SWD STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES
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THE NETHERLANDS

Irrigation water storage tanks made of earth bunds with various linings

A manual for design and construction

Maart 1983

DHV
DHV Consulting Engineers

TWO
Technical Working Group
for Developing Countries

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1. PREFACE

The SWD (Steering Committee on Wind-Energy for Developing Countries) has designed and built windmills for irrigation purposes in several developing countries. One of the essentials for achieving properly regulated irrigation with windmills is water storage.
Experience has shown that the cost of water storage tanks involved can equal the cost of a windmill. Also some types of storage tanks are liable to become damaged during use, sometimes due to lack of knowhow.
Discussions in TWO (a non profit organization set up by employees of DHV) about the technical problems of water storage tanks resulted in a contract between SWD and DHV. Under this contract DHV has prepared designs and construction manuals of irrigation water storage tanks in various types constructed of different materials.
A design and construction manual for brickwork tanks was prepared in December 1981 and in October 1982 a similar manual for ferrocement and ferrocement-brickwork tanks.

The tanks described in the present manual have walls consisting of earth bunds. These tanks which can be constructed by several methods and with various types of linings or construction, will have storage capacities of 30 m^3 - 60 m^3 - 90 m^3 and 150 m^3 like the brickwork and ferrocement tanks.

The authors are grateful for the support and criticism, received from the SWD.

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2. INTRODUCTION

Watertanks for storage of irrigation water are liable to have some losses due to the permeability of the walls. In certain circumstances a 10% loss of water per day may not be a problem. If such losses are not acceptable, more care has to be taken with the impermeability of bottom and bunds. In some cases this will mean applying other linings or a combination of linings such as a clay bund with plastic sheet lining.
Due to the slopes at the perimeter of some of the described tanks shallow water remains standing; this may be a breeding place for mosquitoes.
The area needed for a bund tank is larger than for a brickwork, concrete or ferrocement tank.
A summary of the several types of tanks reads as follows:

- Type I : clay bund
- Type II : coffer dam
- Type III : PVC lining
- Type IV : sand-bentonite lining
- Type V : bitumen lining
- Type VI : lining of concrete or bricks
- Type VII : sand-cement sausages lining

The choice of a type depends largely on the availability of the materials and the costs involved.
Bills of quantities are made for each type of tank to facilitate making cost estimates for specific situations.
A comparison of these bills of quantities will make clear that bund tanks are often much cheaper than other types of tanks.

The main chapters in this manual are:

- a general description of design criteria, location, site clearance and execution of the tanks
- construction materials
- tools
- types of tanks including construction sequences, bills of quantities, drawings and other instructions
- methods for testing materials, to obtain an impression of the quality and suitability of the materials to be used
- calculation methods to be used for the user who is sufficiently knowledgeable and experienced to adapt the tank dimensions if a smaller tank is required.

Annexes contain data on construction materials, and conversion of units, and a bibliography.

3. GENERAL

3.1. Design criteria

The United States Water Conservation Laboratory in Arizona has listed the desired characteristics of an artificial catchment. They are:

1. Run off must be non-toxic
2. Surface should be smooth and impermeable
3. The surface should have a high resistance to weathering and have no internal chemical or physical deterioration
4. The surface need not have great physical strenght but should be able to withstand hail, intense rain, wind, occasional amimals, moderate water flow, plant growth, insects, birds and borrowing animals
5. The treatment should be inexpensive on an annual cost basis. Site preparation and construction costs should be as low as possible
6. Maintenance requirements should be simple and cheap

This manual describes several types of cheap linings, for water storage tanks made of bunds, that satisfy these conditions and require a minimun of skilled labour to construct.

3.2. Location

For irrigation from the tank by means of gravitational flow, the tank has to be situated at the highest part of the field.
If the land is rather flat, the base of the tank has to be constructed about 0.50 m above ground level.
Points to be considered are:

- location in the highest part of the field that has to be irrigated
- site as close as possible to the windmill to reduce the cost of the delivery line
- no obstructions to other field operations
- avoid damage by roots or falling branches by choosing the site away from trees
- it is advisable to choose the site near a road or track, but not one on which a lot of heavy traffic passes

3.3. Soils and rock

Ground materials are usually divided into three types.

These are:

1. Granular : Silts, sand, gravels and boulders which are not cemented together
2. Cohesive : Clays, or materials which have sufficient clay minerals in them for them to act as clays
3. Lithified : Rock

A simple grain size classification for soils is given in the following table:

Grainsize classification of soils

grain diameter (mm)			term
	>	200	Boulder
60	-	200	Cobble
20	-	60	Coarse Gravel
6	-	20	Medium Gravel
2	-	6	Fine Gravel
0.6	-	2	Coarse Sand
0.2	-	0.6	Medium Sand
0.06	-	0.2	Fine Sand
0.02	-	0.06	Coarse Silt
0.006	-	0.02	Medium Silt
0.002	-	0.006	Fine Silt
	<	0.002	Clay

The name of the soil is given by its grain size-distribution. A full description may include such physical properties as relative density (for sands) or strength (for clays) and a description of geological structure. Other features such as colour may be added to help distinguish one stratum of material from another. A description might be "Dense thinly bedded grey fine Sand".
Strength is one of the most important parameters for engineering purposes and so scales of strength have been devised. One such scale is given in the following table which also indicates how a very approximate indication of strength may be obtained by hand.
This strength and also the relative density can be lost by excavating and be improved by compacting.

Field Definition	Extrudes between fingers when squeezed	Very easily moulded with fingers	Moderate finger pressure required to mould	Moulded only by strong finger pressure	Cannot be moulded with fingers	Brittle or very tough
Description	Very soft	Soft	Firm	Stiff	Very Stiff	Hard
Strength Categories	10	20	40	80	160	
	Shear Strengths of Clays (kN/m^2)					

Field definition	Crumbles in hand break easily in hand	Thin slabs broken by heavy hand pressure	Thin slabs broken by light hammer blows	Lumps or core broken by heavy hammer blows	Lumps or core heavy hammer blows. Dull ringing sound	Lumps only chip by blows. Sparks fly	Rocks ring on hammer
description	Very Weak	Weak	Moderately weak	Moderately strong	Strong	Very strong	Extremely strong
		1.25	5	12.5	50	100	200
	Unconfined compressive Strengths of Rocks (MM/m^2)						
Strength Categories	Point Load Strengths of Rocks (MM/m^2)* 0.075	0.3	0.75	3	6	12	

*Based on the approximate relation: Comp. Strength = 16 Point Load Comp. Strength

We may use these terms for description. A typical soil description might be "Stiff laminated brown sandy CLAY".
Permeability depends on the kind of soil and the compaction (see 3.5.).
Sand is a good compactible soil.

Typical names of soil groups	Group symbols	Important engineering properties: Permeability when compacted	Shear strength when compacted and saturated	Compressibility when compacted and saturated	Workability as a construction material	Relative desirability for (No. 1 is considered the best) earthfill dams: Homogeneous embankment
Well-graded gravels, gravel-sand mixtures, little or no fines	GW	Pervious	Excellent	Negligible	Excellent	—
Poorly-graded gravels, gravel-sand mixtures, little or no fines	GP	Very pervious	Good	Negligible	Good	—
Silty gravels, poorly-graded gravel-sand-silt mixtures	GM	Semipervious to impervious	Good	Negligible	Good	2
Clayey gravels, poorly-graded gravel-sand-clay mixtures	GC	Impervious	Good to fair	Very low	Good	1
Well-graded sands, gravelly sands, little or no fines	SW	Pervious	Excellent	Negligible	Excellent	—
Poorly-graded sands, gravelly sands, little or no fines	SP	Pervious	Good	Very low	Fair	—
Silty sands, poorly-graded sand-silt mixtures	SM	Semipervious to impervious	Good	Low	Fair	4
Clayey sands, poorly-graded sand-clay mixtures	SC	Impervious	Good to fair	Low	Good	3
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	ML	Semipervious to impervious	Fair	Medium	Fair	6
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	CL	Impervious	Fair	Medium	Good to fair	5
Organic silts and organic silt-clays of low plasticity	OL	Semipervious to impervious	Poor	Medium	Fair	8
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	Semipervious to impervious	Fair to poor	High	Poor	9
Inorganic clays of high plasticity, fat clays	CH	Impervious	Poor	High	Poor	7
Organic clays of medium to high plasticity	OH	Impervious	Poor	High	Poor	10
Peat and other highly organic soils	Pt	—	—	—	—	—

Source: United States Bureau of Reclamation (1974).

For rocks we have similar descriptions. However, an important addition to a rock description is the state of weathering of the rock. We must say if the rock is fresh (un-weathered) and thus at its greatest strength or has been weakened by weathering to, say, a highly weathered condition. A typical description for rock might be "Highly weathered thinly bedded red coarse weak micaceous SANDSTONE".
It is very difficult for engineers to give an accurate geological identification of a rock type. The geological classifications of rocks are not uniform throughout the world and description often comes only from examination using a microscope. For engineering purposes it is also often considered more important to give an accurate description of the properties of the rock than to give an exact name.
Accordingly, when engineers must name a rock, the name need not be as accurate as a geologist would give but should be not too far from the truth.

3.4. Soil improvement

The locally available clay or silt can be improved by chemical treatments and additives.(see also 4.4.)
Three different types of chemical treatment are known:
- hydrophobic; i.e. a treatment which increases the contact angle between soil particles and any water on them so that water infiltration will be reduced
- dispersing; i.e. a treatment which causes any clay in the soil to disperse or swell and partially seal the soil pores
- stabilisers; i.e. a treatment that improves all properties of the soil like strenght, resistance to weathering and to erosion.

Another type of treatment is mixing the soil with bentonite, which swells when fully saturated and forms a more or less impermeable blanket.

3.5. Permeability

Permeable materials have interconnections between solid particles, which allow the passage of fluid through the material. If the material does not have these passages through it, it is impermeable. The size of the passages governs the permeability and may make the material permeable to one fluid e.g. gas but not to another e.g. water.
For flow to take place through a saturated material there must be a pressure head. In this case we are concerned mostly with water and with its flow through materials and mass.

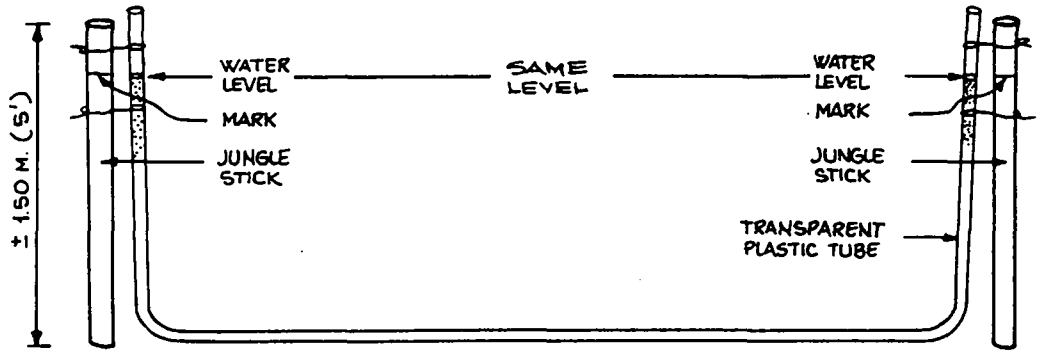
3.6. Execution

- Site clearance

  The site chosen for the tank should be cleared.
  The soil layer is to be excavated to a depth of approx. 0.20 m to be sure that all vegetation, loose surface soil, black soil, stones and roots should be removed.

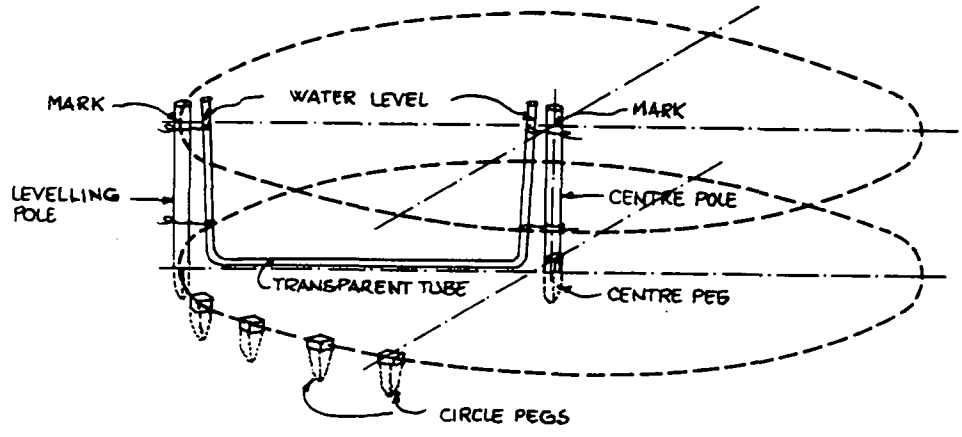
- Levelling

When the site is cleared its surface is levelled with a layer of sand or soil until the required height is reached.
The setting out can be done by driving a post into the ground at the centre point of the tank site and describing a circle, while marking the ground with pegs at approx. 1 meter core to core.



LEVELLING TOOL

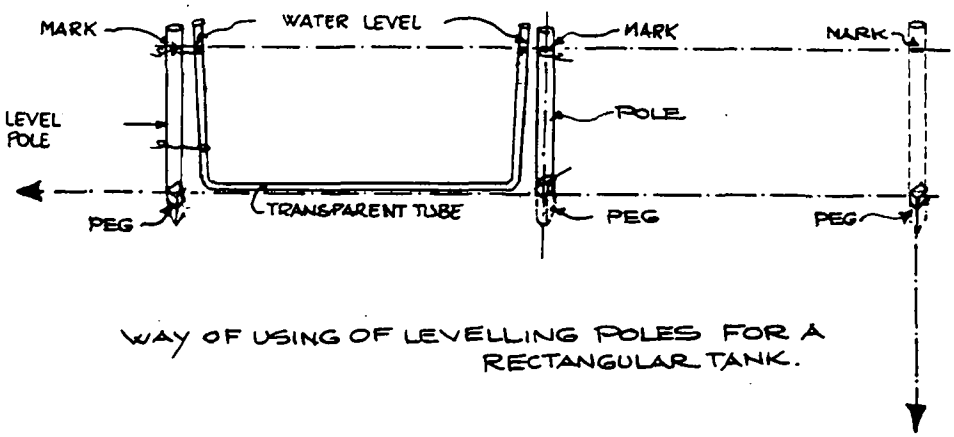
Levelling can be done by means of a levelling tool. Put one pole of the levelling tool on top of the centre peg and the other pole on a peg on the circumference. Hammer the peg on the circumference till the water level in the tube is at the desired mark. Repeat this for all pegs on the circumference.
See figure.



WAY OF USING OF LEVELLING POLES FOR A CYLINDRICAL TANK

The setting out for rectangular tanks (see chapter 4.2.) can be done by putting one pole of the levelling tool on top of a peg on the edge and the other pole on the next peg on the edge. Repeat this for all pegs on the rectangle.

See figure next page.

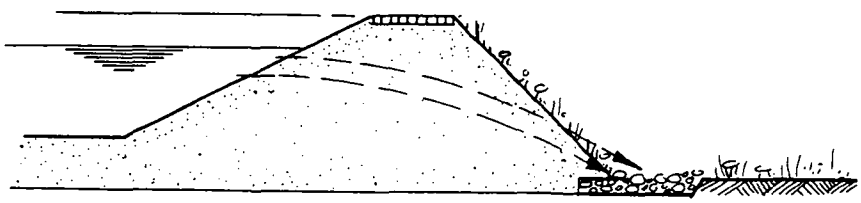


WAY OF USING OF LEVELLING POLES FOR A RECTANGULAR TANK.

The levelling tool can be made very easily with about 15 m of transparent plastic tube.
This tube is fixed with some binding wire to two wooden poles - one on each side of the tube - of equal length (about 1.5 m).
Fill the tube with water to about 0.15 m from the top. Mind that no air is enclosed in the tube filled with water. Stand the poles vertically next to each other on a flat surface and make a mark on the poles at the water levels. Then the levelling tool is ready for use.

- Preparation of foundations

On some sites (see chapter 3.2.) the base of the tank has to be constructed about 0.5 m above ground level.
The earth fill required has to be executed in maximum layer thicknesses of 0.2 m to 0.3 m. These layers need to be compacted by ramming and possibly water sprinkling, if sand is used. If the fill material used is clay, this must be crumbled, compacted and remolded. Oxen can be used for this work. Using sand for bund fill a toefilter at the outside toe of the bund is necessary to catch the seepage and prevent instability of the bund (see figure). For filter material one can use locally available gravel.



A TOEFILTER FILLED WITH STONES TO CATCH THE SEEPAGE AND TO PREVENT INSTABILITY.

- Bunds

  The bunds forming the walls of the tank have to be constructed by heaping up soil. Water must be added to each layer of sandy soil (0,2 m thick) after which it should be compacted with tampers (own manufacture). Clay should be compacted by treading with bullocks, sheep or human feet, untill the heights, sizes and slopes as indicated on the drawings have been reached.
  After finishing the bunds and the base the surface has to be dug and trimmed to shape.
  Stones, roots and other large objects should be removed.
  It is advisable in general to cover the outside of the bunds with rockfill to prevent erosion. Do not use vegetation, it may puncture the sheet if used.

- Crowns of the bunds

  The crown of the bund should be about 1.00 m wide (from the point of view of stability, easy reach and maintenance) and consist of a thin layer of sand, paved with bricks or rockfill.
  To prevent the crown being washed away if the tank overflows, a PVC or concrete overflow has to be made (for detail see type VII details and dimensions).

- Construction

  Tanks and the impermeable layers are constructed differently for each type. For more information it is advisable to read the work sequences for the various types.

- Maintenance

  Maintenance is very important for these newly constructed water tanks. The maintenance should consist of regulary checking of the tank wall and base for erosion.
  If necessary the wall should be repaired immediately.

3.7. Fencing

Before starting the works it is advisable to fence the whole site adequately because goats or other cattle can be a tremendous nuisance around the area and damage the storage tank or even drown in the water. Especially goats find polythene extremely appetising, in addition to which they may pierce it with their sharp hoofs.

4. MATERIALS

4.1. General

In general the choice to be made between the materials described in the manual depends on local availability.
The bills of quantities are not given completed with prices because these may differ from place to place/country to country.
Plastic sheeting materials such as polythene and polyvinyl chloride (PVC) are not manufactured in all countries, but it may be possible to obtain it locally or to import it in large quantities, if a substantial number of storage tanks is to be constructed.

Transport costs of plastic sheeting materials are low because this material has a rather small volume.

4.2. Sheets

- Polythene

  Polythene sheeting is flexible. During its manufacture a black pigment is added to combat rapid degradation on exposure to light.
  Chlorosulfonated polythene has a better resistance to degradation by light.
  Polythene is not termite-proof. However, if it is used on the base of the tank in the form of a blanket of two layers with a layer of mud between them, any holes made in the polythene layers, by termites will be sealed by the mud between the layers.
  This mud will also seal the joints between two parts of polythene sheeting provided the overlap is at least 1.50 m.
  If polythene is used on the inside of the tank, the tankbase and its slopes must be smooth and the polythene sheeting must be covered as soon as possible to prevent degradation of the liner.
  It does not matter if polythene tubing that forms the skin of the sand/cement sausages (described in type VII) is exposed to sunlight and damaged because this tubing is only needed to act as a watertight form of shuttering for the first four weeks.
  Polythene is the cheapest prefabricated sheet material and is available in thicknesses between 0.025 mm and 0.25 mm.
  Whether it is economical to use polythene sheetings often depends on the maximum width of sheeting available.
  The rolls are available in widths of:
  12.00 m in the USA and
  7.50 m in the UK.

- PVC

  PVC (Poly Vinyl Chloride) is not naturally flexible and plasticisers are incorporated to give the sheet flexibility.
  The properties of the plasticisers used in a particular type of PVC sheeting should be checked to see that they are conform the health requirements before the sheet is adopted for use in irrigation water storage tanks.

PVC is not termite-proof and also has only a short life when it is exposed to light; therefore it is generally used in water storage tanks as a burried membrane.
PVC is easier to join than polythene. PVC can be heat joined by means of a flat or soldering iron with an overlap of about 0.20 m and cold joined with glue-cement.
PVC is more resistant to puneture and can be repaired more easily than polythene.
The subgrade which should be compacted and structurally stable must be sterilized (see 4.5.) before installation of PCV lining. The PVC then must be covered as soon as possible to prevent degradation.
PVC is available in thicknesses between 0.25 mm and 0.80 mm. Rolls with widths of upto 20.00 m are available (USA) and in any lenght that is suitable for handling.
For economical reasons a rectangular tank is preferred by using PVC or Polythene sheeting.

4.3. Bentonite

Bentonite is a naturally occurring clay, which contains a high proportion of the mineral sodium montmorillonite. Depending on its exact make up bentonite will expand to between ten and fifteen times its dry volume when fully saturated. So it will crack extensively when it dries out.

To prevent drying out the bentonite layer can be covered by a layer of sand mixed with a small amount of bentonite (10 : 1). The layer itself is a mixture of sand with 25% bentonite. A thickness of 20 cm will give a good watertightness.
Bentonite should not be used on calcareous soils. The calcium carbonate reacts with the sodium montmorillonite and this results in calcium montmorillonite, which does not posess the swelling properties of sodium montmorillonite.
Bentonite in granular form can be added to the water in a storage tank (sprinkling) that is known to be leaking through cracks or seams. The bentonite may be drawn into them and seal them as it swells.

