rubble stones of similar size (cracked or weathered stones should not be used). Wash dusty or dirty stones before use. Some porous stones need to be slightly dampened before use, to reduce excessive suction of moisture from the mortar (Section 1.1.3 in Module 2).

Quantities: For 1 m³ of finished masonry (approximately):

Stone : 1,2 m³

Sand : 0,36 m³

Cement : 2 × 50 kg bags (1:6 mix)
3 × 50 kg bags (1:4 mix)

Mortar mix: The mixture of mortar for masonry which is structural or will frequently be in contact with water is 1:4 (cement:sand by volume), otherwise 1:6 should be used.

Thoroughly mix the sand and cement before adding water. Only a little water should be used for a good quality mixture.

The quantity of mortar to be mixed should not be more than a mason can use within one hour.

Joints and bond: Joints should be between 10 mm and 40 mm thick. The bond should allow a minimum overlap of ¼ length of the smaller stone (Figure 5.54). Mortar joints on the face of the masonry should be pointed and raked to produce a durable finish.

No stone should touch another but should be laid into mortar. Most of the stones should be laid as stretchers (i.e. along the face of the wall). However, headers or through stones should be laid at regular intervals to bond the two faces of the wall together.

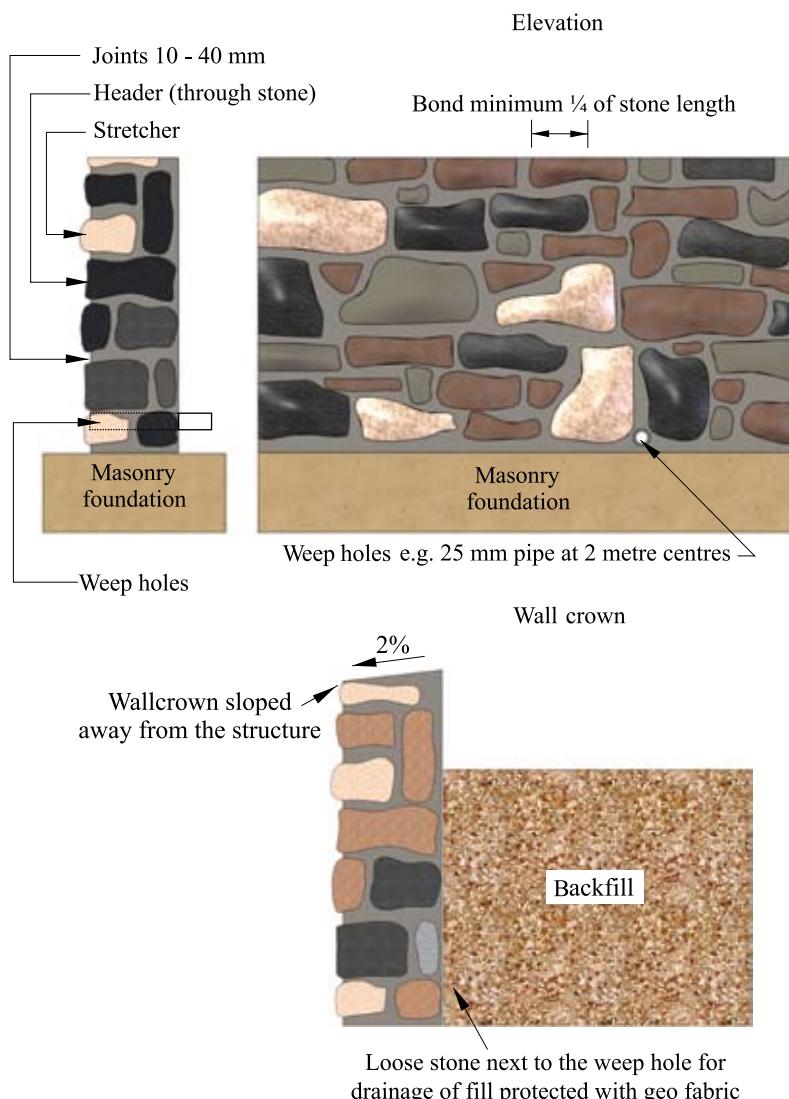


Figure 5.54: Stone masonry requirements

Curing:

Mortar needs to be cured to achieve satisfactory strength. After the mortar has set, the masonry work should be covered with sacking and kept damp for at least four days.

4.3 General technique for gabion work

Foundations should be excavated level and cleaned as for a conventional structure, with any unsuitable material removed and replaced with good soil, stone or gravel and then compacted. The baskets should be erected in their final position. Cages should be woven together using 3 mm binding wire, securing all edges every 150 mm with a double loop. The binding wire should be drawn tight with a pair of heavy duty pliers and secured with multiple twists. The connected baskets should be stretched and staked with wires and pegs to achieve the required shape.

Filling should be carried out by hand, using hard durable stones not larger than 250 mm and not smaller than the size of the mesh. The best size range is 125 – 200 mm. The stones should be individually and tightly packed with a minimum of voids. They must not be tipped into the baskets.

