CONSULTANCY SERVICES
WIND ENERGY
DEVELOPING COUNTRIES

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THE NETHERLANDS

Irrigation water storage tanks made of ferrocement and a combination of ferrocement and brickwork

A manual for design and construction

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DHV

DHV Consulting Engineers

TWO
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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 the 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 know-how.
Discussions in TWO (a non profit organization set up by employees of DHV) about the technical problems at water storage tanks resulted in a contract between SWD and DHV. Under this contract DHV has prepared designs and construction manuals (as described in this publication for irrigation water-storage tanks made of Ferrocement).
A design and construction manual for brickwork tanks was prepared in December 1981. The Ferrocement tanks will have storage capacities of 30 m^3 - 60 m^3 - 90 m^3 and 150 m^3 just as the brickwork tanks.

Designs will also be made for tanks constructed of earth bunds with various linings.
Designs for tanks constructed with a combination of Ferrocement and brickwork are included in this manual.

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

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Until 1984 CWD had the name SWD, Steering Committee Wind Energy Developing Countries. Where the name SWD occurs in any publication or drawing, it should be read as CWD.

2. INTRODUCTION

Watertanks for storage of irrigation water may 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, the walls of the tanks have to be thickened and/or treated with a coating. Some suitable coatings are described.

Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small wire diameter mesh.
The mesh may be may of metallic or other suitable materials.
The construction of ferrocement can be divided into four principal phases:

- fabricating the formwork/mould
- applying mesh and reinforcement to the skeletal framing
- plastering
- curing

The mortar is a cement-sand mix that is trowelled onto and between the wire mesh.
Because its very high tensile strength in comparison to reinforced concrete, thin walled ferrocement is an attractive material for the construction of water storage tanks.

The tanks designed and described in this manual are cylindrical with a flat floor. Cylindrical tanks are rather simple to construct and require considerably less material in comparison with other tanks.
Tanks have been designed with a capacity of 30 - 60 - 90 and 150 m^3 in the following types.

<u>Type I</u> <u>Range of preference</u>

Ferrocement tank, wall and slab connected, for the following capacities and heights:

- capacity 30 m^3 height 1.25 m
- capacity 60 m^3 height 1.25 m
- capacity 90 m^3 height 1.25 m
- capacity 150 m^3 height 1.90 m

<u>Type II</u> Ferrocement tank, wall and slab connected, with a capacity of 150 m^3 and a height of 1.25 m.

<u>Type III</u> Ferrocement tank, wall and slab constructed with a sliding joint, for the following capacities and heights:

- capacity 90 m^3 height 1.25 m
- capacity 150 m^3 height 1.25 m

Type IV   Ferrocement tank, wall and "foundationring" (trench beam) connected, but with a separate bottom slab consisting of concrete or impermeable soil
Furthermore as type I

Type V   As type I but with an extra outer brickwork wall.

The main chapters is this manual are:
- "Summery of the several types", which describes the advantage and the disadvantage of the several types.
- "Construction materials" which describes the materials to be used.
- "Construction" giving the skills required and the methods of working.
- "Tools" the tool to be used.
- "Types of tanks" the description of the tanks with 4 storage capacities including drawings, bill of quantities and sequence of work.
- "Testing" describes the test to be carried out to be certain that material faults will be avoided during construction.
- "Calculation" describes the structural calculations and the design criteria.

In Annex 4 a bibliography is given for the readers who want more information on ferrocement.

3. SUMMARY OF THE SEVERAL TYPES

In this chapter a comparison is made between the several properties of the different types.
These properties can be distinguished as follows:
- water permeability
- quantity of materials
- realization
- durability
- need for maintenance
- frost-resistance
- resistance against charges in humidity and temperature
- quality of workmanship

Because of lack of skilled labour, lack of good materials, lack of money it is not always possible to build the best tank. But this comparison may serve as a guideline in making a choice of a suitable tank for specific circumstances and limitations.

3.1. Water permeability

Water tanks for storage of irrigation water may suffer some losses due to permeability of the walls. A daily loss of 10% of the water may not be a great problem under some circumstances. In other cases it may be of importance that some types are more waterproof than others.
Type I is a good waterproof structure. The floor is continuous with the wall and the diameter is limited to 10 meter.
Type II (for capacity of 150 m^3 only) gives less certainty in regard to waterproofing. The floor is still continuous with the walls but the diameter is 12.36 m so that the tankwall will have more shrinkage-cracks and more chance of waterpermeability.
Type III avoids the shrinkage-cracks inherent to large diameters because of the sliding-joint structure. Special attention should be paid to the connection between the bottomslab and the wall.
If this connection is carried out carefully and with skilled labour, this type can also be ranked under the rather good waterproof structures.
Type IV has the disadvantage in comparison with type I that there is a seam in the bottom of the slab. The seam will be filled with tar. If the tar is of a good quality and the seam is filled accurately, this type can be ranked under the rather good waterproof structures.
Type V is am improvement of type I. The brickwork outerwall gives better protection against changes in humidity and temperature. So this type may be ranked under the very good waterproof structures.

3.2. Quantity materials

The final price of the tanks will vary according to local conditions but will mainly depend on the following:

Materials:
----
the cost of the sand, cement and steel wire or mesh reinforcement

Formwork:
----
the cost of the formwork, made either for one usage with temporary local materials, or being a more permanent construction made of steel sheeting and angle iron. The latter may be used many times.
In type V the outer brickworkwall is used as formwork.

Wages:
-----
the cost of wages of plasterers and labourers, if the tank is not built entirely by self help

Supervision:
----
the cost of supervision during construction

Transportation:

the cost of transporting the materials and supervisors

The relative quantities needed for tanks made with different materials are shown in the bill of quantities and a more detailed breakdown of wire mesh and woven mesh is added.
Depending on the country and the area concerned, great differences of costs may be expected when building one or more of these tanks.
On the basis of the bill of quantities and a breakdown of the reinforcement, the user of this manual can easily calculate the cost per ferrocement tank.

3.3. Realization

In particular the small capacity tanks (30 and 60 m^3) have been desgined for construction by relatively unskilled workers.
When larger tanks are to be built (90 and 150 m^3) it is advisable that skilled labour carries out the supervision or even the works themselves.
The sliding joints, formwork and the survey are very important items.
Formwork for small tanks may be simple, but when the formwork is intended to be reused or is for large tanks it can be rather complicated.
Tanks up to a capacity of 150 m^3 can be built by one man in about 100 hours, using powered mixing equipment and a pick-up truck to collect the aggregate. The advantage of type V is that no formwork is needed. The outer brickworkwall has the function as formwork.

3.4. Durability, need for maintenance

Maintenance costs for these tanks after construction are usually negligible - they will give a trouble free life.

Tanks up to 150 m^3 have been built for over 30 years. Up till now the costs for maintenance have been low and the tanks are still in use.

