SWD STEERING COMMITTEE
WIND ENERGY
DEVELOPING COUNTRIES

Irrigation Water Storage Tanks made of Brickwork

A manual for design and construction

December 1981

DHV
DHV Consulting Engineers

TWO
Technical Working Group
for Developing Countries

CONTENTS

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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 developing countries. To achieve properly regulated irrigation, water storage is a necessity.
Up to now, water storage tanks have been built using general construction materials.
Experience shows that the cost of water storage tanks can equal the cost of a windmill. Also some storage tanks were liable to damage during use and because of lack of know-how.
Discussions with TWO resulted in a contract between SWD and DHV. Under this contract DHV prepared designs and construction manuals as described in this publication.
As a first step, designs and construction manuals have been prepared for masonry tanks with storage capacities of 30 m3 - 60 m3 - 90 m3 and 150 m3. These are described in this booklet.

Designs for tanks made of bund walls, ferro cement, plastic foil tubes with stabilized soil and a combination of ferro cement and masonry will be prepared in a later stage.

The authors are grateful for the support, and critisism, that they received from the SWD.

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C. Pieck

2. IRRIGATION WATER STORAGE TANKS MADE OF BRICKWORK

2.1. Introduction

Descriptions and drawings have been made showing masonry tanks with a capacity of 30-60-90 and 150 m3 with five several types. As shown, several constructions are possible.

A summery of the several types of tanks reads as follows:

Page

Type 1: a fully brickwork tank, walls and slabs, without a bund earth wall
Type II: same as type I but with a bund earth wall
Type III: brickwork ringfoundation with a bund earth wall. The remaining bottomslab of the tank will be made of clay (impermeable soil)
Type IV: as type III but with a different foundation of the brickwork ring
Type V: as type III or IV but with tie rods made of steelstrips and without a bund earth wall

In the description of each type of tank a short building instruction is given with some characteristic properties. In the notes, added to the description, some differences between the tanks are shown.
Furthermore, on page 73 a review is presented which helps in choosing the type of tank to be constructed.
The drawings show details with dimensions for each tank and are completed with a bill of quantities.
The content, text and illustrations of the manual are primarily keyed to a semi-professional reader, although professional engineers may also find the manual useful.
One chapter describes methods of testing total masonry walls and of the building materials. For reasons of safety it may be necessary to test the "sample wall" as well as the materials before starting construction of a tank. In the last chapter consideration is given to the theory of the structural calculations for the tanks.

2.2. Construction manual

2.2.1. Site clearance and preparation of foundations

The site chosen for the tank should be cleared. At least the topsoil with a layer of approx. 200 mm is to be excavated to be sure that all vegetation, loose surface soil and black soil are removed.
If necessary the surface should be (roughly) levelled.
After clearance it is advisable to backfill a sand and/or gravel layer of approx. 200 mm thick.
The ensuing compaction is done by means of ramming with (self-made) tampers.
When for backfill sand is used compaction can also be done by sprinkling with a little water and ramming.

2.2.2. Construction materials

2.2.2.1. Bricks

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 tank should be moistened during the first three weeks or protected by means of a cover (plastic foil).

2.2.2.2. Cement

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.

2.2.2.3. Sand

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.

2.2.2.4. Water

The water must be clean and free from acid chemicals, salt and organic matters.
Salt water should never be used.

2.2.2.5. Mortar mix

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 sand (fine aggregate)

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 brick work and mortar. However, it should not be forgotten that any such reduction in quality may result in a less rigid construction and will certainly 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.
Water should be clean and free from harmfull matter, (see chapter "Testing"). 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.

2.2.3. Constructions

When the site for the tank is cleared, its surface is levelled with a 200 mm thick layer of sand and/or gravel. The setting out can be done by driving a post into the ground at the centre point of the tank site and scribing a circle, while marking the ground at approx. 1 meter core to core with pegs.

2.2.3.1. Instructions for bricklaying

- Clean foundation where bricks are to be laid
- Mark line of brickwork every 1 meter or so with pegs
- Mix the mortar (1 part cement, 2 tot 2½ parts sand)
- Add water to the dry mortar until the mortar can be handled well (beware of too much water)
- Moisten the bricks before laying so that the bricks do not transport water from the joints since such process causes joint cracks due to shrinkage.
  Bricks are not to b e moved or repositioned once the hardening process has begun.
  Spread "a good and ample mortar bed" for the first layer, making certain that the correctly placed masons line is worked to.
- Do not place the mortar too far "in advance" of the proceeding bricks as the hardening process will start before the bricks are laid in their final positions.
  All heading joints (vertical) must be completely filled.
- Trowel off all excess mortar from the joints and re-usė it.
  No "dead" mortar retrieved from the ground or other surface must be re-used.

While laying bricks it is important to pay attention to the following rules for bonding:

- No vertical joints should be placed above each other.
- No closers must be used which are smaller than half the standard brick size locally available.

2.2.4. Plaster

To ensure a more watertight construction it is advisable to scrape out the innerwall and slab joints and to apply an approximately 15 mm thick, rendering to the inner surfaces of the tank.
1 Part of cement to 5 parts of sand by volume batching.

2.2.5. Tools

The tools required are picks and shovels for levelling, spades, hammers (and nails), bricklayer's tools and accessories like trowel, pegs, cord wooden posts, mortar tub, plumb line, measuring tape, wheelbarrow and buckets.

2.2.6. Plastic foil or lining

The floor of the tank can be formed of a layer of polyethylene sheeting, approximately 1 mm thick laid between two layers of sand (see type V).
To ensure a more waterthight construction it is advisable to place an overlap of polyethylene sheeting in the horizontal brickwork jointing, both the sheeting and overlap then being joined by means of a flat or soldering iron.

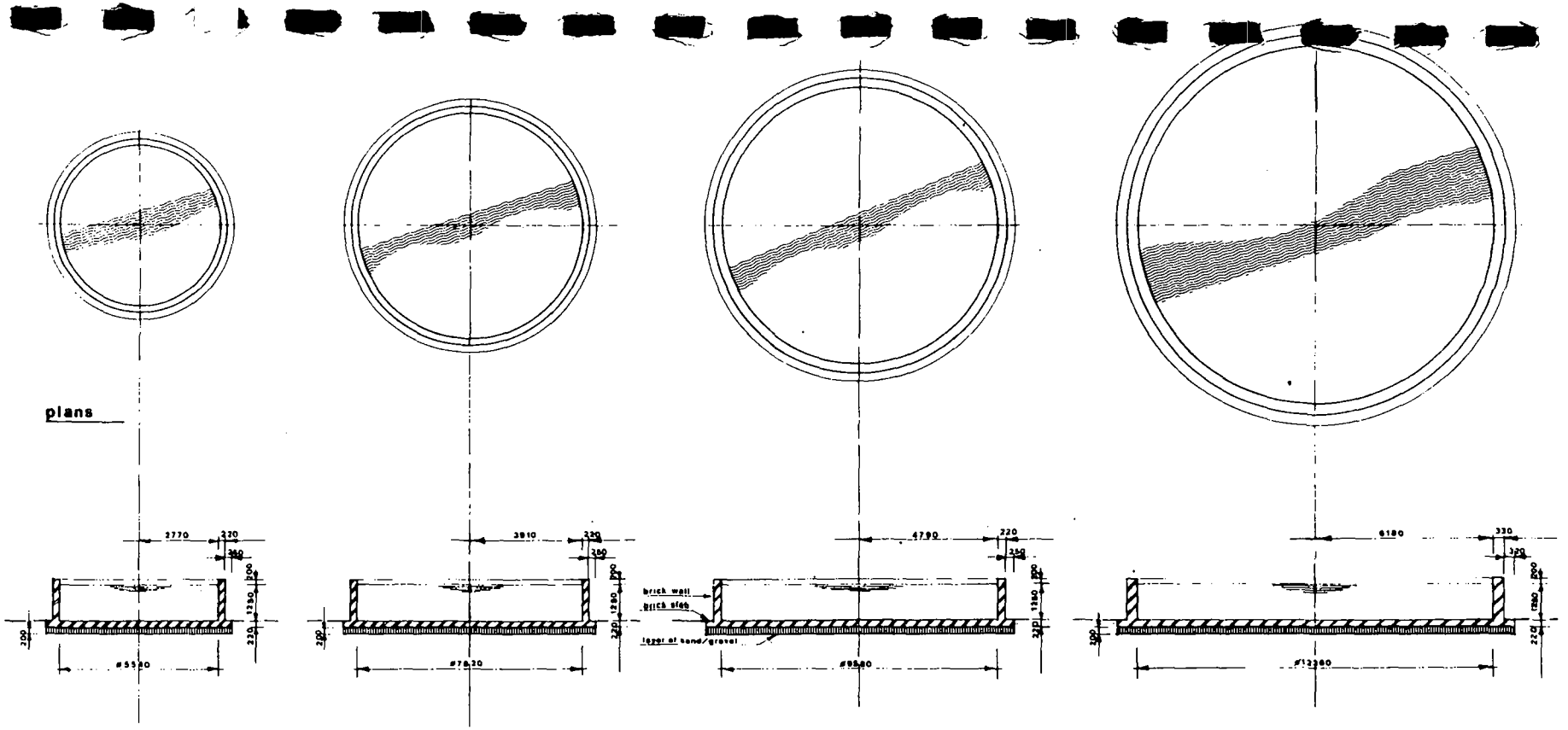
2.2.7. Bund earth wall

To protect the tank construction against climatic influences it is advisable to form a bund around the tank circumference.
A second advantage is that the bund will reduce the tensile forces and bending moments in the tankwall. When in type V a bund earth wall will be used the tierods made of steelstrips will not be a necessity.
This bund is formed by heaping the excavated earth against the outside of the tank. When bad soil conditions are found (vegetation, black soil, loose surface soil) also the bund earth wall should have a proper foundation. In respect of this point the site clearance and preparation of the foundations are to be extended till the outer circumference of the bund earth wall and to be carried out as mentioned in 2.3.2., 2.3.3. and 2.3.4.
After piling up the excavated earth against the outside of the tank the bund is finished by compaction.
This is done by ramming with (home-made) tampers or sprinkling with litte water.

2.3. - Work instructions

- Drawings

2.3.1. Watertank Type 1



TYPE I

capacity 30 m³ | capacity 60 m³ | capacity 90 m³ | capacity 150 m³

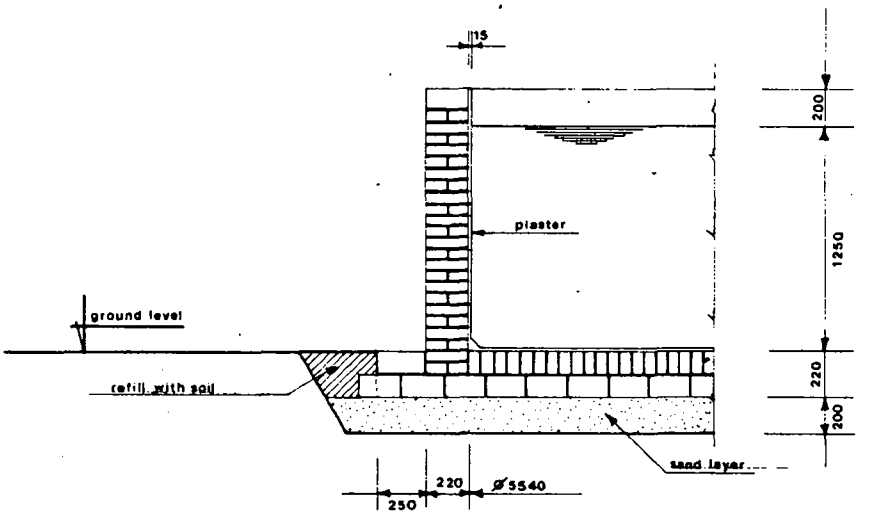
0 1 2 3 4 5
scale in meters

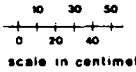
THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS
IN COOPERATION WITH — TWO — AMERSFOORT

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE I GENERAL LAY OUT	measures in mm date 810616
	TWO DHV

TYPE I

work sequence and description	notes and recommandations
- clear the area of the site where the tank is proposed to be constructed - Remove a layer of approx 400 mm of the topsoil - Refill with a sand and/or gravel layer of approx 200 mm - The refill is to be compacted with (self-made) tampers When this fill consists of sand only, the compaction can also be done by sprinkling with a little water and ramming - If necessary the surface is to be levelled - Mark the circumference of the tankslab with pegs (pegs core to core 1 metre) - Mix the cement and sand to a dry mortar - Add water to the dry mortar until the mortar can be handled well - Start bricklaying the tankslab - On the bottom of the tankslab the circumference of the tankwall can be marked - Continue with bricklaying of the tankwall. - On top of the tankwall a bricklayer of edge coping is to be applied (see page 51.) - Refill the outer circumference with soil - The refill is to be compacted - Scrape out the joints of the inside of the wall and of the slab (approx 20 mm) and apply a rendering (plaster) to the inner surfaces of the tank	- As indicated in the details (see page 52) the toplayer of the bottom should be started only after finishing the first layer. - The bonds are indicated in the details as well (see page 51.) - When the bricks are of a good quality and the sizes are approx equal, joints of ± 12 to 15 mm are preferred - Take special care of the joint between the tankslab and the tankwall. - The joint should be cleaned and moistened before bricklaying of the tankwall starts. - When heavy loads are expected on the foundation part of the bottom outside the wall a bond earth wall is advisable (see also type II) - Immediately after bricklaying (after each day) the finished parts of the tank are to be protected against weather influences. Therefore these parts should be moistened or covered during at least the first three weeks.





TYPE I capacity 30 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		8300	
cement	bag (40 ltr)		19	
sand coarse	m³		2	
excavation	m³		16.5	
sand layer	m³		7.4	
refill with soil	m³		1.6	
plaster cement sand	bag m³		3 0.6	
materials				
labour	mandays			
total cost				

TYPE I
Capacity 30 m³

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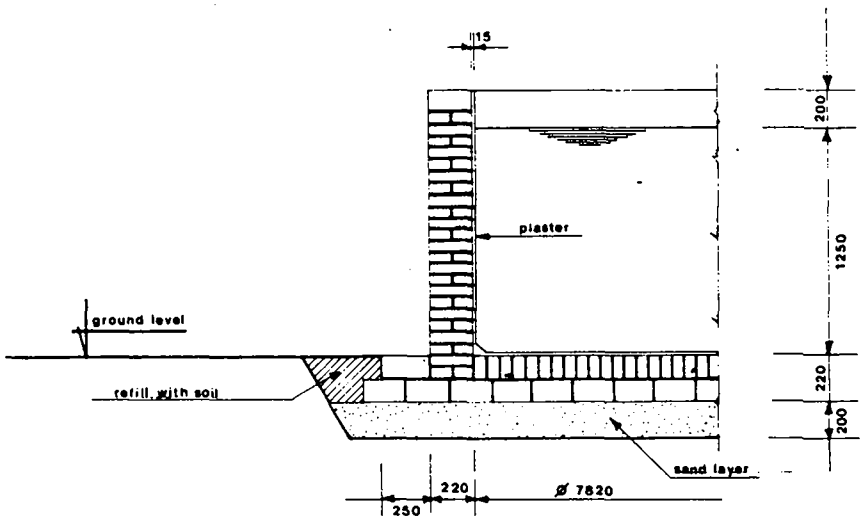
IRRIGATION WATER STORAGE TANKS		
TYPICAL DESIGN	SWD	
MASONRY CONSTRUCTION		
TYPE I DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707	
	TWO	OHV



10 30 50
0 20 40
scale in centimeters

TYPE I capacity 60 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		13600	
cement	bag (40 ltr)		27	
sand coarse	m³		2	
excavation	m³		29	
sand layer	m³		13.5	
refill with soil	m³		2.2	
plaster cement sand	bag m³		5 1	
materials				
labour	mandays			
total cost				

TYPE I
Capacity 60 m³

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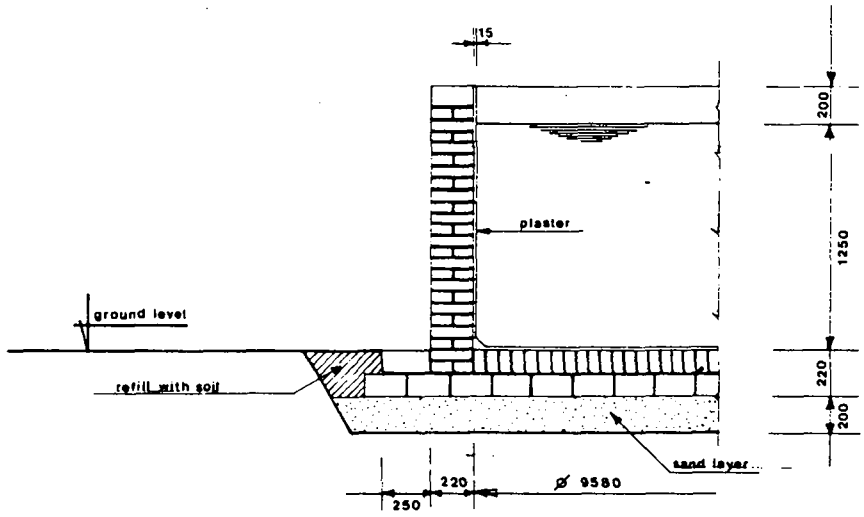
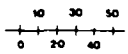
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE I DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV





TYPE I capacity 90 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		18500	
cement	bag (40 ltr)		36	
sand coarse	m³		3	
excavation	m³		41	
sand layer	m³		18.5	
refill with soil	m³		2.2	
plaster cement sand	bag m³		8 1.5	
materials				
labour	mandays			
total cost				