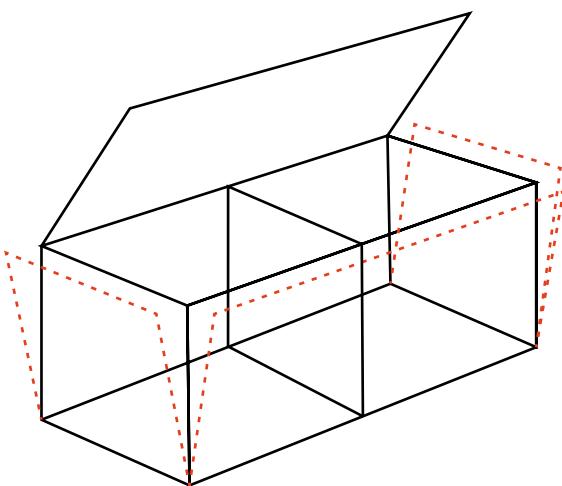


Boxes of 1 metre height should be filled to $\frac{1}{3}$ height. Horizontal bracing wires should then be fitted and tensioned with a windlass, to keep the vertical faces even and free of bulges. Further bracing should be fixed after filling to $\frac{2}{3}$ height. 500 mm height boxes should be braced at mid-height only. 250/330 mm height gabions do not require internal bracing.

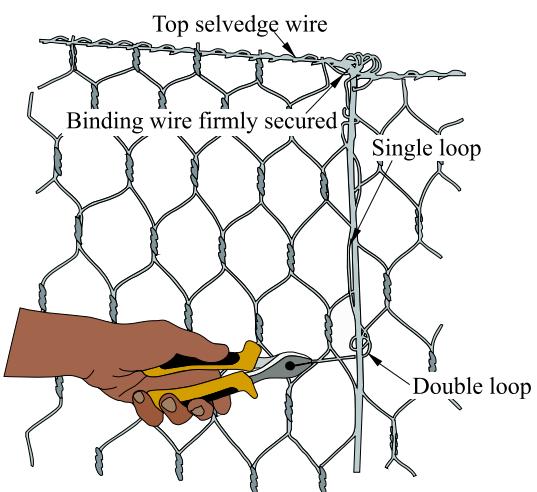
Where water falls directly onto the top of the gabion, vertical bracing wire should also be fitted to secure the gabion lid when closed. The stones should be carefully packed to about 30 – 50 mm above the top of the box walls to allow for settlement. Smaller material can be used to fill the voids on the top face, but excessive use of small stones should be avoided.

The lids are then closed and stretched tightly over the stones. Carefully use crowbars if necessary. The corners should be temporarily secured to ensure that the mesh covers the whole of the box. The lid should then be securely woven to the tops of the walls removing stones. If necessary, remove stones to prevent the lid from being overstretched.

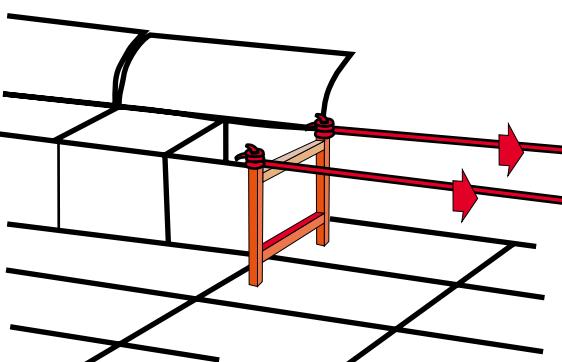
1. Assemble cage



2. Weave boxes securely together



3. Stake and stretch cages to required shape



4. intermediate bracing

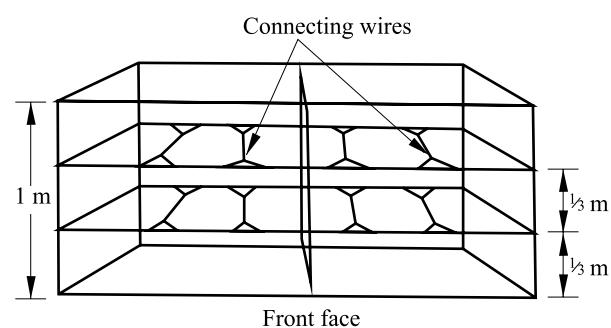
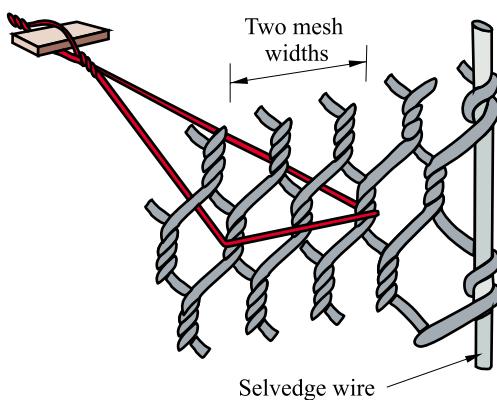


Figure 5.55: Gabion construction (continued overleaf)



5. Windlass bracing



6. Close and secure lid

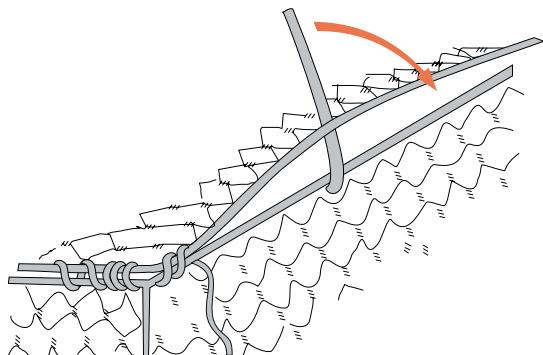


Figure 5.55: Gabion construction

5. Notes to consultants/designers

5.1 General

Soil erosion in South Africa has been, and always will be, a major problem. Some 120 – 300 millions of tons of topsoil are eroded and deposited in the reservoirs and sea annually. The concomitant problems affecting the underground water supply, agriculture and dams are equally very real problems.