3.5. Frost resistance

Not one type of the tanks described in this manual can be built in frost areas.
The tankbottom is projected at the same level as the surrounding area. For a good frostresistant tank the bottom should be at least 500 tot 600 mm below surface level. When it is considered to build an irrigation tank in frost-areas, a completely different type of tank should be designed.

3.6. Resistance against changes in humidity and temperature

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. Tank type V has even better resistance to weather influences due to the outer brickwork wall which gives more protection from temperature changes. Only in combination with a large diameter (> 10 meter), tropical areas and a arid climat the chance of cracking of the brickwork wall is great.
As the above circumstance occurs tank type V can not be used. The variant mentioned on page 100 is then advisable.

3.7. Quality of workmanship

It has already been mentioned that relatively small tanks can be constructed with unskilled workers.
Experience has shown that farmers are able to construct these ferrocement tanks themselves. Small equipment such as P-loaders and powered mixing machines are very useful. When larger tanks are to be built (90 and 150 m^3) it is advisable that skilled labour carries out the supervision.
Preparing the formwork requires special knowledge. If the formwork is going to be re-used 10 or 20 times, skilled labour should gave special attention to its construction and its assembly.

The properties of the various tanks, as described above, are given in table form hereunder.

3.8. Summary

type					
I	II	III	IV	V	Properties
+	□	+	□	++	water impermeability
					quantity materials realization:
+	-	□	□/+	+	- small tanks
□	□	□	□	□	- large tanks
+	+	+	+	++	durability
+	+	+	+	+	need for maintenance
-	-	-	-	-	frost-resistance
					resistance against changes in humidity and temperature
+	+	+	+	++	- small tanks
+	+	+	+	□	- large tanks
					quality of workmanship required:
□	□	□/+	□/+	+	- small tanks
+	+	+	+	+	- large tanks

- poor
□ reasonable
\+ good
++ very good

4. CONSTRUCTION MATERIALS

4.1. 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 recommended. The cement must be stored in a dry place.

The Portland cement should be fresh. Old and/or wet bags containing Portland cement must be removed.
Water should be clean and free from harmful matter, (see Chapter "Testing"). Where tests can be carried out they should be in accordance with the local standards.

4.2. 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 of shrinkage will be greater than that of a mortar made with fine sand.

4.3. Water

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

4.4. Aggregate

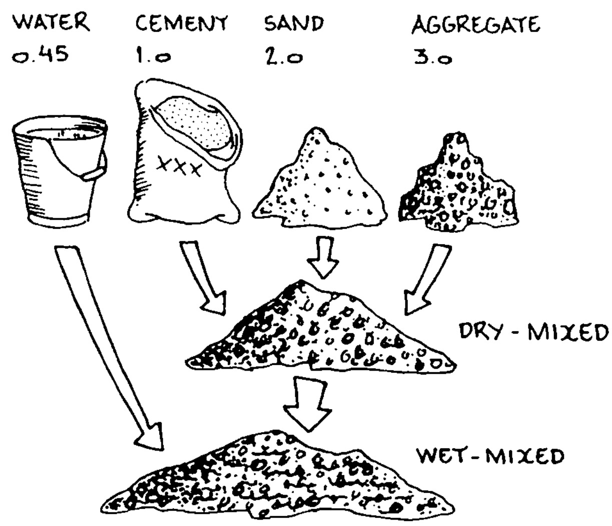
Coarse aggregate for concrete used for construction of the water tank-base should be well graded with a maximum size of 20 mm, crushed gravel, strong and non-porous and should be free from acid chemicals, salt and organic matters.

Aggregates with a high shrinkage percentage during drying (e.g. dolerites and whinstones) should be well wettened before using.

4.5. Mortar mix

4.5.1. Mortar for concrete

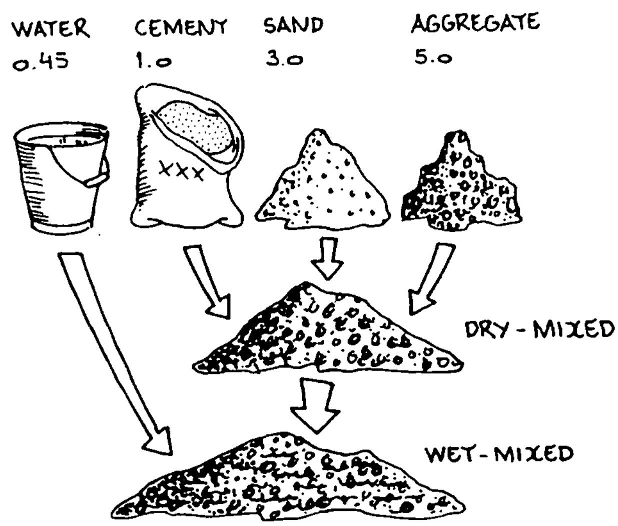
A general mix is:



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

4.5.2. Mortar for screed concrete

A general mix is:



- 1 volume part of cement
- 3 volume parts of sand
- 5 volume parts of aggregate
- 0.45 weight parts of water

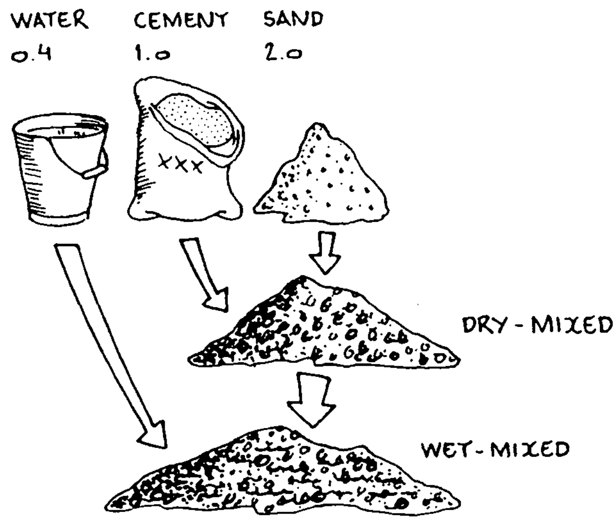
4.5.3. Other mixes are allowed if skilled labour is available

These mixes should be in accordance with the local standards.