TYPE I
Capacity 90 m³

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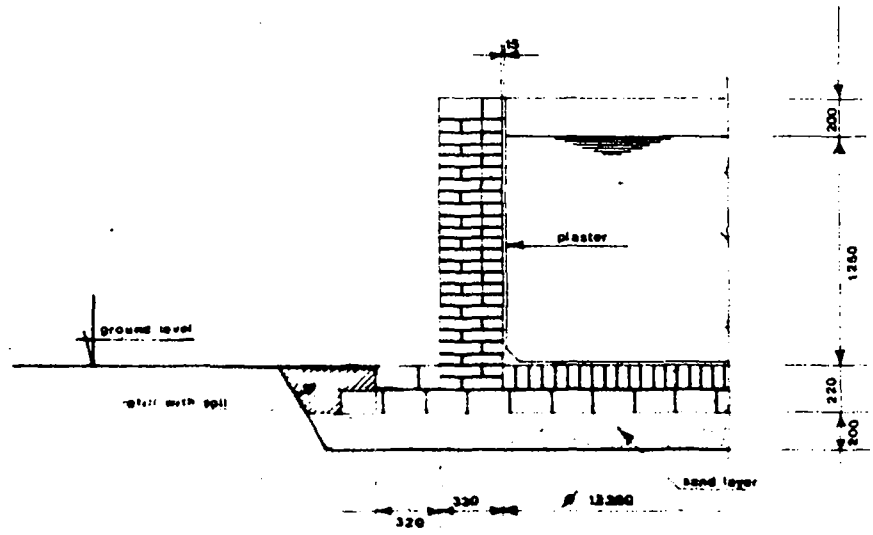
IRRIGATION WATER STORAGE TANKS		
TYPICAL DESIGN	SWD	
MASONRY CONSTRUCTION		
TYPE I DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707	
	TWO	DHV



10 30 50
0 20 40
scale in centimeters

TYPE I capacity 150 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 210 x 110 x 55 mm	piece		32700	
cement	bag (40 lb)		64	
sand coarse	m³		5	
excavation	m³		70	
sand layer	m³		32	
refill with soil	m³		3.5	
plaster cement sand	bag m³		11 2.5	
materials				
labour	mandays			
total cost				

TYPE I
Capacity 150 m³

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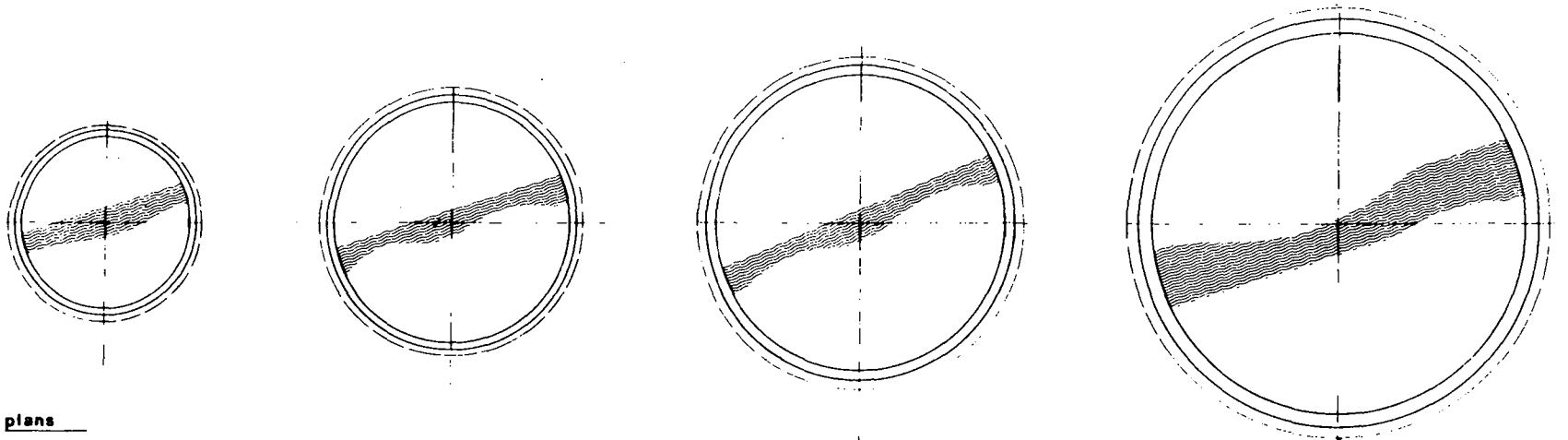
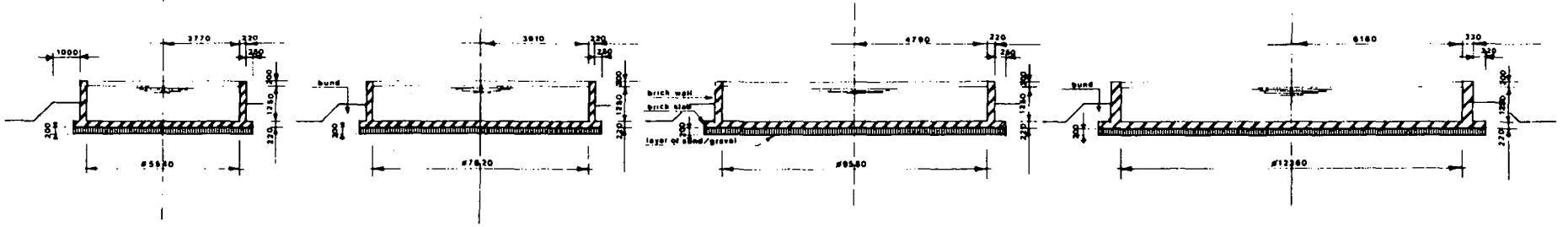
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE I DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV

2.3.2. Watertank Type II



plans



sections

TYPE II

capacity 30 m³ | capacity 60 m³ | capacity 90 m³ | capacity 150 m³

0 1 2 3 4 5

scale in meters

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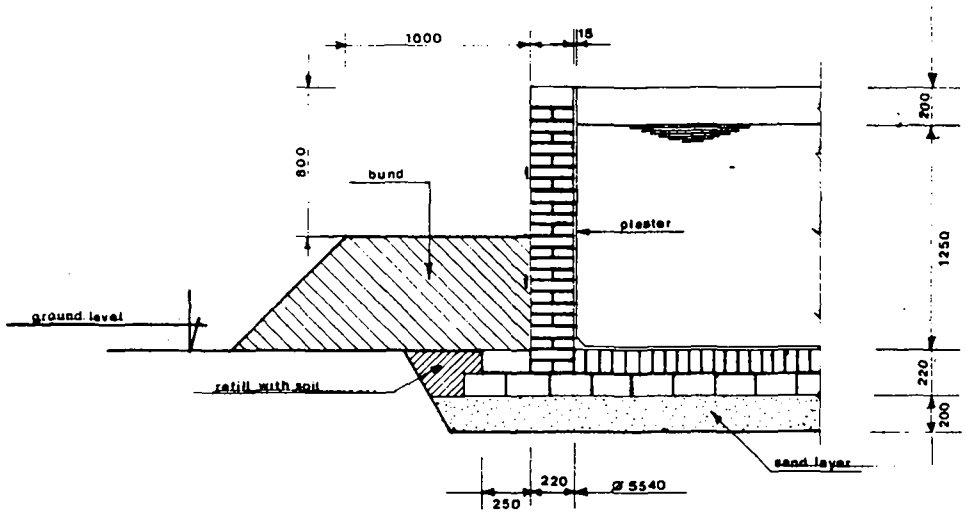
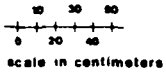
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE II GENERAL LAY OUT	measures in mm date 810616
	TWO

TYPE II

work sequence and description	notes and recommandations
- clear the area of the site where the tank is proposed to be constructed	
- remove a layer of approx. 400 mm of the topsoil	
- when bad soil conditions are found (vegetation, blacksoil, loose surface soil) also the topsoil under the bund earth wall is to be removed	- to avoid settlements of the bund earth wall
- refill with a sand and/or gravel layer of approx. 200 mm	
- the refill is to be compacted with (self-made) tampers	
- when the fill consists of sand only, the compaction can also be done by sprinkling with a little water, and ramming	
- if necessary the surface is to be levelled	
- mark the circumference of the tankslab with pegs (pegs core to core 1 metre)	
- mix the cement and sand to a dry motar	
- add water to the dry motar until the mortar can be handled well	
- start bricklaying the tankslab	- As indicated in the details (see page ...) the toplayer of the bottom should be started only after finishing the first layer
- on the bottom of the tankslab the circumference of the tankwall can marked	
- continue with bricklaying of the tankwall	- The bonds are indicated in the details as well (see page ..)
- on top of the tankwall a bricklayer of edge coping is to be applied (see page 51)	- When the bricks are of a good quality and the sizes are approx. equal joints of ± 12 to 15 mm are preferred
- refill the outer circumference with soil	- take care of the joint between the tankslab and the tankwall
- the refill is to be compacted	- the joints should be cleaned and moistened before bricklaying of the tankwall starts
- scrape out the joints of the inside of the wall and of the slab (approx. 20 mm) and apply a rendering (plaster) to the inner surfaces of of the tank	- immediately after bricklaying (after each day) the finished parts of the tank are to be protected against weather influences

- refill a bund earth wall of approx. 0,65 m heigth around the hole circumference of the tank
- the refill is to be compacted
- therefore these parts should be moistened or covered during at least the first three weeks
- use the topsoil that was removed earlier





TYPE II capacity 30 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		8300	
cement	bag (40 ltr)		19	
sand	m^3		2	
excavation	m^3		16.5	
sand layer	m^3		7.4	
refill with soil	m^3		1.6	
bund	m^3		20	
plaster cement sand	bag m^3		3 0.6	
materials				
labour	mandays			
total cost				

TYPE II
Capacity 30 m³

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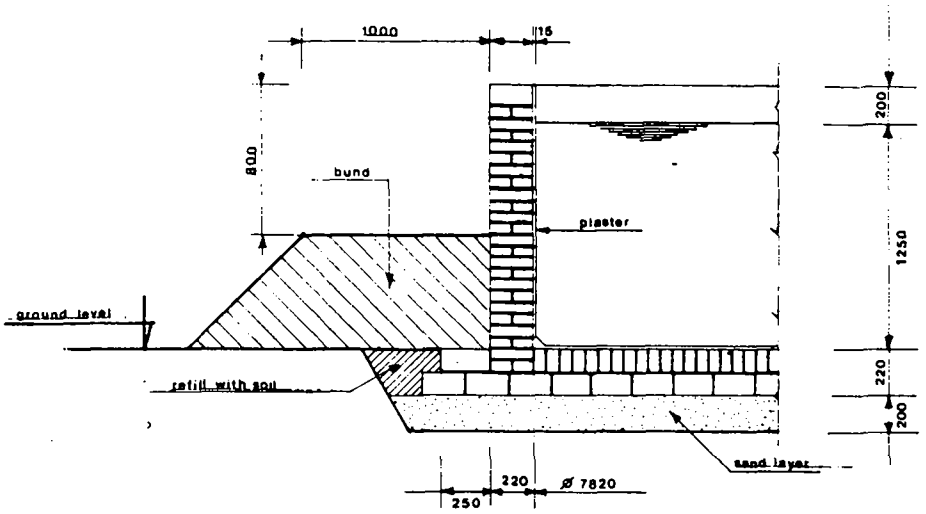
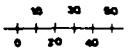
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE II DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV





scale in centimeters

TYPE II capacity 60 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		13600	
cement	bag (40 ltr)		27	
sand coarse	m³		2	
excavation	m³		29	
sand layer	m³		13.5	
refill with soil	m³		2.2	
bund	m³		25.5	
plaster cement sand	bag m³		5 1	
materials				
labour	mandays			
total cost				

TYPE II
Capacity 60 m³

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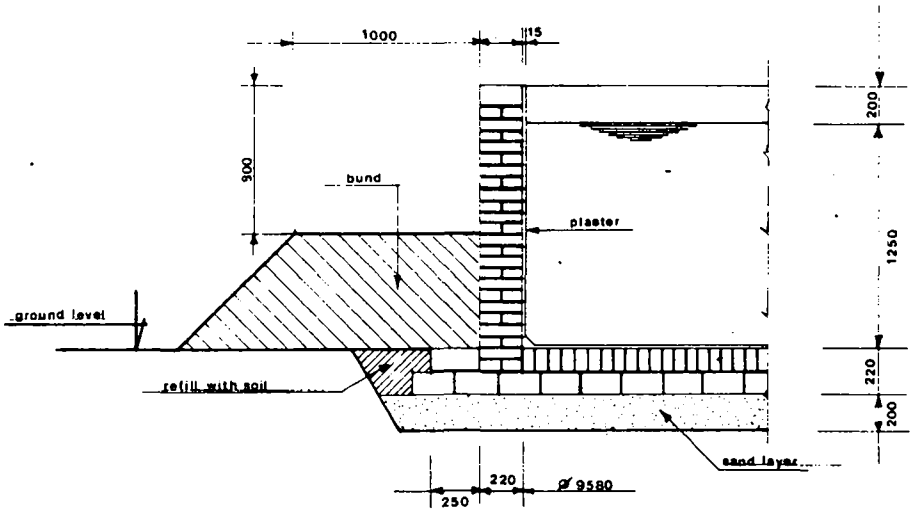
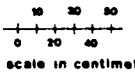
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE II DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV





TYPE II capacity 90 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		18500	
cement	bag (40 ltr)		36	
sand coarse	m³		3	
excavation	m³		41	
sand layer	m³		18.5	
refill with soil	m³		2.2	
bund	m³		35	
plaster cement sand	bag m³		8 1.5	
materials				
labour	mandays			
total cost				

TYPE II
Capacity 90 m³

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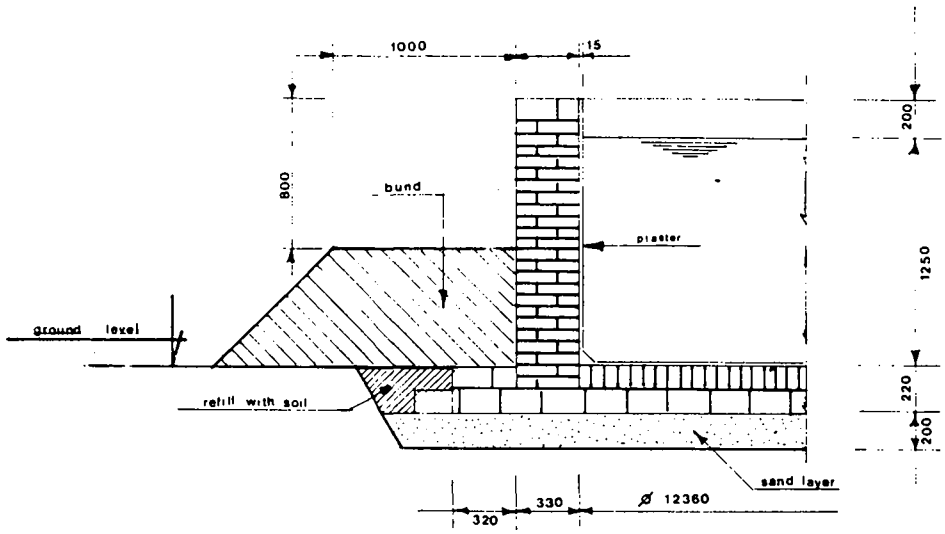
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE II DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707
	TWO | DHV



10 30 50
0 20 40
scale in centimeters

TYPE II capacity 150 m³

PRICE LEVEL

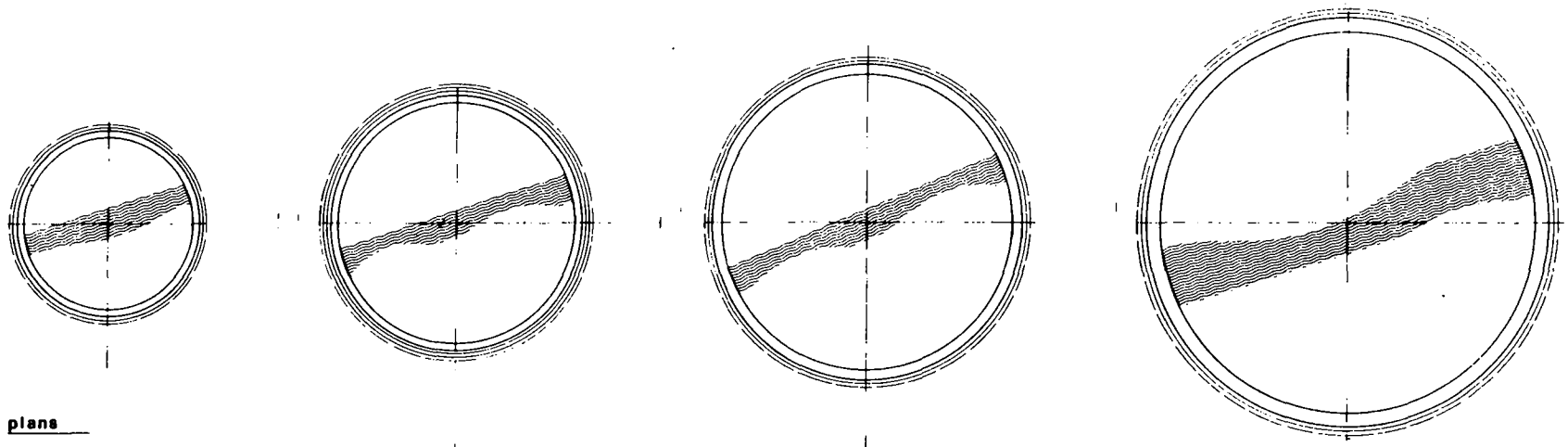
ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		32700	
cement	bag (40 ltr)		64	
sand coarse	m³		5	
excavation	m³		70	
sand layer	m³		32	
refill with soil	m³		35	
bund	m³		39	
plaster cement sand	bag m³		11 2.5	
materials				
labour	mandays			
total cost				

TYPE II
Capacity 150 m³

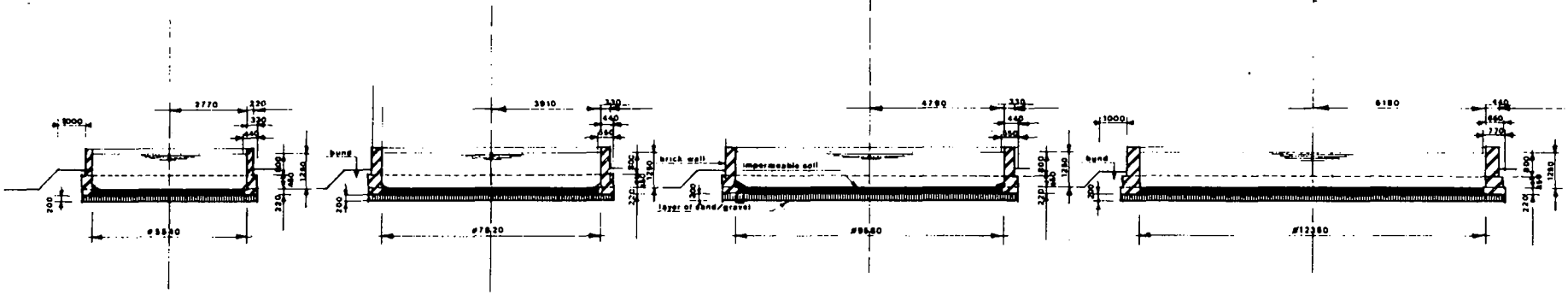
THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT.