The problems occur wherever the formation/sub grades consist of non-plastic material or dispersive soils. Excessive erosion will occur specifically in side drains, catch-water drains, open/untreated cut faces and areas where there is a concentration of storm water.

Where longitudinal gradients are steeper than about 4% the water flows at high speed. Therefore, if no protective measures are taken, scouring is likely to occur on soils prone to erosion. The simplest way of dealing with scouring is by reducing the volume of water. In addition, erosion control checks can be constructed to reduce the velocity of water. They hold back the silt carried by the water flow and provide a series of stretches with gentle gradients interrupted by small waterfalls.

5.2 Erosion-control structures

5.2.1 Scour checks

Scour checks are usually constructed of natural stones, wooden stakes and natural vegetation (Figure 5.56). For larger erosion areas, gabions or concrete weirs are constructed (Figure 5.57). The level of the scour check must be a minimum of 0,2 m below the edge of the carriageway, in order to avoid the water flow being diverted out of the side drain/channel. Therefore, the constructed scour checks have to be controlled with a template. An indication of the interval at which scour checks are constructed, depends on the gradient as shown in Table 5.2. The gradient of the side drain/channel should be checked using a spirit level and tape, Abney level or line and level.

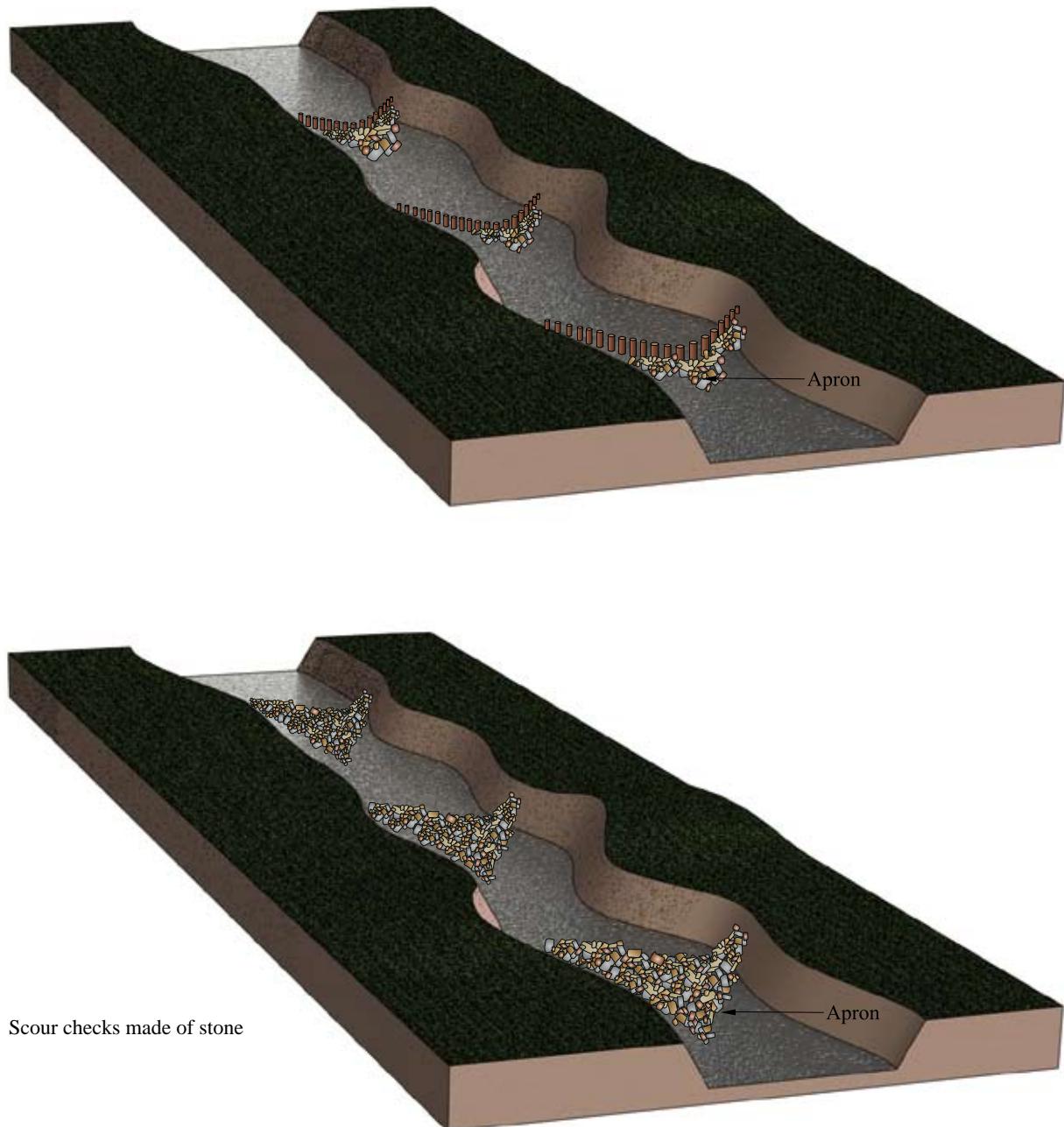
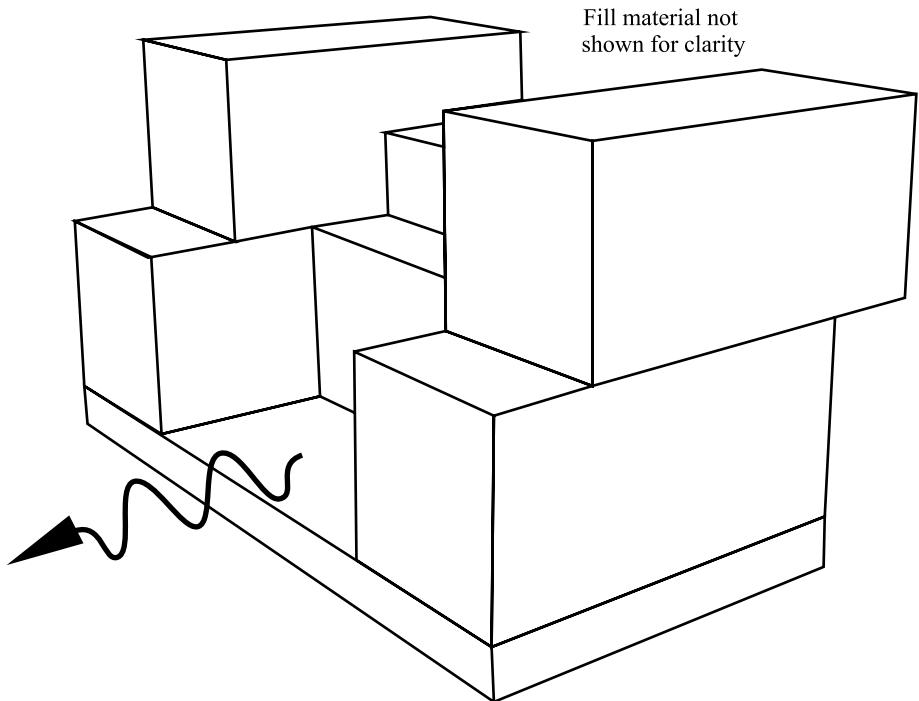