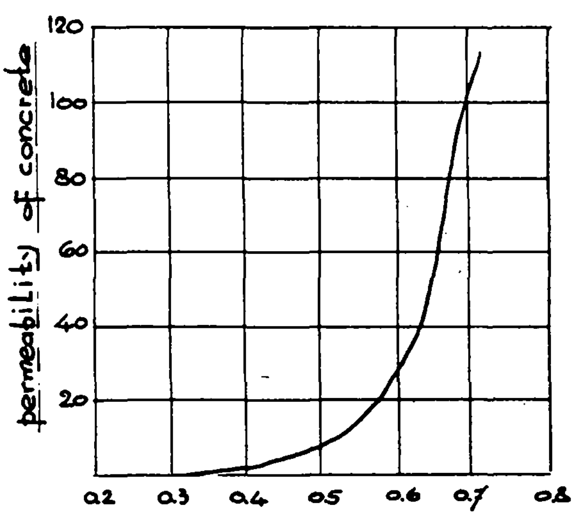
4.5.4. Mortar for ferrocement

The mortar consists of sand, cement and water with the following mixtures:

- 1 volume part of cement
- 2 volume parts of sand
- 0.4 weight parts of water



The importance of water - cement ratio on the permeability of the concrete can be seen from the figure below:



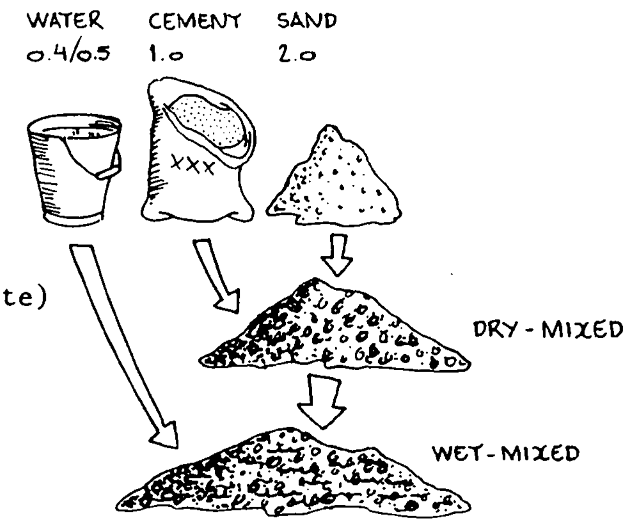
Water cement ratio in mortar (by weight)

The diameter of the sand for mortar for ferrocement should be between 0.015 mm (minimum) and 2.5 mm (maximum) but there should not be an excess of fine particles.

Handmixing is satisfactory, but for better quality the paddle-bladed mixer is recommended.
Conventionally powered concrete mixers are also suitable, but they can only handle rather wet mixes.

4.5.5. Mortar for brickwork

Mortars for brickwork are a mixture of cement, sand and water, each in the correct proportion. In this case cement mortar mixes are advisable:



- 1 volume part of cement
- 2 volume parts of sand (fine aggregate)
- 0.4/0.5 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 brick work and mortar.
The mortar must be thouroughly 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.

4.6. Bricks

The bricks must be of good quality in order to obtain a watertight structure. Prior to laying, the bricks must be moistend with water.
To prevent cracking of the mortar caused by shrinkage and high temperatures brickwork should be moistened during the first week or protected by means of a cover (plastic foil).

4.7. Steel bars

Steel bars with a diameter of 5, 6, 8 and 10 mm are used, depending of the size of the water tank. The surface of these bars should be totally free from greese, oil, detergents and other organic matter. They should be conform to BS 4449-4461 and BS 4482 (or equivalent).

4.8. Tying wire

For tying the steel bars and the mesh layers galvanised wires of gauge number 24, 25 or 26 (see Annex 1) are recommended.

4.9. Admixtures

Water proofing chemicals or other additives to the cement mortar should be given special consideration. The choice of additive, the amount added and the method of use should comply with approved standards or should be based on actual performance tests. However, by definition admixtures should not be used in ordinary structural concrete, but only in special structural concrete. Calcium chloride should never be added in the case of reinforced concrete slabs.

4.10. Plastic foil or polyethylene sheeting

It is advisable to spread plastic foil or polyethylene sheeting over the site of the tank before the mortar is poured. This sheeting prevents direct contact between wet mortar and soil. The floor of the tank can be formed of a layer of polyethylene sheeting, 0.25 mm - 0.50 mm thick, laid between two layers of sand. To ensure a more watertight construction it is advisable to place an overlap of polyethylene sheeting in the groove of the ringbeam both the sheeting and overlap then being joined by means of a flat or soldering iron (especial type IV).

4.11. Types of meshes

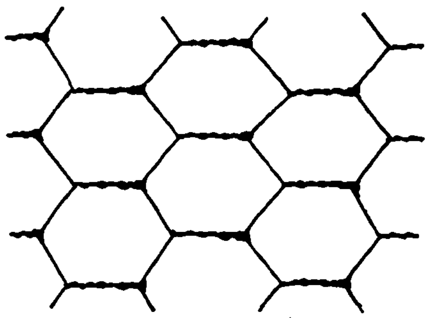
There are many different kinds of reinforcing meshes available for ferrocement structures. A general requirement is flexibility.
The wire mesh could be woven on site from coils; a simple handloom could be adapted for weaving the wire into mesh.
Generally the mesh does not need to be welded.
Nongalvanized wire is suitbable, but it will rust if it is stored in the open air too long. Standard galvanized meshed are adequate. Never use aluminium of aluminium painted wire because aluminium may react with the cement and give a very poor bond between the wire and the mortar.
In the following pages some types of meshes are described, i.e.:

1. Hexagonal wire mesh or chicken mesh
2. Welded wire mesh
3. Woven mesh
4. Expanded metal mesh
5. Watson mesh

4.11.1. Hexagonal wire mesh or chicken mesh

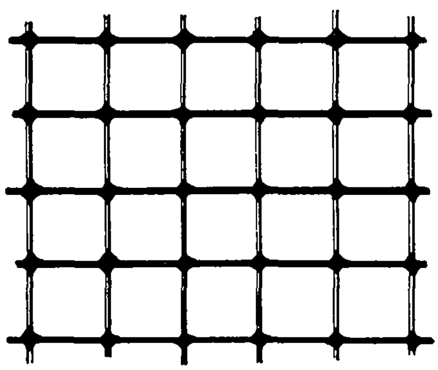
Hexagonal mesh or chicken mesh is fabricated from cold drawn wire which is generally woven into hexagonal patterns. It is galvanised either before or after fabrication.

This mesh is fabricated in different sizes and gauges.
Hexagonal wire mesh or chicken mesh is the most popular and commonly used mesh readily available in most countries.



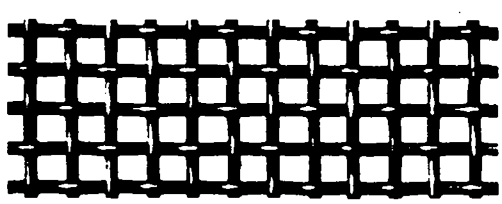
4.11.2. Welded wire mesh

Welded wire mesh is fabricated from gauge wires, half-inch spaces are normally used in this mesh. These wires are made of low to medium tensile strength steel and are much stiffer than hexagonal wire mesh. However, welded wire mesh may have weak spots at intersections inadequate welding during the manufacturing process.
In general welded wire mesh is galvanised after welding.