IRRIGATION WATER STORAGE TANKS		
TYPICAL DESIGN	SWD	
MASONRY CONSTRUCTION		
TYPE II DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810710	
	TWO	DHV

2.3.3. Watertank Type III



plans



sections

TYPE III

capacity 30 m³ | capacity 60 m³ | capacity 90 m³ | capacity 150 m³

0 1 2 3 4 5
scale in meters

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
MASONRY CONSTRUCTION	
TYPE III GENERAL LAY OUT	measures in mm date 810616
	TWO | BHV

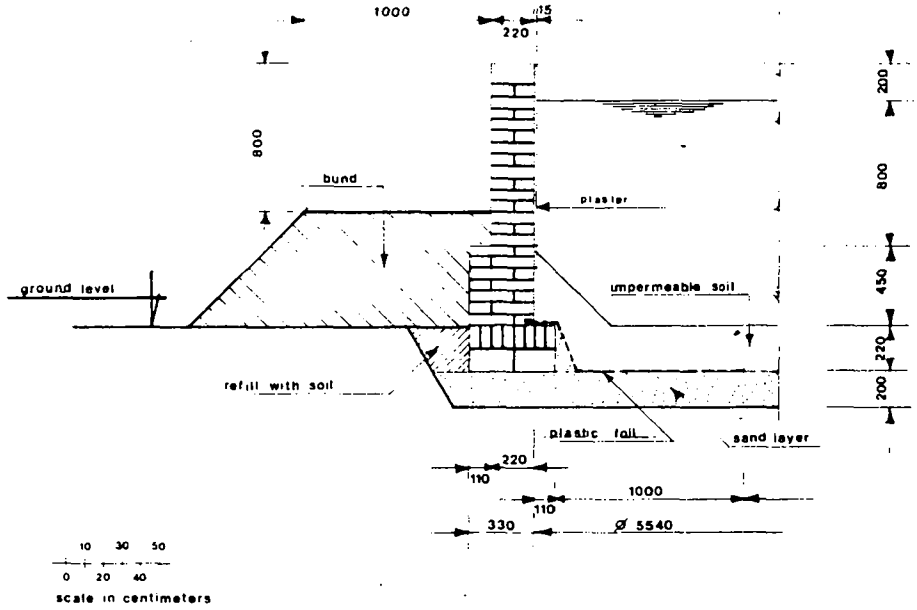
TYPE III

work sequence and description	notes and recommendations
- clear the area of the site where the tank is proposed to be constructed	
- remove a layer of approx. 400 mm of the topsoil	
- when bad soil conditions are found (vegetation, black soil, loose surface soil) also the topsoil under the bund earth wall is to be removed	- to avoid settlements of the bund earth wall
- refill with a sand layer of approx. 200 mm	
- the refill is to be compacted with (self-made) tampers. The compaction can also be done by sprinkling with a little water and ramming	
- if necessary the surface is to be levelled	
- mark the circumference of the tank-foundation with pegs (pegs core to core 1 metre)	
- mix the cement and sand to a dry mortar	
- add water to the dry mortar until the mortar can be handled well	
- start bricklaying the tankfoundation to a heigth of 220 mm (4 brick-layers)	- the bonds are indicated in the details (see page 50)
- apply a polyethylene sheeting on the top of the sand layer around the in-side of the tank foundation The joints in the plastic foil are to be sealed by means of a flat or soldering iron	when the bricks are of a good quality and the sizes are approx. equal, joints of ± 12 to 15 mm are prefered - take care of the joint where the plastic foil will be brought in. The joint should be cleaned and moistened before brick-laying of the above part starts
- the plastic foil is to be brought into the joints of the bricks as indicated on the drawing	
- continue bricklaying the tankfoundation and tankwall	- immediately after bricklaying (after each day) the finished parts of the tank are to be protected against weather influences
- on top of the tankwall a bricklayer of of edge coping is to be applied (see page 5.1.)	
- fill the bottom of the tank with impermeable soil of approx. 220 mm	- therefore these parts should be moistened or covered during at least the first three weeks

- refill the outer circumference with soil
- the refill is to be compacted
- scrape out the joints of the inside of the wall (approx. 20 mm) and apply a rendering (plaster) to the inner surfaces of the tank
- refill a bund earth wall of approx. 0,65 height around the hole circumference of the tank
- the refill is to be compacted

- Use the topsoil that was removed earlier

* Type III and type IV are variants.
Minor differences in respect of the quantities of materials incorporated in the types III and IV are indicated in the schedule of quantities.



TYPE III capacity 30 m³

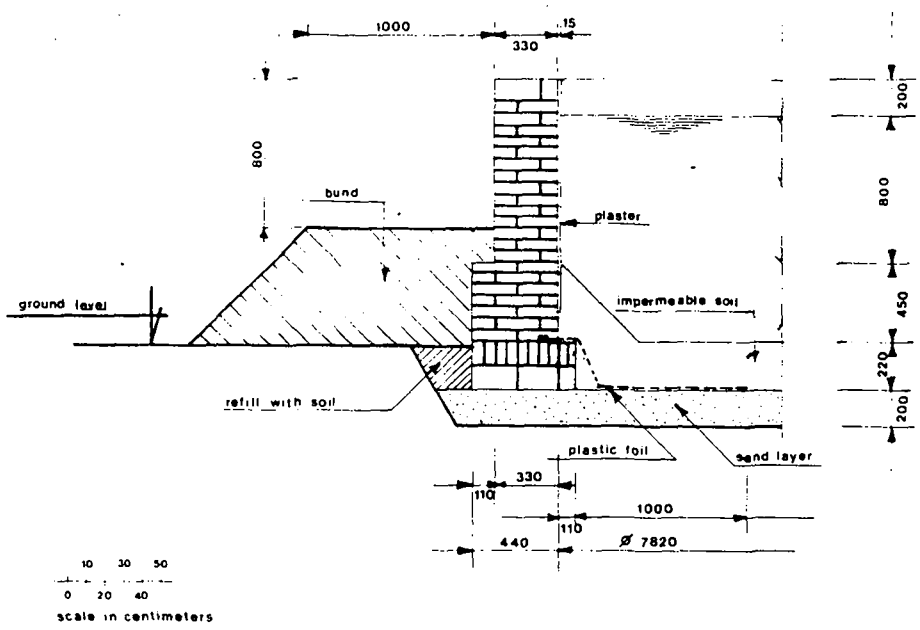
PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		5400	
cement	bag (40ltr)		11	
sand	m³		1	
excavation	m³		15	
sand layer	m³		6.7	
refill with soil	m³		1.7	
bund	m³		20	
plaster cement sand	bag m³		1 0.3	
plastic foil	m²		22	
impermeable soil	m³		5.3	
materials				
labour	mandays			
total cost				

TYPE III
Capacity 30 m³

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
MASONRY CONSTRUCTION	
TYPE III DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO 13HV



TYPE III capacity 60 m³

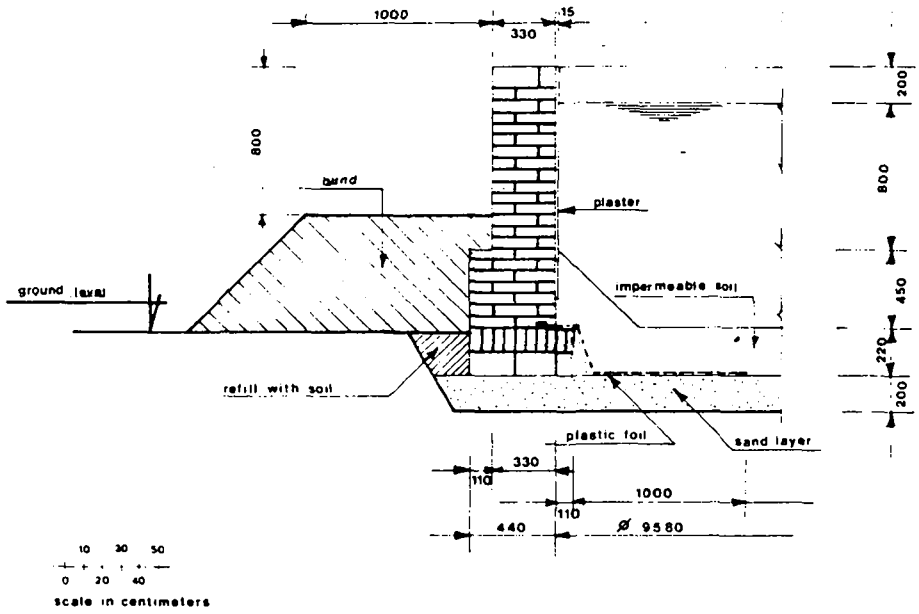
PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		11200	
cement	bag (40 ltr)		22	
sand	m³		1.8	
excavation	m³		28	
sand layer	m³		11	
refill with soil	m³		2.2	
bund	m³		24	
plaster cement sand	bag m³		2 0.4	
plastic foil	m²		32	
impermeable soil	m³		11	
materials				
labour	mandays			
total cost				

TYPE III
Capacity 60 m³

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	
MASONRY CONSTRUCTION		
TYPE III DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707	
	TWO	GHV



TYPE III capacity 90 m³

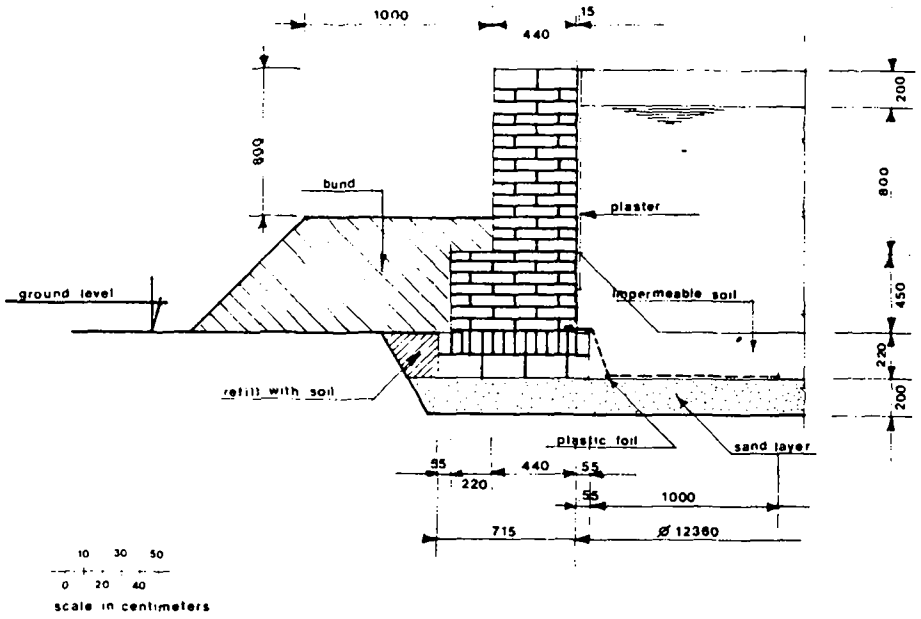
PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		13000	
cement	bag (40 ltr)		26	
sand	m^3		2	
excavation	m^3		39	
sand layer	m^3		18	
refill with soil	m^3		2.2	
bund	m^3		36	
plaster cement	bag		3	
sand	m^3		0.5	
plastic foil	m^2		45	
impermeable soil	m^3		19	
materials				
labour	mandays			
total cost				

TYPE III
Capacity 90 m3

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
MASONRY CONSTRUCTION	
TYPE III DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV



TYPE III capacity 150 m³

PRICE LEVEL

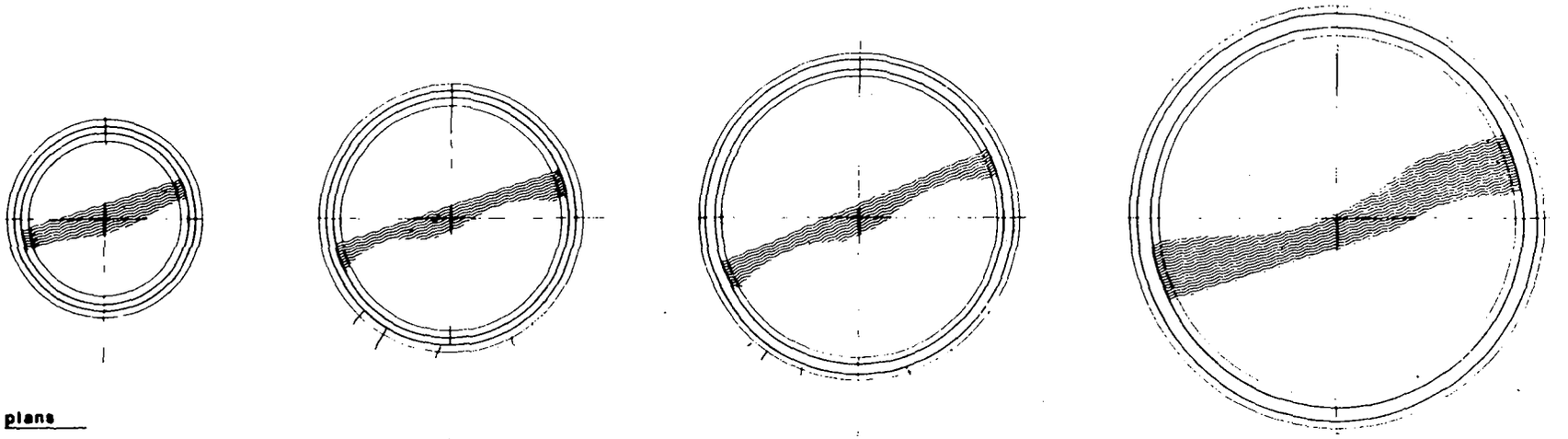
ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		23500	
cement	bag (40 ltr)		46	
sand (course)	m³		3.6	
excavation	m³		65	
sand layer	m³		31	
refill with soil	m³		2.5	
bund	m³		38	
plaster cement sand	bag m³		3 0.6	
plastic foil	m²		54	
impermeable soil	m³		26	
materials				
labour	mandays			
total cost				

TYPE III
150 m3

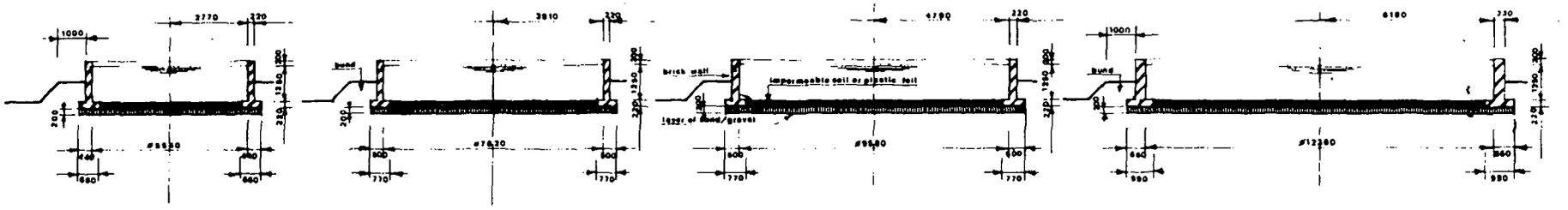
THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT.