4.4. Chemicals

Chemical treatment of permeable soil is only possible for soils which won't crack on drying out. In § 3.4. the different kinds of chemical treatments are given. The chemicals must be used as a lining.
With sodium methyl silanolite the most effective chemical treatment, which produces hydrophobic soil, is given. A 30% solution at a rate of 500 lb of this chemical per acre will produce a 0.01 m (0,4 inch) thick layer of hydrophobic soil.
The combination of a solution of aluminium chloride and distilled water has a good resistance against erosion, whereafter a solution in distilled water of potassium stearate was applied. The double application is considered a disadvantage.
The use of sodium polyphosphate needs very skilled labourers. The subsoil must be especially prepared and protected from light.

Sprayable liquid vinyl polymer has excellent properties for stabilising sandy soils. At high concentrations it has been tested for the control of seepage on highly compacted subsoils.

4.5. Bitumen

Bitumen is a product obtained from the distillation of crude oil and has often been used to create waterproof membranes in water storage tanks.
It may be used in combination with a reinforcement like glass fibre or polypropylene.
Generally reinforced bitumen membranes are more durable than unreinforced bitumen membranes.
The subgrade must be thoroughly sterilized to prevent puncture by the growth of vegetation. Diesel fuel at the rate of 4-6 liter per m^2 will be sufficient, but a sterilizer may be harmfull, pollution of groundwater and so on.
Before applying the bitumen the subgrade must be compacted to achieve structural stability. Especially when bitumen is locally available, a cheap method is spraying of the bitumen membrane.
A hot bitumen (350-400 degrees F) can be applied to the wetted subgrade by pouring it with cans untill a membrane with a thickness of 0.06 m has been achieved.
Pouring is started at the base of the storage tank and is continued up the slope. When the bitumen has hardened it should be inspected for thin areas or holes which can be locally patched.
The sand or gravel covering layer should be placed as soon as the bitumen membrane has been completed and should be lightly rolled into the surface.
To prevent damage to the bitumen membrane the covering layer should not be pushed down the slope or allowed to slide down.
Prefabricated bitumen rolls and panels as waterproof linings for water storage tanks are also available.

4.6. Brickwork/concrete

The bricks must be of good quality in order to obtain a watertight structure. Prior to laying, the bricks must be moistened with water. To prevent cracking caused by shrinkage and high temperatures the layer should be moistened during the first four weeks or protected by means of a cover (plastic foil).
The cement to be used in the mortar should be an ordinary Portland cement (in accordance with BS 12 or similar specification). In the case of aggressive soil due to a high salinity, Portland cement 5 or blast furnace cement must be used.
Lower strength cements are not recommendable. The cement must be stored in a dry place.
The first requirement for sand is that it should be free from organic and chemical impurities which may weaken the mortar.
A coarse silica sand is probably the best for the purpose. The use of coarse sand will lessen the workability of the mortar but its resistance to shrinkage will be greater than that of a mortar made with fine sand.

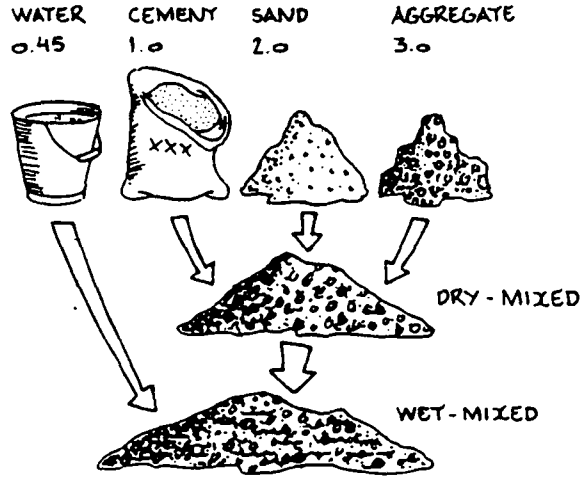
The water must be clean and free from acid chemicals, salt and organic matters.
Salt water should never be used.
Mortars for brickwork are a mixture of cement, sand and water, each ingredient having the correct proportion. For a maximum brickwork resistance to water pressure the following cement mortar mixes are advisable:

a. 1 volume part of Portland cement
   2 volume parts of sand (fine aggregate)

b. 1 volume part of Portland cement
   2,5 volume parts of sand (fine aggregate)

c. 1 volume part of strong hydraulic powder-lime
   0,25 volume part of Portland cement
   2,5 volume parts of sand (fine aggregate)

A mortar for concrete is a mixture of cement, sand, aggregate and water, each ingredient having the correct proportion.
A general mix is:



1 volume part of Portland cement
2 volume parts of sand
3 volume parts of aggregate
0.45 weight parts of water

If bricks of a somewhat lower quality are used, the quality of the mortar should also be lower (for instance 1 : 4½) in order to prevent shrinkage differences between the brickwork and mortar. However, it should not be forgotten that any such reduction in quality may result in a less watertight structure.
The mortar must be thoroughly mixed and workable although one should remember that a dry mortar is stronger than a wet one.
In any event the weight ratio of water to cement must not exceed 0.5 : 1.
The Portland cement should be fresh. Old and/or wet bags with Portland cement are to be removed.

Where tests can be carried out they should be in accordance with the codes locally applicable. The aggregate (sand) should be free from vegetable soil and black soil.

5. TESTING

5.1. Introduction

If possible it is recommended that the materials to be used and the subsoil should be tested on site. This chapter gives some guidelines for testing of available soil.

5.2. Simple field identification tests for soil

Preliminary

- Look at the whole sample
- Is it mainly a coarse or fine soil?
- Are there any fibres or roots?
- Is it dull or dirty?

a. Appearance

If the soil is fibrous or dirty in appearance, test for organic material.

b. Feel

Sands and gravel feel coarse and gritty. Silts and clay are hard or floury when dry and soft or sticky when wet. Clay when wet will stain the fingers and can only be removed by washing.

c. Composition

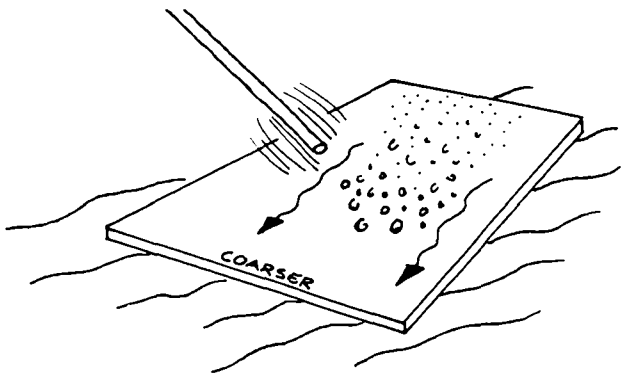
Estimate how much of each fraction is in sandy soil and separate coarse from fine material by hand.

d. Organic (smell) test

Take a sample of the soil and smell it. If it has an earthy or vegetable smell it is probably organic. Warm the sample and the odour will become distinct.

Vibration test

(For particle size distribution). Place a dry sample on a board. Hold the board at a slope and tap lightly with a stick. The finer material will move up the slope or remain in place, the coarser will move down the slope.



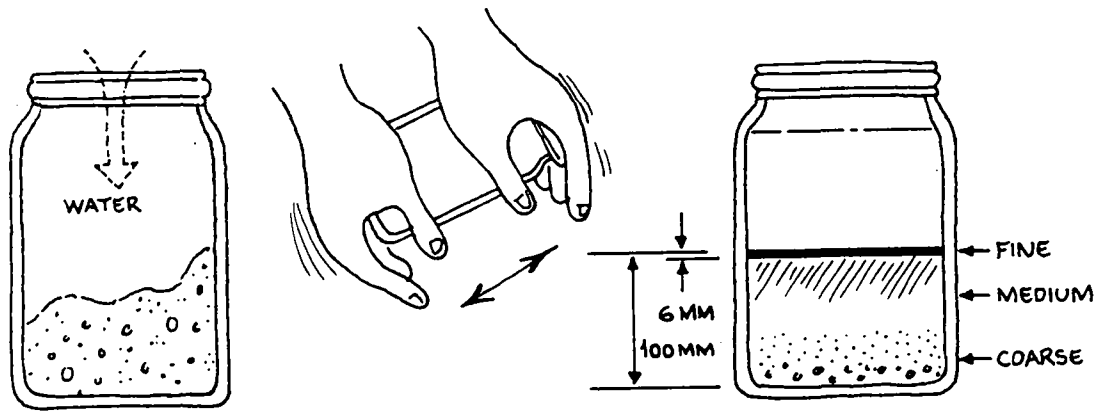
If there are many different sizes between the largest and the smallest, the sample is well-graded. This means it will compact well. If only a few sizes can be seen, then it is single-sized or poorly graded.

Settling test

This test can also be used to determine the amount of soil (dirt) in river sand used for masonry or concrete work.

Place a sample of sand in a bottle or a glass jar with straight sides. Add water and shake well. Then put it down to allow the mixture to settle. Gravel and coarse sand will settle immediately. Fine sand and coarse silt will settle more slowly taking about 30 seconds. Clay and fine silt fractions will not settle for several hours.

In the sample, the approximate quantities of each size can be seen as layers, the finer materials being different in colour. For sand which is used for masonry and concrete work, the amount of clay and silt must be less than 6%, otherwise the sand has to be washed.



Cohesion test

(To show whether there is sufficient building material in the soil).

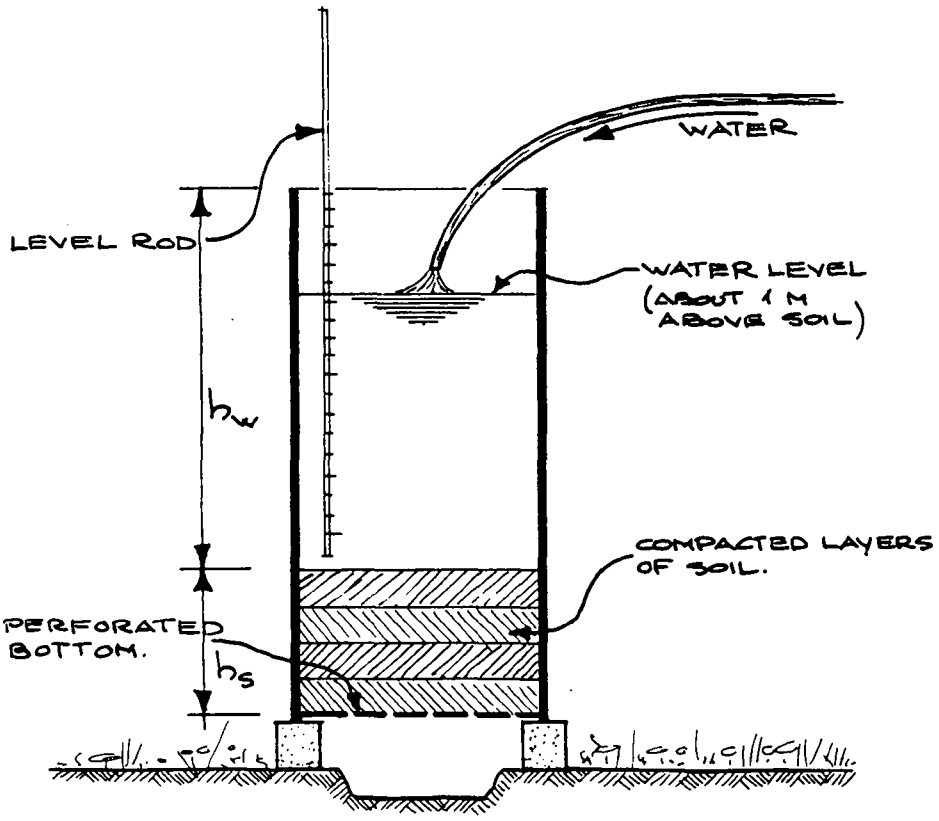
Take a handfull of damp material and mould it into a ball.

a. With gravels the material will not stick together unless there are fine materials present.
b. With sands the damp material will stick together, but if no fine materials are present it will crumble at a touch.
c. If the ball stays together, even when placed on a sheet of paper, silts or clays are present, which means the material is suitable for bunds (see § 3.3.).

Permeability test

This test can give an impression of the permeability of a clay soil compacted in a standard way. Take a large barrel (e.g. an oil drum), perforate the bottom, and stand the barrel on some kind of frame, free of the ground. Place the soil in small layers in the barrel and compact it layer after layer. Try to imitate the future situation (fill to about 0.5 m). After compaction fill the rest of the barrel with water (upto e.g. 1 m).
The water level must not decrease more than 10% per day.
If the water level does decrease more than 10% per day, it means that in practice the soil layer will have to be thicker, or that another type of soil must be used for the bunds.
If only smaller barrels are available the decrease of the water level can be lower, f.i. a water layer of 0.8 m and a soil layer of 0.4 m requires a decrease of water level of about 7%.
In general:

- $v \leq 0.033 \times i$ in which
- v = decrease of waterlevel in %
- i = hydraulic gradient = $\frac{hw}{hs} = \frac{\text{water level}}{\text{soil thickness}}$ so
- $v \leq 0.033 \times \frac{0.8}{0.4} = 0.067$ m/day
- i.e. about 7%



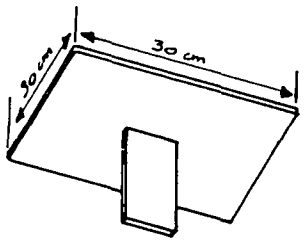
PERMEABILITY TEST
WITH AN OIL DRUM.

6. TOOLS

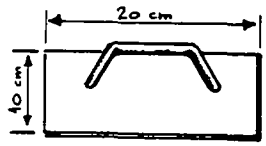
Excavation marking out tools	- wheelbarrow - buckets - post - pegs - tape (measure) - 2 kg string line - shovels - pickaxes for excavation - mattocks for groundlevelling - woodsaw - spirit level - plumbline, measuring tape
Tools to compact	- tampers (selfmade) - oxen/bullocks
Tools for driving piles	- heavy hammer or - drop weight with driving leads and pulley
Tools for the frame work	- pins or wire - ladder - hammer - planks and stakes

Where needed tools to spray the bitumen.
A roller to roll the sand into the bitumen.

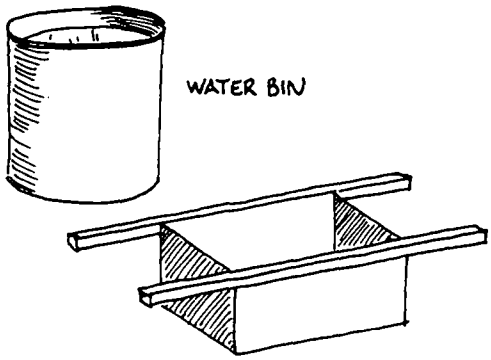
Tools for the sand-cement sausages type (VII)	- filling tool - perforating tools - flat board (wood)
Mixing mortar tools	- plastic sheeting - mixing box 70 x 120 x 35 cm - gauging/measuring box 50 x 50 x 40 cm - sieve 5 mm maximum openings for sand - shovel for mixing - water container/bins - concrete mixer
Tools for placing the mortar mix	- plasterers steel hand floats - hand hawks - trowelling boards - wire brush - chisels
Tools for finishing	- plastic sheeting for curing the mortar



WOODEN MORTAR HOLDER
(HAWK)



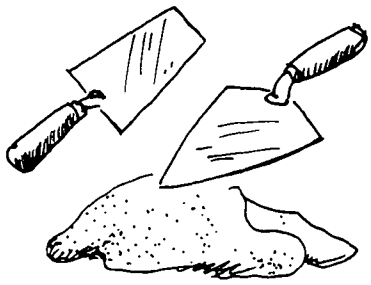
FLOAT



WATER BIN

MEASURING BOX 50 x 50 x 40 cm

PLASTERERS STEEL HAND



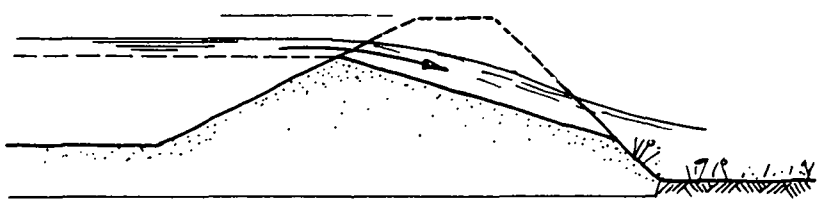
7. STABILITY CONDITIONS

7.1. General aspects

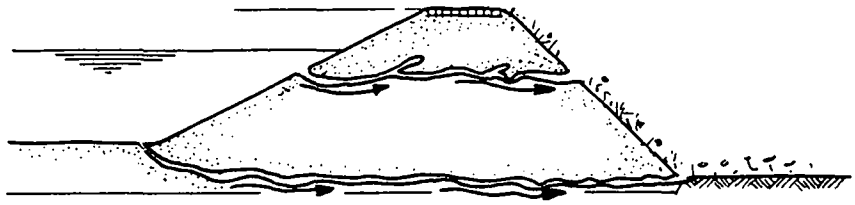
There are two kinds of stability: macrostability i.e. the stability of a mass of earth along a plane of sliding and microstability i.e. the stability of the small soil particles under the slope line.
The size of the designed bunds make extensive calculations of the macrostability unnecessary. Under normal circumstances, macrostability will be ensured, if inclines of slope for clay are less than 45° and for sand less than 38°.
The microstability may be affected by seepage because of an even small permeability of a sand bund. For these bunds a toefilter can be a solution see § 3.6.).
The microstability of the outside slope can also be improved by a layer of rockfill or clay with vegetation.
Seepage might cause transportation of small soil particles and piping (see figure). This will disturb the stability.

7.2. Causes of failure

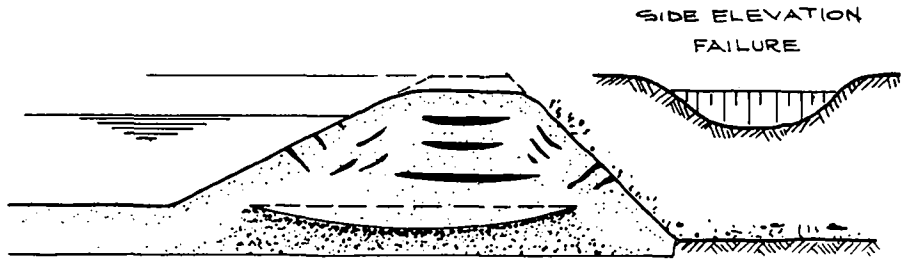
From the engineering point of view, there are a number of reasons, why failures occur. Experience has shown that these causes can be divided into five categories:
1. Site conditions not investigated
2. Errors in design
3. Poor construction
4. Inadequate maintenance
5. Statistically remote phenomena (extreme rainfall, tornado, earthquakes)