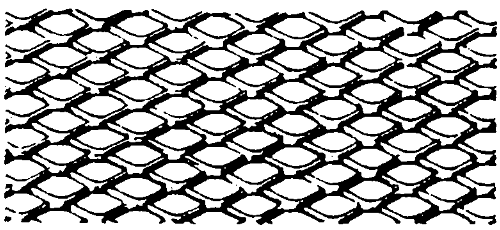
4.11.3. Woven mesh

The wires of woven mesh are simply woven into the desired grid size and have no welding at the intersections.
In this mesh the wires are not perfectly straight and there is a certain amount of play.
One of the difficulties is that it cannot easily be held in position but once stretched it readily conforms to the curves required.



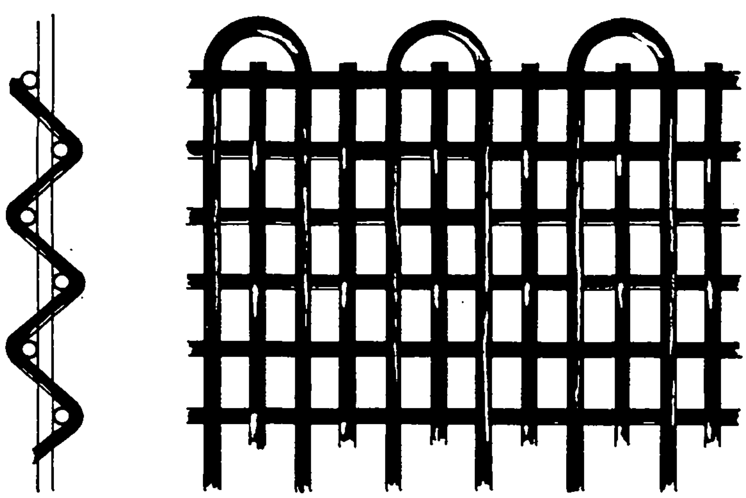
4.11.4. Expanded metal mesh

Expanded metal mesh is also known as metal plasterer's lathing.
It is made by cutting a thin steel sheet in such a way that diamond shaped openings are formed when the metal is stretched out.
Expanded metal is not as strong as the woven mesh, but on a cost to strenghth ratio, expended metal has the advantage.



4.11.5. Watson mesh

Watson mesh consists of straight high-tensile wire held together by transverse crimped wire. The high-tensile wires are placed in two planes, parallel to each other, and are crossed in a transverse direction by mild steel wires.
The elastic limit is only exceeded in the tie wire and then only in the vicinity of the crimp.
Also the wire of Watson mesh is straight without twists , crimps, pressings, punchings or welds.
Watson mesh provides complete flexibility and is thus adaptable for a variety of shapes.



4.11.6. General characteristics of different types of meshes

			number of wires per m' (running meters)		surface steel area A mm^2/m'		standard sizes m (l x h)	
	wire spacings mm	wire surface mm^2/wire	longitudinal	transverse	longitudinal	transverse		roll
hexagonal wire mesh or chicken mesh	13 x 13 x 0.7	0.38	77	77	29.26	29.26	25 x 1	X
	20 x 20 x 0.7	0.38	50	50	19	19	50 x 1	X
	25 x 25 x 0.8	0.50	40	40	20	20	50 x 1	X
	40 x 40 x 0.9	0.64	25	25	16	16	50 x 1	X
	50 x 50 x 1	0.79	20	20	15.8	15.8	50 x 1	X
welded wire mesh	6 x 6 x 0.6	0.28	167	167	46.76	46.76	25 x 1.22	X
	8 x 8 x 0.8	0.50	125	125	62.5	62.5	25 x 1.22	X
	10 x 10 x 0.9	0.64	100	100	64	64	25 x 1.22	X
	12 x 12 x 1.0	0.79	83	83	65.57	65.57	25 x 1.22	X
	18 x 18 x 1.4	1.54	56	56	86.24	86.24	25 x 1.22	X
	24 x 24 x 1.6	2.00	42	42	84	84	25 x 1.22	X
	24 x 50 x 1.6	2.00	42	20	84	40	25 x 1.22	X
woven mesh	9 x 9 x 1.2	1.13	111	111	125.43	125.43	25 x 1.20	X
	10.9x10.9 x1.8	2.54	92	92	233.68	233.68	25 x 1.20	X
	11.3x11.3x 1.4	1.54	88	88	135.32	135.52	25 x 1.20	X
	14.9x14.9 x 2	3.14	67	67	210.38	210,38	25 x 1.20	X
expanded metal mesh	10 x 4.3 x 0.5	1 x 0.5 = 0.5	232	100	116	50	25 x 0.5	X
	10 x 4.4 x 1	1.5 x 1 = 1.5	227	100	340.5	150	25 x 0.5	X
	28 x 10 x 1	2.5 x 1 = 2.5	100	36	250	90	10 x 0.5	X
	42 x 12 x 1	2.5 x 1 = 2.5	83	24	207.5	60	10 x 0.5	X
	42 x 13 x 2	3 x 2 = 6.0	77	24	462	144	10 x 0.5	X
	44 x 0.7 x2	2 x 2 = 4.0	115	23	460	92	2 x 1	
	62 x 21 x 2	2.5 x 2 = 5.0	48	16	240	80	2 x 1	
Watson mesh	Only available in Australia and New Zealand							

4.12. Formwork (Moulds)

For the construction of ferrocement watertanks as described in this publication a mould is needed to support the reinforcement before trowelling and to provide a base for the first rendering of the wall and the cover.

Well made formwork is expensive but will, with care, last for many years so that the initial cost can be spread over the numerous tanks that are built.

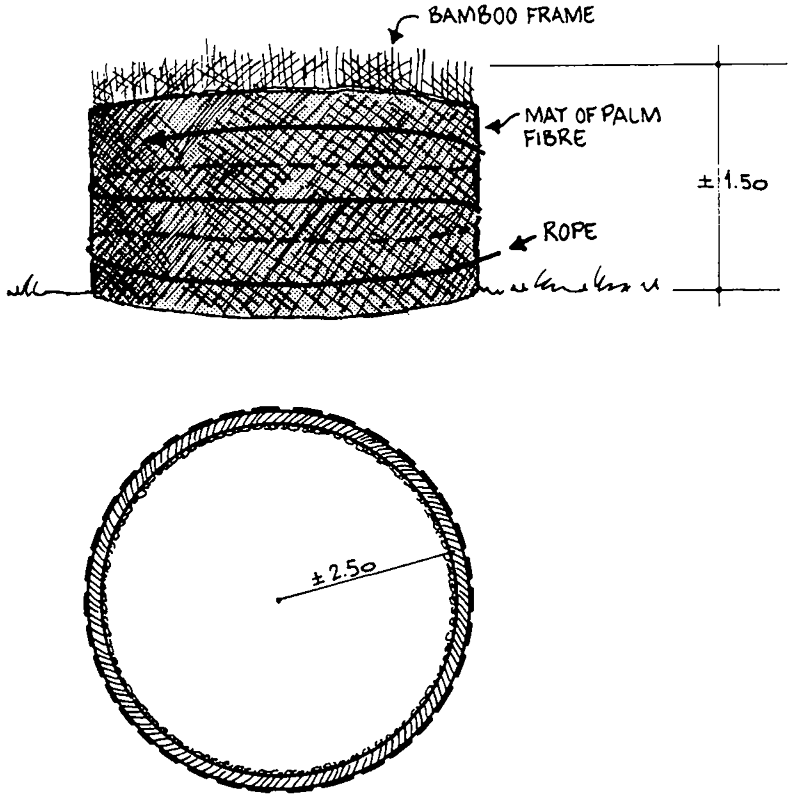
In publications several mould designs are given, varying from makeshift formwork or weld mesh frames to steel/plywood moulds.