Figure 5.56: Scour checks



Typical layout



Typical longitudinal section

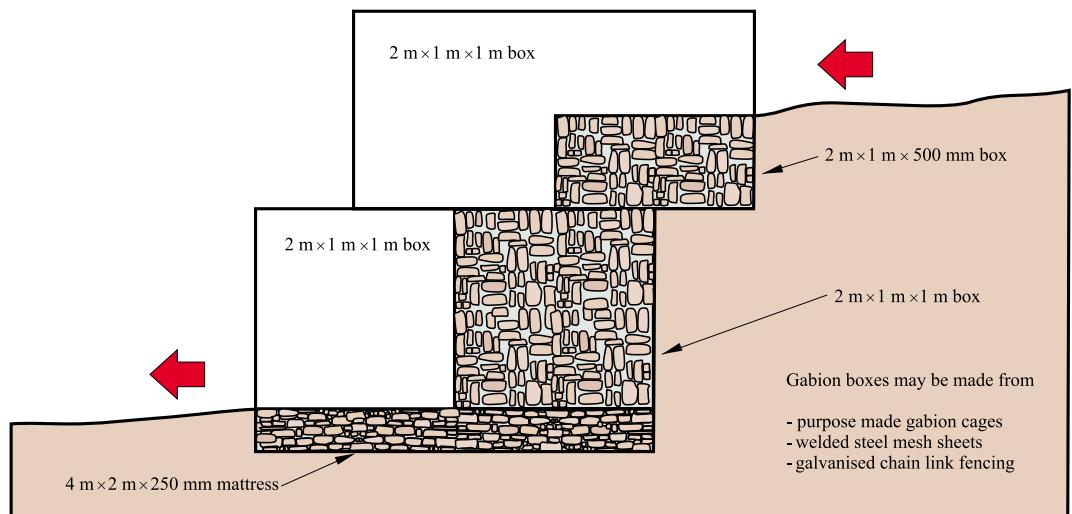


Figure 5.57: Gabion erosion protection structure

Gradient of drain/channel	Scour check spacing
4% (1 in 25) or less	Not required
5% (1 in 20)	20 m
8% (1 in 12,5)	10 m
10% (1 in 10)	5 m
12% (1 in 8)	4 m

Table 5.2: Scour check spacing

Scour checks should not be constructed on roads with gradients of less than 4% (1 in 25). This would encourage too much silting of the drain and lead to road damage.