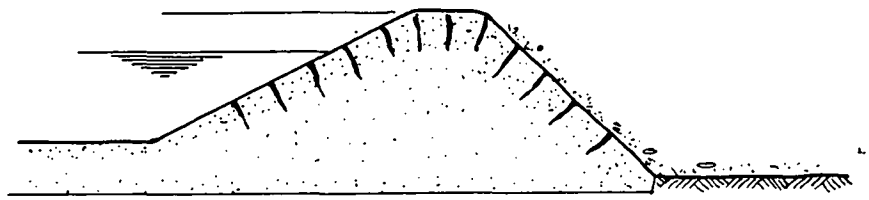
OVERTOPPING - WASHING OUT EMBANKMENT



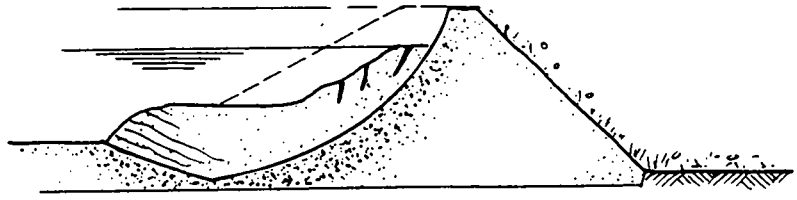
SEEPAGE EROSION OR PIPING THROUGH
THE DAM AND/OR ITS FOUNDATION



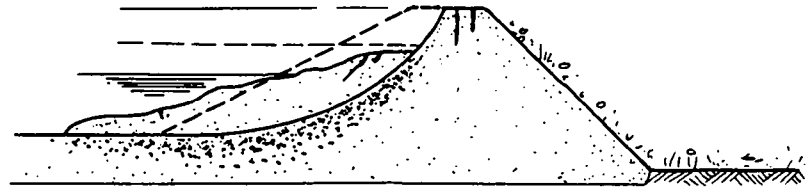
CRACKING OF THE DAM/BUND
DUE TO FOUNDATION SETTLEMENT



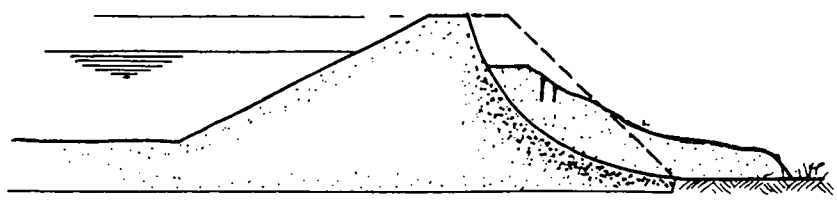
CRACKING OF DAM DUE TO
DESICCATION AND SHRINKAGE



SLIDE DUE TO WEAK FOUNDATION



UPSTREAM SLIDE DUE TO
SUDDEN DRAWDOWN OF TANK/RESERVOIR



DOWNSTREAM SLIDE DUE
TO WEAK EMBANKMENT

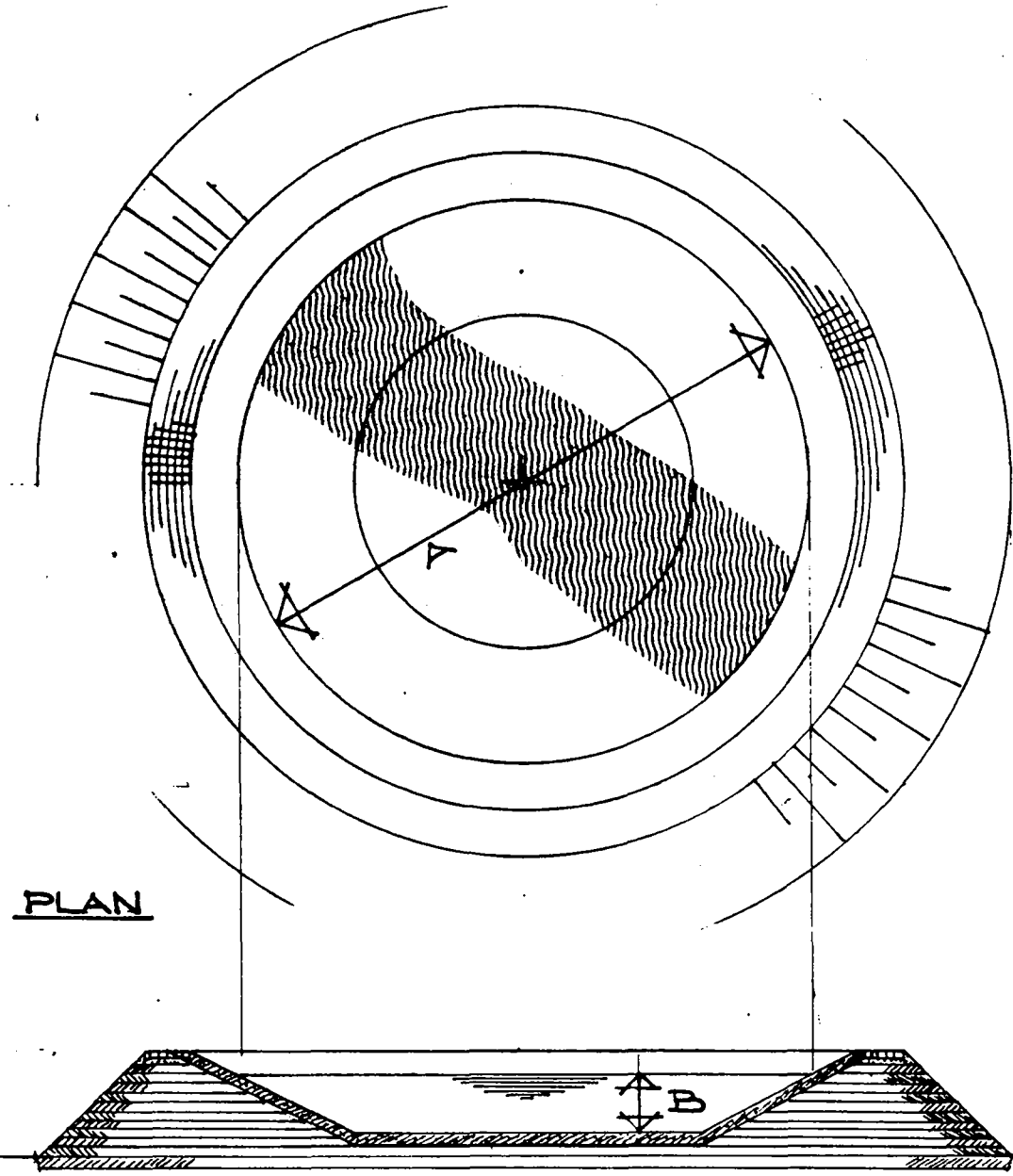
FLOW SLIDE IN LOOSE
FINE SAND OR SILT

Particulary in our case for the narrow type of bunds the horizontal equilibrium must be ensured.
An example of a check calculation of the coffer dam type is given in the next paragraph.

8. TYPES OF TANKS

8.1. Type I: Clay bund

Short description:
A bund simply build up from clay, in small layers on an impermeable subsoil.



PLAN

SECTION

capacity m^3	A m	B m
30	8,00	1,25
60	10,30	1,25
90	12,00	1,25
150	14,90	1,25

TYPE I CLAY BUND

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

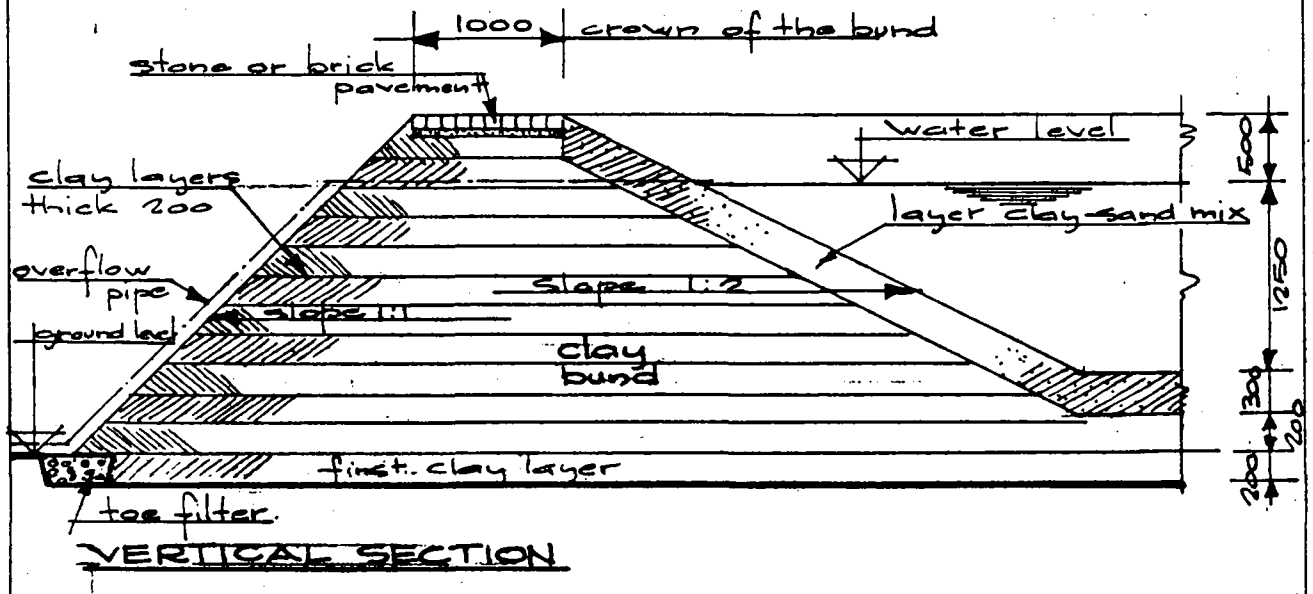
EARTH BUND CONSTRUCTION

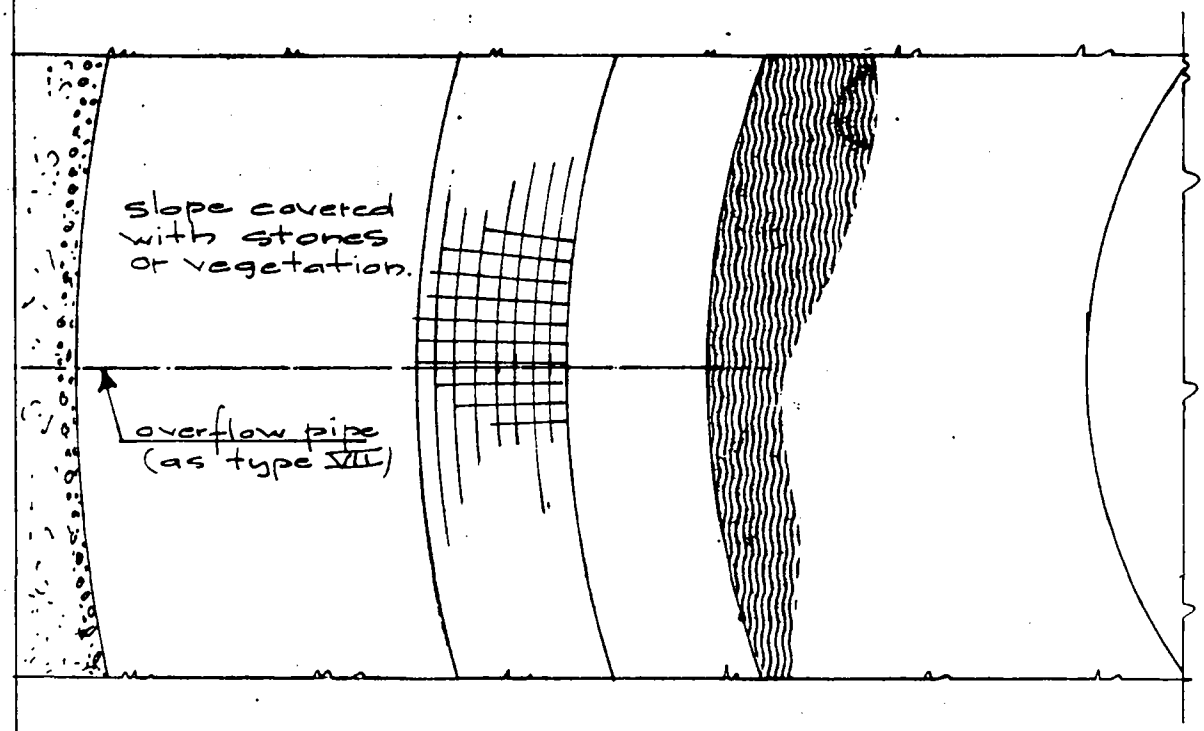
TYPE I GENERAL LAY OUT

SWD

measures in mm
date 820921

TWO

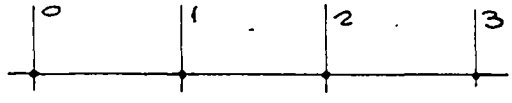




TOP VIEW (PART OF THE BUND)

TYPE I CLAY BUND

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH - TWO - AMERSFOORT



IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE I

DETAILS AND DIMENSIONS

SWD

measures in mm

date 820921

TWO

work sequence and description	notes and recommendations
- cover the inside of the bund-side and the base with a layer of a clay-sand mixture of about 0.30 m thick to prevent the clay from drying out	
- cover the outside of the bund with rockfill or vegetation to prevent erosion	- this side of the bund must have a steep slope to prevent cattle from approaching the water
- cover the crown of the bund (being about 1.00 m of wide) with a 0.15 m sand layer paved over with bricks or rockfill	
- make a toefilter as described on page 11	

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	43		
layer	m^3			
(clay/mud)	m^3			
refill with clay	m^3	43		
bund	m^3	260		
clay (base)	m^3	3		
clay-sand mix	m^3	30		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement 21x10x8)	piece	1700		
plaster sand	m^3			
plaster cement	bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope covering				
- stones	m^2	143		
- grass				
- seed				
fencing	m^2	68		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE I
capacity 30 m^3

TYPE I
BILL OF QUANTITIES

date 021005

TWO DHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	56		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	56		
bund	m^3	325		
clay (base)	m^3	13		
clay-sand mix	m^3	42		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3			
bricks pavement (21x10x8)	piece	2000.		
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope covering				
- stones	m^2	165		
- grass				
- seed				
fencing	m^2	75		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH - TWO - AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE I
capacity 60 m^3

TYPE I
BILL OF QUANTITIES

date 821005

TWO DHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	66		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	66		
bund	m^3	370		
clay (base)	m^3	24		
clay-sand mix	m^3	54		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement 21x10x8)	piece	2300		
plaster (sand / cement)	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope covering				
= stones				
= grass	m^2	192		
= seed				
fencing	m^2	80		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE I
capacity 90 m^3

TYPE I
BILL OF QUANTITIES

date 821005

TWO

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	86		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	86		
bund	m^3	450		
clay base	m^3	52		
clay-sand mix	m^3	80		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement 21x10x8)	piece	2700		
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope-covering				
- stones				
- grass	m^2	212		
- seed				
fencing	m^2	90		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE I
capacity 150 m^3

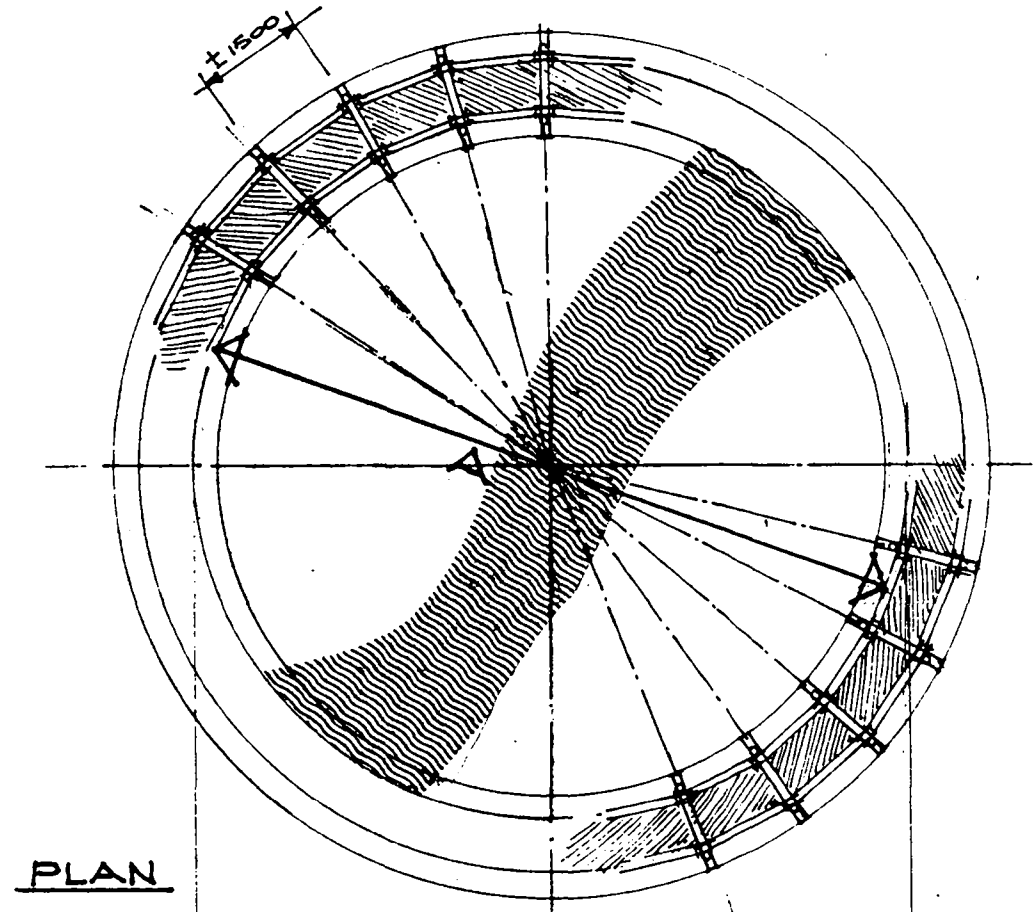
TYPE I
BILL OF QUANTITIES

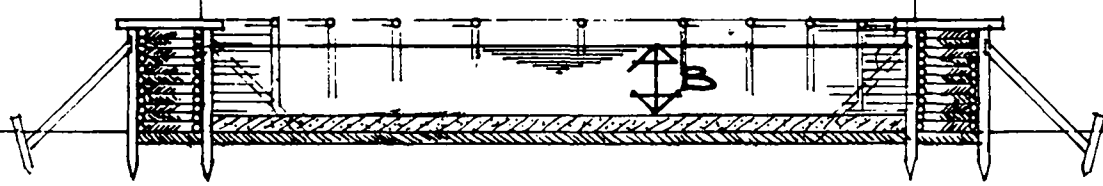
date 821005

TWO DHV

8.2. Type II: Coffer dam

Short description:
A dam of clay-layers between wooden stakes with a impermeable clay base.





capacity m³	A m	B m
30	5,60	1,25
60	7,90	1,25
90	9,60	1,25
150	12,40	1,25

TYPE II COFFER DAM

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

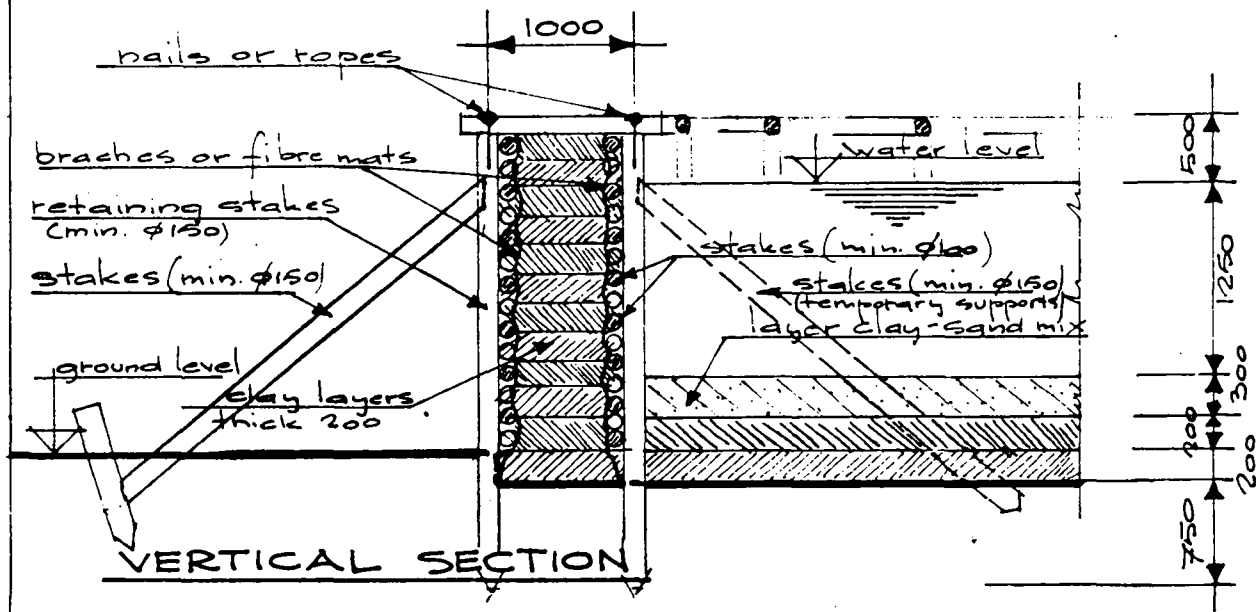
EARTH BUND CONSTRUCTION

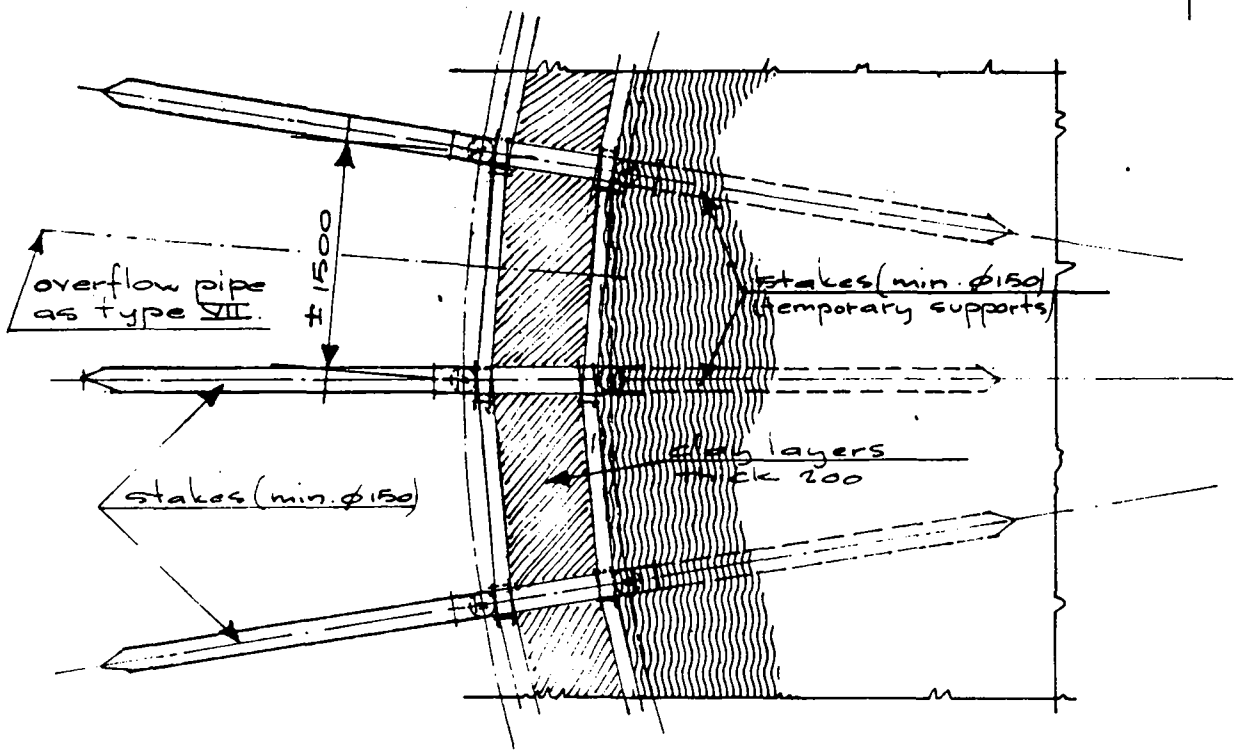
TYPE II GENERAL LAY OUT

SWD

measures in mm
date 820921

TWO DHV





TYPE II COFFER DAM

THIS DESIGN WAS REALIZED UNDER AUSPICES OF THE STEERING COMMITTEE FOR NATURAL DEVELOPING COUNTRIES - SWD - AT BOUWCENTRUM AMERSFOORT IN THE NETHERLANDS IN COOPERATION WITH SWD AMERSFOORT

0 1 2 3

Scale in meters.