Experience has shown that quality formwork makes construction work almost foolproof and is therefore recommended for any tank programme in which more than a few tanks are to be built.
In particular, for the fairly large and large types of tanks described in this manual, it is highly recommended to make use of a solid formwork. Locally available materials are often suitable for use in the construction of moulds.
The main requirement of the formwork is that it should be rigid enough to hold without deflection the weight of the mortar as it is being applied and cured.

The following types of formwork are described in this manual:
1. Formwork made of a bambooframe reinforced with palmfibre mats
2. Shuttering made of flattened oildrums
3. Formwork made of circular corrugated galvanized iron sheets
4. Formwork made of steel rings with a lining of plywood

4.12.1. Formwork made of a bambooframe reinforced with palmfibre mats

This is a woven mat of palmfibre which is wrapped around a bamboo framework and is fastened with ropes. It does not give support to the reinforcement which therefore must be self-supporting (e.g. vertical reinforcing wire or bamboo strips are needed to support the horizontal reinforcement). This mould is not stable either so that during plastering from the inside the mould will tend to become pressed slightly outward resulting in a thicker wall and a higher cement and sand consumption.
Palm fibre mats can be used for the construction of about 5 tanks before replacement becomes necessary.



Mould made of a bambooframe reinforced with palmfibre mats

4.12.2. Shuttering made of flattened oildrums

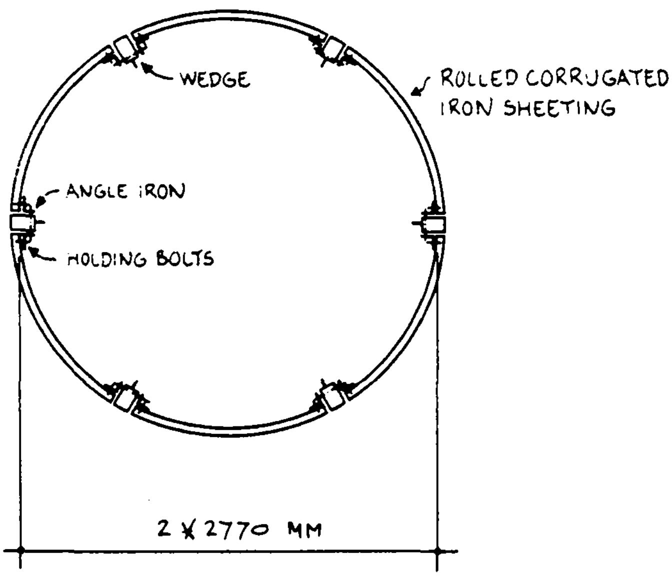
If these are available, a mould made of flattened oildrums is cheap and easy to construct.
Oildrums are cut and flattened, after which the flattened sheets are connected and bent into a circular shape
This can be done by drilling small holes in the sheets and fixing the sheets together with tie-wire. This type of formwork has been constructed successfully by farmers in Arizone, U.S.A. It should be classified under the "outside moulds", in other words the mortar should be applied on the inside of the tank.

4.12.3. Formwork made of circular corrugated galvanized iron sheets

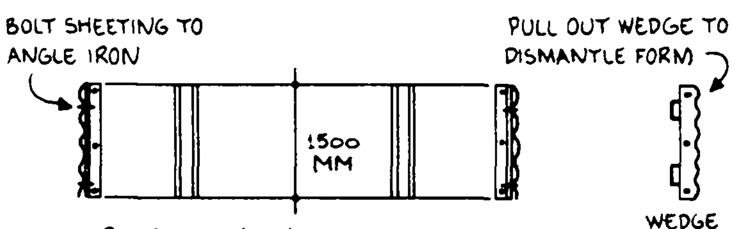
This type of formwork has been used with great success.
The formwork consists of 0.6 mm corrugated galvanized iron sheets rolled to the prescribed radius.
Steel angle iron (40*40*5 mm) is bolted vertically on the inside face at the ends of each set of sheets - this allows the sheets to be bolted together to form a circle. Between the ends of each section a wedge is placed; this can be pulled out to allow the formwork to be dismantled.

The main advantage of the corrugated sheets - besides durability, cheapness and lightness in transportation - is that they allow an accurate measure of the final wall thickness, because the corrugations on both the inside and outside faces of the tank must be filled with mortar and trowelled smooth.
This is of great importance in self-help construction as it reduces the need for skilled supervision and the risk of thin, weak spots in tank wall.

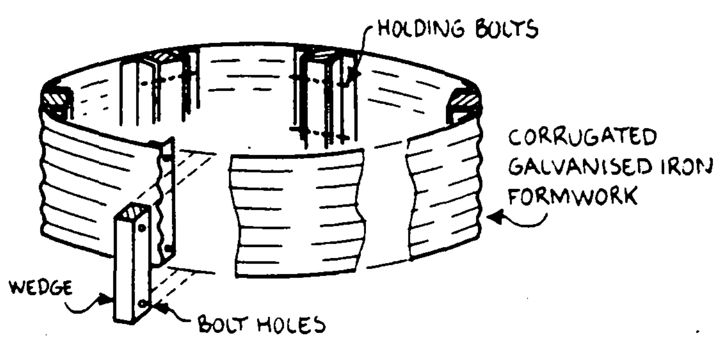
Example of a standard formwork to make a 30 m^3 tank