After the basic scour check has been constructed, an apron should be built immediately downstream; either using stones or grass sods pinned to the ditch invert with wooden pegs. The apron will help resist the forces of the waterfall. Grass sods should be placed against the upstream face of the scour check to prevent water seeping through the scour check and to encourage silting behind the scour check.

Scour checks must be designed to be sufficiently embedded in the surrounding material (both the base and sides), to prevent water under-cutting or flowing around the sides of the structure

5.3 Drainage – general

5.3.1 Sub surface drainage

In isolated cases, ground water can pose a problem for the road improvement works. This occurs where the road alignment intercepts the ground-water table and spring water is present for long periods.

If the alignment cannot be changed to avoid such locations, then specific drainage measures may be required e.g. culverts or ditches possibly lined with hand-packed stone or filled with clean crushed stone (French drains).

5.3.2 Mitre drains

Mitre drains (or turn-out drains) lead the water away from the side drains to the adjoining land (Figure 5.58). This must be achieved in the correct manner to avoid causing erosion at the discharge point. Therefore, mitre drains should be provided as often as possible so that the accumulated water volume in each drain is not high. Wherever possible, they should be constructed at intervals of 20 m along the road alignment. ('Little and often' should be the guiding principle for water discharge.)

Care should be taken to ensure that mitre drains discharge without causing nuisance or damage to land. The cross section of the mitre drain should have at least the same capacity as the side drain. Mitre drains should have a gradient of 2 to 5% (1:50 to 1:20) and could be lined with concrete or stone.

Common mistakes in the construction of mitre drains

- Constructing mitre drains on the top side of a natural cross slope. This merely causes more intensive flow lower down the road.
- Slope of mitre constructed too flat or sloping back towards the road.
- Ponding of water at the entrance of the mitre.
- Shape of mitre a V-drain instead of flat-bottom drain.
- Incorrect use of cut material caused by the drain being placed/cut to the top side of the slope instead of the lower side of the slope.