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE III DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810710 TWO DHV

2.3.4. Watertank type IV



plans



sections

TYPE IV

capacity 30 m³ | capacity 60 m³ | capacity 90 m³ | capacity 150 m³

0 1 2 3 4 5

scale in meters

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
MASONRY CONSTRUCTION	
TYPE IV GENERAL LAY OUT	measures in mm date 810616
	TWO DHV

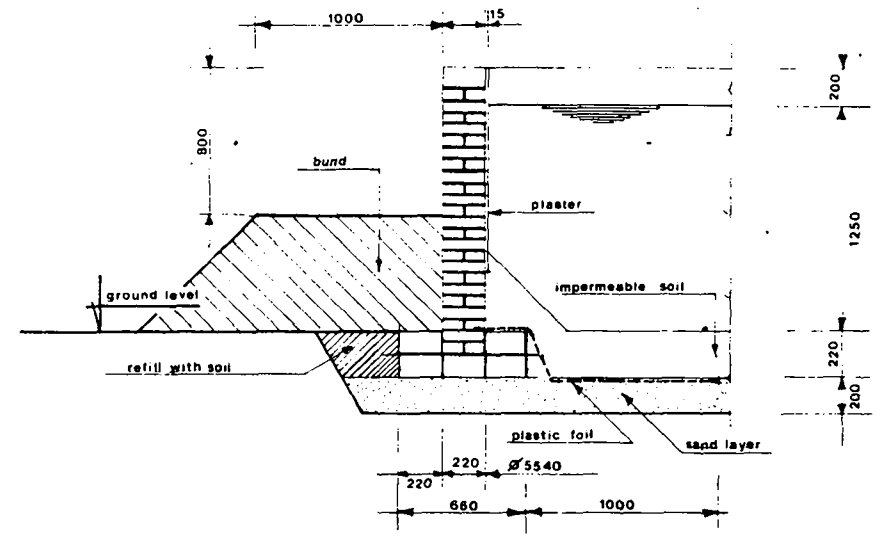
TYPE IV

work sequence and description	notes and recommendations
- clear the area of the site where the tank is proposed to be constructed	
- remove a layer of approx. 400 mm of the topsoil	
- when bad soil conditions are found (vegetation, black soil, loose surface soil) also the topsoil under the bund earth wall is to be removed	- to avoid settlements of the bund earth wall
- refill with a sand layer of approx. 200 mm	
- the refill is to be compacted with (self-made) tampers. The compaction can also be done by sprinkling with a little water and ramming	
- if necessary the surface is to be levelled	
- mark the circumference of the tank-foundation with pegs (pegs core to core 1 metre)	
- mix the cement and sand to a dry mortar	
- add water to the dry mortar until the mortar can be handled well	
- start bricklaying the tankfoundation to a heigth of 220 mm (4 brick-layers)	- the bonds are indicated in the details (see page 50)
- apply a polyethylene sheeting on the top of the sand layer around the inside of the tank foundation The joints in the plastic foil are to be sealed by means of a flat or soldering iron	when the bricks are of a good quality and the sizes are approx. equal, joints of ± 12 to 15 mm are prefered - take care of the joint where the plastic foil will be brought in. The joint should be cleaned and moistened before brick-laying of the above part starts
- the plastic foil is to be brought into the joints of the bricks as indicated on the drawing	
- continue bricklaying the tankfoundation and tankwall	- immediately after bricklaying (after each day) the finished parts of the tank are to be protected against weather influences
- on top of the tankwall a bricklayer of of edge coping is to be applied (see page 51)	
- fill the bottom of the tank with impermeable soil of approx. 220 mm	- therefore these parts should be moistened or covered during at least the first three weeks

- refill the outer circumference with soil
- the refill is to be compacted
- scrape out the joints of the inside of the wall (approx. 20 mm) and apply a rendering (plaster) to the inner surfaces of the tank
- refill a bund earth wall of approx. 0,65 height around the hole circumference of the tank
- the refill is to be compacted

- Use the topsoil that was removed earlier

* Type III and type IV are variants.
Minor differences in respect of the quantities of materials incorporated in the types III and IV are indicated in the schedule of quantities.



10 30 50
0 20 40
scale in centimeters

TYPE IV capacity 30 m³

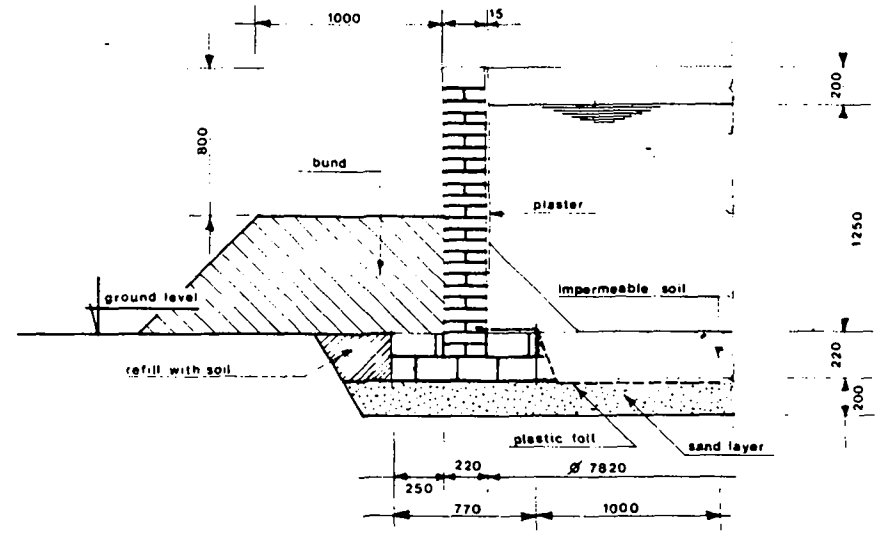
PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		5400	
cement	bag (40 ltr)		11	
sand coarse	m³		1	
excavation	m³		17	
sand layer	m³		8	
refill with soil	m³		1.8	
bund	m³		23	
plastic foil	m²		35	
plaster cement sand	bag m³		2 0.5	
impermeable soil	m³		4.5	
materials				
labour	mandays			
total cost				

TYPE IV
Capacity 30 m3

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
MASONRY CONSTRUCTION	
TYPE IV DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV



10 30 50
0 20 40
scale in centimeters

TYPE IV capacity 60 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		8900	
cement	bag (40 ltr)		18	
sand coarse	m³		1.5	
excavation	m³		30	
sand layer	m³		13.5	
refill with soil	m³		2.4	
bund	m³		26	
plastic foil	m²		65	
plaster cement	bag		2	
sand	m³		0.5	
impermeable soil	m³		9.3	
materials				
labour	mandays			
total cost				

TYPE IV
Capacity 60 m³

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

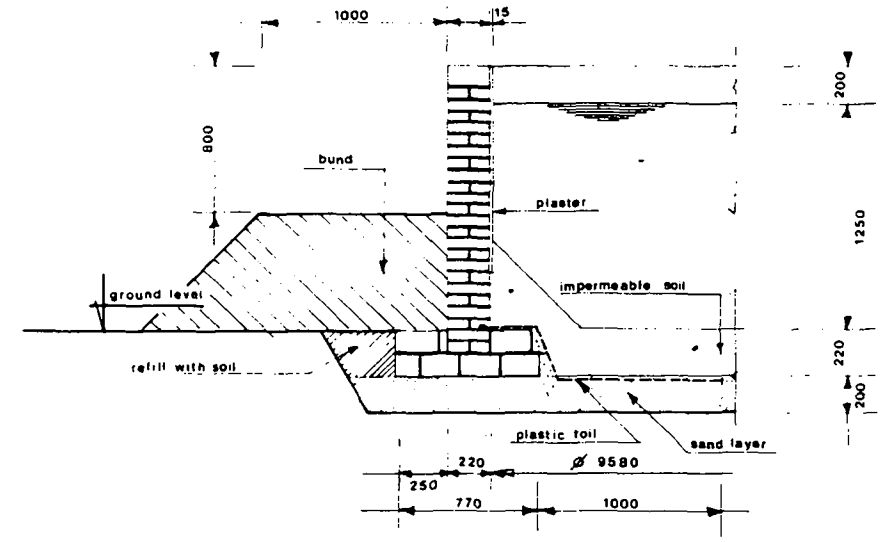
MASONRY CONSTRUCTION

TYPE IV
DETAIL AND DIMENSIONS
BILL OF QUANTITIES

SWD

measures in mm
date 810707

TWO | DHV



10 30 50
0 20 40
scale in centimeters

TYPE IV capacity 90 m³

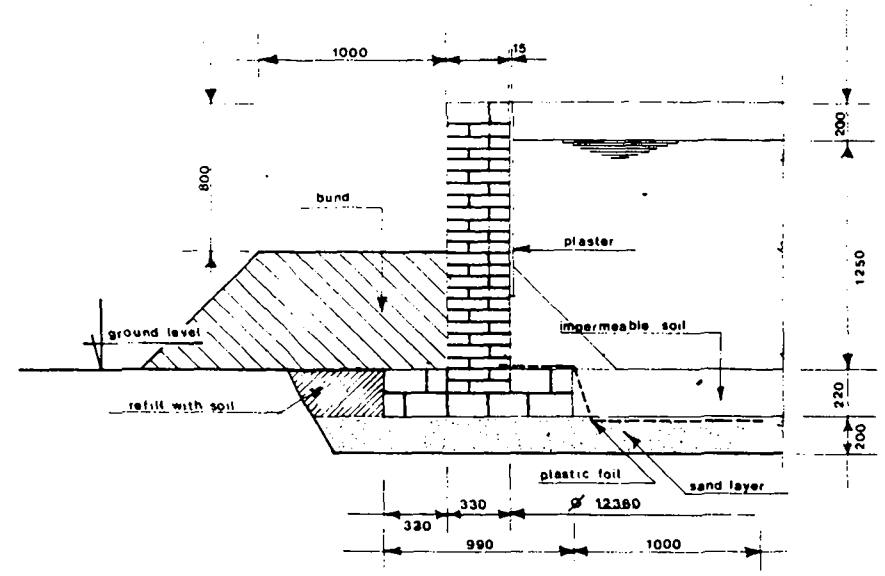
PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		9600	
cement	bag (40 ltr)		20	
sand coarse	m³		1.5	
excavation	m³		41	
sand layer	m³		18.5	
refill with soil	m³		2.2	
bund	m³		35	
plastic foil	m²		92	
plaster cement	bag		3	
sand	m³		0.5	
impermeable soil	m³		19	
materials				
labour	mandays			
total cost				

TYPE IV
Capacity 90 m³

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
MASONRY CONSTRUCTION	
TYPE IV DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV



10 30 50
0 20 40
scale in centimeters

TYPE IV capacity 150 m³

PRICE LEVEL

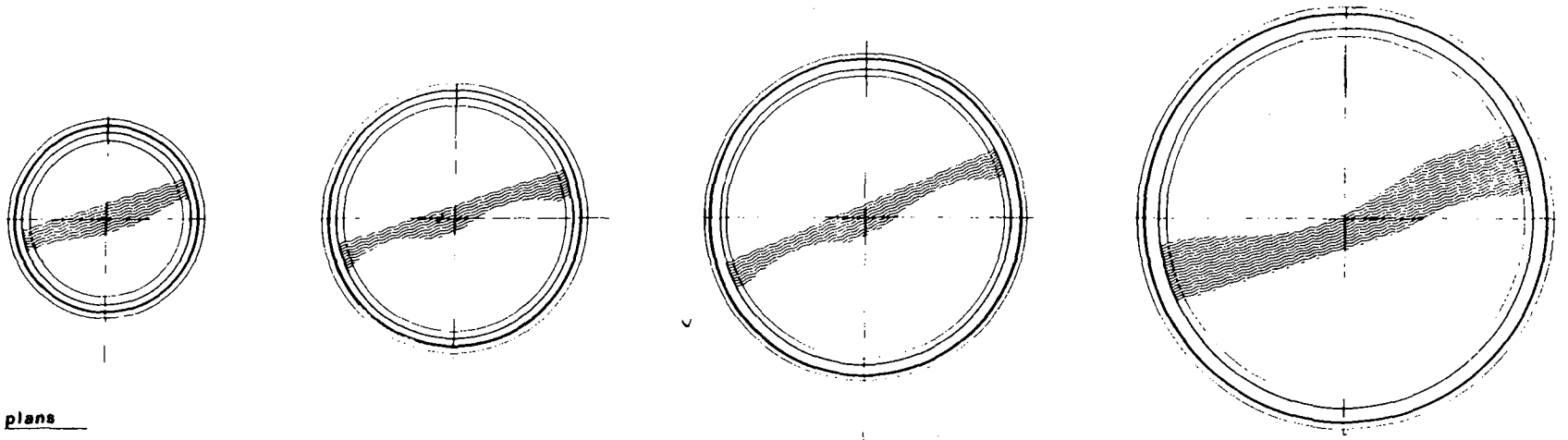
ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		17750	
cement	bag (40 ltr)		34	
sand coarse	m^3		2.7	
excavation	m^3		70	
sand layer	m^3		33	
refill with soil	m^3		4.3	
bund	m^3		39	
plastic foil	m^2		160	
plaster cement sand	bag m^3		3 0.5	
impermeable soil	m^3		24	
materials				
labour	mandays			
total cost				

TYPE IV
Capacity 150 m3

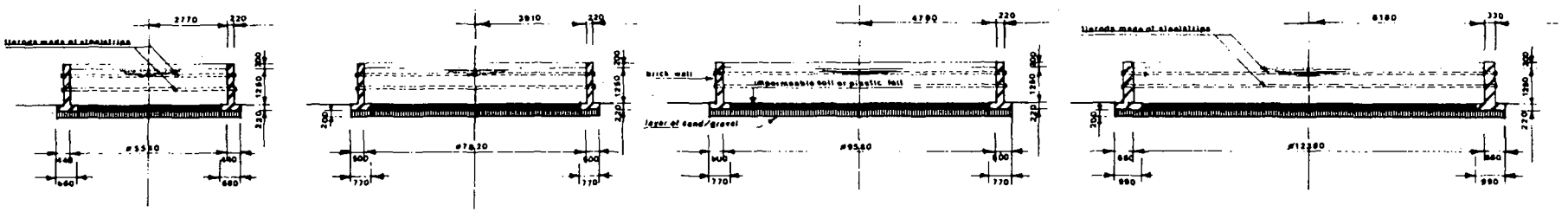
THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES — SWD — PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — TWO — AMERSFOORT.

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
TYPE IV DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707 TWO DHV

2.3.5. Watertank type V



plans



sections

TYPE V

capacity 30 m³ | capacity 60 m³ | capacity 90 m³ | capacity 150 m³

0 1 2 3 4 5
scale in meters

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
MASONRY CONSTRUCTION	
TYPE V GENERAL LAY OUT	measures in mm date 810616
	TWO | BMV

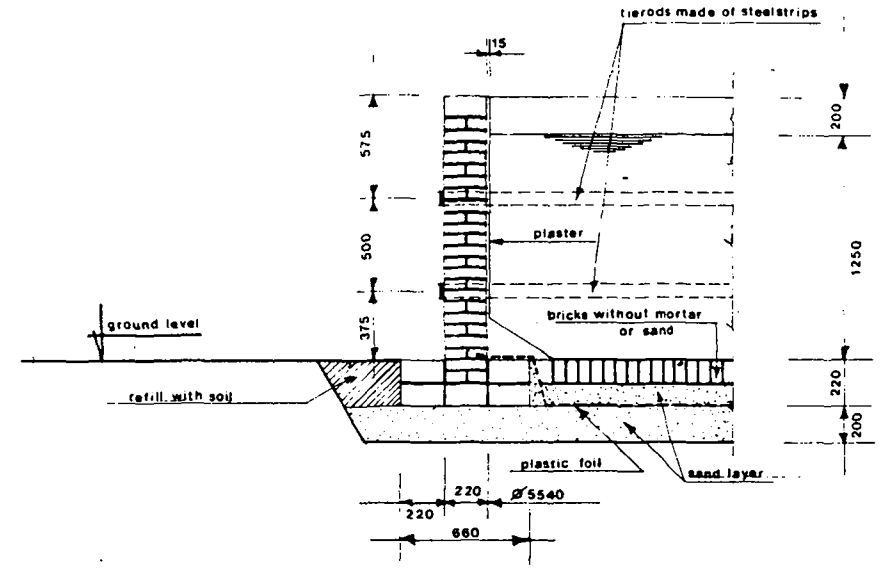
TYPE V*

work sequence and description	notes and recommendations
- clear the area of the site where the tank is proposed to be constructed - remove a layer of approx. 400 mm of the topsoil - refill with a sand layer of approx. 200 mm - the refill is to be compacted with (self-made) tampers. The compaction can also be done by sprinkling with a little water and ramming - if necessary the surface is to be levelled - mark the circumference of the tank-foundation with pegs (pegs core to core 1 metre) - mix the cement and sand to a dry mortar - add water to the dry mortar until the mortar can be handled well	
- start bricklaying the tankfoundation to a height of 220 mm (4 brick-layers) - apply a polythene sheeting on the top of the sand layers. The joints in the plastic foil are to be sealed by means of a flat or soldering iron - the plastic foil is to be brought into the the joints of the bricks as indicated on the drawing - fill the bottom of the tank with a sand layer of 110 mm so that the plastic foil is closed up and protected against damages - continue bricklaying the tankfoundation and tankwall - on top of the tankwall a bricklayer of edge coping is to be applied (see page 51)	- the bonds are indicated in the details (see page 50) - when the bricks are of a good quantity and the sizes are approx. equal, joints of ± 12 to 15 mm is prefered - take care of the joint where the plastic foil will be brought in. The joint should be cleaned and moistened before brichlaying of the above part starts. - immediately after brick-laying (after each day) the finished parts of the tank are to be protected aginst weather influences. Therefore these parts should be moistened or covered during at least the first three weeks
- apply on the bottom of the tank a second layer consisting of bricks without mortar (110 mm) - refill the outer circumference with soil - the refill is to be compacted	

- scrape out the joints of the inside of the wall (approx. 20 mm) and apply a rendering (plaster) to the inner surfaces of the tank
- bold two tie rods made of steelstrips around the tankwall (for details see page 53.)