PLAN



CROSS SECTION



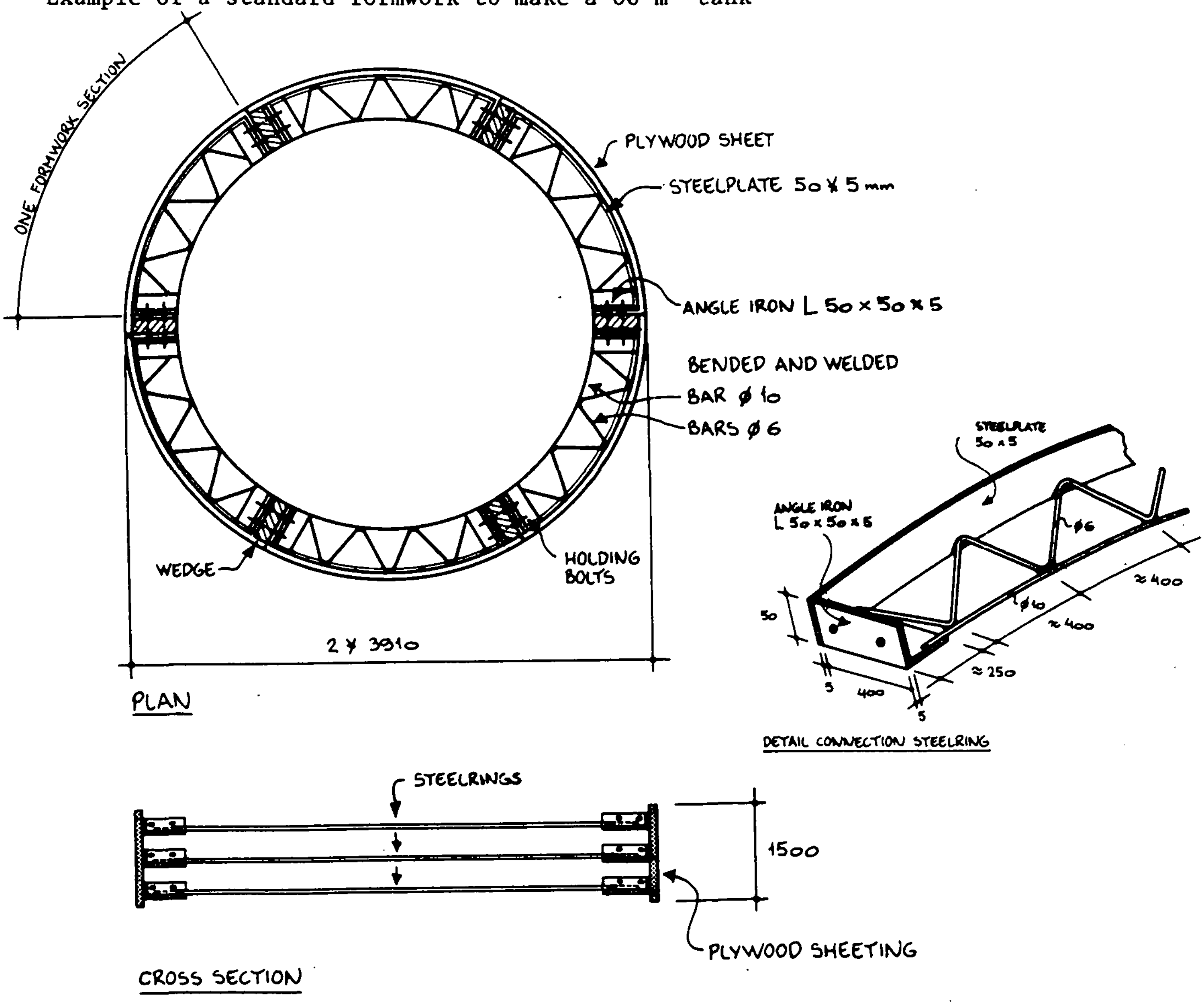
ASSEMBLING THE FORMWORK

4.12.4. Formwork made of iron rings with a lining of plywood

This type of formwork is the most expensive but also the most solid. If a number of the same tanks, with the same capacity and diameter, are to be built it is highly recommended to use a formwork made of a solid plywood structure.
A steel/plywood mould consists of three steel "rings" which are faced on the outside with sheets of plywood.
The first plastering is done on the outside and the rigidity of the mould makes a good control of the thickenss of the plastering possible.

The "assembled" steelrings can be used hundred of times if properly maintained, while the plywood sheets need replacing after being used about 20 times.
An alternative shows that some of the steelrings and the plywood sheets can be constructed in advance and that all parts are to be assembled (bolted together) on the area chosen for the tank.
If the ring section can be stocked properly after use the mould can be used time and time again.

Example of a standard formwork to make a 60 m^3 tank



4.13. Painting and coating

After curing and drying the watertank for a week painting operations can be carried out.
In general, experience has shown that plastered ferrocement structures need no protection, but in many cases painting or coating is used as waterproofing, to provide more protection for the reinforcement bars and mesh, or for aesthetic reasons.

4.13.1. Types of coating

The outside of the tank

The outside of the tank can be painted with an non-toxic ordinary paint, as normally used for aesthetic purposes. For added protection, organic coatings (vinyl and epoxy types are well-known) can be used, but any type of coating applied should have several of the following characterics:

- good adhesion ot mortar
- impermeability to water and chemicals
- tolerance of alkanity in the ferrocement
- non-toxicity
- suitable for use by unskilled labour
- simple application technique
- the painting/coating should be fast drying
- maintenance should be easy

Vinyl coatings will fulfil all these demands.

Another successful waterproof finish coating can be made on site. An exemple of a good home-made sealing solution is a mixture of:

- 73% water
- 26% calcium chloride
- 1% sodium silicate (waterglass)

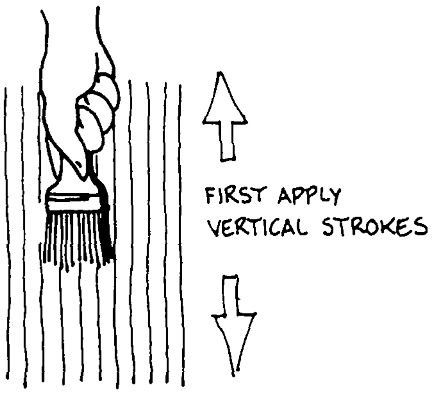
The inside of the tank

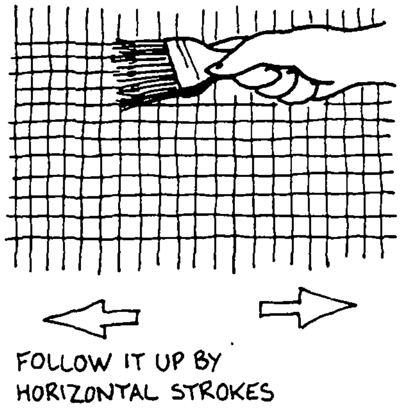
If a better impermeability is required (perhaps after the testing results) the inside can be coated with two or three coats of the following mix, using the preparation described above:
1 gallon sealing solution (as above)
2 gallons of water
½ bag of Portland cement

4.13.2. Methods of application

Any surface to be coated or painted must be dry and thoroughly cleaned. Interior and exterior surfaces should be brushed with a wire brush to ensure that loose particles, dust or dirt are removed.

Generally two coats of paints are applied.
One coat of paint is applied in vertical strokes, followed by a second coat in horizontal strokes.
Coatings should normally not be applied at temperatures lower than 50°F (10°C).





It is necessary to allow a 24 hours drying period between the two coats, or as specified by the paint manuafacturer.
The coating must be capable of sealing by absorption cracked surfaces, hairline surface cracks, pinholes and other minor defects and also of preventing corrosion of exposed parts of steel frames and mesh.