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

SWD

EARTH BUND CONSTRUCTION

TYPE II

DETAILS AND DIMENSIONS TWO

820921

work sequence and description	notes and recommendations
- fill the coffer dam and build up the tank base in layers of max. 0.20 m crumbled clay	
- also these layers are to be compacted with tampers and/or by letting sheep and/or oxen walk over them	- the soil can also be improved if it is not of the necessary quality (see page 9)
- insert a PVC or concrete overflow in the coffer dam at the height of the highest water level	- this overflow pipe is to prevent the top of the coffer dam being eroded by spillover
- connect the overflow pipe with an irrigation channel	
- control the height of the coffer dam by a jungle-stick marked at the height of the dam) on the already hammered pegs	
- cover the base with a layer of a clay-sand mixture of about 0.30 m thick to prevent the clay from drying out	
- cover the crown of the coffer dam with a 0.15 m sand layer paved over with bricks or rockfill	

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	9		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	9		
clay (dam)	m^3	50		
clay (base)	m^3	5		
clay-sand-mix	m^3	7		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
stakes (ϕ150)	m^1	360		
stakes (ϕ100)	m^1	530		
wood preservative	m^3			
nails				
ropes	m^1	50		
fibre mats	m^2	110		
stones	m^3			
bricks	piece			
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	9		
cover-dam				
- stones	m^2	20		
- grass				
- seed				
fencing	m^2	46		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE II
capacity 30 m^3

TYPE II
BILL OF QUANTITIES

date 821005

TWO

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	15		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	15		
clay (dam)	m^3	65		
clay (base)	m^3	10		
clay-sand mix	m^3	15		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
stakes (ø150)	m'	465		
stakes (ø100)	m'	700		
wood preservative	m^3			
nails				
ropes	m'	70		
fibre mats	m^2	145		
stones	m^3			
bricks	piece			
plaster sand	m^3			
plaster cement	bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	9		
cover-dam				
- stones	m^2	28		
- grass				
- seed				
fencing	m^2	53		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE II
BILL OF QUANTITIES

SWD

code 821005

TWO UHV

TYPE II
capacity 60m³

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	21		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	21		
clay (dam)	m^3	75		
clay (base)	m^3	15		
clay-sand mix	m^3	22		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
stakes. (ϕ 150)	m^1	530		
stakes (ϕ 100)	m^1	900		
wood preservative	m^3			
nails				
ropes	m^1	90		
fibre mats	m^2	165		
stones	m^3			
bricks	piece			
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	9		
cover-dam				
- stones				
- grass	m^2	34		
- seed				
fencing	m^2	58		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE II BILL OF QUANTITIES

SWD

date 821005

TWO DHV

TYPE II
capacity 90m³

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	33		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with clay	m^3	33		
clay (dam)	m^3	95		
clay (base)	m^3	25		
clay-sand mix	m^3	36		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
stakes (ø150)	m^1	660		
stakes (ø100)	m^1	990		
wood preservative	m^3			
nails				
ropes	m^1	100		
fibre mats	m^2	205		
stones	m^3			
bricks	piece			
plaster sand	m^3			
plaster cement	bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	9		
cover-dam				
= stones	m^2	42		
= grass				
= seed				
fencing	m^2	67		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH - TWO - AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE II
BILL OF QUANTITIES

SWD

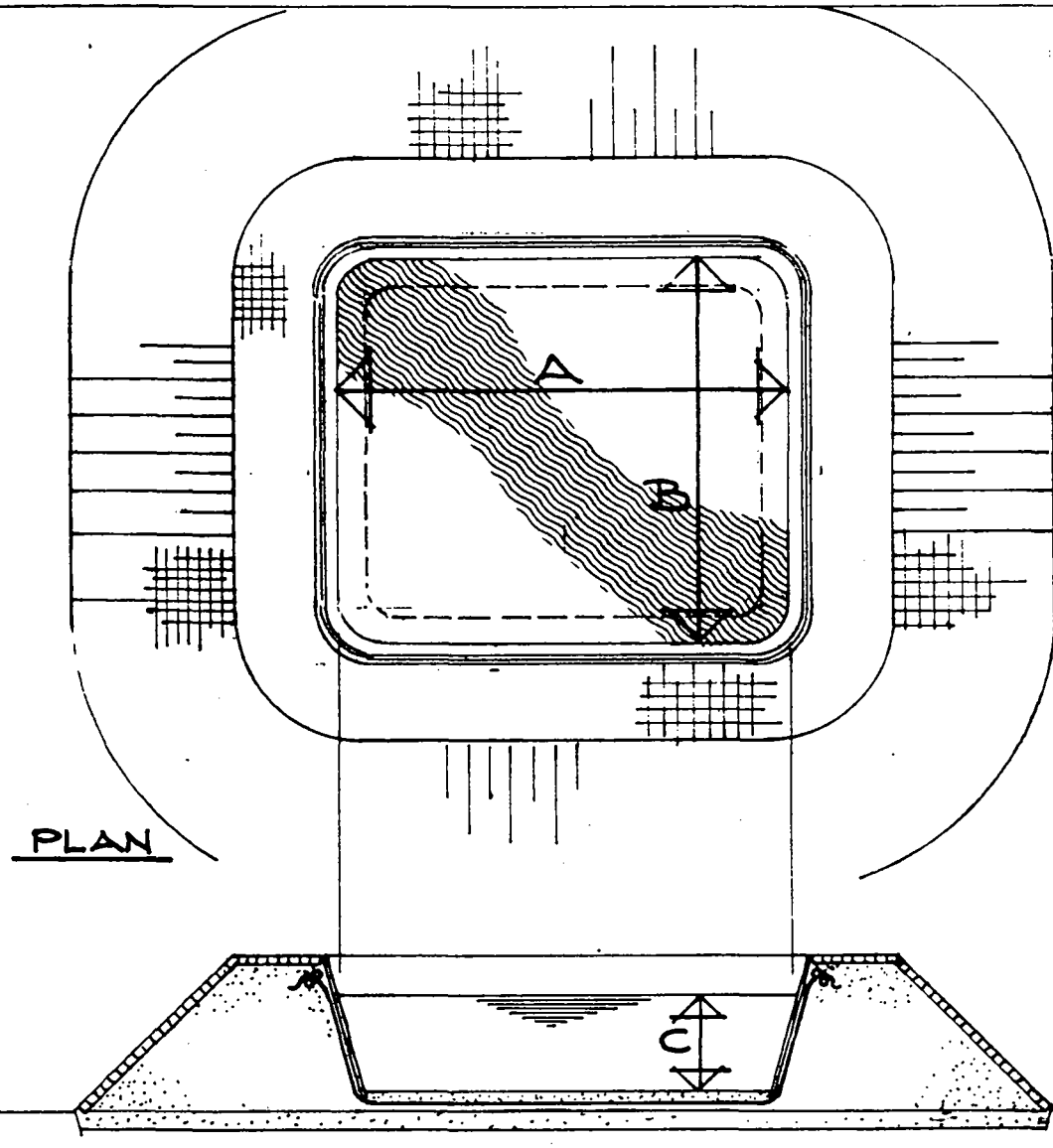
date 821005

TWO

TYPE II
capacity 150 m^3

8.3. Type III: PVC-lining

Short description:
A bund of available soil with a lining of PVC over het base and the inside of the bund wall.



PLAN

SECTION

depends on the width of the sheeting.

capacity m^3	A m	B m	C m
30	6,50	4,50	1.25
60	8,50	6,50	1.25
90	9,50	8,50	1.25
150	12.50	10,50	1.25

TYPE III PVC LINING

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

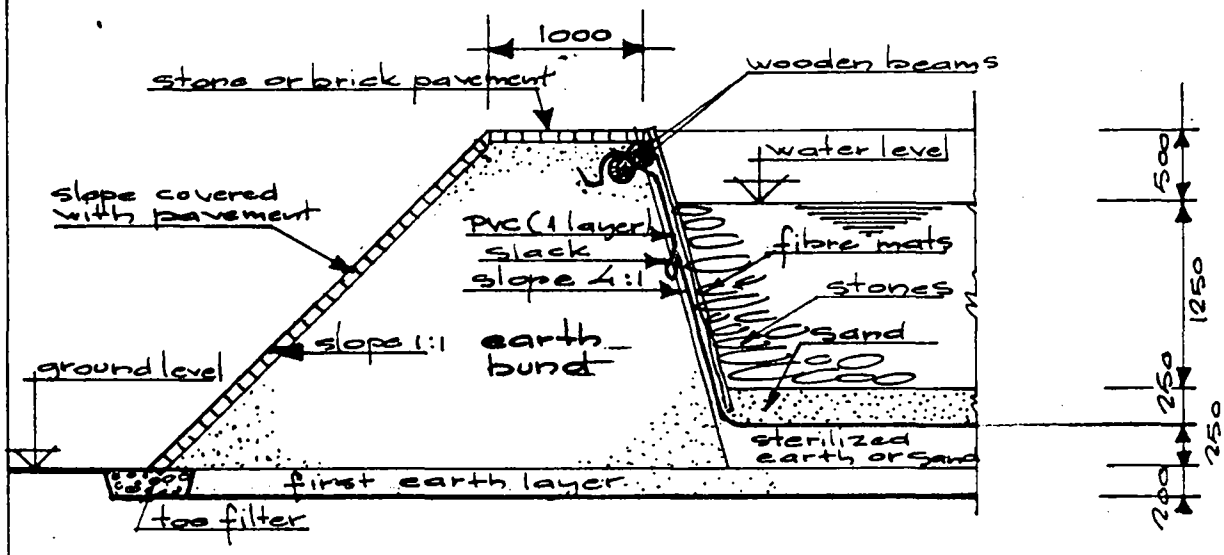
EARTH BUND CONSTRUCTION

TYPE III GENERAL LAY OUT

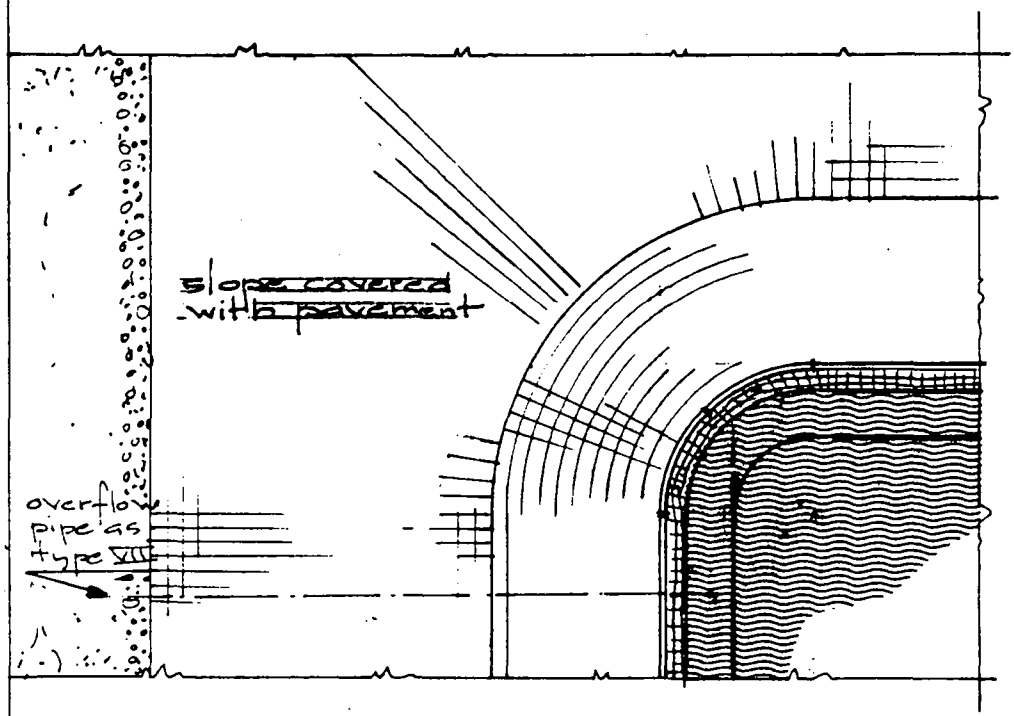
SWD

measures in mm
date 820921

TWO



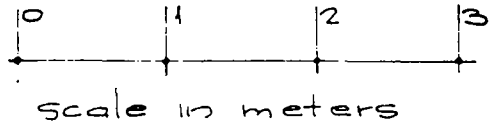
VERTICAL SECTION



TOP VIEW (CORNER OF THE BUND)

TYPE III PVC LINING

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH - TWO - AMERSFOORT



IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

SWD

EARTH BUND CONSTRUCTION

measures in mm
date 920921

TYPE III
DETAILS AND DIMENSIONS

TWO

TYPE III: PVC-lining

work sequence and description	notes and recommendations
- fence the area of the site	- cattle can be a hindrance and would damage the bund construction
- clear the area of the site where it is proposed to construct the tank	- test the quality of the local subsoil (see page 17)
- remove a layer of approx. 0.20 m of the top soil	- to avoid settlements and under seepage under the earth bund
- fill with a layer of soil of approx. 0.20 m	
- the fill is to be compacted with tampers (self made) and/or by letting oxen walk over it	- tools are described in this manual (see page 21)
- if necessary the surface is to be levelled	
- mark the inner and outer circumference of the bund with pegs (pegs core to core 1 meter)	
- setting out can be done by putting down the levelling tool on the top of each peg	- for more information about levelling and the levelling tool see page10)
- hammer the peg till the water level in the tube reached the desired marks	
- build up the earth bund and the tank base in layers of 0,20 m	
- these layers are also be compacted with tampers and/or by letting oxen walk over them	- the base of the tank has to be constructed 0.50 m above ground level to allow gravitational flow
- insert a PVC or concrete overflow in the bund at the height of the highest water level	- this overflow pipe is to prevent the top of the bund being eroded by spillover
- connect the overflow pipe with an irrigation channel	
- the groundwork is completed when the outlines and slopes have reached the height, dimensions and gradients indicated on the drawings	- depending on the kind of soil the slopes may deviate from the drawings
- control the height of the bund by placing a jungle-stick (marked at the height of the bund) on the already hammered pegs.	

work sequence and description	notes and recommendations
- the slope and the base have to be as smooth as possible	- the soil may not contain gravel or other sharp objects because these may damage the plastic sheet
- compact the surface of the soil of the base and the slopes with tampers	
- sterilize the soil with a sterilant for instance diesel fuel	- a layer of soil 0.30 m thick on the base and on the slopes will be sufficient
- place a conserved wooden or bamboo beam at the top of the inside of the bund (see drawing)	- conserving can be done by singeing the surface slightly or saturing the wood with oil
- fold the plastic sheet over this beam and entrench the sheet	- choose a type of plastic sheeting and join the sheet as described in the chapter "materials". Use a sheet with a high resistance to puncture, great flexibility, a high tear resistance and easy to splice and repair - it must be laid with some slack to prevent stresses due to the expansion or contraction of the sheet
- put another conserved wooden or bamboo beam connected with a fibre mat over the plastic sheet to protect this sheet on the inside of the bund wall	
- cover the plastic sheet on the base with a layer of sand of about 0.25 m thick to protect the sheet	
- put stackable stones on the base upto the waterline against the fibre mat on the bund wall to assure the stability; the slope of it depends on the sizes of the stones	
- cover the outside of the bund with rockfill to prevent erosion	- do not use vegetation, it may puncture the sheet

work sequence and description	notes and recommendations
- cover the crown of the bund (being about 1.00 m of wide) with a 0.15 m sand layer paved over with bricks or rockfill - make a toe-filter as described on page 11	

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	31		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	31		
bund	m^3	225		
base (earth)	m^3	5		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2	80		
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
sterilizing oil	m^3	0,4		
stakes (ø 150')	m'	50		
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2	37		
stones	m^3	5		
bricks pavement (21x10x8)	piece	1300		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope-covering				
= stones				
= grass	m^2	130		
= seed				
fencing	m^2	70		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE III BILL OF QUANTITIES

SWD

date 821005

TWO DHV

TYPE III
capacity 30m³

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	41		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	41		
bund	m^3	360		
base (earth)	m^3	11		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2	125		
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
sterilizing oil	m^3	0,6		
stakes (ϕ 150)	m^1	65		
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2	52		
stones	m^3	7,5		
bricks pavement (mixed)	piece	1750		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope-covering				
= stones }	m^2	155		
= grass }				
= seed }				
fencing	m^2	78		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE III BILL OF QUANTITIES

SWD

date 821005

TWO 13HV

TYPE III
capacity 60m³

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	51		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	51		
bund	m^3	490		
base (earth)	m^3	17		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2	165		
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
sterilizing oil	m^3	0,8		
stakes (ø 150)	m'	78		
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2	64		
stones	m^3	9		
bricks (pavement 21x10x8)	piece	2000		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope-covering				
= stones	m^2	175		
= grass				
= seed				
fencing	m^2	84		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH - TWO - AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE III
capacity 90 m^3

TYPE III
BILL OF QUANTITIES

date 821005

TWO ISHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	68		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	68		
bund	m^3	730		
base (earth)	m^2	28		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2	240		
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
sterilizing oil	m^3	1,2		
stakes (ø150)	m'	100		
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2	83		
stones	m^3	11,5		
bricks (pavement / fixing)	piece	2450		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope-covering				
- stones	m^2	210		
- grass				
- seed				
fencing	m^2	94		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE III BILL OF QUANTITIES

SWD

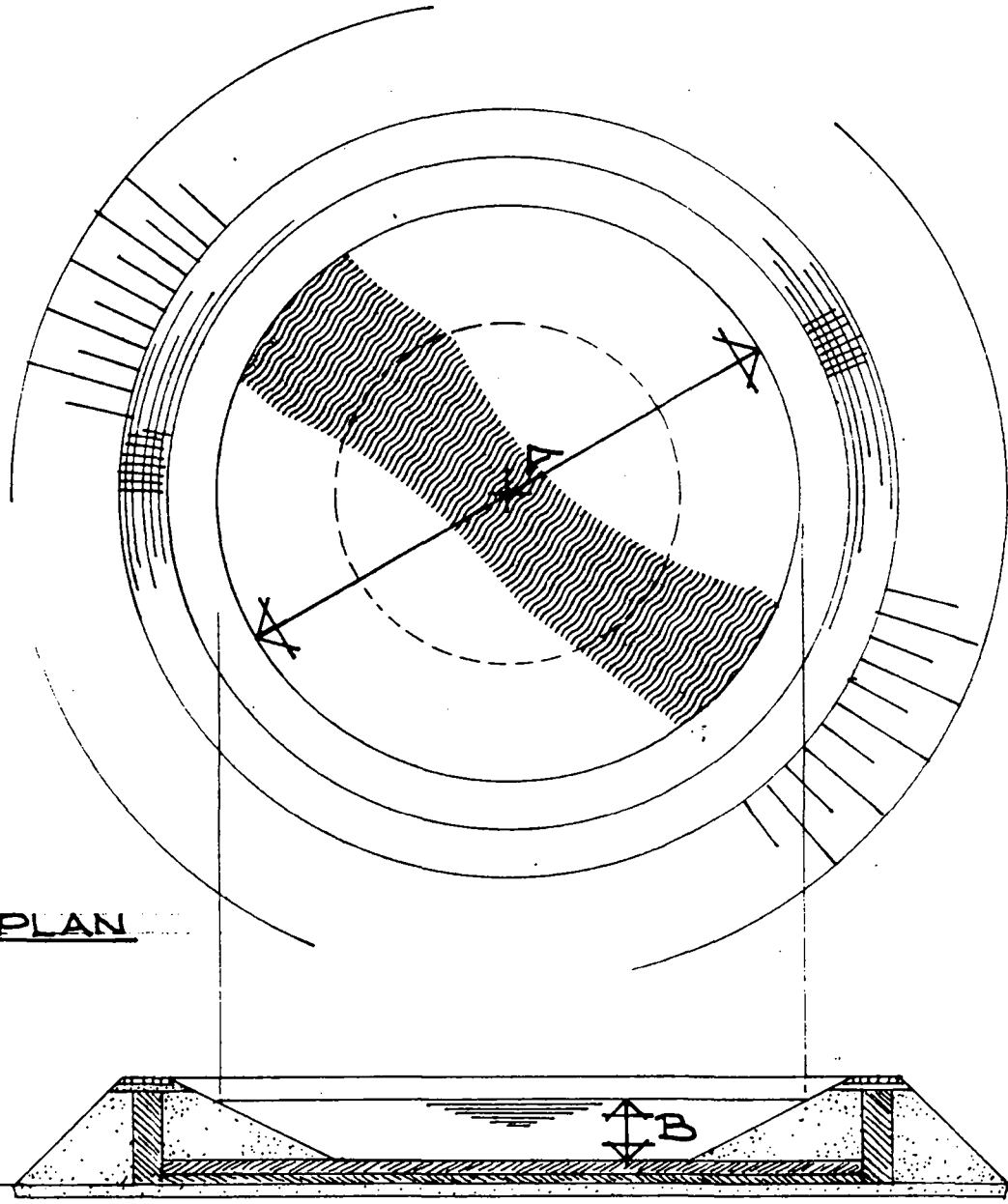
date 821005

TWO DHV

TYPE III capacity 150 m^3

8.4. Type IV: Sand-bentonite lining

Short description:
A bund of available soil with a lining of a sand-bentonite layer over the base and in the bund.