- it is advisable to protect the tierods against corrosion in advance. (painting, hot deep galvanised)

* This type of tank not to be used in hot and dry tropical countries



10 30 50
0 20 40
scale in centimeters

TYPE V capacity 30 m³

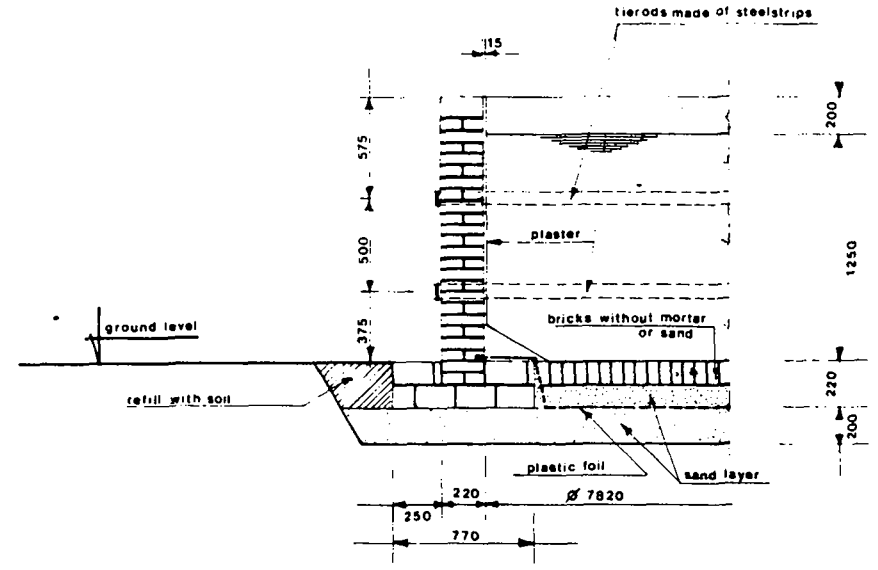
PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		5400	
cement	bag (40 ltr)		11	
sand coarse	m³		1	
excavation	m³		17	
sand layer	m³		8	
refill with soil	m³		1.8	
bricks slab	piece		1450	
plastic foil	m²		35	
plaster cement sand	bag m³		2 0.5	
tierods	6,26 m'		6	
materials				
labour	mandays			
total cost				

TYPE V
Capacity 30 m³

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
MASONRY CONSTRUCTION	
TYPE V DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm. date 810707 TWO DHV



10 30 50
0 20 40
scale in centimeters

TYPE V capacity 60 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		8900	
cement	bag (40 ltr)		18	
sand coarse	m³		1,5	
excavation	m³		30	
sand layer	m³		13.5	
refill with soil	m³		2.4	
bricks slab	piece		2850	
plastic foil	m²		65	
plaster cement	bag		2	
sand	m³		0.5	
tierods	8,65 m'		6	
materials				
labour	mandays			
total cost				

TYPE V
Capacity 60 m3

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

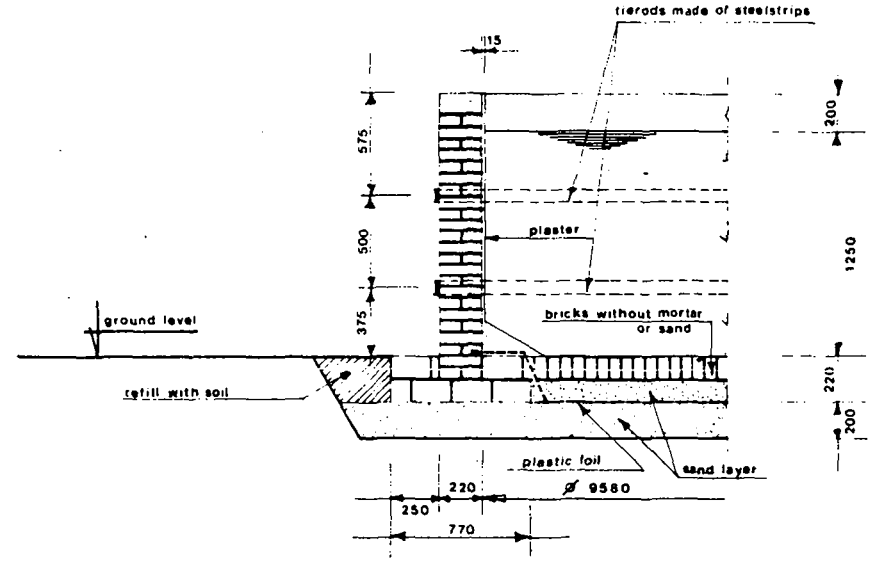
MASONRY CONSTRUCTION

SWD

TYPE V
DETAIL AND DIMENSIONS
BILL OF QUANTITIES

measures in mm
date 810707

TWO DHV



10 30 50
0 20 40
scale in centimeters

TYPE V capacity 90 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		9600	
cement	bag (40 ltr)		20	
sand coarse	m³		1.5	
excavation	m³		41	
sand layer	m³		25.6	
refill with soil	m³		2.2	
bricks slab	piece		4500	
plastic foil	m²		80	
plaster cement sand	bag m³		3 0.5	
tierods	10,26 m'		6	
materials				
labour	mandays			
total cost				

TYPE V
Capacity 90 m³

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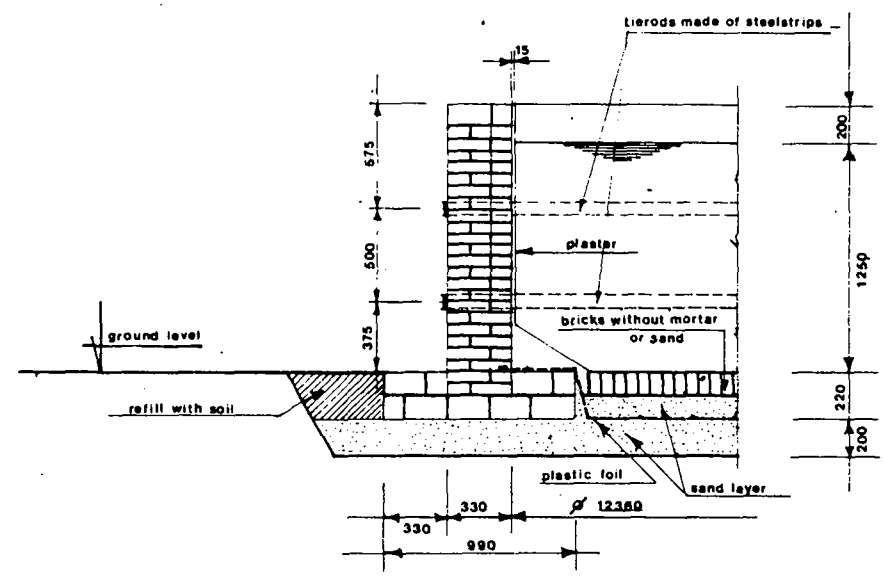
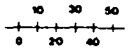
IRRIGATION WATER STORAGE TANKS		
TYPICAL DESIGN	SWD	
MASONRY CONSTRUCTION		
TYPE V DETAIL AND DIMENSIONS BILL OF QUANTITIES	measures in mm date 810707	
	TWO	DHV





scale in centimeters

TYPE V capacity 150 m³

PRICE LEVEL

ITEM	UNIT	UNIT PRICE	QUANTITY	PRICE
bricks 220 x 110 x 55 mm	piece		17700	
cement	bag (40 ltr)		34	
sand coarse	m³		3	
excavation	m³		70	
sand layer	m³		32	
refill with soil	m³		4.5	
bricks slab	piece		7550	
plastic foil	m²		160	
plaster cement sand	bag m³		3 0.5	
tierods	13,63 m'		6	
materials				
labour	mandays			
total cost				

TYPE V
Capacity 150 m³

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

MASONRY CONSTRUCTION

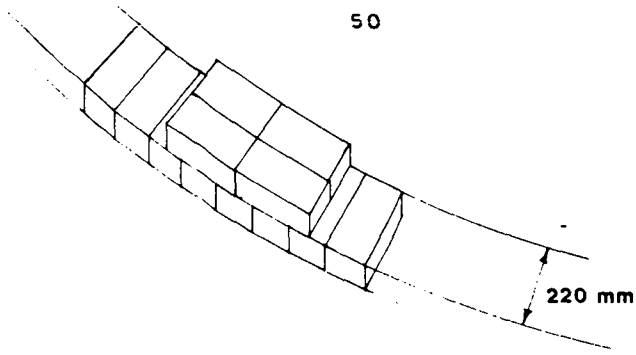
TYPE V
DETAIL AND DIMENSIONS
BILL OF QUANTITIES

SWD

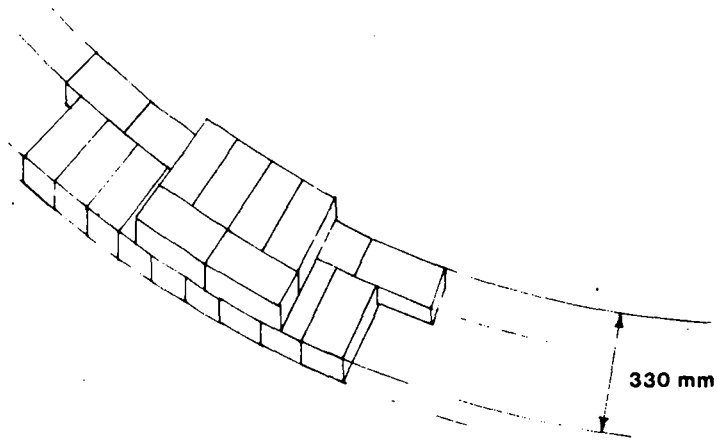
measures in mm
date 810707

TWO | DHV

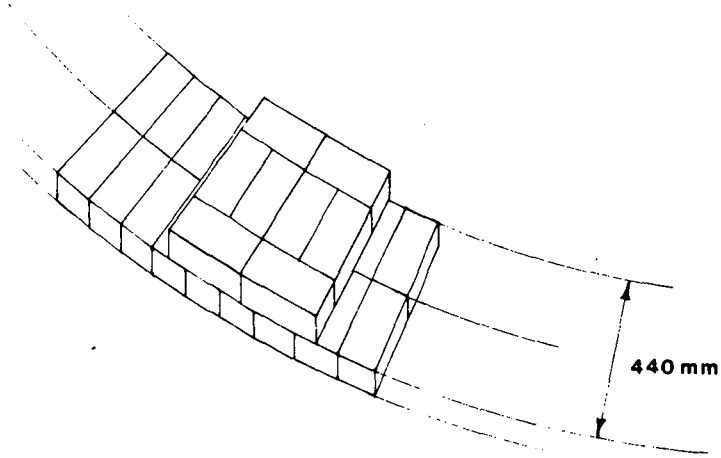
2.3.6. Typical details



brickwork bond for a wall
of 220 mm thickness



brickwork bond for a wall
of 330 mm thickness



brickwork bond for a wall
of 440 mm thickness

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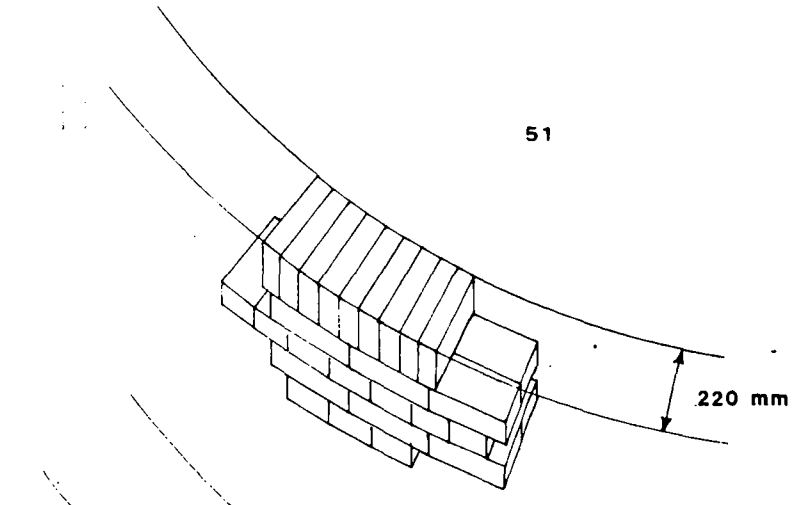
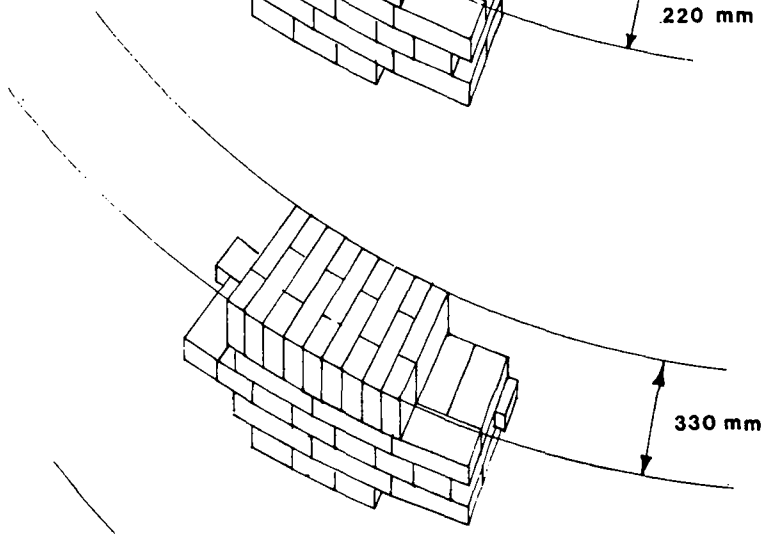
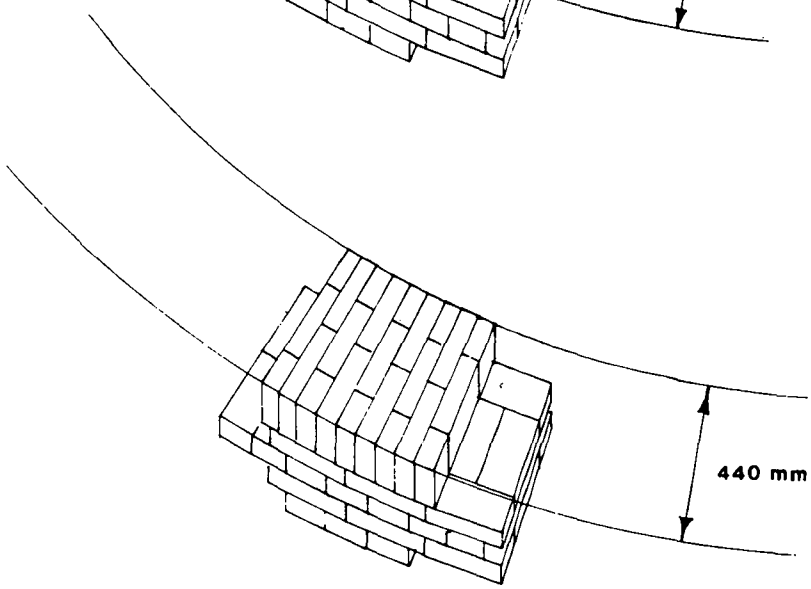
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
DETAILS BRICKWORK BOND	measures in mm date 810715
	TWO BHV



brick on edge coping for
a wall of 220 mm thickness



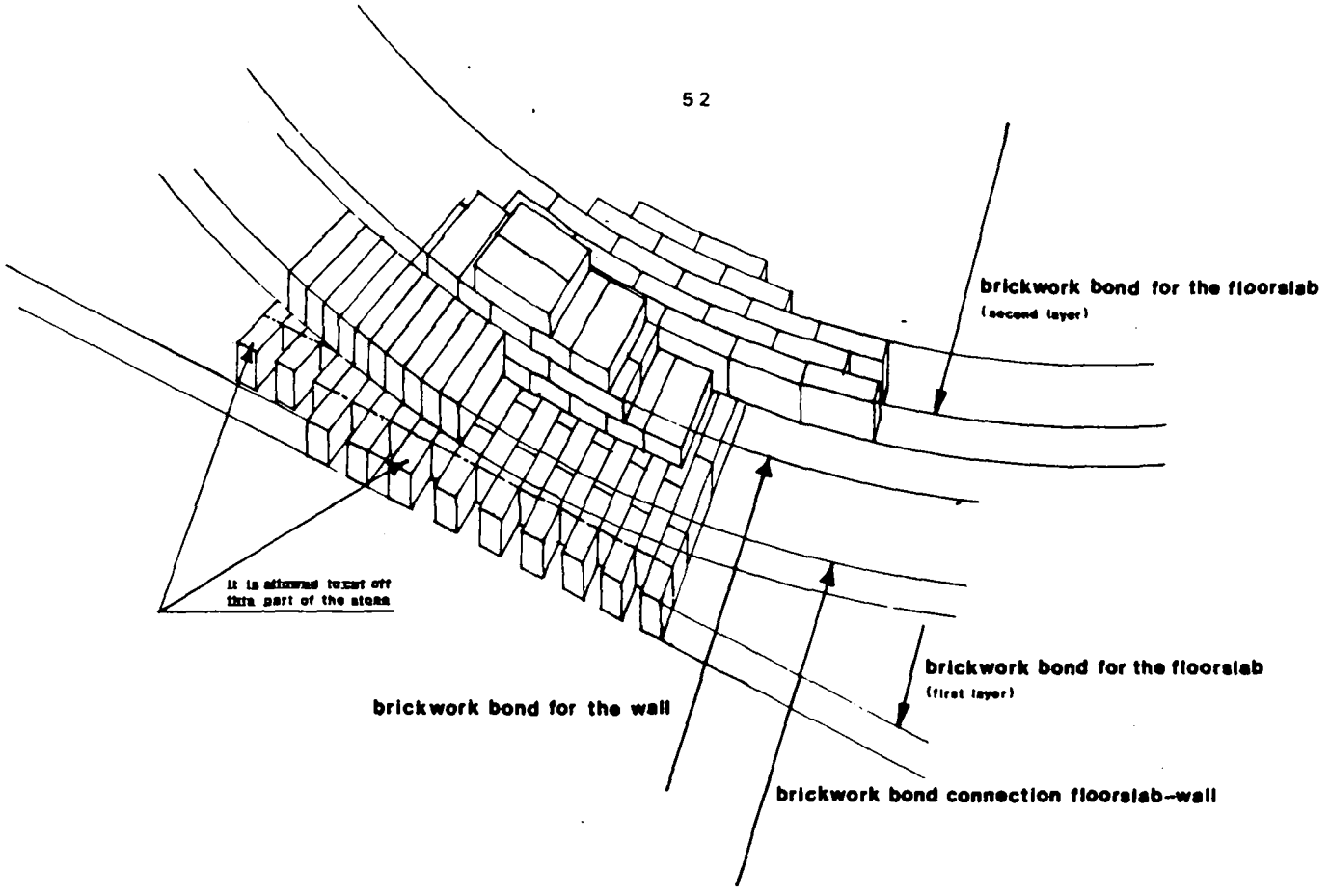
brick on edge coping for
a wall of 330 mm thickness