5. CONSTRUCTION

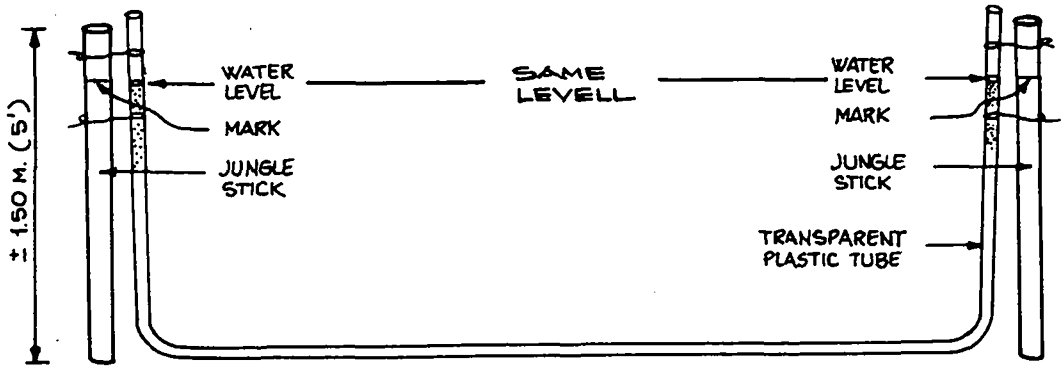
5.1. Location, site clearance and preparation of foundations

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:

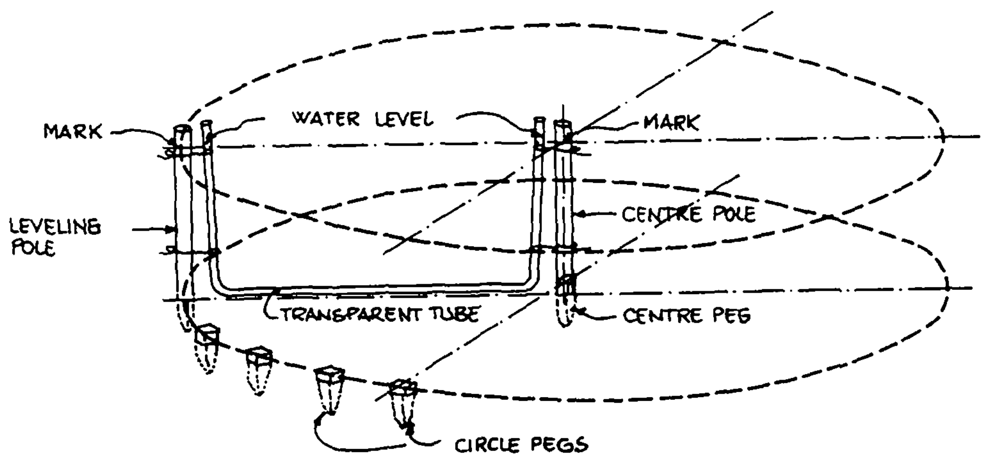
- location in the highest part of the field that has to be irrigated
- site as close as possible to the windmill to reduce the cost of the delivery line
- no obstructions to other field operations
- avoid damage by roots or falling branches by choosing the site away from trees
- it is advisable to choose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

The site chosen for the tank should be cleared. At least the topsoil with a layer of approx. 270 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 achieved by ramming with (self-made) tampers.
If sand is used for backfill, compaction can also be done by sprinkling with a little water and ramming.

When the site for the tank is cleared, its surface is levelled. 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 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 the peg on the circle. Hammer the peg on the circle till the water level in the tube is at the desired marks. Repeat this for all pegs on the circle.
See figure below.



LEVELLING TOOL



Now the ringtrench can be dug and the ring of the formwork made from board or plywood.

It is advisable to spread plastic foil or polyethylene sheeting over the site of the tank before the screed layer or slab is poured.

5.2. Construction of the floor slab

If necessary, depending on the type of soil, a blinding layer of sand or screed concrete, 2 cm thick, can be made.
After the bars are cut to the specified lengths and bent to proper profiles, they have to be tied to each other as indicated on the drawings.
After placing the reinforcement and controlling the position of the starterbars, the concrete can be poured. The position of the starter bars is very important. The surface of the slab can then be levelled.
The concrete can be cured by wettening or covering with plastic foil or wet sacking. Now a week must be allowed for the concrete to harden.

Refill with soil

After finishing the floor slab, the outer circumference must be refilled with soil.

5.3. Construction of the wall

Mould

After the week's curing time, the formwork or mould has to be erected and slightly oiled. Some of the various types of formwork are described in this manual (see page 16). In general the formwork should be rigid enough to hold the weight of the mortar when it is being applied.

Mesh and reinforcement wire

Step-by-step method for choosing reinforcement.
<u>Example I</u>

Tank type I, capacity of 30 m^3 (height of 1.25 m)
1. Look into chapter "Calculation of the tanks" page 131 graphics.
2. Graphic one shows the results of the calculation for a tank with a capacity of 30 m^3.
   Necessary reinforcement for:
3. a. bending stress on the connection wall/slab = 140 mm^2/m'
   To reach a good surface bording with the wire mesh the cover on the first layer should be in between of 8 mm and 12 mm.
   The starter bars can be chosen:
4. In this case 65-150 (A = 131 mm^2) will be sufficient.
5. b. Bending stress on certain height of the wall = 75 mm^2/m'
   To reach a good surface bording with the wire mesh the cover of the first layer should be in between of 8 m and 12 m.
   The wire mesh can be chosen:
6. Make a choise out of the different types of meshes indicated on the table on page .
7. In this case a hexagonal wire mesh type 13x13x0.7 is suitable. (A = 29.26 mm^2/m' in longitudinal and transversal direction).
8. 4 layers of this type will be sufficient to reach the reinforment required.
9. c. hoop stress = 210 mm^2/m'
10. check this with the indicated hoop stress in the tables on page 131.
11. The reinforcement can be built up in two elements:
12. 1. hoop wire bars Ø 5-150 = 131 mm^2
13. 2. wire mesh 4 x 29.26 = 117 mm^2

   total 248 mm^2
   which is sufficient.

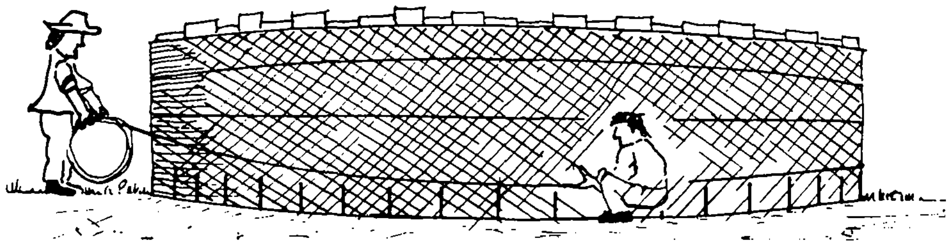
<u>Example II</u>

Tank type III capacity of 90 m^3 (height of 1.25 m).
1. Look into chapter "Calculation of the tanks" page "ferrocement tank, wall and slab constructed with a sliding joint".
2. hoop stress indicated in this table = 544 mm^2/m'.
3. The reinforcement can be built up in two elements:
4. 1. hoop bars Ø 8-150 = 336 mm^2/m'
5. 2. wire mesh 5 x 62.5 = 312 mm^2/m'

   total 648 mm^2/m'
   which is sufficient.