PLAN

SECTION

capacity m^3	A m	B m
30	8,00	1,25
60	10,30	1,25
90	12,00	1,25
150	14,90	1,25

TYPE IV SAND-BENTONITE LINING

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

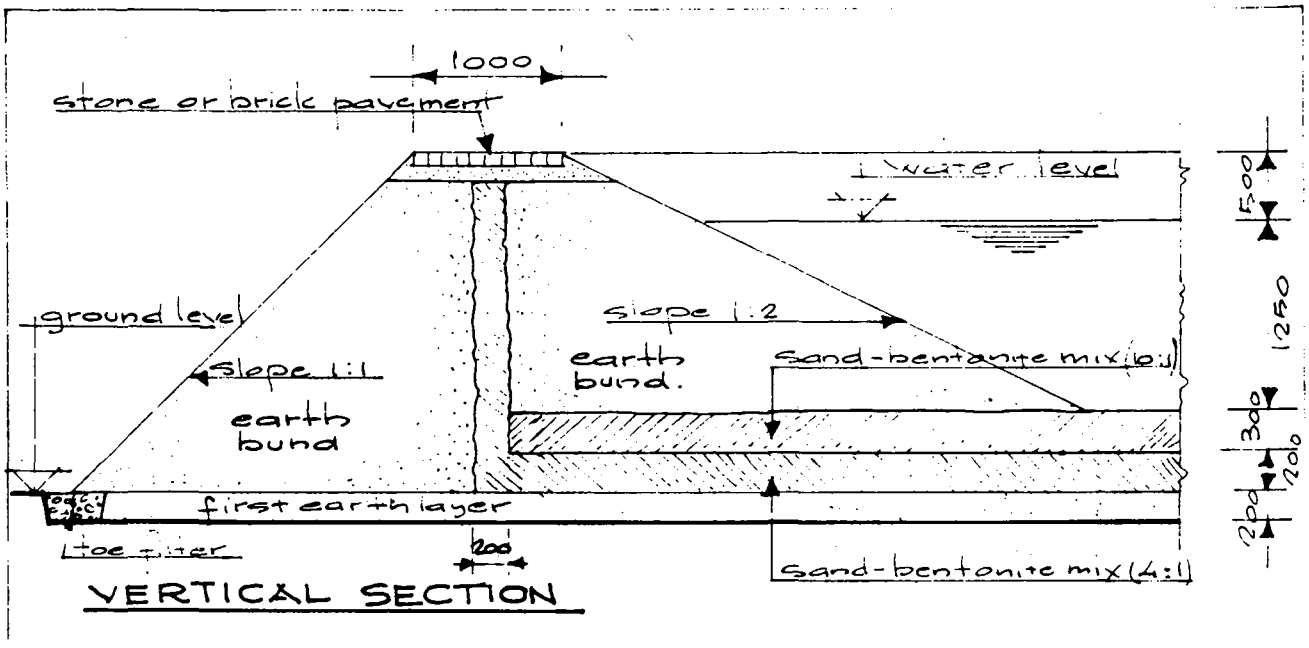
TYPE IV GENERAL LAY OUT

SWD

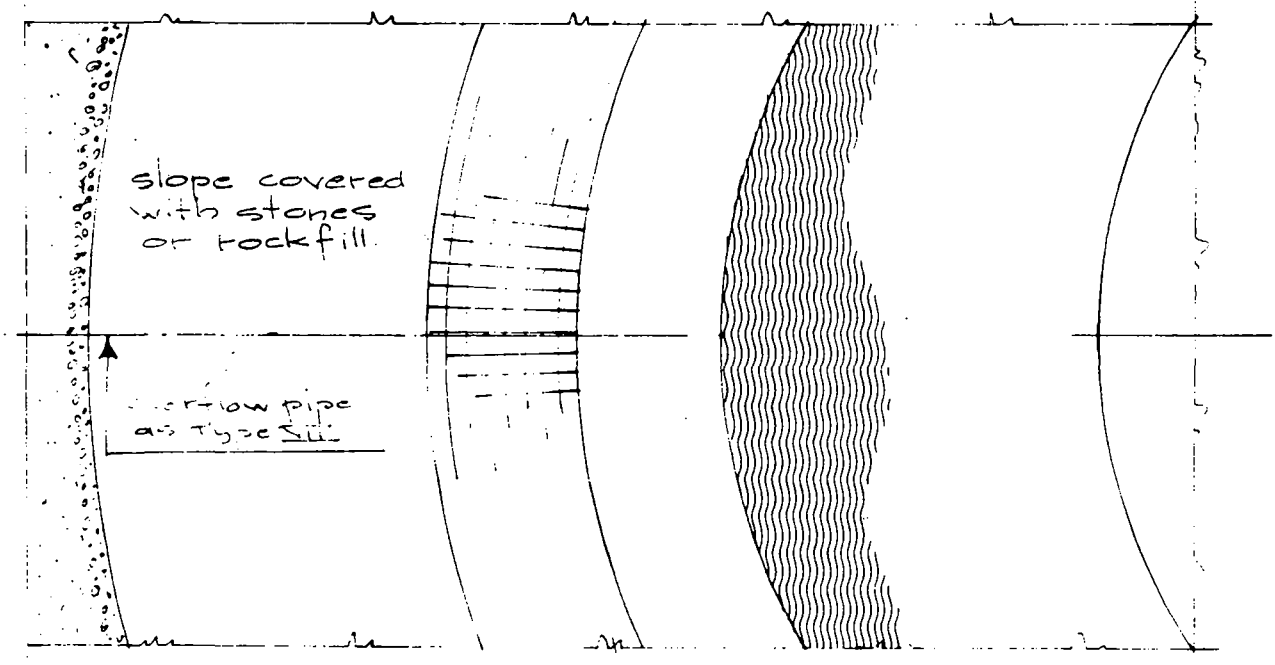
measures in mm

date 820921

TWO



VERTICAL SECTION



TOP VIEW (PART OF THE BUND)

TYPE IV SAND-BENTONITE LINING

0 1 2 3

Scale in meters

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

SWD

EARTH BUND CONSTRUCTION

TYPE IV

DETAILS AND DIMENSIONS TWO

TYPE IV: Sand-bentonite lining

work sequence and description	notes and recommendations
- fence the area of the site	- cattle can be a hindrance and would damage the bund construction
- clear the area of the site where it is proposed to construct the tank	- test the quality of the local subsoil (see page 17)
- remove a layer of approx. 0.20 m of the top soil	- to avoid settlements and seepage under the earth bund
- fill with a layer of clay of approx. 0.20 m	
- the fill is to be compacted with tampers (self made) and/or by letting oxen walk over it	- tools are described in this manual (see page 21)
- *if necessary the surface is to be* levelled	
- mark the inner and outer circumference of the bund with pegs (pegs core to core 1 meter)	
- setting out can be done by putting down the levelling tool on the top of each peg	- for more information about levelling and the levelling tool see page10)
- hammer the peg till the water level in the tube reached the desired marks	
- build up the earth bund in layers of 0.20 m - 0.30 m with (radial) width 0.20 m of sand/bentonite mixture (4:1) as indicated on the drawing	- bentonite can be affected by calcareous soils
- cover the tank base with a 0.20 m layer made up of the same mixture as described above	- try to keep the base wet to prevent shrinkage cracks. The base has to be constructed 0.50 m above groundlevel to allow gravitation flow
- cover the tank base with a following layer (thick 0.30 m) consisting of sand/bentonite mixture of 10 : 1	- a pure bentonite layer may be unstable
- compact these layers with tampers	- bentonite in granular form can be added to water in a storage tank which is known to be leaking though cracks or seams.

work sequence and description	notes and recommendations
	Bentonite may be drawn into the cracks and in swelling may seal them, therefore it is advisable to keep an extra quantity of bentonite apart to be able to repair cracks
- insert a PVC or concrete overflow in the bund at the height of the highest water level - connect the overflow pipe with an irrigation channel	- this overflow pipe is to prevent the top of the bund being eroded by spillover
- the groundwork is completed when the outlines and slopes have reached the height, dimensions and gradients indicated on the drawings - control the height of the bund by placing a jungle-stick (marked at the height of the bund) on the already hammered pegs.	- depending on the kind of soil the slopes may deviate from the drawings
- cover the outside of the bund with rockfill or vegetation to prevent erosion - cover the crown of the bund (being about 1.00 m of wide) with a 0.15 m sand layer paved over with bricks or rockfill - make a toe-filter as described on page 11	- this side of the bund must have a steep slope to prevent cattle from approaching the water

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	43		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	43		
bund	m^3	245		
bentonite (bund + base)	m^3	28		
sand (bund + base)	m^3	175		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3			
bricks (pavement (21x10x8))	piece	1700		
plaster sand	m^3			
plaster cement	bag			
tar	m^3			
glue	m^3			
tar paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope-covering				
- stones	m^2	143		
- grass				
- seed				
fencing	m^2	68		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE IV BILL OF QUANTITIES

SWD

date 821005

TWO

TYPE IV
capacity 30 m^3

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	56		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	56		
bund	m^3	360		
bentonite (bund)	m^3	41		
sand (base)	m^3	253		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement) (building)	piece	2000		
plaster sand	m^3			
cement	bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope-covering				
= stones	m^2	165		
= grass				
= seed				
fencing	m^2	75		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE IV capacity 60m³

TYPE IV BILL OF QUANTITIES

date 821005

TWO OHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	66		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	66		
bund	m^3	340		
bentonite (bund)	m^3	52		
sand (+ base)	m^3	318		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement) (glazed)	piece	1300		
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope-covering				
= stones	m^2	182		
= grass				
= seed				
fencing	m^2	80		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE IV BILL OF QUANTITIES

SWD

date 021005

TWO

TYPE IV
capacity 90m³

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	86		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	86		
bund	m^3	410		
bentonite (bund + base)	m^3	73		
sand (bund + base)	m^3	450		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
chem. treatment	m^3			
asph. bitumen	m^3			
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3			
bricks (pavement / riglond)	piece	2700		
plaster (sand / cement)	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope-covering				
= stones				
= grass	m^2	212		
= seed				
fencing	m^2	90		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE IV
capacity 150 m^3

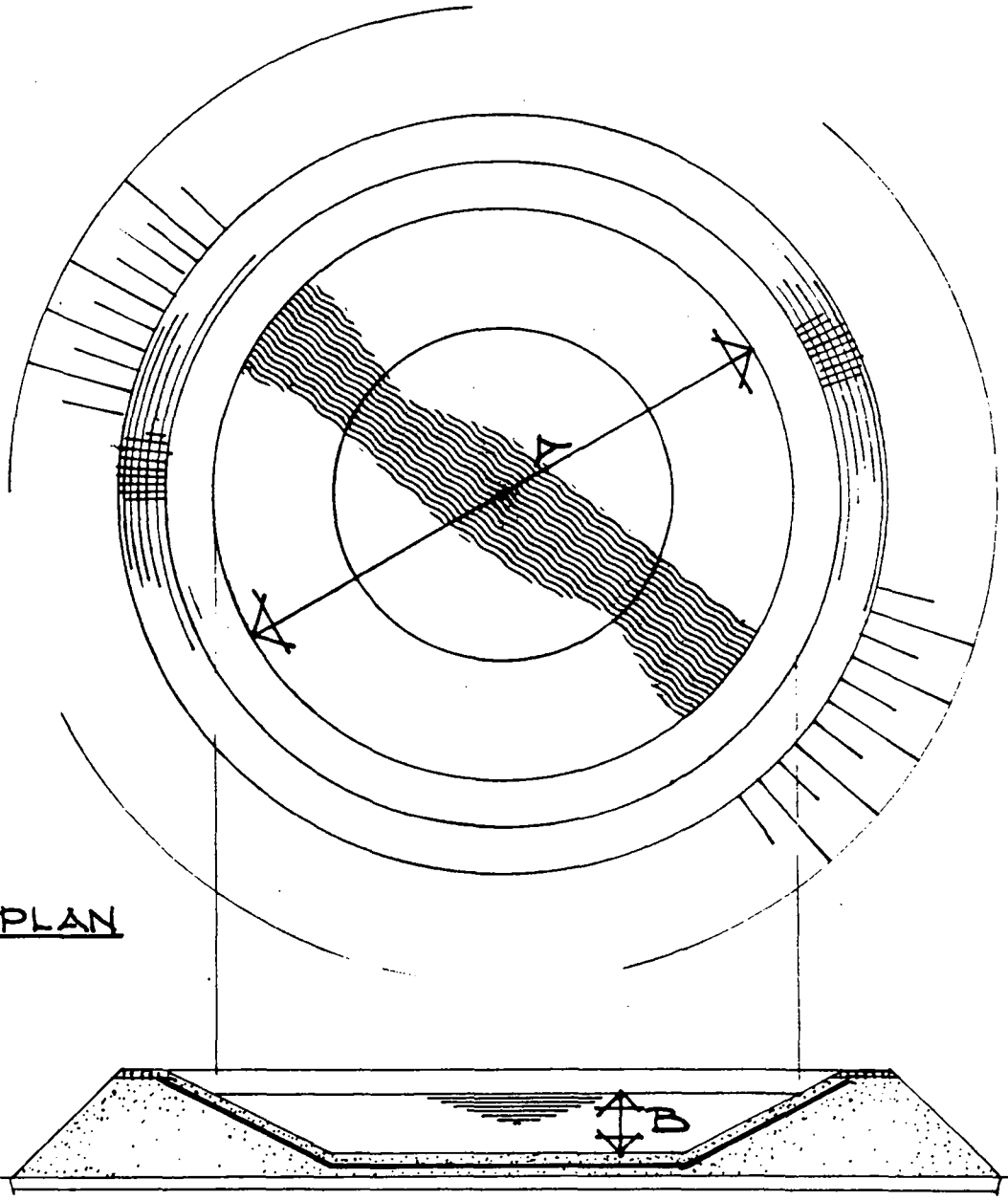
TYPE IV
BILL OF QUANTITIES

date 821005

TWO DHV

8.5. Type V: Bitumen lining

Short description:
A bund of available soil with a lining of bitumen over the base and the inside slopes of the bund.



PLAN

SECTION

capacity m³	A m	B m
30	8.00	1,25
60	10,30	1,25
90	12,00	1,25
150	14,90	1,25

TYPE V BITUMEN LINING

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

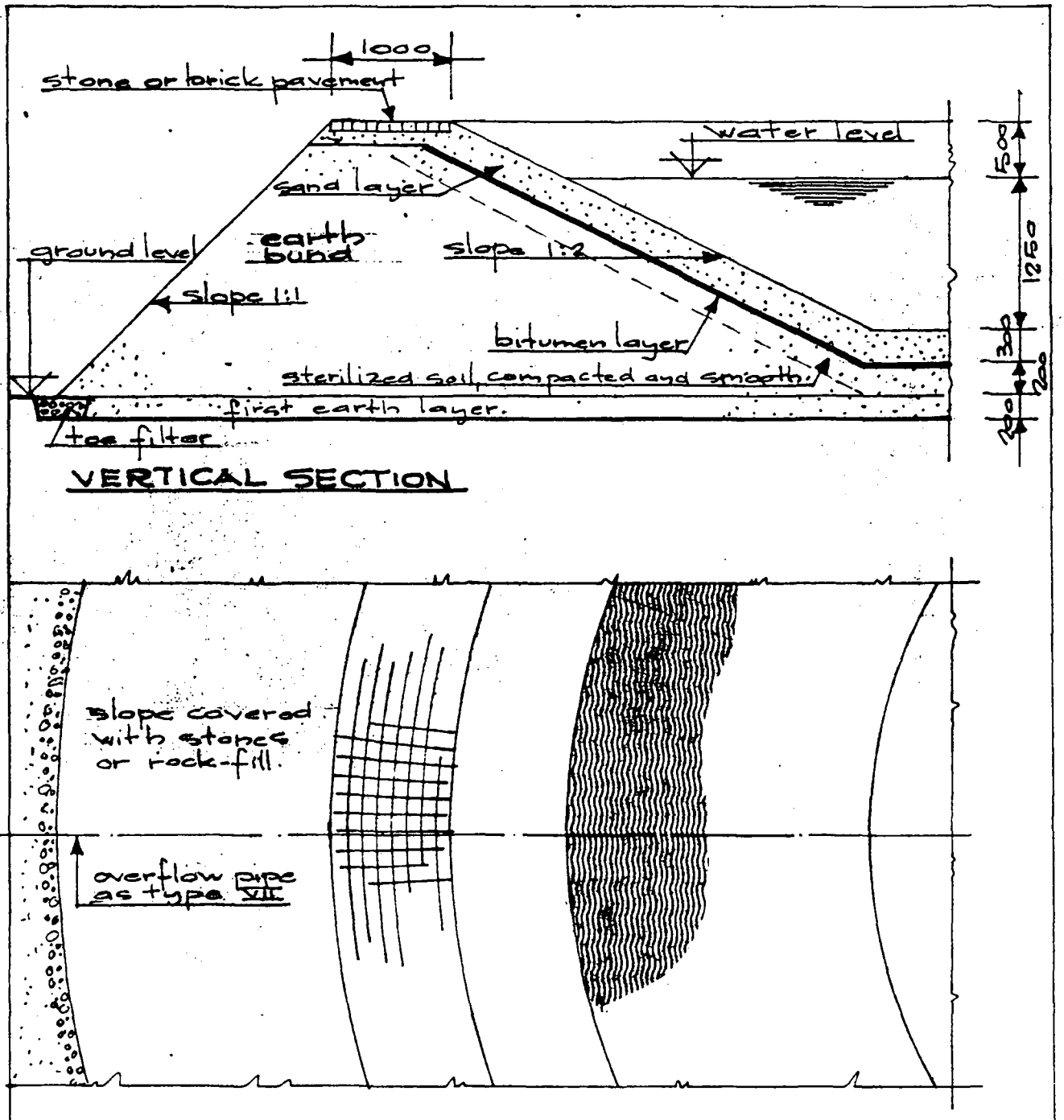
TYPE V GENERAL LAY OUT

SWD

measures in mm

date 820921

TWO

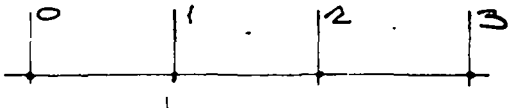


VERTICAL SECTION

TOP VIEW (PART OF THE BUND)

TYPE V BITUMEN LINING

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT



scale in meters

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE V

DETAILS AND DIMENSIONS

SWD

measures in mm

date 820921

TWO | DHV

TYPE V: Bitumen lining

work sequence and description	notes and recommendations
- fence the area of the site	- cattle can be a hindrance and would damage the bund construction
- clear the area of the site where it is proposed to construct the tank	- test the quality of the local subsoil (see page 17)
- remove a layer of approx. 0.20 m of the top soil	- to avoid settlements and seepage under the clay bund
- fill with a layer of earth of approx. 0.20 m	
- the fill is to be compacted with tampers (self made) and/or by letting oxen walk over it	- tools are described in this manual (see page 21)
- if necessary the surface is to be levelled	
- mark the inner and outer circumference of the bund with pegs (pegs core to core 1 meter)	
- setting out can be done by putting down the levelling tool on the top of each peg	- for more information about levelling and the levelling tool see page10)
- hammer the peg till the water level in the tube reached the disered marks	
- build up the earth bund and the tank base in layers of 0.20 m - 0.30 m	
- these layers are also be compacted with tampers and/or by letting oxen walk over them	- the base of the tank has to be constructed 0.50 m above ground level to allow gravitational flow
- insert a PVC or concrete overflow in the bund at the height of the highest water level	- this overflow pipe is to prevent the top of the bund being eroded by spillover
- connect the overflow pipe with an irrigation channel	
- the groundwork is completed when the outlines and slopes have reached the height, dimensions and gradients indicated on the drawings	depending on the kind of soil the slopes may deviate from the drawings
- control the height of the bund by placing a jungle-stick (marked at the height of the bund) on the already hammered pegs.	