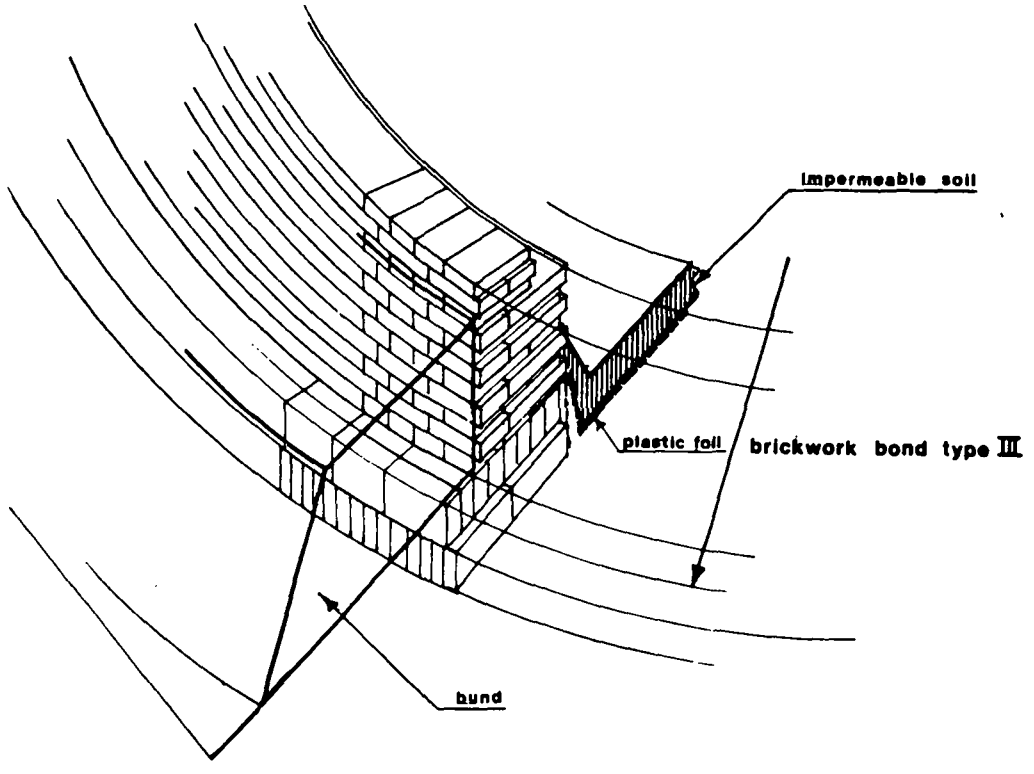


brick on edge coping for
a wall of 440 mm thickness

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.

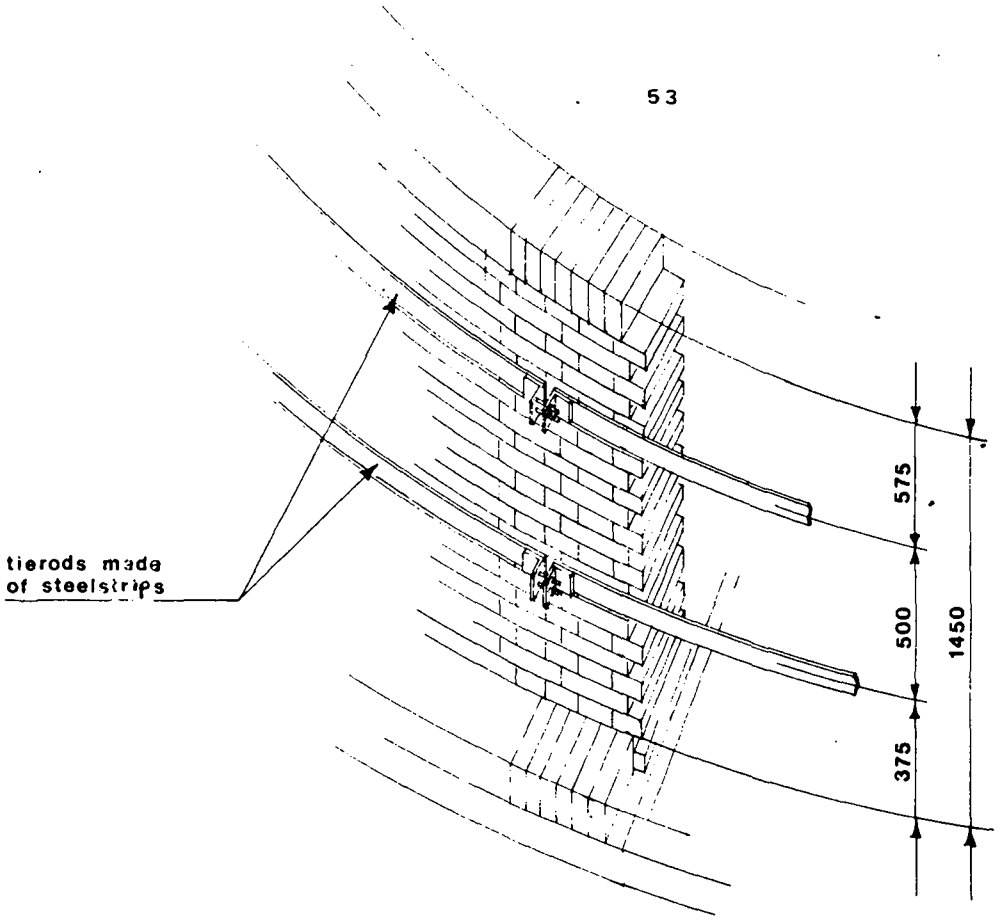
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
DETAILS BRICKWORK BOND	measures in mm date 810713
	TWO DHV

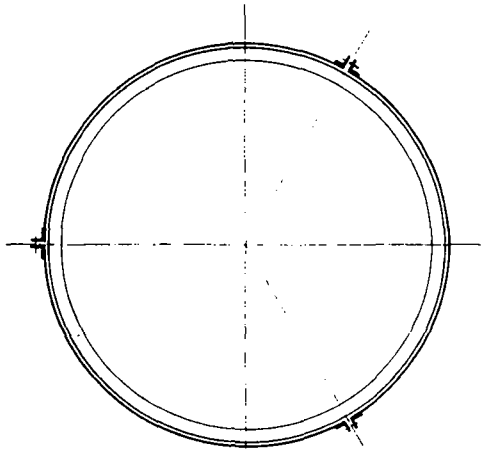




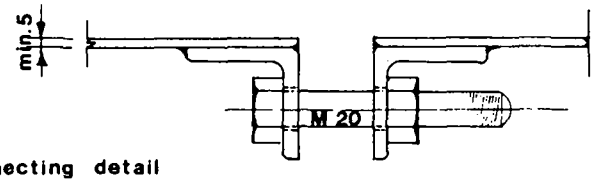
THIS RESEARCH WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE UNDERGRADY DEVELOPMENT COUNTRIES — SWD — PO BOX 88 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH — IWO — AMERSFOORT.

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
MASONRY CONSTRUCTION	
DETAILS BRICKWORK BOND	measures in mm date 810713
	TWO

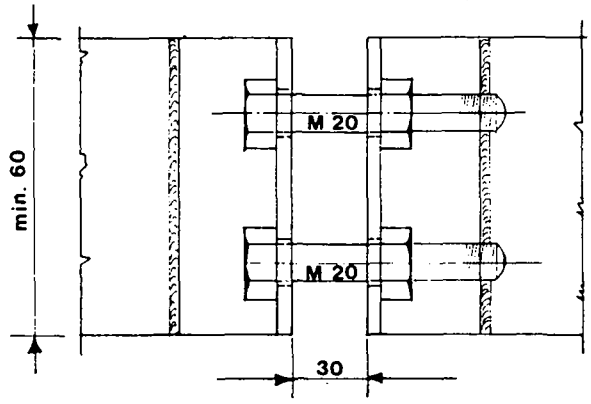




divide the steelstrip
into three parts



connecting detail



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
MASONRY CONSTRUCTION	
DETAILS BRICKWORK BOND	measures in mm date 810715
	TWO | DHV

2.4. Testing

2.4.1. Introduction

If possible it is recommended to test the materials to be used.
The descriptions in this chapter will give some guidelines for testing of bricks, local available.

The question arises how a brick wall in the field or on a farm should be tested to obtain information about cracks and collapse. The critical moment is the moment when the brick wall begins to crack, since in a cracked wall leakage will occur and the tank will be unsuitable. In developing countries test equipment is not always available.
Therefore it must be determined with limited means, whether the brick, the mortar and the brick wall are of such quality that with a reasonable certainty the watertank can be constructed without risk of collapse.
If test equipment is available, it is strongly recommended to make use of it.
However, we assume that the only way to test a brick wall will be to use local materials and local equipment.

2.4.2. Testing construction materials

2.4.2.1. Choice of bricks

The choice of bricks depends on:
a. the functional requirements
b. the waterproof requirements
c. the climatic circumstances

- At testing, a brick must be able to withstand a compressive stress of at least 10 N/mm^2.
- A "brick for damp proof work" is the most suitable one.
- The bricks can be examined as to their outward, physical and mechanical properties.
- Bricks with visible hair cracks must be discarded.

With a little practice it is possible to judge the quality of bricks by hitting them against each other and noting the resonance.
A clear sound generally indicates a brick of good quality and of highly tensile and compressive strength.

- Another method of determining the specific gravity of the bricks is to find the density. The density has a direct relationship with the waterproof quality and stress-resistance properties of a brick type.
  A specific gravity between 19 kn/m^3 and 21 kn/m^3 indicates a "brick for damp proof work".
  A standard brick (220*110*55 mm) will then weigh 2,66 kg.

- The choice of the brick is also depending on the prevailing climatic conditions.
  In countries with changes in humidity and temperatures cracking due to shrinkage may occur (bricks with a low specific shrinkage percentage are advisable).
  In frost-prone areas the watertank should be emptied before the frost period starts.

2.4.2.2. 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

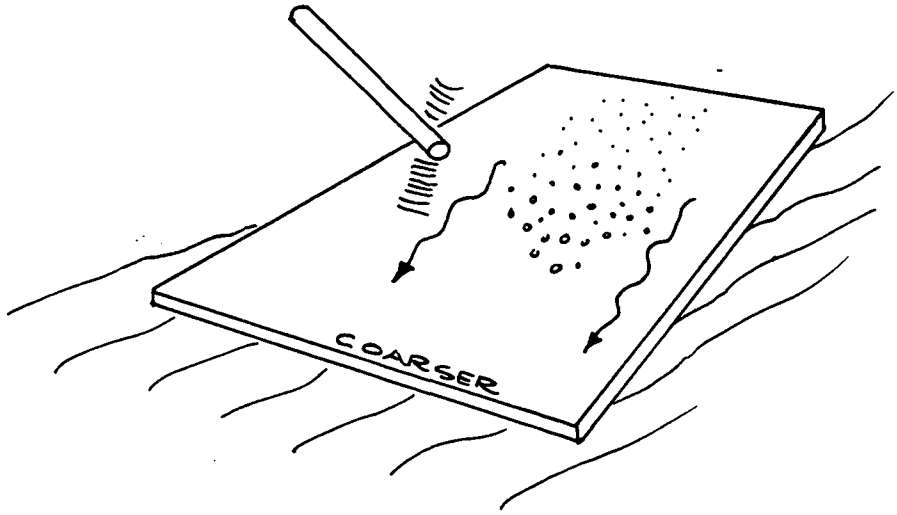
Estimate how much of each fraction is in the soil and separate coarse from fine material by hand.

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.



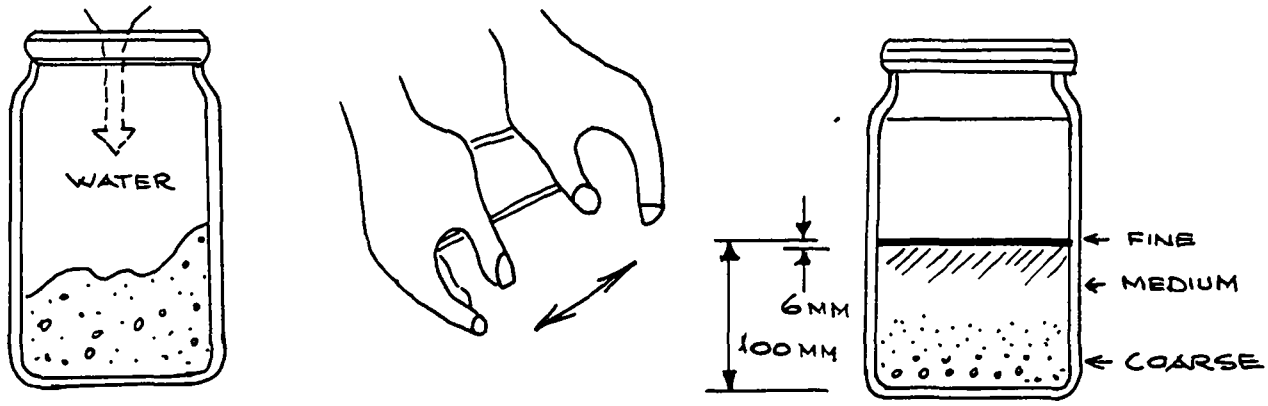
If there are many different sizes between the largest and the smallest, the sample is well-graded. This means it will compact well. If only a few sizes can be seen, then it is single-sized or poorly graded.

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 in a bottle or a glass jar with straight sides. 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 handful of damp material sample 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 building.

2.4.3. Testing masonry construction

2.4.3.1. Testing of a brick wall

To be able to obtain any indications with respect to the tensile strength of a complete brick wall a test can be carried out and is described here.
There are of course many test methods, but for the countries referred to above a very simple test will probably be difficult enough. The general requirements are as follows:

- The dimensions and the shape should be as equal as possible.
- Since the first cracks will occur in the joints, special attention should be paid to the laying of the bricks.
- A good adhesion of the mortar to the surrounding bricks is very important because of the fact that joints are the most critical parts in the brick wall.