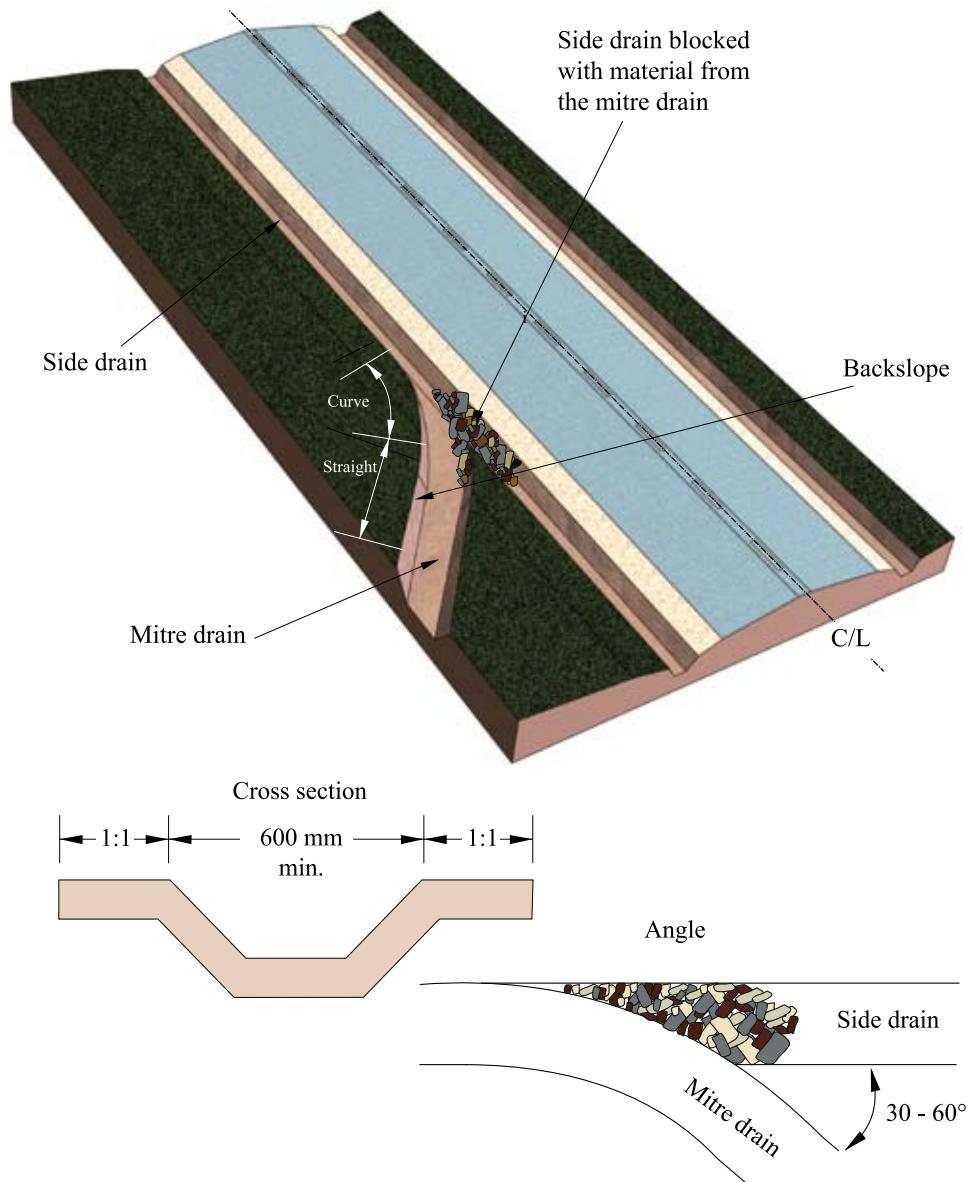


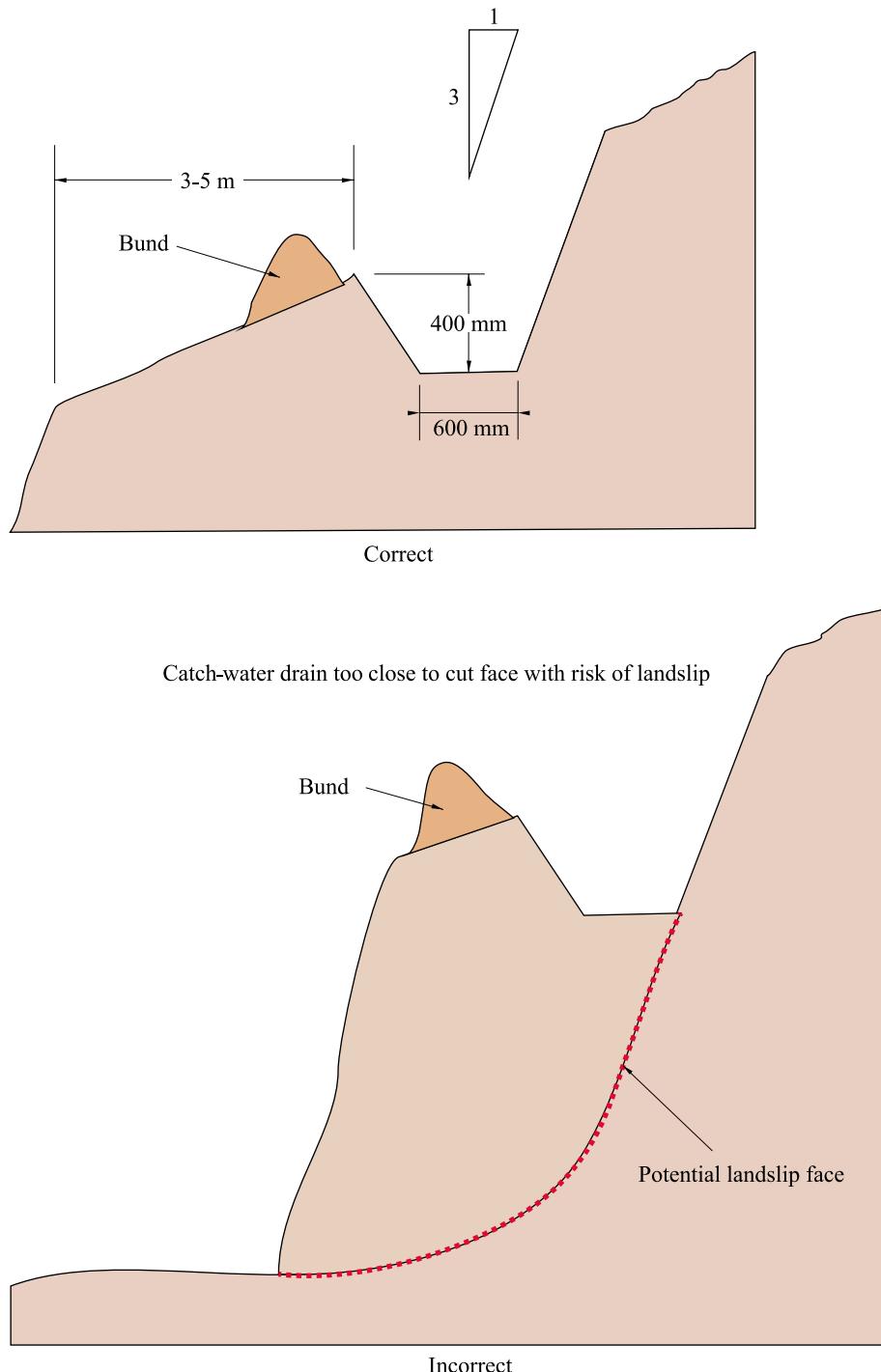
Figure 5.58: Mitre drain

5.3.3 Catch-water drains

Where the road is situated on a hillside, a significant amount of water may flow down the hill towards the road. This may cause damage to the cut face of the road and even cause land slips. Where this danger exists, a catch-water drain (Figure 5.59) should be installed to intercept this surface water and carry it to a safe point of discharge; usually a natural watercourse.

The catch-water drain should normally be constructed at least 3 to 5 metres away from a cut face. It must drain satisfactorily throughout its length and must not be close to the cut face, as this increases the danger of a landslip.