work sequence and description	notes and recommendations
- sterilize the soil with a sterilant, for instance diesel fuel	- a layer of soil of 0.30 m thick on the base and on the slopes will be sufficient - the soil has to have a ±tructural stability, being well compacted and smooth
- make a water proof lining, by creating a membrane by hand pouring or spraying bitumen with, if necessary a prime and seal coating as a liner for the inside slope and the base	- it is advisable to start with a layer of a prefabricated glass or polypropylene mat as a reinforcement, before spraying or pouring the bitumen layer
- cover the bituminous lining on the inside slopes with a layer of sand or gravel lightly rolled in to protect the bitumen from oxidation	- for more information about bitumen and the cover layer of sand (see page 14)
- cover the outside of the bund with stones or rockfill to prevent erosion	- this side of the bund must have a steep slope to prevent cattle from approaching the water
- cover the crown of the bund (being about 1.00 m of wide) with a 0.15 m sand layer paved over with bricks or rockfill	
- make a toe-filter as described on page 11	

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	43		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	43		
bund	m^3	260		
base (earth)	m^3	3		
sand layer	m^3	30		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	0,45		
bitumen	m^3	7		
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3			
bricks (pavement / lixiond)	piece	1700		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope covering				
= stones				
= grass	m^2	143		
= seed				
fencing	m^2	60		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE V BILL OF QUANTITIES

SWD

date 821005

TWO IBHV

TYPE V
capacity 30 m^3

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	56		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	56		
bund	m^3	325		
base (earth)	m^3	13		
sand layer	m^3	42		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	0,65		
bitumen	m^3	11		
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3	2000		
bricks (pavement / ~~paving~~)	piece			
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope covering				
= stones				
= grass	m^2	165		
= seed				
fencing	m^2	75		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

TYPE V
capacity 60m³

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE V
BILL OF QUANTITIES

SWD

date 821005

TWO DHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	66		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	66		
bund	m^3	370		
base (earth)	m^3	24		
sand layer	m^3	54		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	0,05		
bitumen	m^3	14		
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement 21x15x8)	piece	2300		
plaster sand/cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope covering				
- stones	m^2	182		
- grass				
- seed				
fencing	m^2	80		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE V
capacity 90 m^3

TYPE V
BILL OF QUANTITIES

date 821005

TWO | BHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	86		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	86		
bund	m^3	450		
base (earth)	m^3	52		
sand layer	m^3	80		
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	1,2		
bitumen	m^3	20		
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement / fixlers)	piece	2700		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope covering				
- stones				
- grass	m^2	212		
- seed				
fencing	m^2	90		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

TYPE V
capacity 150 m^3

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

TYPE V
BILL OF QUANTITIES

SWD

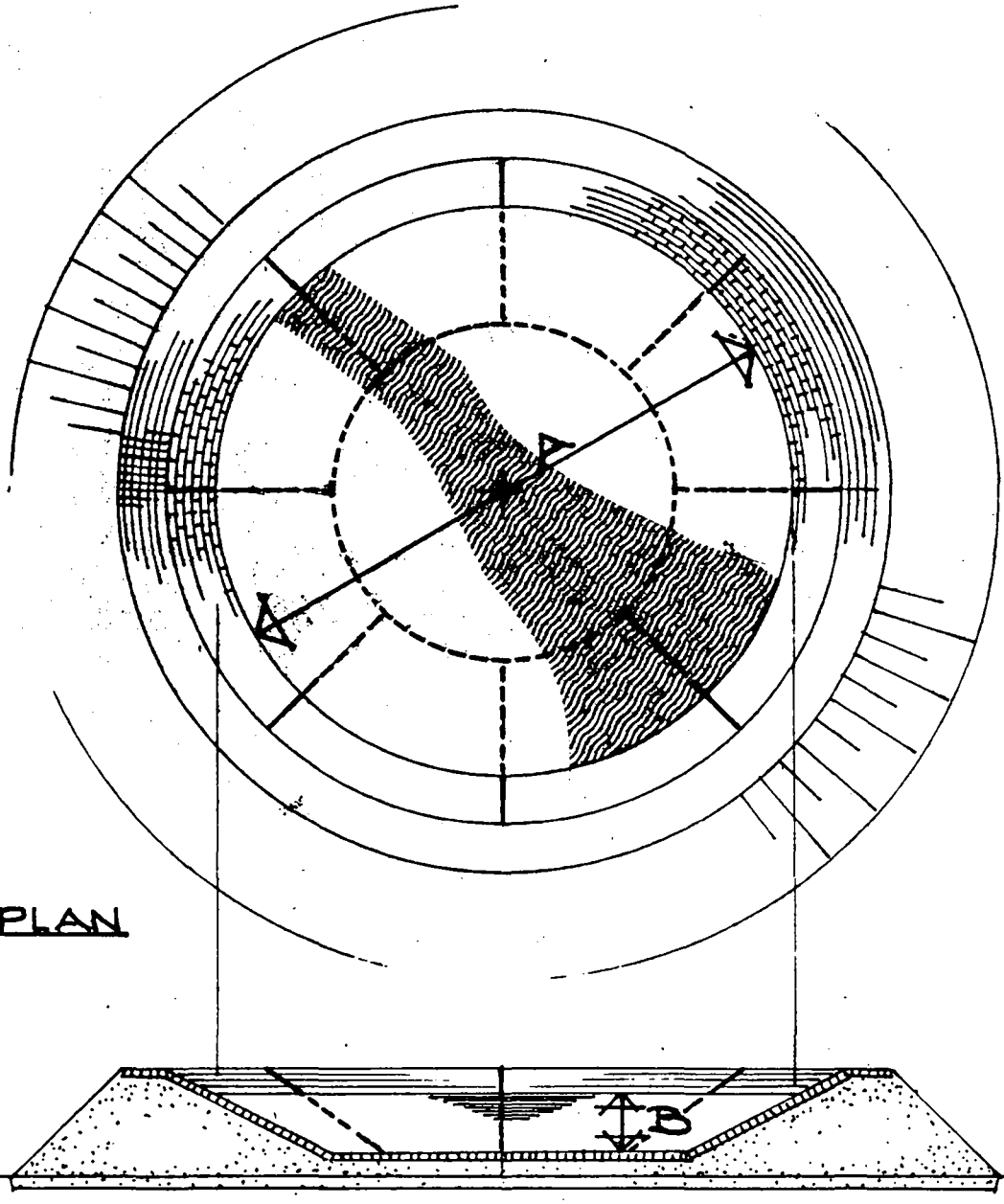
date 821005

TWO

8.6. Type VI: Lining of bricks or concrete

Short description:

A bund of available soil with a lining of bricks or concrete over the base and inside slopes of the bund.



PLAN

SECTION

capacity	A	B
30	8,00	1,25
60	10,30	1,25
90	12,00	1,25
150	14,90	1,25

TYPE VI LINING OF BRICKS

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT.

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

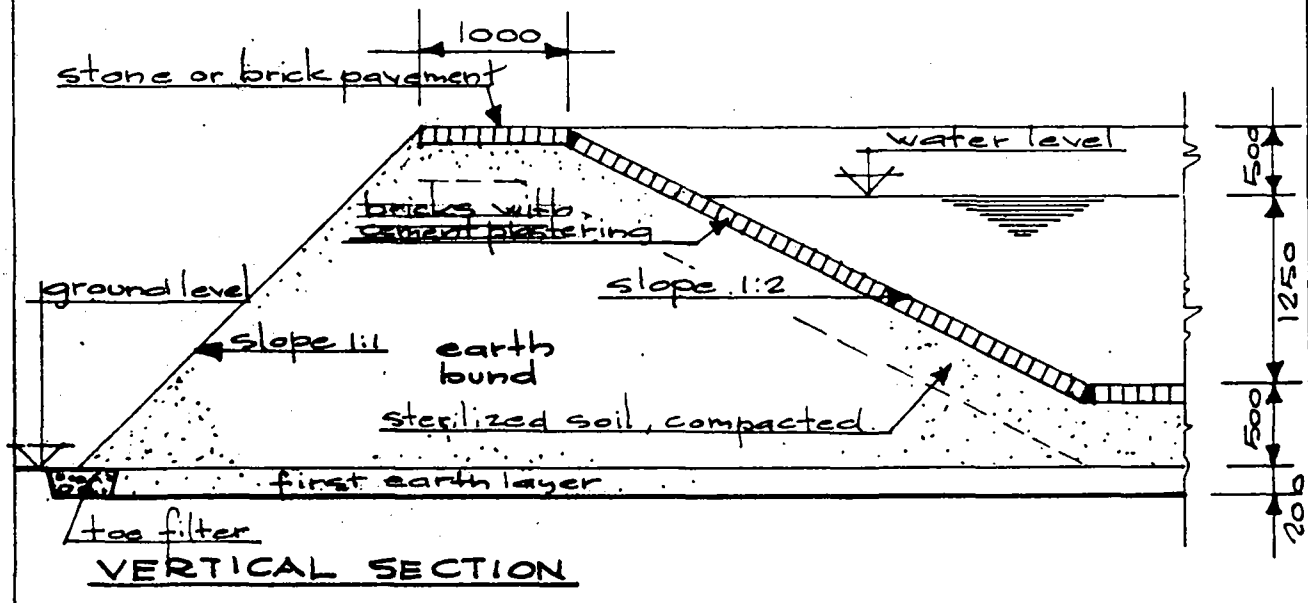
EARTH BUND CONSTRUCTION

TYPE VI GENERAL LAY OUT

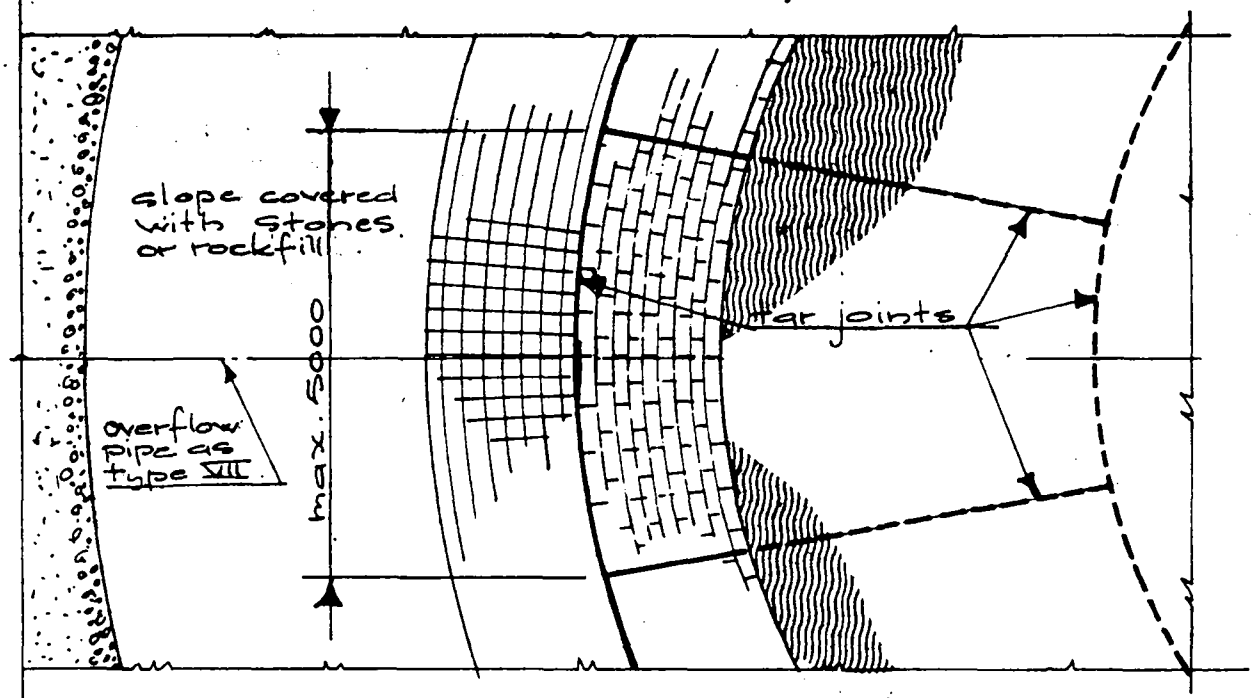
SWD

measures in mm
date 820921

TWO



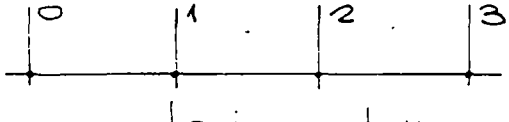
VERTICAL SECTION



TOP VIEW (PART OF THE BUND)

TYPE VI LINING OF BRICKS

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 65 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH - TWO - AMERSFOORT



IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

SWD

EARTH BUND CONSTRUCTION

TYPE VI

DETAILS AND DIMENSIONS

measures in mm

date 820921

TWO

TYPE VI: Lining of bricks or concrete

work sequence and description	notes and recommendations
- fence the area of the site	- cattle can be a hindrance and would damage the bund construction
- clear the area of the site where it is proposed to construct the tank	- test the quality of the local subsoil (see page 17)
- remove a layer of approx. 0.20 m of the top soil	- to avoid settlements and seepage under the earth bund
- fill with a layer of clay of approx. 0.20 m	
- the fill is to be compacted with tampers (self made) and/or by letting oxen walk over it	- tools are described in this manual (see page 21)
- if necessary the surface is to be levelled	
- mark the inner and outer circumference of the bund with pegs (pegs core to core 1 meter)	
- setting out can be done by putting down the levelling tool on the top of each peg	- for more information about levelling and the levelling tool see page10)
- hammer the peg till the water level in the tube reached the desired marks	
- build up the earth bund and the tank base in layers of maximally 0.20 m thick with crumbled clay	
- these layers are also be compacted with tampers and/or by letting oxen walk over them	- the base of the tank has to be constructed 0.50 m above ground level to allow gravitational flow
- insert a PVC or concrete overflow in the bund at the height of the highest water level	- this overflow pipe is to prevent the top of the bund being eroded by spillover
- connect the overflow pipe with an irrigation channel	
- the groundwork is completed when the outlines and slopes have reached the height, dimensions and gradients indicated on the drawings	- depending on the kind of soil the slopes may deviate from the drawings
- control the height of the bund by placing a jungle-stick (marked at the height of the bund) on the already hammered pegs.	

work sequence and description	notes and recommendations
- sterilize the soil with a sterilant for instance diesel fuel	- a layer of soil 0.30 thick on the base and on the slopes will be sufficient
- compact the soil on the base and the slopes with self-made tampers	- the soil must have a structural stability and be well compacted
- start bricklaying	- the bricks must be of good quality in order to obtain a watertight structure
- mix the mortar (1 part cement, 2 to 2½ parts of sand)	
- add water to the dry mortar until the mortar can be handled well	- beware of too much water; the water must be clean and free off acid chemicals, salt and organic materials
- moisten the subsoil and the bricks before laying	- moistening is important because the soil and the bricks may not transport water from the joints
- spread "a good and ample mortar bed" on each brick to connect the bricks; start at the base of the tank	- Such a process would result in cracks due to shrinkage
- do not place the mortar too far "in advance", before the bricks are laid in their final positions	- bricks are not to be moved or repositioned once the hardening process has begun
- fill all joints completely	- no joints should be placed -
- make vertical joints in the slopes at 5.00 m intervals and fill them with tar	above each other; no "dead" mortar retrieved from the ground or other surface must be re-used
- cover the bricks with a layer of cementplaster, 0.015 m thick	- the mix of the mortar for the plaster has to be 1 part cement, 2½ to 3 parts of sand
- cover the bricks/layer that has already been laid with plastic sheeting or wet sacking	- it is important to prevent the bricks/layer and the cement-plaster from drying out; this curing period should be take place in the first week after plastering

work sequence and description	notes and recommendations
- Note - instead of a lining of bricks with cementplaster it is possible to make a layer of concrete with a minimum thickness of 0.06 m	- then a plastic sheet is to be spread over the area and have a reinforcement for the slab and the slopes (Ø5-200), mix cement sand and gravel to a dry mortar (1:2:3); level the surfaces and cover them with a plastic sheeting for the first four weeks
- cover the outside of the bund with rockfill to prevent erosion	- this side of the bund must have a steep slope to prevent cattle from approaching the water
- cover the crown of the bund (being about 1.00 m of wide) with a 0.15 m sand layer paved over with bricks or rockfill - make a toe-filter as described on page 11	

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	43		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	43		
bund	m^3	280		
base earth	m^3	3		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	0,45		
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
bricks (lining 25x12x8)	piece	4400		
bricks (pavement 23x10x8)	piece	1700		
plaster cement sand	m^3 bag			
tar	m^3	1,3		
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope covering				
- stones	m^2	143		
- grass				
- seed				
fencing	m^2	68		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 83 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VI
capacity 30m³

TYPE VI
BILL OF QUANTITIES

date 821005

TWO

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	56		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	56		
bund	m^3	350		
base earth	m^3	13		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	0,65		
asph. bitumen	m^3			
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
bricks (lining 22x11x8cm)	piece	6500		
bricks (pavement 21x10x6)	piece	2000		
plaster sand	m^3			
plaster cement	bag			
tar	m^3	1,7		
glue	m^3			
tar-paper	m^2			
wire gauge ...	m^1			
tubes (pvc)	m^1	10		
slope covering				
= stones	m^2	165		
= grass				
= seed				
fencing	m^2	75		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VI capacity 60m³

TYPE VI BILL OF QUANTITIES

date 821005

TWO UHV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	66		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	66		
bund	m^3	400		
base earth	m^3	24		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m'			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	0,05		
asph. bitumen	m^3			
stakes (wood)	m'			
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
bricks (lining 22x11x8)	piece	8200		
bricks (pavement 21x10x8)	piece	2300		
plaster cement sand	m^3 bag			
tar	m^3	2		
glue	m^3			
tar-paper	m^2			
wire gauge ..	m'			
tubes (pvc)	m'	10		
slope covering				
= stones	m^2	192		
= grass				
= seed				
fencing	m^2	80		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VI
capacity 90 m^3

TYPE VI
BILL OF QUANTITIES

date 821005

TWO

TYPE II: Coffer dam

work sequence and description	notes and recommendations
- fence the area of the site	- cattle can be a hindrance and would damage the bund construction
- clear the area of the site where it is proposed to construct the tank	- test the quality of the local subsoil (see page 17)
- remove a layer of approx. 0,20 m of the top soil	- to avoid settlements and seepage under the coffer dam
- fill with a layer of clay of approx. 0.20 m	
- the fill is to be compacted with tampers (self made) and/or by letting oxen walk over it	- tools are described in this manual (see page 21)
- if necessary the surface is to be levelled	
- mark the inner and outer circumference of the coffer dam with pegs (pegs core to core 1 meter)	
- setting out can be done by putting down the levelling tool on the top of each peg	- for more information about levelling and the levelling tool see page10)
- hammer the peg till the water level in the tube reached the desired marks	
- build up the coffer dam by driving the retaining stakes (Ø 0.15 m) in a radial distance of 1.00 m and a tangential distance of approx. 1.50 m about, till one third of the necessary retaining height is driven in the subsoil	- all the wooden piles have to be conserved by singeing the wooden surface or saturating the wood with oil A bamboo stake is a good alternative to a wooden pile
- make a closed wall of horizontal planks or piles (Ø 0.10 m) against the the vertical framework and fill the gaps between these with branches or fibre mats	
- join the retaining stakes with nails, ropes or wire	
- place the supporting stakes (Ø 0.15 m) against the retaining stakes to support the coffer dam	- the supporting stakes on the inner side of the tank are temporary. After filling of the coffer dam and before making the tank base they must be taken away

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	96		
layer (sand/gravel)	m^3			
(clay/mud)	m^3			
refill with soil	m^3	96		
bund	m^3	400		
base earth	m^3	52		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2			
polythene (tubing)	m^1			
pvc	m^2			
butyl	m^3			
bentonite	m^3			
sterilizing oil	m^3	1,2		
asph. bitumen	m^3			
stakes (wood)	m^1			
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
bricks (lining 22x11x6cm)	piece	11800		
bricks (pavement 21x10x6cm)	piece	2700		
plaster sand cement	m^3 bag			
tar	m^3	2,5		
glue	m^3			
tar-paper	m^2			
wire gauge ..	m^1			
tubes (pvc)	m^1	10		
slope covering				
= stones				
= grass	m^2	212		
= seed				
fencing	m^2	90		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VI capacity 150 m^3

TYPE VI
BILL OF QUANTITIES

date 821005

TWO UHV

8.7. Type VII: Sand-cement sausages

Short description:
A bund of available soil with a lining of polythene and sand/cement sausages over the base and the inside slopes of the bund.