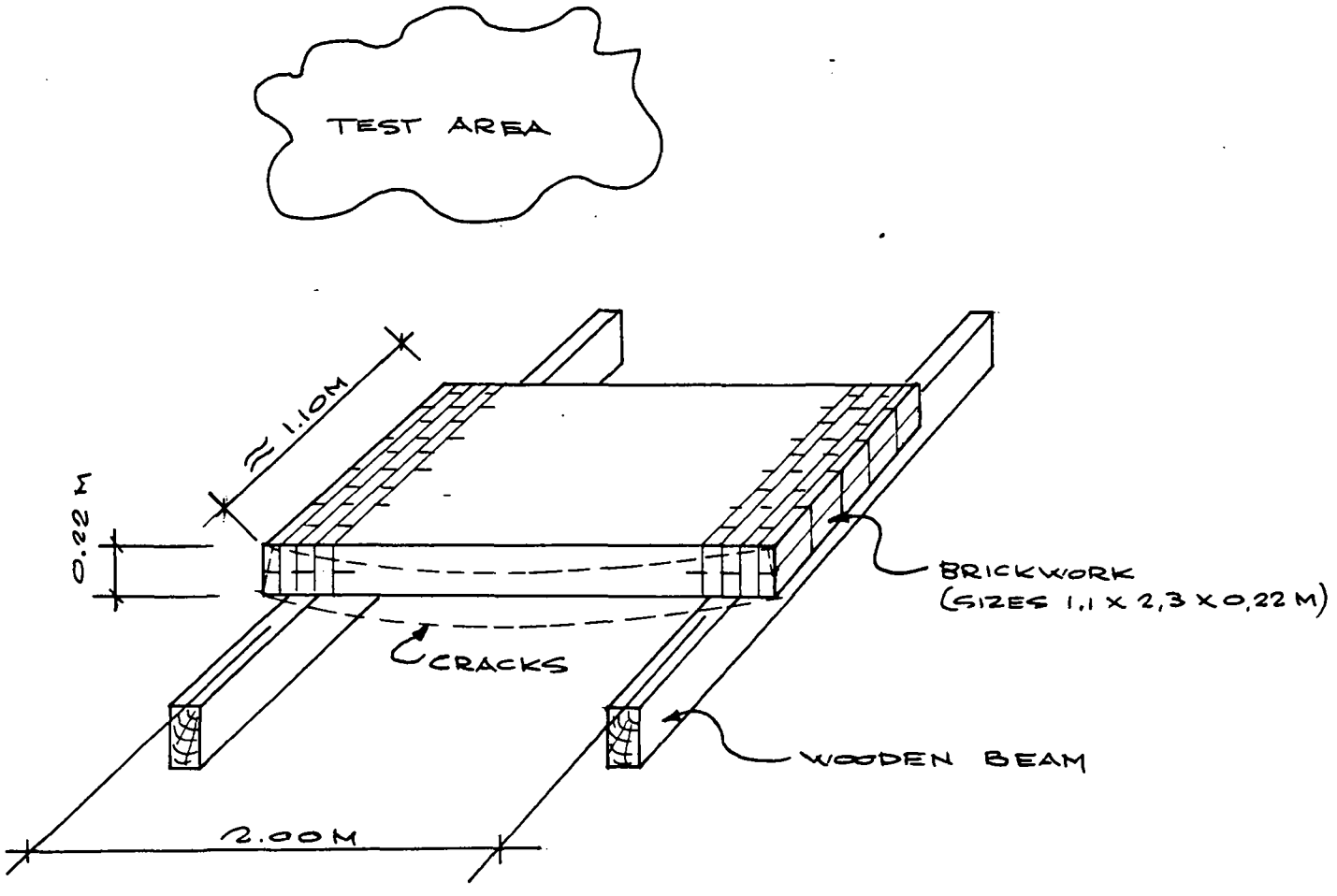
Test

To be sure that a brickwork wall has sufficient strength to carry the loadings, a test piece can be made that can be tested on failure, cracking and possible deformation.
There is a relationship between tensile stresses and bending tensile stresses, whereby it may safely be assumed that the permissible tensile stress is equal to the permissible bending tensile stress.

An easy test can be carried out as described below. The working order is as follows: (see also the drawing).

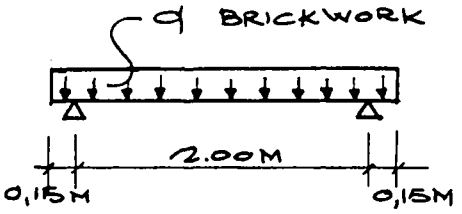
- A suitable area is chosen.
- *Two wooden straight beams are dug into the top soil with a core to core distance of 2.0 metre.
- The surface is levelled.
- The top of the levelled surface and the wooden beams are covered with plastic foil.
- A 220 mm thick wall of 1.10 metre height and approx. 2.3 m in length is made on top of the plastic foil and supported by the two wooden beams (the total weight of the brick wall is approx. 1000 kg).
- The bricks and the mortar should be the same as those used for the watertank to be executed.
- The brickwork bond is indicated on the drawing below (the stretcher joints run vertically over the 1.10 m height to enable the most critical situation to be simulated).

* The brickwork wall can also be made on top of a temporary shuttering to be constructed. After hardening of the mortar the shuttering is to be removed from underneath the brickwork, with the exception of two supports, core to core 2.0 metre.



- After hardening of the mortar (approx. 3 to 4 weeks) the test can be carried out.
- Between the wooden beams the soil is to be dug out to such a depth, that the underside of the brickwork can be inspected for cracking and deflections.
- The plastic foil underneath the brickwork is to be cut away.

The first load case occurs when the brickwork slab is supported by the wooden beams only (first test-step).
The bending moment due to self weight of the slab is then as follows:



g brickwork = 4 KN/m'
(to be checked)

$M = \frac{1}{8} * 4 * 2^2 = 2$ KNm/m'

$W = \frac{1}{6} * 1 * 0.22^2 = 0.0081$ m^3

σ bending moment $= \frac{2*10^6}{0.0081*10^9} = 0.2469$N/mm^2

with a load factor of $\gamma = 2.5$

σ permissible $= \frac{0.2469}{2.5} = 0.099$ N/mm^2 ($\cong 0.1$)

* For symbols see annex IV.

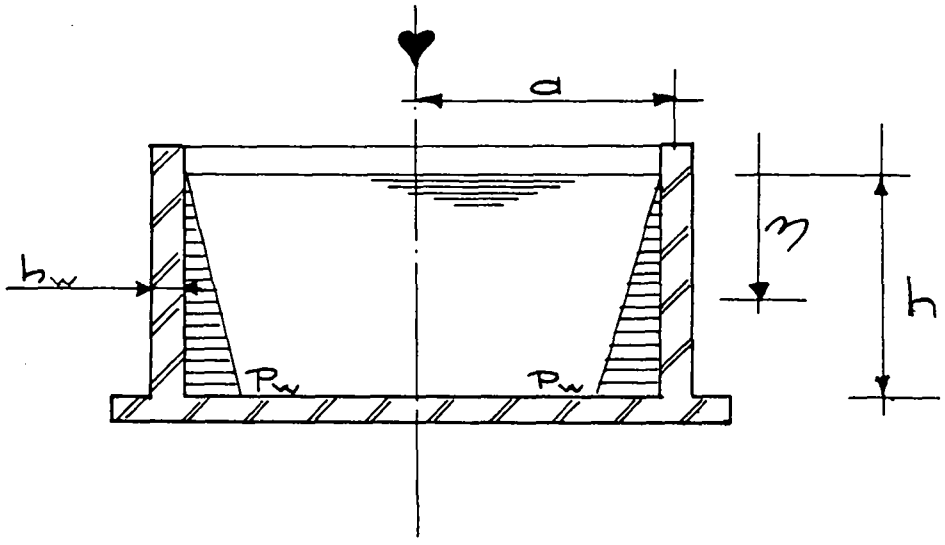
This is approximately the calculated bending tensile stress on the watertank filled with water.
This means that when no cracks occur in the above load case, the wall is strong enough and construction of the watertank can start.
To obtain more information about the behaviour of the wall it would be interesting to load "the brickwork slab" until failure occurs.
Such a test could be carried out by loading the slab step by step with a uniform load of cement bags. After each loading step it is necessary to note all changes like cracks, deflection as well as crack widths (a safety coefficient can be calculated with the formula:

$$\gamma = \frac{\sigma \text{ bending moment}}{0.1}$$

2.5. General starting points for the structural calculations
(For symbols see annex IV)

- To calculate the ring forces and the bending moments in the irrigation tanks the cylinder theory has been used a.o. according to: "Theorie und Berechnung rotations-symmetrischer Bauwerke" by Dr. Gyula Markus
- Where applicable, tables and coefficients from this book are added.
- With the above theory the following formulaa are used:

$$K = \sqrt{\frac{3(1-\mu^2)}{ah}} \quad , \quad N_Q = pa\ F_N \qquad My = pah\ \frac{FM}{w}$$



a	=	Radius of the tank
h	=	The max. water height
h_w	=	wall thickness
p_w	=	water pressure on the bottom of the tank

- Since less is known with respect to the quality of the bricks and the mortar, the stresses in the masonry should be limited:
  a. Where horizontal or vertical reinforcement is to be used the tensile or bending stresses must not exceed 0.15 N/mm^2.
  b. Where the tank will be executed without any reinforcement the tensile or bending stresses must not exceed 0.10 N/mm^2.

Where possible, a sample of a wall should first be made and tested. The method of testing the interpretation of the results obtained, is described in Chapter 2.4.

- The wall should be made not less than 220 mm thick.
- To reduce cracking it is important to execute the wall in a masonry bond as indicated on the drawings. Furthermore, shrinkage and cracking can be prevented by raising the ground around the perimeter of the irrigation tank to a level of approximately 800 mm below the rim level of the tank wall.
- In particular the connection between the bottom slab and the wall should be carried out, very carefully in a masonry bond as indicated to protect the tank against too much leakage.
- Irrigation tanks with capacities of 30, 60, 90 and 150 m^3 are calculated and drawn in 5 types.

  Type I : a fully brickwork tank, walls and slabs, without a bund earth wall.

  Type II : same as type I but with a bund earth wall.

  Type III : brickwork ring foundation with a bund earth wall. The remaining slab will be made of clay (impermeable soil).

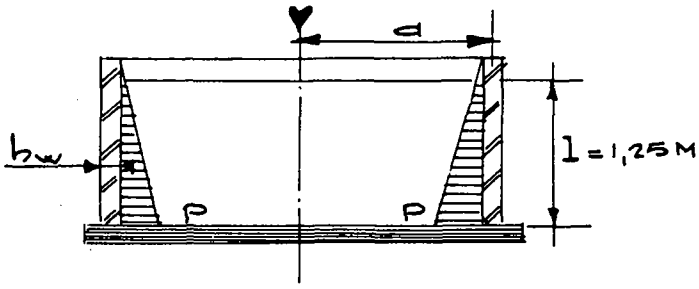
  Type IV : as type III but with a different foundation of the brickwork ring.

  Type V : as type III or IV but with tie rods made of steel strips and without a bund earth wall.

2.5.1. Calculation of the tanks

Type 1 and 2 with a monolithic bottom slab in brickwork or concrete

2.5.1.1. Tank capacity of 30 m³



$$K = \sqrt{\frac{\sqrt{3(1-\mu^2)}}{ah}}$$

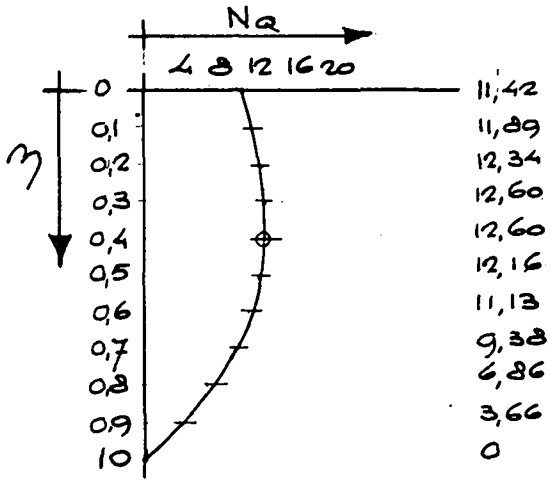
$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{2.77*0.22}} = 1{,}67$$

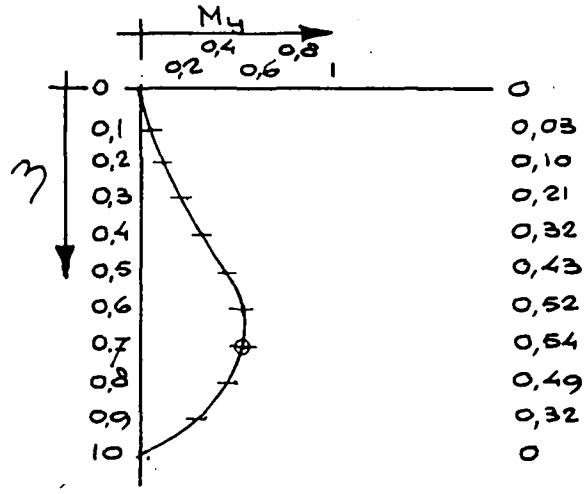
$$Kl = 1.67 * 1.25 = 2.09$$

l = 1.25 m
a = 2.77 m
hw = 0.22 m
μ = 0.2

N_Q = pa F_n
My = pah $\frac{FM}{W}$

pa = 10*1.25*2.77 = 34.6
pah = 7.62





N_Q (KN/m')

$$A_h = \frac{12.6*10^3}{110} = 115 \text{ mm}^2$$

M_y (KNm/m')

$$A_v = \frac{0.54*10^6}{90x110} = 55 \text{ mm}^2$$

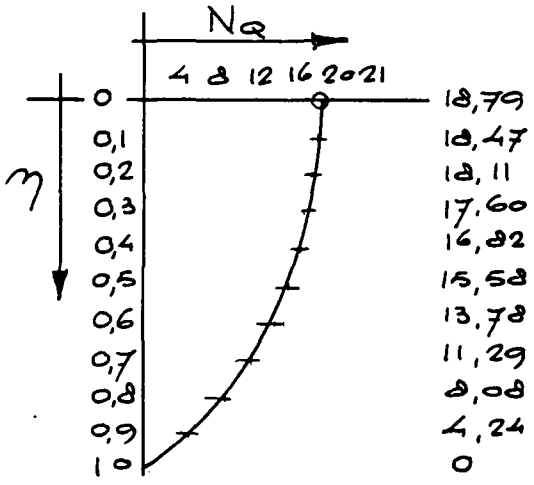
$$\sigma \text{ brickwork (h)} = \frac{12.6*10^3}{220*1000} = 0.0573 \text{ N/mm}^2 \ (< 0.10)$$

$$\sigma \text{ brickwork (v)} = \frac{0.54*10^6*6}{1000*220^2} = 0.0669 \text{ N/mm}^2 \ (< 0.10)$$

→ non-reinforced, wall thickness 220 mm

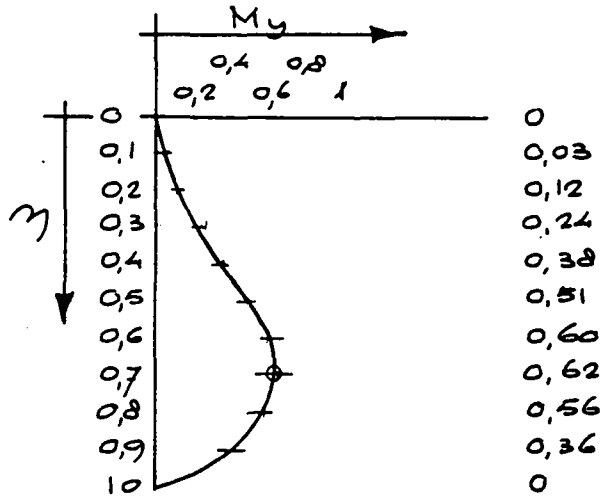
2.5.1.2. Tank capacity of 60 m³

l	=	1.25 m	K	=	$\sqrt{\frac{\sqrt{3}\ (1-02.)}{3.91*0.22}}$	= 1,405
a	=	3.91 m				
hw	=	0.22 m	Kl	=	1.76	
μ	=	0.2 m	pa	=	10*1.25*3.91	= 48.88
			pah	=		= 10.75



N_Q (KN)/m'

$$A_h = \frac{18.79*10^3}{110} = 170 \text{ mm}^2$$



M_y (KNn)/m'

$$A_v = \frac{0.62*10^6}{90* 100} = 62 \text{ mm}^2$$

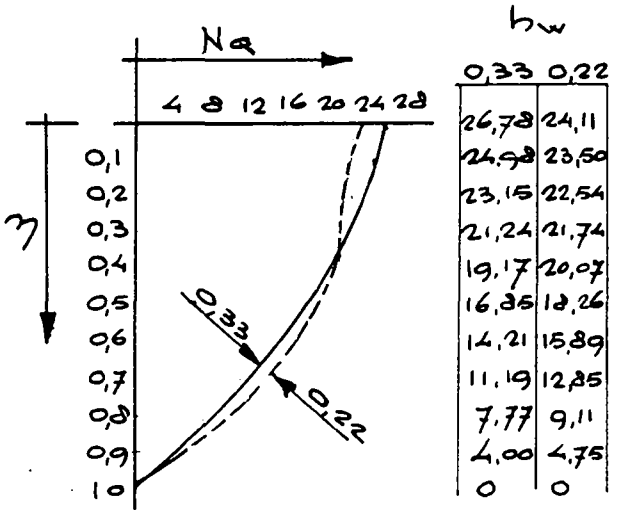
$$\sigma \text{ brickwork (h)} = \frac{18.79*10^3}{220*1000} = 0{,}085 \text{ N/mm}^2 \ (< 0{,}10)$$

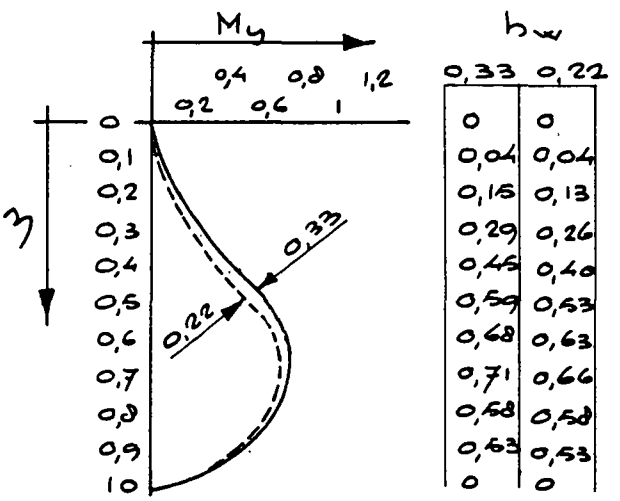
$$\sigma \text{ brickwork (v)} = \frac{0.62*10^6*6}{1000*220^2} = 0{,}077 \text{ N/mm}^2 \ (< 0.10)$$

→ non-reinforced, wall thickness 220 mm

2.5.1.3. Tank capacity of 90 m^3

l	=	1.25 m	K	=	$\frac{\sqrt{3\ (1-0.2^2)}}{4.79*0.22}$ = 1.27	
a	=	4.79 m				
h_w	=	0.22/0.33 m	Kl	=	1.27*1.25	= 1.59
μ^w	=	0.2	pa	=	10*1.25*4.79	= 59.88
			pah_w			= 13.17





N_Q (KN)/m'

$A_h = \frac{24.11*10^3}{110}$ = 220 mm^2/m'

My (KNn)/m'

$A_v = \frac{0.66*10^6}{90*110}$ = 67 mm^2/m'

σ brickwork (h) = $\frac{24.11*10^3}{220*1000}$ = 0.11 N/mm^2 (too high)

σ brickwork (v) = $\frac{0.66*10^6*6}{1000*220^2}$ = 0.082 N/mm^2

→ with a wall thickness of 220 mm a tension band is to be used, e.g. a steel strip of 60*5 mm (2 strips).