Normally the material excavated from the drain is placed on the downhill side to form a bund. Vegetation cover should be established as soon as possible in the invert and sloping sides of the catch-water drain and bund to resist erosion. If the drain has a steep gradient then additional scour checks or an adequate lining should be installed.



Extreme care is required in locating and constructing catch-water drains to avoid making the situation worse.

Figure 5.59: Catch-water drain



5.4 Materials

Scour checks are usually constructed of natural stones, wooden stakes or natural vegetation. Larger structures comprise gabions, stone masonry or concrete weirs.

Mitre and catch-water drains may be lined with vegetation, concrete or stone (Module 3). It is always cheaper to source local material for the construction of these structures.

The long-term objective is to establish complete grass cover over the silted scour checks to stabilise them. Grass is usually effective in preventing erosion and should be planted on all slopes where erosion is likely to occur. The type of grass should be strong, fast growing and providing good coverage. Usually suitable grasses may be found at the work site and may be removed by the grubbing gang as a grass turf. A grass turf is formed by excavating an area of live grass and lifting the grass complete with about 50 mm of topsoil and roots still attached. The turfs can be replanted in another location.

Note

Grass turfs/sods give a faster and more effective protection to slopes than planted grass. They can often be cut in the grubbing activity. The size of the turfs should not be smaller than 200 mm x 200 mm. Wooden pegs may be required to secure them on steep slopes. They will probably require watering to re-establish them.

5.5 Construction plant and equipment

Installation of gabion/stone masonry or concrete weirs may require special training. Concrete and cement mortars, if required, can be mixed by hand (Module 2). Hand mixing can produce high quality concrete and mortar but requires that the mixing team receive intensive training in technique and quality control.

Tools commonly required include spades, shovels, picks, rakes, garden forks, club hammers, spirit levels, straight edges, watering cans, string lines, measuring tapes, boning rods, pegs and wheelbarrows.

5.6 Construction – general

The most important soil-erosion control is the careful selection of sites for culverts and erosion control structures. A good guide is the little and often principle for the discharge of water, to avoid potentially harmful concentrations of flow. For the discharge, existing natural waterways should be utilised wherever possible.



MODULE 7: Process for placing pipes without the use of plant

1. General

The process described in this Module is applicable to the placing of small diameter concrete storm-water pipes without the use of plant.

The process reduces the risk of damage to the pipe ends and bedding, while manoeuvring them into position and reduces the strain on workers levering the pipes into position.

2. Equipment

The equipment list for pipe laying is:

- 2 No. Rope slings
- 3 No. Steel rollers: \pm 75 mm diameter steel pipes
- 2 No. Skids: Old grader blades
- 1 No. 'Koevoet': Steel reinforcing bar

3. Pipe laying process

STEP 1



The process of trench excavation is managed in such a way that the excavated material is placed on the side of the trench, opposite to that from which the pipes are to be handled.

STEP 2



Pipes are hand lowered into the trench with the aid of rope slings around the pipes, onto three rollers (\pm 75 mm steel pipes) which run on two skids (old grader blades).

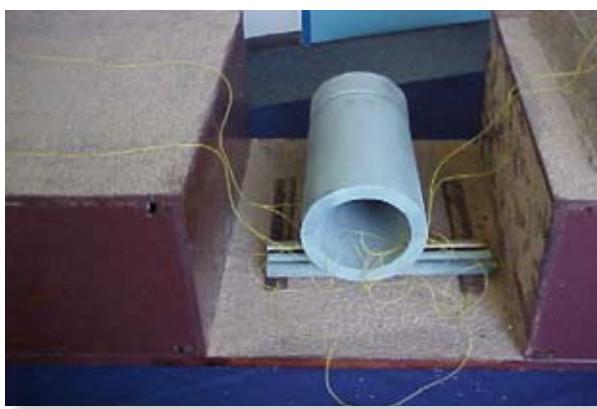


**STEP 3**

The concrete pipe is rolled onto rollers into its position to align with the previous pipe.

**STEP 4**

The end of the pipe adjacent to the existing pipe is raised with a suitable 'koevoet' (steel reinforcing bar) using the existing pipe as a fulcrum and the two back rollers moved forward.

**STEP 5**

The 'koevoet' is then removed. Then, with the concrete pipe in its correctly aligned position, the two front rollers are removed from the pipe.



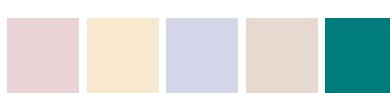
**STEP 6**

Using the two rollers which have been removed as a fulcrum, the last roller is removed.