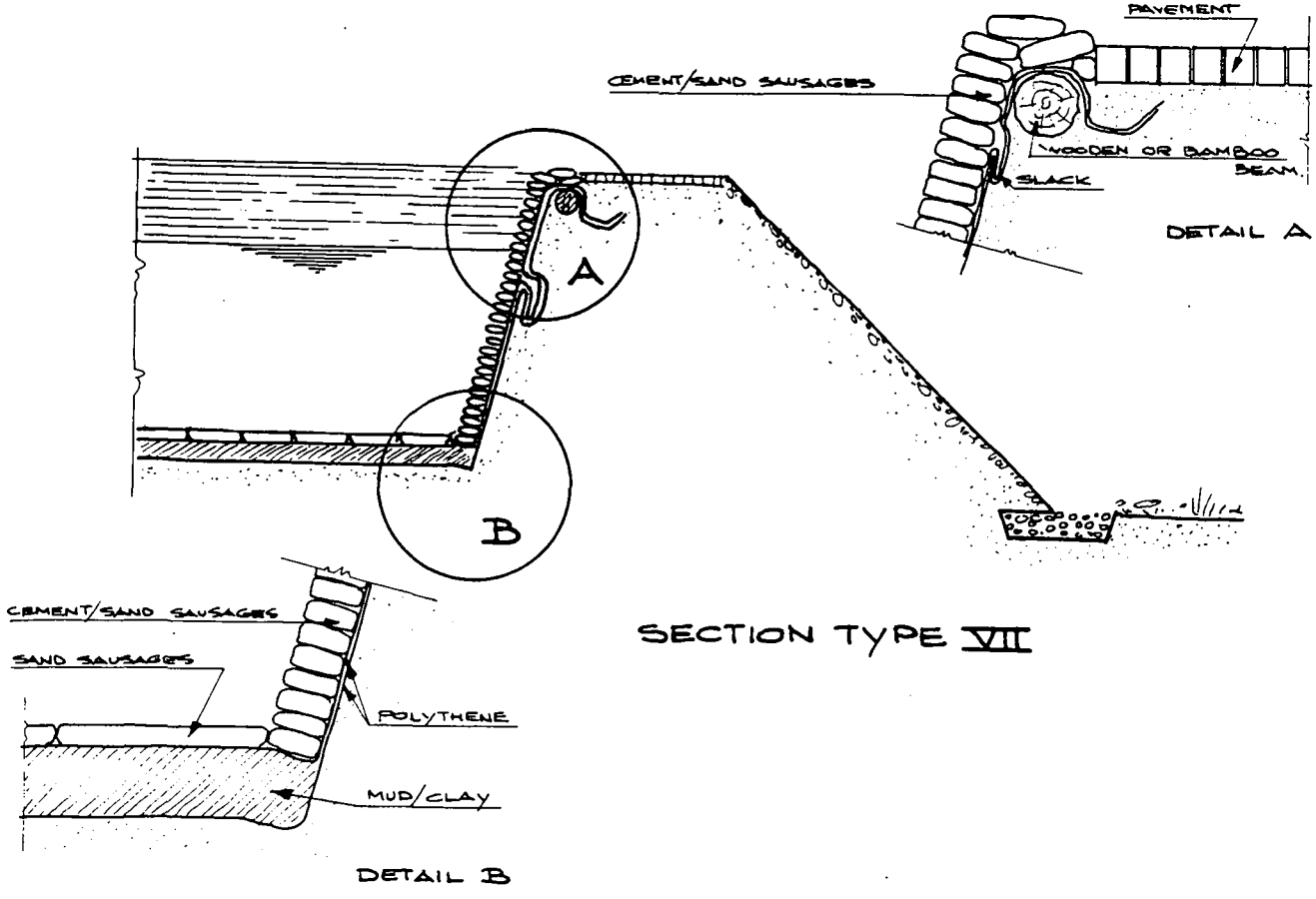
TYPE VII - Storage tank made of sand/cement sausages

- General description
  This system of storage of irrigation water has been developed by Doxiadis Ionides Associates Ltd. of Ripley, Surrey (UK) in collaboration with Doxiadis Associates International of Athens and is employed by ITDG in Botswana and in Sudan.

  For fencing, site clearance, levelling, preparation of foundations and bund constructions see descriptions in chapter 3 and the work-sequence of type VII.

- Polythene sheeting

  If the surface is free of all sharp objects and irregularities and satisfactory sterilised (with dieselfuel) to prevent plant growth, polythene (0.025-0.25 mm thickness) can be laid. It must be laid with some slack to prevent introducing stresses due to the expansion or contraction of the polythene. It is advisable to start laying two layers at the top of the slope and to anchor the sheeting in a trench after folding it over a preserved wooden beam.
  Polythene expands on heating and it is best to lay at low temperatures and protected from light. It should be laid at a time of day when winds are not expected and as soon as the first layer is down a layer of mud or clay of 0.15 m thick must be laid on the part covering the base (see drawing).

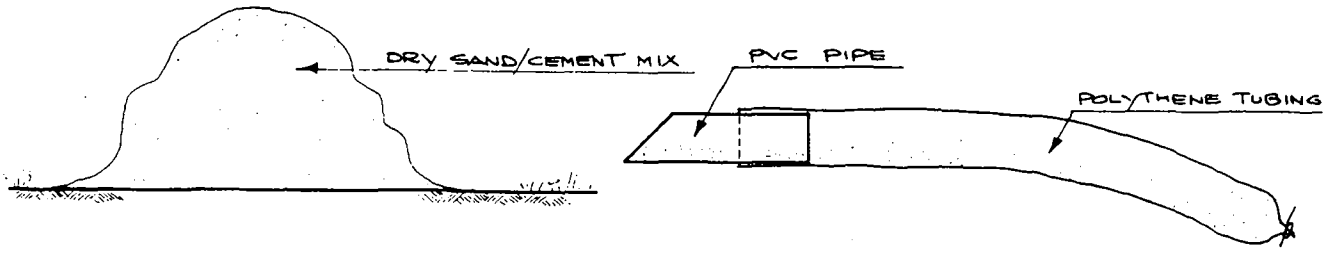


A second layer of polythene of the same thickness and quality is then laid on the layer of mud/clay.
The joints between the polythene sheeting can be formed:
- by applying an overlap of 1.50 m
- with a 1.00 m wide high quality tape
- with special polythene sheeting glue, in case an overlap of minimally 0.10 m must be available. It is advisable to glue only when the weather is dry.

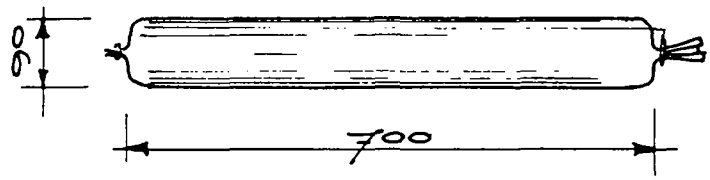
It is essential that the mud/clay layer between the two polythene layers should be kept in a moist condition all the time to give body and provide a cushioning effect for the sausages.

- Sausages
The use of sand sausages and sand-cement sausages is an essential part of the structure.
The sausages which are used as a lining for the base, consist of a sand filling inside a polythene tube. The sausages used as a lining for the sloping sides of the tank consist of a sand/cement mix inside a polythene tube.

The sausages have to be made of thin polythene tubing (0.025-0.25 mm thick) with a diameter of about 0.09 m. This tubing is to be cut into lengths of about 0.80 m and tied at one end.
Filling of the tubing with a dry sand/cement mix (14:1) can then start.
To make filling the tubing easier it is advisable to use a piece of PVC piping of the same diameter as the tubing and cutting one end of this pipe under 45°.
When this piece of piping is inserted into the tube, it is easy to scoop up the dry mix. (see drawing).



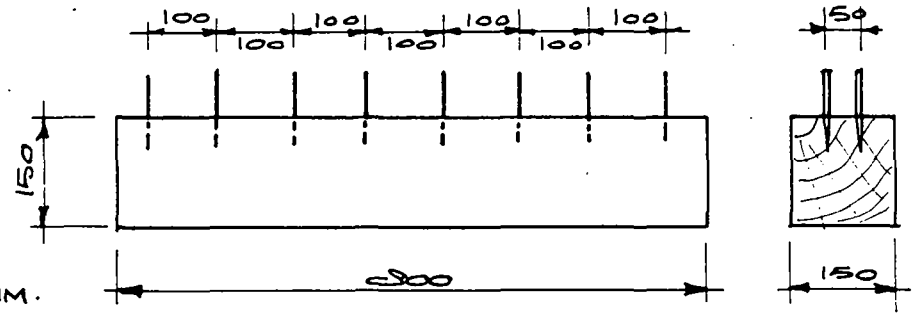
After filling the tubing the other end can be tied.
The most satisfactory length of the sausages will be about 0.70 m while the thickness should be about 0.09 m, in diameter.



At the moment before use, the sausages have to be perforated with a number of small holes in a line along the lengths after which they are to be laid with the perforation downward in a tub or basin of water and left there for five minutes.

Perforating the sausages can be easily done by one of the following tools:

FIG. A



MEASURES IN MM.

The perforating tool as shown in fig. A is made of a wooden beam with wire nails hammered into it at the intervals indicated on the drawing. After that remove the heads of the wire nails and the tool is ready.
Another perforating tool is easy to make by cutting a piece of wire (gauge 13) and shaping it as indicated in figure B.

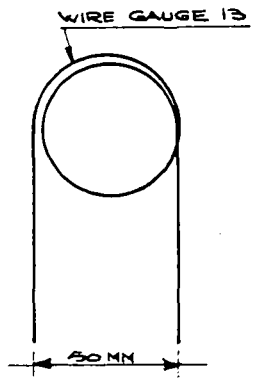
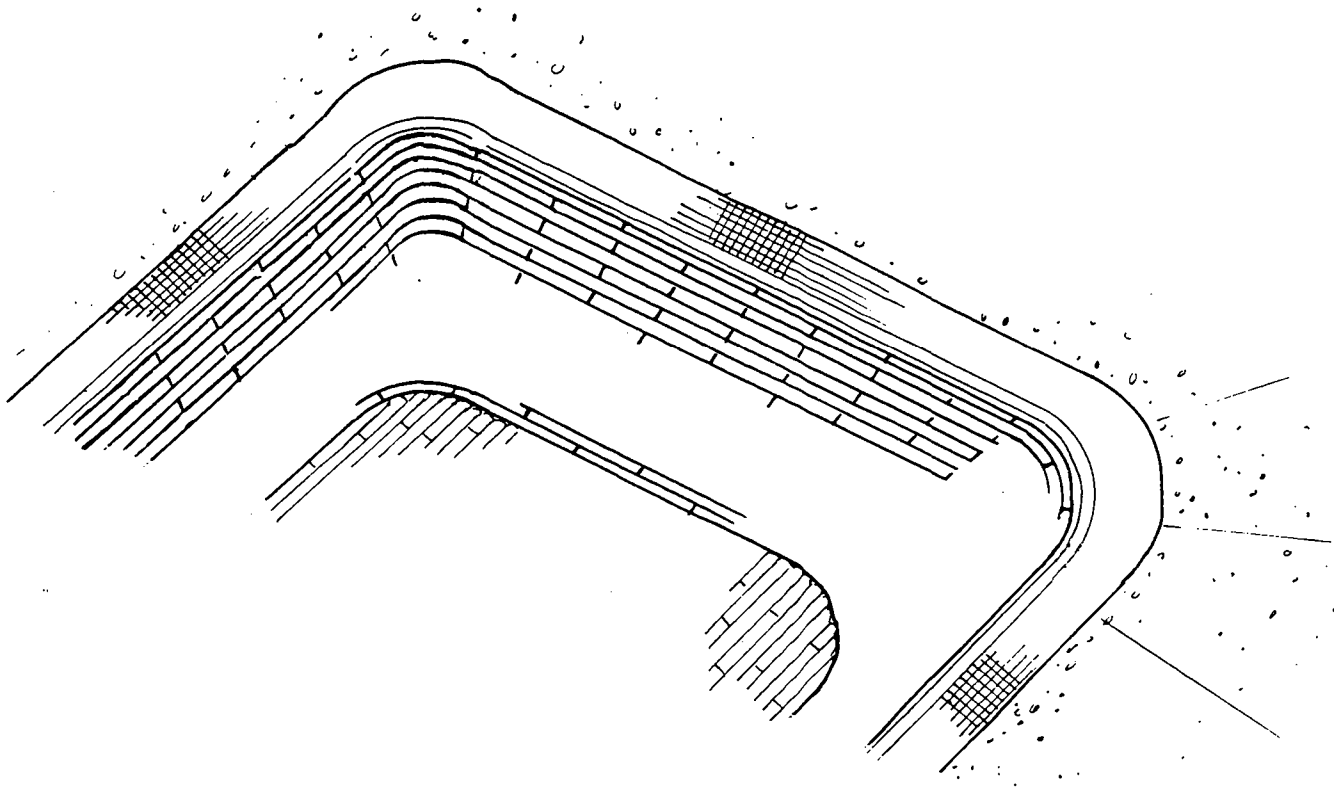


FIG. B

When the sausages are lying in the water, water will seep into the sand/cement mixture by capillary action, moistening the mix thoroughly but not saturating it.

(Of course it is not necessary to perforate the sausages which are filled only with sand).
The polythene skin of the sausages will prevent the contents from drying out quickly (which is especially important in arid countries) so the cement is able to cure fully, creating maximum strenght.
That is the reason why a much smaller proportion of cement can be used than in brickwork mortar.
After moistening, the sausages have to be laid on the lining of the slopes in a stretcher-bond (exactly the same way as bricks, but with no mortar). Then they must be tamped down, using a flatboard to compact the layer.



To bind the sausages together it is advisable to push 1.00 m lengths of gauge 8 wire through the sausages, at intervals of 2.00 m as reinforcing pins (see fig. C) or to attach them to one another with wire gauge 20 as indicated on fig. D.

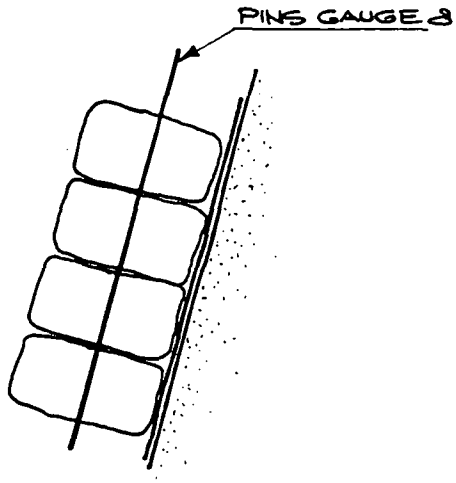


FIG. C

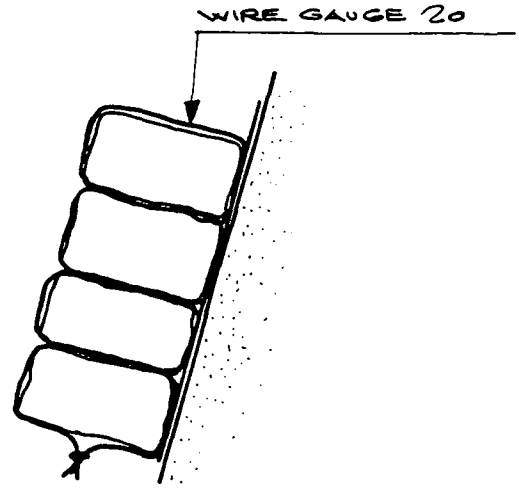
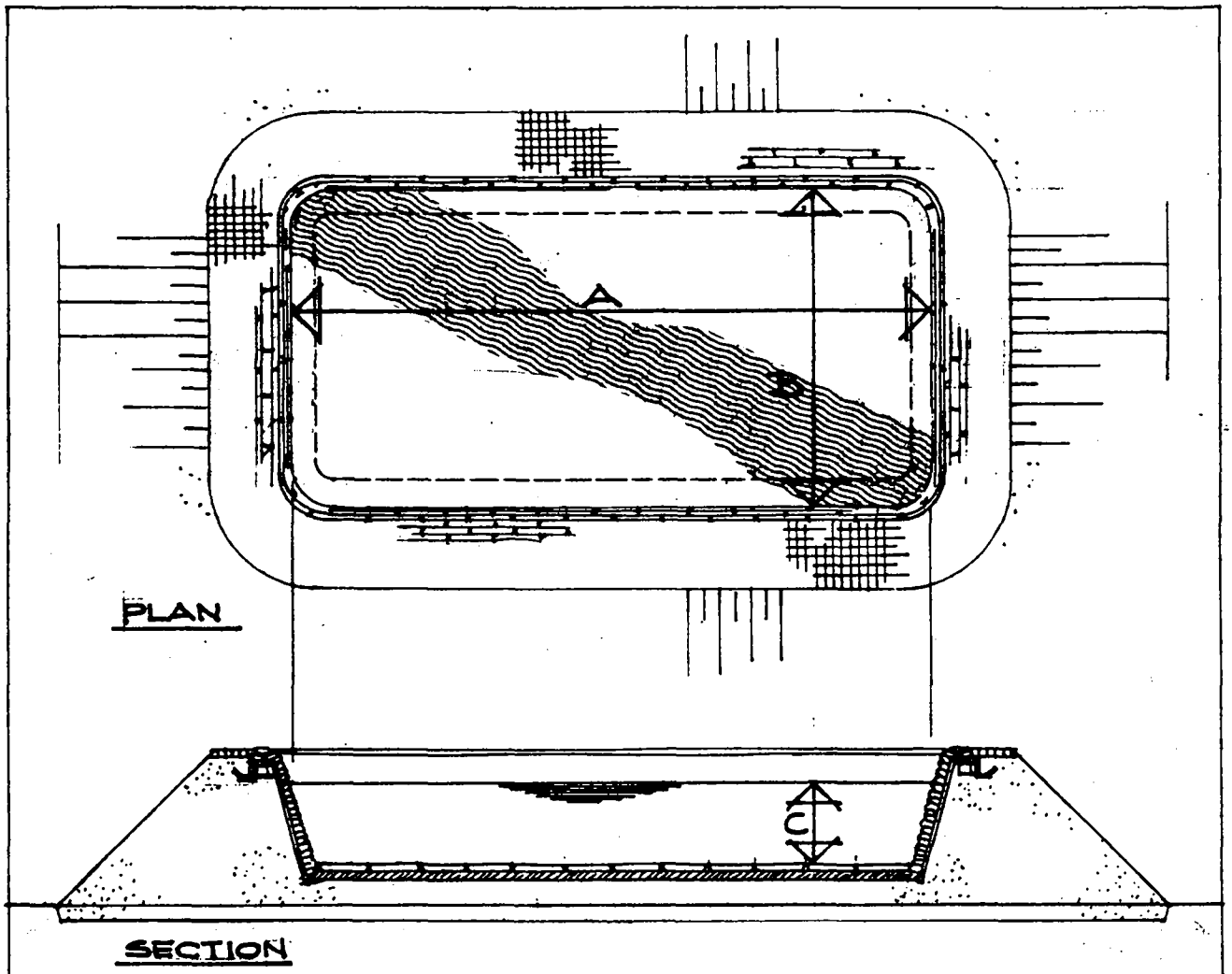


FIG. D

Before laying the sausages on the slopes of the tank, the surface of the base (on the second layer of polythene) has to be covered with a layer of sand sausages (i.e. those containing no cement) to be laid in a stretcher-bond (exactly the same way as bricks, but with no mortar).
Then the sausages have to be tamped down, using a flat board to compact the layer.



depends on the width of the sheeting

capacity	A	B	C
30	6,50	4,50	1,25
60	8,50	6,50	1,25
90	9,50	8,50	1,25
150	12,50	10,50	1,25

TYPE VII SAND-CEMENT SAUSAGES

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

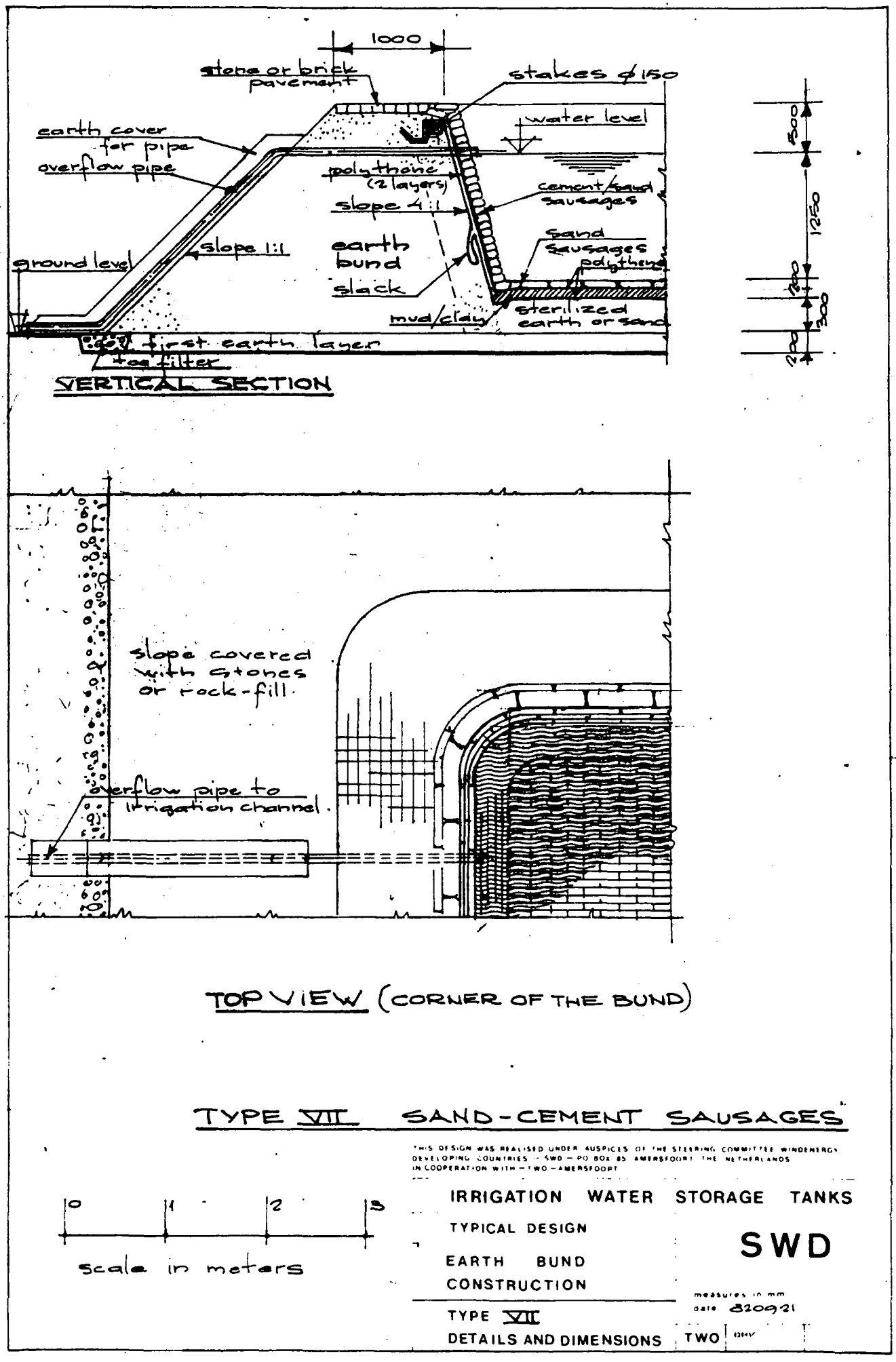
EARTH BUND CONSTRUCTION

TYPE VII GENERAL LAY OUT

SWD

measures in mm
date 820921

TWO UHV


1000
stone or brick pavement
stakes ϕ150
water level
earth cover for pipe
overflow pipe
polythene (2 layers)
cement/sand sausages
slope 4:1
slope 1:1
earth bund
slack
sand sausages polythene
ground level
mud/clay
sterilized earth or sand
first earth layer
toe filter
VERTICAL SECTION
500
1250
300
300
slope covered with stones or rock-fill
overflow pipe to irrigation channel
TOP VIEW (CORNER OF THE BUND)
TYPE VII SAND-CEMENT SAUSAGES
THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH - TWO - AMERSFOORT
0 1 2 3
scale in meters
IRRIGATION WATER STORAGE TANKS
TYPICAL DESIGN
SWD
EARTH BUND CONSTRUCTION
measures in mm
date 820921
TYPE VII
DETAILS AND DIMENSIONS
TWO