With a wall thickness h_w = 330 mm →

K = $\frac{\sqrt{3\ (1-0.2^2)}}{4.79*0.33}$ = 1.04 Kl = 1.30

See Table →

$A_h = \frac{26.78*10^3}{110} = 243 \text{ mm}^2/\text{m}'$ $\qquad A_v = \frac{0.71*10^6}{140*110} = 46.0 \text{ mm}^2/\text{m}'$

σ brickwork (h) $= \frac{26.78*10^3}{330*1000} = 0.0812 \text{ N/mm}^2 \ (< 0.10)$

σ brickwork (v) $= \frac{0.71*10^6*6}{1000*330^2} = 0.039 \text{ N/mm}^2 \ (< 0.10)$

→ with a wall thickness of 330 mm: "non-reinforced"

2.5.1.4. Tank capacity 150 m³

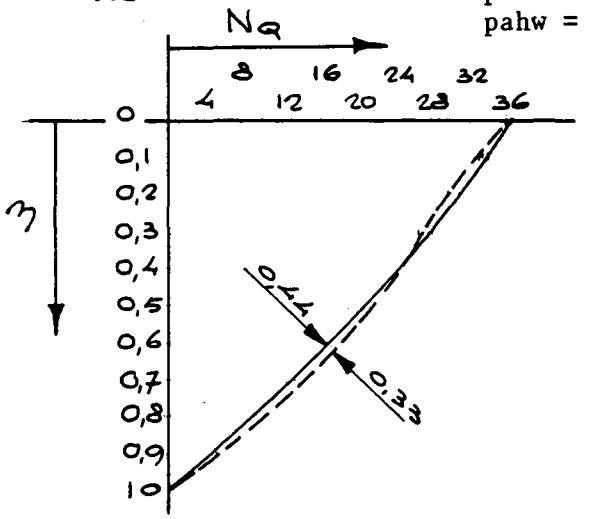
l = 1.25 m
a = 6.18 m
hw = 0.33/0.44 m
μ = 0.2

K = $\frac{\sqrt{\sqrt{3}\,(1-0.2^2)}}{6.18*0.33} = 0.91$

Kl = 1.14

pa = 10*1.25*6.18 = 77.25

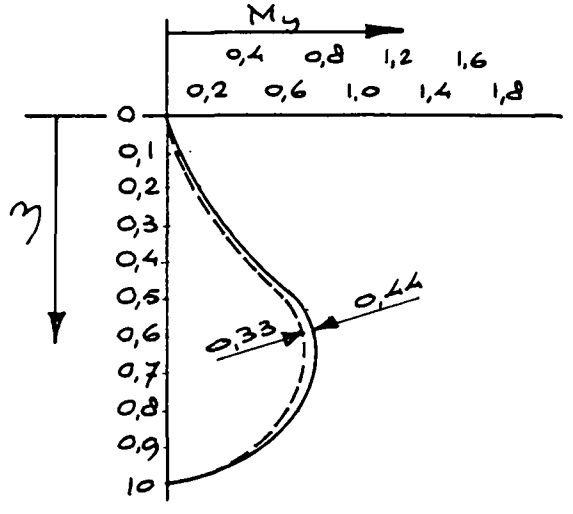
pahw = 10*1.25*6.18*0.33 = 25.49
0.44 = 58.24



hw 0,44	0,33
37,72	36,25
34,20	33,28
30,68	30,30
27,12	27,25
23,52	24,09
19,86	20,73
16,08	17,13
12,02	13,24
8,22	9,06
4,14	4,61
0	0

NQ (KN)/m'

$A_h = \frac{36,25*10^3}{110} = 330\ mm^2$



hw 0,44	0,33
0	0
0,05	0,04
0,18	0,15
0,35	0,30
0,53	0,46
0,69	0,60
0,80	0,69
0,82	0,71
0,71	0,63
0,45	0,40
0	0

My (KNn)/m'

$A_v = \frac{0,71*10^66}{140*90} = 56\ mm^2$

σ brickwork (h) = $\frac{36.25*10^3}{330*1000}$ = 0.11 N/mm² (too high)

σ brickwork (v) = $\frac{0.71 *10^6*6}{1000*330^2}$ = 0.039 N/mm²

→ with a wall thickness of 220 mm a tension band is to be used, e.g. a steel strip of 80 * 5 mm² (2 strips)

with a wall thickness h_w = 440 mm

K = 0.79 K1 = 1.0

See Table →

$A_h = \frac{37.72*10^3}{110}$ = 343 mm²/m' $A_v = \frac{5,82\ E6}{200*90}$ = 46 mm²/m'

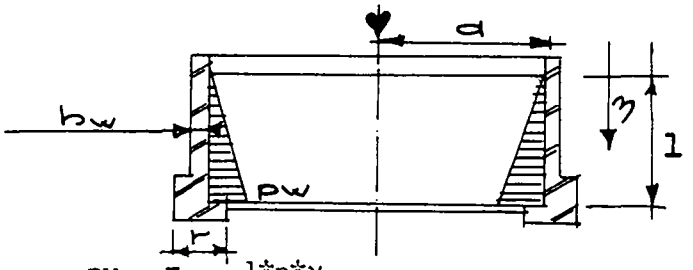
σ brickwork (h) = $\frac{37.72*10^3}{440*1000}$ = 0,086 N/mm² (< 0.10)

σ brickwork (v) = $\frac{0.82 *10^6*6}{1000*440^2}$ = 0.025 N/mm²(< 0.10)

→ with a wall thickness of 440 mm: "non-reinforced"

2.5.1.5. Type III, IV and V

Ring foundation only at the bottom of the tank wall carried out in brickwork, concrete or impermeable soil



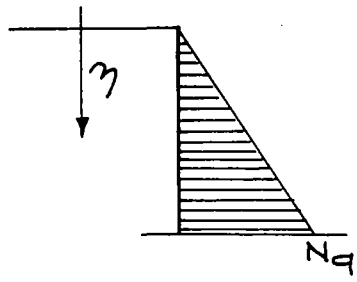
Formule:

$$N_{Q^o} = \frac{apw}{l}\,\eta$$

pw = 1*p*γ
p = 10 KN/m³
η = 1

capacity m³	l	a	hw	r	pw	$N_{Q^o}(\eta = 1)$
30	1.25	2.77	0.22	0.44	12.5	34.63 KN/m'
60	1.25	3.91	0.33	0.55	12.5	48.87 "
90	1.25	4.79	0.33	0.55	12.5	59.87 "
150	1.25	6.18	0.44	0.77	12.5	77.25 "

Calculation of hw



with $\sigma_{brickwork} = 0.10$ N/mm²

hw	=	220 mm	N_{qmax}	= 0.10 * 220 * 1000	=	22	KN/m'
-	=	330 mm	"	= "	=	33	"
-	=	440 mm	"	= "	=	44	"
-	=	550 mm	"	= "	=	55	"
-	=	660 mm	"	= "	=	66	"
-	=	770 mm	"	= "	=	77	"

In practice the above results lead to the following wall thicknesses

thickness (hw)

Tank with a capacity of 30 m³

- Top of the wall up to $\eta = \frac{22}{34.63} * 1.25 = 0.80$ m — 220 mm

- Bottom of the wall $\sigma_{brickwork} = \frac{34.63E3}{1000 * 440} = 0.079$ N/mm² — 440 mm

Tank with a capacity of 60 m³

- Top of the wall up to $\eta = \frac{33}{48.87} * 1.25 = 0.85$ m — 330 mm

- Bottom of the wall $\sigma_{brickwork} = \frac{48.87E3}{550 * 1000} = 0.089$ N/mm² — 550 mm

Tank with a capacity of 90 m³

- Top of the wall up to $\eta = \frac{33}{59.87} * 1.25 = 0.70$ m — 330 mm

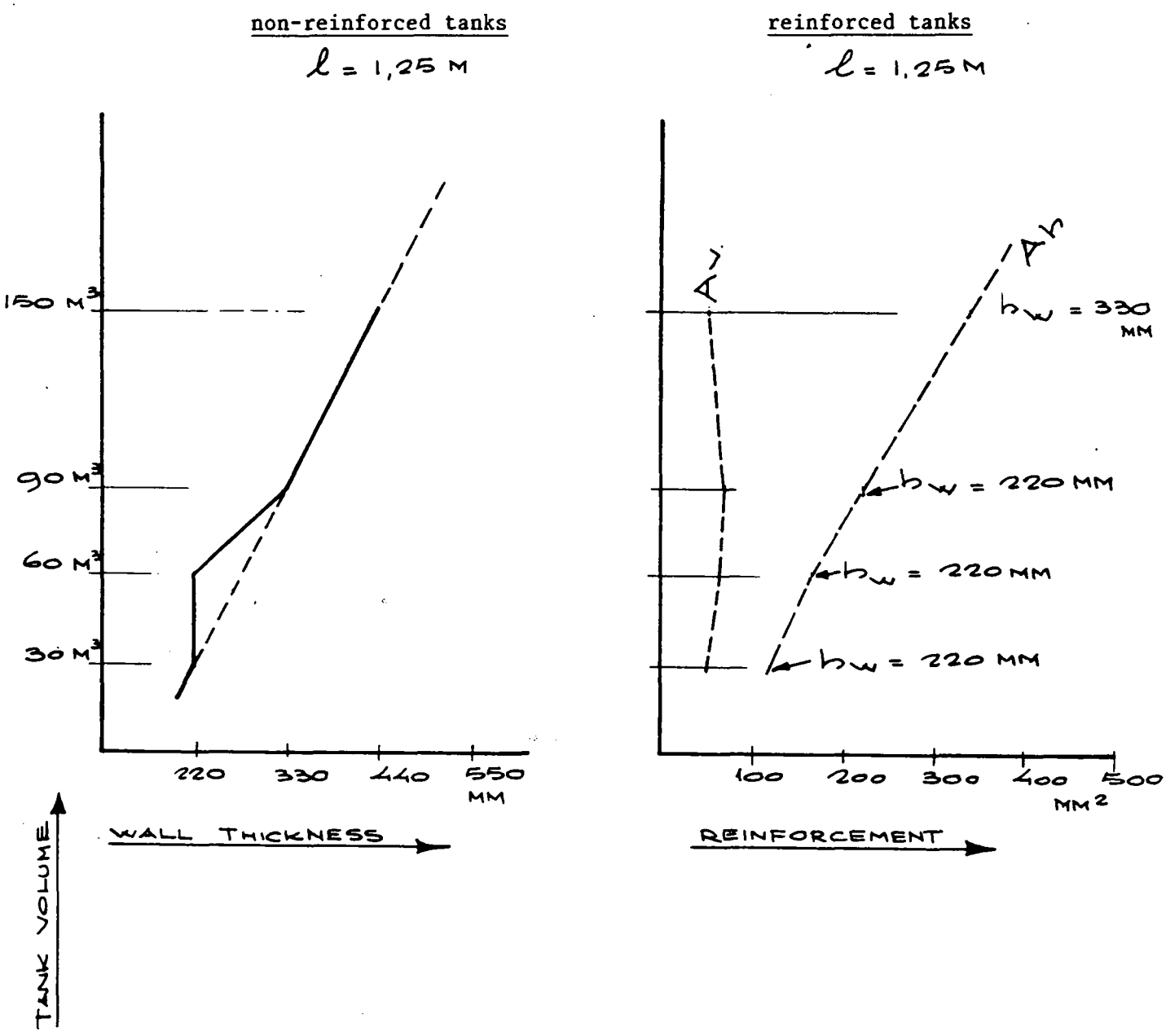
- Bottom of the wall $\sigma_{brickwork} = \frac{59.87E3}{550 * 1000} = 0.109$ N/mm² — 550 mm

Tank with a capacity of 150 m^3 *)	thickness
- Top of the wall up to $\eta = \frac{44}{77.25} * 1.25 = 0.80$ m	440 mm
- Bottom of the wall $\sigma_{brickwork} = \frac{77.25E3}{770 * 1000} = 0.10$ N/mm^2	770 mm

*) Uneconomical solution.

ANNEX 1

Variant* = tankwall carried out with reinforcement



*Not indicated as type in this booklet.

ANNEX 2

REVIEW OF THE SEVERAL TYPES

Type I	II	III	IV	V	
+	+	□	□	+	water-permeability
more	more	less	less	more	quantity materials
□	+	+	+	+	realization
+	+	□	□	+	durability
less	less	more	more	more	sensity for maintenance
-	-	-	-	-	frost-resistance
□	++	++	++	□	resistance against changes in humidity and temperature
□	□	+	+	++	quality of workmanship

- = bad
□ = reasonable
+ = good
++ = very good

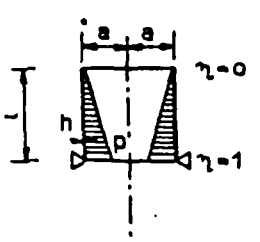
ANNEX 3

DESIGN TABLE

In accordance with:

Markus, "Theorie und Berechnung rotationssymmetrisscher Bauwerke"

	ξ \ η	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
F_N	1	+0,4883	+0,4427	+0,3971	+0,3511	+0,3045	+0,2569	+0,2082	+0,1580	+0,1064	+0,0536	0
	2	+0,3516	+0,3574	+0,3621	+0,3630	+0,3565	+0,3384	+0,3052	+0,2540	+0,1840	+0,0973	0
	3	+0,1123	+0,2037	+0,2931	+0,3754	+0,4424	+0,4837	+0,4877	+0,4435	+0,3439	+0,1905	0
	4	−0,0038	+0,1184	+0,2402	+0,3595	+0,4698	+0,5590	+0,6079	+0,5922	+0,4877	+0,2829	0
	5	−0,0167	+0,0963	+0,2110	+0,3295	+0,4509	+0,5671	+0,6571	+0,6846	+0,6014	+0,3677	0
	6	−0,0061	+0,0956	+0,2006	+0,3076	+0,4248	+0,5495	+0,6670	+0,7376	+0,6909	+0,4471	0
	7	−0,0002	+0,0970	+0,1985	+0,2985	+0,4073	+0,5283	+0,6573	+0,7618	+0,7581	+0,5202	0
	8	+0,0008	+0,0997	+0,1983	+0,2971	+0,3993	+0,5120	+0,6407	+0,7669	+0,8059	+0,5870	0
$\frac{F_M}{\omega}$	1	0	−0,0013	−0,0046	−0,0090	−0,0138	−0,0180	−0,0207	−0,0212	−0,0185	−0,0117	0
	2	0	−0,0038	−0,0135	−0,0271	−0,0421	−0,0561	−0,0663	−0,0695	−0,0623	−0,0405	0
	3	0	−0,0029	−0,0112	−0,0244	−0,0416	−0,0608	−0,0790	−0,0911	−0,0894	−0,0635	0
	4	0	0	−0,0021	−0,0078	−0,0177	−0,0364	−0,0591	−0,0821	−0,0942	−0,0763	0
	5	0	+0,0009	+0,0023	+0,0021	−0,0025	−0,0145	−0,0360	−0,0651	−0,0905	−0,0851	0
	6	0	+0,0006	+0,0021	+0,0037	+0,0035	−0,0021	−0,0179	−0,0471	−0,0822	−0,0907	0
	7	0	+0,0001	+0,0007	+0,0021	+0,0038	+0,0031	−0,0060	−0,0309	−0,0711	−0,0937	0
	8	0	−0,0001	0	+0,0007	+0,0024	+0,0041	+0,0007	−0,0179	−0,0591	−0,0944	0



$$N_\varphi = paF_N; \qquad M_y = pah\frac{F_M}{\omega};$$

ANNEX 4

List of symbols

A_h	=	reinforcement for the ring forces
A_v	=	reinforcement for the bending moments
a	=	radius of a tank
F_m	=	coefficient for M
F_n	=	coefficient for N_Q^y
h_w	=	wall thickness
l	=	the max. water height in a tank
l_t	=	theoretical span of a beam or slab
M	=	bending moment (general)
M_y	=	bending moment in the height of a tank
N_Q^y	=	ring force
p_w	=	water pressure on the bottom of a tank
q	=	uniform load on a beam or slab
W	=	Resisting moment to bending
σ_b	=	bending stress in N/mm^2
σ_t	=	tensile stress in N/mm^2
q	=	load factor, a coefficient against collapse
μ	=	poisson ratio
η	=	coefficient of the height

ANNEX 5

2.7. Bibliography

1. Watt S.B.
Ferrocement Water Tanks
London 1978

2. Markus Gyula
Theorie und Berechnung rotations symmetrischer Bauwerke

3. Basic course in rural technology for gramodaya workers and leaders. Sarvodaya Shramadana Movement, Rural Technical Surveys, Colombo, 1980.

4. v. Oss J.F.
Warenkennis en Technologie
J.H. de Bussy 1956

5. Jellema Meischke Muller
Bouwkunde
Waltman 1972

6. F.W. Knipschild
Stand der Technik der Abdichtung von Deponien mit HDPE

CP/JdL/MBi/JeP/S24/M