**STEP 7**

All the equipment is then moved to the position of the next pipe to be placed, and the process repeated



MODULE 8: Indicative production and task rates

Indicative production rates and team sizes for selected activities based on a 7-hour production day

Activity	Description	Unit	Recommended production rate
Clear and grub	Clearing	m^2	150 – 300
	Clearing and grubbing	m^2	80 – 150
Excavation (trenches)	$\pm 0,500$ mm wide 0,0 – 1,0 m deep	m	7 – 10
	$\pm 0,500$ mm wide 1,0 – 1,25 m deep	m	5 – 7
	Normal width and depth	m^3	3 – 6
Excavation (earthworks) (In wider excavations double handling may have to be arranged.)	Soft class 1 (soil)	m^3	2,5 – 5,0
	Intermediate (soil)		2,0 – 3,0
	Hard (soil)		1,0 – 2,0
Spreading	Earthworks	m^3	7,0 – 12,0
	Remove oversize material		2,0 – 3,0
Hauling (wheelbarrows)	0 – 20 m	m^3	10,0 – 13,0
	40 – 60 m		8,0 – 10,0
	60 – 80 m		6,0 – 8,0
	80 – 100 m		5,0 – 6,0
Backfilling	Trenches	m^3	4,0 – 8,0
	Excavation		2,0 – 5,0
Pitching	Plain stone pitching	m^3	2,0 – 4,0
	Grouted stone pitching		1,0 – 3,0
Masonry walls		m^3	0,6 – 2,0
Gabion construction		m^3	0,4 – 1,5
Concrete	Mixing	m^3	0,7 – 2,0
	Placing		1,0 – 4,0

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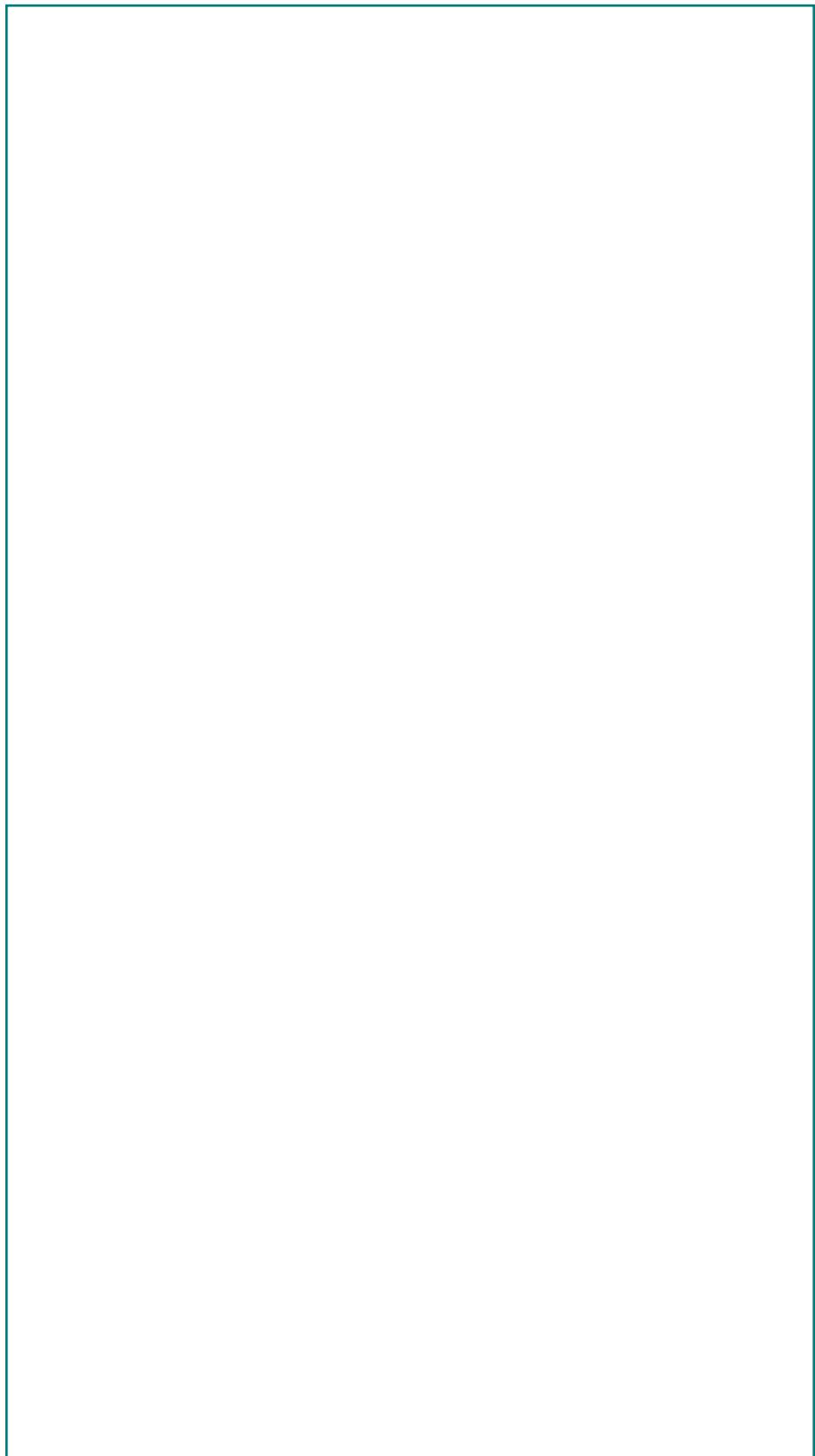
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Notes



"We have made the firm commitment to confront the challenges of poverty and joblessness. We have made the solemn pledge that we will do everything possible to achieve the goal of a better life for all our people."

President Thabo Mbeki