TYPE VII: Sand-cement sausages

work sequence and description	notes and recommendations
- fence the area of the site	- cattle can be a hindrance and would damage the bund construction
- clear the area of the site where it is proposed to construct the tank	- test the quality of the local subsoil (see page 17)
- remove a layer of approx. 0.20 m of the top soil - fill with a layer of clay of approx. 0.20 m	- to avoid settlements and seepage under the earth bund
- the fill is to be compacted with tampers (self made) and/or by letting oxen walk over it	- tools are described in this manual (see page 21)
- if necessary the surface is to be levelled - mark the inner and outer circumference of the bund with pegs (pegs core to core 1 meter)	
- setting out can be done by putting down the levelling tool on the top of each peg	- for more information about levelling and the levelling tool see page10)
- hammer the peg till the water level in the tube reached the desired marks - build up the earth bund and the tank base in layers of 0.20 m -0.30 m	
- these layers are also be compacted with tampers and/or by letting oxen walk over them	- the base of the tank has to be constructed 0,50 m above ground level to allow gravitational flow
- insert a PVC or concrete overflow in the bund at the height of the highest water level	- this overflow pipe is to prevent the top of the bund being eroded by spillover
- connect the overflow pipe with an irrigation channel - the groundwork is completed when the outlines and slopes have reached the heights, dimensions and gradients indicated on the drawings; remark: a slope of 4 : 1 only for cohesive soil - control the height of the bund by putting a jungle-stick (marked at the height of the bund) on the already hammered pegs.	

work sequence and description	notes and recommendations
- sterilize the soil with a sterilant, for instance diesel fuel	- a layer of soil 0.30 m thick on the base and on the slopes will be sufficient
- compact the surface of the soil of the base and the slopes with tampers tampers	- the soil must have a structural stability and must be well compacted
- place a conserved wooden or bamboo beam at top inside of the bund (see drawing)	- the beams can be conserved by singeing the surface or saturating with used oil
- fold the plastic sheet over this beam and anchor the sheet provisional by entrenching	- choose a type of plastic sheeting and join the sheets as described in chapter "materials". It must be laid with some slack to prevent stresses due to the expansion or contraction of the sheet
- a layer of mud or clay (0.15 m thick) has to be laid on the part of the sheet of the base	
- fold another layer of the same plastic sheet over this beam and entrench the two sheets definitively	
- make sausages for the base and the slope by cutting polythene tubing into lenghts of about 0.80 m tying them at one end	- it is advisable to use thin polythene tubing (0.025 - 0.25 mm thick)
- fill the sausages for the base with sand only and tie the other end	- to make filling easier use a PVC-pipe as described in the chapter on "sausages".
- the (sand) sausages for the base have to be laid in a stretcher bond	- laid in the same way as bricks but with no mortar
- tamp the sausages down, using a flat board to compact the layer	
- then fill the sausages for the slopes with a dry sand/cement mix (14:1) and tie the other end	- to make filling easier use a PVC-pipe as described in the chapter on "sausages".
- perforate the sausages with a number of small holes. When a great number of sausages has been filled and perforated, moistening can be started	- perforating the sausages can be easily done with a perforating tool as described in the chapter on "sausages"
- moisten the perforated sausages by laying them downward in a tub or basin of water and leaving them there for five minutes	

work sequence and description	notes and recommendations
- after moistening the sausages have to be laid on the sheet of the slopes in a stretcher-bond	- laid in exactly the same way as bricks, but with no mortar
- tamp the sausages down using a flat board to compact the layer	
- bind the sausages together by pushing 1.00 m lengths of gauge 8 wires through the sausages every 2.00 m.	- binding the sausages together can also be done with gauge 20 wire as indicated on the drawing
- cover the outside of the bund with stones or rockfill to prevent erosion	- this side of the wall must have a steep slope to prevent cattle from approaching the water
- cover the crown of the bund (being about 1.00 m of wide) with a 0.15 m sand layer paved over with bricks or rockfill	
- make a toe-filter as described on page 11	

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	31		
layer (sand/gravel)	m^3			
(clay/mud)	m^3	3		
refill with soil	m^3	31		
bund	m^3	225		
base (earth)	m^3	5		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2	200		
polythene (tubing)	m^1	900		
sand (sausages)	m^3	5,5		
cement (sausages)	m^3	0,3		
bentonite	m^3			
sterilizing oil	m^3	0,4		
asph. bitumen	m^3			
stakes (ø150)	m^1	50		
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3			
bricks (pavement 21x10x8)	piece	1300		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
wire gauge 8	m^1	50		
wire gauge 20	m^1	450		
tubes (pvc)	m^1	10		
slope covering				
- stones				
- grass	m^2	130		
- seed				
fencing	m^2	70		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES - SWD - PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH - TWO - AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VII
capacity 30 m^3

TYPE
BILL OF QUANTITIES

date 821005

TWO DIV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	41		
layer (sand/gravel)	m^3			
(clay/mud)	m^3	7		
refill with soil	m^3	41		
bund	m^3	360		
base (earth)	m^2	11		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2	300		
polythene (tubing)	m'	1400		
sand (sausages)	m^3	0,5		
cement (sausages)	m^3	0,4		
bentonite	m^3			
sterilizing oil	m^3	0,6		
asph. bitumen	m^3			
stakes (ϕ 150)	m'	65		
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks (pavement 21x10x8)	piece	1750		
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
wire gauge 8	m'	80		
wire gauge 20	m'	700		
tubes (pvc)	m'	10		
slope covering				
= stones				
= grass	m^2	155		
= seed				
fencing	m^2	78		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VII
capacity 60m³

TYPE VII
BILL OF QUANTITIES

date 82 10 05

TWO

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	51		
layer (sand/gravel)	m^3			
(clay/mud)	m^3	10		
refill with soil	m^3	51		
bund	m^3	490		
base (earth)	m^3	17		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2	400		
polythene (tubing)	m^1	1850		
sand (sausages)	m^3	11		
cement (sausages)	m^3	0,5		
bentonite	m^3			
sterilizing oil	m^3	0,8		
asph. bitumen	m^3			
stakes (ϕ150)	m^1	80		
wood preservative	m^3			
nails				
ropes	m^1			
fibre mats	m^2			
stones	m^3			
bricks (pavement (glazed))	piece	2000		
plaster sand / cement	m^3 / bag			
tar	m^3			
glue	m^3			
wire gauge 8	m^1	185		
wire gauge 20	m^1	925		
tubes (pvc)	m^1	10		
slope covering				
= stones	m^2	175		
= grass				
= seed				
fencing	m^2	84		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VII capacity 90 m^3

TYPE VII BILL OF QUANTITIES

date 821005

TWO DMV

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
excavation	m^3	68		
layer (sand/gravel)	m^3			
(clay/mud)	m^3	17		
refill with soil	m^3	68		
bund	m^3	730		
base earth	m^3	28		
compacted soil	m^3			
impermeable soil	m^3			
polythene (sheet)	m^2	560		
polythene (tubing)	m'	2600		
sand (sausages)	m^3	15,5		
cement (sausages)	m^3	0,6		
bentonite	m^3			
sterilizing oil	m^3	1,2		
asph. bitumen	m^3			
stakes (ø150)	m'	100		
wood preservative	m^3			
nails				
ropes	m'			
fibre mats	m^2			
stones	m^3			
bricks pavement (2 layers)	piece	2450		
plaster sand cement	m^3 bag			
tar	m^3			
glue	m^3			
wire gauge 8	m'	260		
wire gauge 20	m'	1300		
tubes (pvc)	m'	10		
slope covering				
= stones				
= grass	m^2	210		
= seed				
fencing	m^2	94		
total materials				
	mandays	hours	rates	
labour				
TOTAL COST OF STORAGE TANK				

THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

SWD

TYPE VII capacity 150 m^3

TYPE VII BILL OF QUANTITIES

date 821005

TWO DHV

9. RELATIVE COMPARISON AND SUMMARY

In this chapter a comparison is made between the several properties of the different types not related to local conditions.
The following properties can be compared:
- water impermeability
- execution/quality of the skill
- resistance required against changes in humidity, temperature and light intensity
- area
- chances of polution by the lining material used
- dependability/reliability/durability
- possibilities for repair
- cleaning possibilities/need for maintenance
- resistance to use and damage by animals
- resistance to vegetation
- frost-resistance

Repetition of typenumbers:
Type I : Clay bund
Type II : Cofferdam
Type III : PVC lining
Type IV : Sand-bentonite lining
Type V : Bitumen lining
Type VI : Lining of bricks or concrete
Type VII : Sand-cement sausages

9.1. Water impermeability

Water tanks for storage of irrigation water may suffer some losses because of the permeability of the walls. Under some circumstances a daily loss of 10% of the water may not be a great problem. In other cases it may be of importance that some types are more waterproof than others.
The impermeability of type I depends very much on the quality of the existing subsoil. If the quality is good, the impermeability will be good.
The impermeability of type II also depends on the quality of the work.
Type III can become very impermeable, but this depends very much on the construction. One crack is enough to destroy the impermeability.
In the beginning type IV will have a very good water impermeability. But, bentonite is very sensitive to shrinkage when drying out. It is possible that after rewetting of the bentonite, the permeability will be worse than before shrinkage. As said, bentonite can be used for repair the watertighness by sprinkling.
The impermeability of the bitumen lining of type VI depends very much on the quality of the work, which should be carried out by skilled workers.
A brickwork or concrete lining (type VI) can give very good results. But settlements and differential settlements may cause cracks, thus affecting the permeability and the durability of the tank. If properly constructed type VII can give a very good water impermeability. The lining is protected by the sausages and therefore less sensitive to cracks.

9.2. Execution/quality of the workskill

For type II to IV and VII relatively unskilled labour is sufficient, but larger tanks of the these types require supervision of skilled labour too.

9.3. Frost resistance

Types III, VI and VII are not frost resistant.
For types III and VII the foil will crack when frozen; for type VI the brickwork or concrete may break.
Types I and IV will have the best frost resistance.

9.4. Resistance to changes in humidity, temperature and light intensity

Type VI: Immediately after trowelling the tankwall (after each day) the finished parts of the tank must be protected against weather influences. Therefore, these parts should be moistened or covered during at least the first week.
In tropical areas it is advisable to continue moistening for another week.
All the tanks described have good resistance to changes in humidity and temperature.
Type III+VII (foil) must be protected against powerful light.
Type III: Immediately after laying the PVC sheet on the base of the tank, the PVC has to be covered with a layer of sand (thickness approx. 0.25 m). The PVC sheet on the slopes has to be covered with fibre mats.
Type VII: After laying the polythene sheets on the base of the tank, the polythene has to be covered with a layer of sand sausages and the polythene sheets on the slopes have to be covered with sand/cement sausages.

9.5. Area required

Types I, III and V demand the largest area. The circular form fits in best with the type of earth bund.
Type II can be built on the smallest surface area in different forms (in relation to its capacity) The size of the rectangular forms depends on the width of the sheeting available.

9.6. Chances of pollution by the lining material used

Some kinds of foil may pollute the water.
The bentonite lining or the bitumen lining may also give pollution problems (when the water is used as drinking-water).

9.7. Dependability/reliability/durability

The dependability and reliability of all the tanks described is reasonable good, but depends on the construction methods. A well protected lining against all kinds of influences will give a high durability.

9.8. Possibility for repair

Types III, V, VI and VII are not easy to repair (cracks or holes are difficult to find). The protection layer must be removed.
Type IV (bentonite) is easy to repair (see "notes and recommendations").
Types I and II are hard to repair, because the permeability is no local problem, but concerns the complete tank. One may try to improve the complete ground surface as referred to in the "worksequence and description".

9.9. Cleaning possibilities/need for maintenance

The variants with a smooth surface offers the best cleaning possibilities. In sharp corners dirt may stick together and attract snails, mosquitoes and other disease-spreading insects.
A smooth surface can be found in type I and IV, while the protecting toplayer in type I, II, III and IV can be cleaned or changed.

9.10. Resistance to use and damage by animals

The area around the tank has to be fenced to protect it against animals (see chapter on fencing). Nevertheless the slopes of the clay walls of 1 : 1 give a reasonable protection against cattle. Where foil is used, it may be eaten by goats.
The wooden framework may be demolished by termites.

9.11. Resistance to vegetation

Perforation of the lining by roots, weed, cane, etc. may affect the impermeability, especially of thinner linings.
The linings of clay or bentonite have a good resistance to vegetation.

9.12.

Summary

Properties	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII
Impermeability	+	+	++	++	+	++	++
execution quality of work	□	+	+	+	+	□	+
resistance changes in humidity, temperature and light int.	+	+	□	+	+	□	□
area required little=++ much= -	+	++	-	□	-	□	+
resistance to pollution by the lining material used	++	++	□	□	□	++	□
dependability/ reliability durability	+	□	□	+	+	□	□
possibility for repair	-	-	□	+	□	□	□
cleaning possibilities need for maintenance	□	□	□	□	+	+	-
resistance, use and damage by animals	++	+	-	+	+	+	-
resistance to vegetation	++	++	-	++	-	□	-
frost-resistance	+	□	□	+	□	-	-

- = poor □ = reasonable + = good ++ = very good

ANNEX 1

SIZES OF WIRES AND STEEL RODS

A. Gauge Numbers and Millimeter Equivalents of Wires

Gauge no.	Wire diameter		Gauge no.	Wire diameter	
	in.	mm		in.	mm
1	0.300	7.620	16	0.065	1.651
2	0.284	7.214	17	0.058	1.473
3	0.259	6.579	18	0.049	1.245
4	0.238	6.045	19	0.042	1.067
5	0.220	5.588	20	0.035	0.889
6	0.203	5.156	21	0.032	0.813
7	0.180	4.572	22	0.028	0.711
8	0.165	4.191	23	0.025	0.635
9	0.148	3.759	24	0.022	0.559
10	0.134	3.404	25	0.020	0.508
11	0.120	3.048	26	0.018	0.457
12	0.109	2.769	27	0.016	0.406
13	0.095	2.413	28	0.014	0.356
14	0.083	2.108	29	0.013	0.330
15	0.072	1.829	30	0.012	0.305

B. Common Sizes of Steel Rods Used for Skeletal Steel

Size	Rod diameter		Cross-sectional area		Perimeter		Weight	
							per ft	per m
in.	in.	mm	in^2	mm^2	in.	mm	lb	kg
3/16	0.187	4.749	0.027	17.419	0.587	14.909	0.094	0.042
0.200	0.200	5.080	0.031	19.999	0.628	15.951	0.107	0.048
1/4	0.250	6.350	0.049	31.612	0.785	19.939	0.167	0.075
0.276	0.276	7.010	0.059	38.064	0.867	22.021	0.203	0.092
5/16	0.312	7.924	0.076	49.032	0.980	24.892	0.261	0.118
3/8	0.375	9.525	0.110	70.967	1.178	29.921	0.376	0.170
7/16	0.437	11.099	0.150	96.774	1.373	34.874	0.511	0.231
1/2	0.500	12.700	0.196	126.451	1.571	39.903	0.688	0.312

ANNEX 2

CONVERSION OF COMMON UNITS

Metric and SI (International System) Units

Length

1 in. (inch)	=	25.4000 mm	(millimeter)
1 in. (inch)	=	2.5400 cm	(centimeter)
1 in. (inch)	=	0.0254 m	(meter)
1 ft (foot)	=	0.3048 m	(meter)
1 yd (yard)	=	0.9144 m	(meter)
1 mile (mile)	=	1.6093 km	(kilometer)
1 n mile (nautical mile)	=	1.8531 km	(kilometer)

Area

1 $in.^2$ (square inch)	=	645.1600 mm^2	(square millimeter)
1 ft^2 (square foot)	=	0.0929 m^2	(square meter)
1 yd^2 (square yard)	=	0.8361 m^2	(square meter)
1 acre (acre)	=	4,046.8600 m^2	(square meter)
1 sq mile (square mile)	=	2.5899 km^2	(square kilometer)

Volume

1 $in.^3$ (cubic inch)	=	16.3871 cm^3	(cubic centimeter)
1 ft^3 (cubic foot)	=	0.0283 m^3	(cubic meter)
1 yd^3 (cubic yard)	=	0.7645 m^3	(cubic meter)

Force

1 lb (pound)	=	4.4482 N	(Newton)
1 kg (kilogram)	=	9.8066 N	(Newton)
1 ton (ton)	=	9.9640 kN	(kilo Newton)

Force (weight)/unit length

1 lb/in. (pound per inch)	=	0.1751 N/mm	(Newton per millimeter)
1 lb/ft (pound per foot)	=	14.5939 N/m	(Newton per meter)
1 ton/ft (ton per foot)	=	32.6903 kN/m	(kilo Newton per meter)

Pressure, stress, strength (force per unit area)

1 $lb/in.^2$ (pound per square inch, psi)	=	0.6895 N/cm^2	(Newton per square centimeter)
1 $lb/in.^2$ (pound per square inch, psi)	=	6,894.7600 N/m^2	(Newton per square meter)
1 lb/ft^2 (pound per square foot, psf)	=	47.8303 N/m^2	(Newton per square meter)
1 lb/ft^2 (pound square foot, psf)	=	4.8820 kg/m^2	(kilogram per square meter)
1 $ton/in.^2$ (ton per square inch)	=	15.4443×10^6 N/m^2	(Newton per-square meter)
1 ton/ft^2 (ton per square foot)	=	107.2520 kN/m^2	(kilo Newton per square meter)
1 N/m^2 (Newton per square meter)	=	1 Pa	(Pascals)
1 kg/cm^2 (kilogram per square centimeter	=	0.0981	MPa (Mega Pascals)

Bending moment or torque

1 lb in. (pound inch)	=	0.1129	Nm (Newton meter)
1 lb ft (pound foot)	=	1.3558	Nm (Newton meter)
1 ton ft (ton foot)	=	3.0370	kNm (kilo Newton meter)

Mass

1 g (gram)	=	28.35	oz (ounce)
1 lb (pound)	=	453.5929	g (gram)
1 lb (pound)	=	0.4536	kg (kilogram)
1 ton (ton)	=	1,000.00	kg (kilogram)
1 kg (kilogram)	=	2.2046	lb (pound)

Density (mass per unit volume)

1 $lb/in.^3$ (pound per cubic inch)	=	27.6799 g/cm^3	(gram per cubic centimeter)
1 lb/ft^3 (pound per cubic foot)	=	16.0185 kg/m^3	(kilogram per cubic meter)
1 ton/yd^3 (ton per cubic yard)	=	1,328.94 kg/m^3	(kilogram per cubic meter)
1 lb/yd^3 (pound per cubic yard)	=	0.5933 kg/m^3	(kilogram per cubic meter)

Measurement of liquid

1 l (liter)	=	0.2200 Imperial gallon
1 l (liter)	=	0.2642 U.S. gallon
1 gal (gallon)	=	0.0038 cu m (cubic meter)
1 gal/min (gallon per minute)	=	0.0038 cu m/min (cubic meter per minute)

ANNEX 3

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