In vertical direction a distribution reinforcement is necessary. If a wire mesh is chosen with the same steel area in longitudinal and transverse direction than this will provide sufficient for distribution reinforcement.

The wire mesh and the reinforcing wire can be wound and carefully tightened around the formwork with number and distances as indicated on the drawings.



Mortar mixing

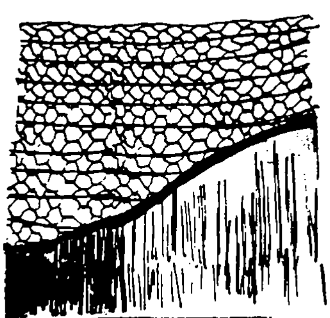
The mortar must be prepared with the correct proportions of materials. To assure these proportions it is very important to use measuring boxes or buckets. Measuring the materials on a shovel does not give reliable results. It is not advisable to use more water, because then the mortar will have a higher permeability to water and will be less strong and durable.
To make a mix more workable, a better graded sand or a greater proportion of cement should be used.
Although increasing the proportion of cement in the mortar will make it more workable, the risk of wide shrinkage cracks will be greater and of course the cost will also rise. Hand mixers can handle drier mixes than the concrete mixer.

Plastering

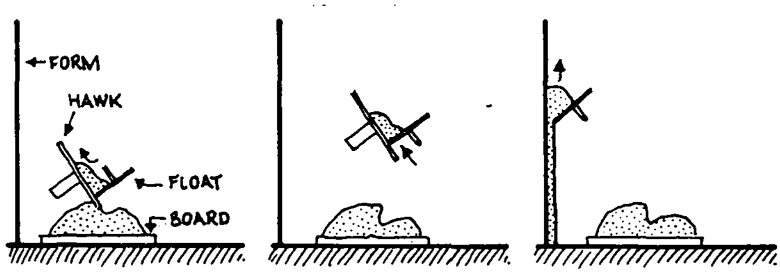
The plastering of the tank is the major part of the construction work. It is very important that this is done within one day. Choose a day on which no rain can be expected. In order not to waste time on the day of plastering, the mesh wire cylinder and all materials and tools required should be put ready the day before. Make firm arrangements with a gang of masons and helpers who will have to start early in the morning and continue till the job is over. For a 30 m^3 tank a gang of at least 7 masons and 5 helpers should be arranged.
The sequence of work is as follows:
- mix cement and sand to a dry mortar (1 : 2)
- for the volume-batching use measuring boxes or buckets
- the mortar can be mixed by hand or by a powered concrete mixer
- add water to the dry mortar in the proportion of cement : water = 1 : 0.45 (by weight)

- carry the prepared mortar to the side of the wall on a trowelling board; the board prevents dirt from reaching mortar, and any surplus mortar can be caught on it
- start plastering; apply the mortar to the wall quickly; this can be done by hand with a plasterer's steel handfloat and a handhawk. The mortar is trowelled from the base of the wall upwards. Each layer of plastering should be approx. 10 mm thick; depending on the wall thickness, 4-5-6- or 7 layers are to be applied.
- each layer should be bonded sufficiently but not hardened completely; after this the surface has to be roughened by a wire brush or a trowel.
- if the first layer is not finished or plastering must be interrupted for several hours, it is desirable to keep the construction joint as free of dust as possible
- clear the surface and remove loose materials before applying the next layer; if joints are necessary they must be made in a horizontal line around the tank
- the plastering operation is compeleted when the total thickness has been reached
- remove the formwork/mould after hardening of the last layer of the wall
- plaster the inside of the tank to the indicated thickness and until the reinforcement is fully covered
- trowel both surface very smooth by means of a toe-slipper; if a rough surface is required to ensure a good bonding surface for painting, the wall should be washed down with a sponge.

The joint between the tankslab and the tankwall should be painted twice with a bituminouspaint (on both sides) to get a watertight joint.



THE PLASTER BUILD-UP



1. MORTAR ONTO HAWK 2. MORTAR ONTO FLOAT 3. MORTAR ONTO FORM

5.4. Curing

Curing should be such that the concrete will have satisfactory durability and strength, that the tank will suffer a minimum of distortion, be free of excessive effloreseence and that subsequent shrinkage will not cause undue cracking in the structure.

To achieve these objectives it may be necessary to insulate the concrete so that it is maintained at a suitable temperature, or so that the rates of evaporation of moisture from the surfaces are kept to appropriate values, or both.
The curing period should be the first week after plastering. In that time the surface should not be permitted to dry out, therefore the walls should be covered with black plastic or wet sacking.

Curing is very important to ensure strong tanks and to avoid cracking due to shrinkage.

5.5. Testing

After curing the water tank should be tested by filling it with water (see also chapter 8).

5.6. Painting

If after testing the water tank shows a cracked surface, thorough painting/coating should be sufficient to seal the cracked surface.
After drying of the water tank for a week, the tank is ready for painting if desired. For paint application see the description in this manual (page 24).

4.7. Earth bund wall

To make easily accessible, watertank type I - 150 m^3 (variant A) may be considered for this type.
Such a bund is formed by heaping the excavated earth against the outside of the tank. If bad soil conditions are found (vegetation, black soil, loose surface soil) the bund earth wall should also have a proper foundation. This involves site clearance and preparation of the foundations being extended to the outer circumference of the bund earth wall.

After the excavated earth has been piled up against the outside of the tank the bund is finished by compaction.
This is done by ramming with (home-made) tampers together with sprinkling with a little water, if the soil is sandy.

5.8. Instructions for bricklaying (type V)

- Clean foundation where bricks are to be laid
- Mark line of brickwork every 1 meter or so with pegs
- Mix the mortar (see mortar for brickwork page 11)
- 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 this can cause joint cracks due to shrinkage.

Bricks are not to be 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-use it.
No "dead" mortar retrieved from the ground or other surface must be re-used.

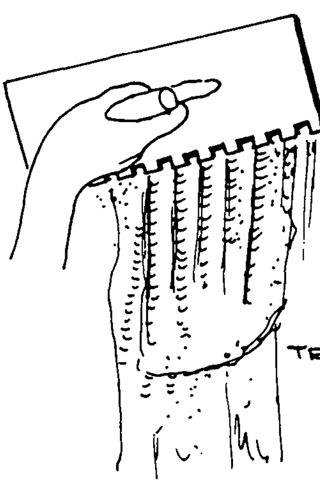
While laying bricks it is important to pay attention to the following rules for bonding:
- No vertical joints should be placed above each other.
- No closers must be used which are smaller than half the standard brick size locally available.

6. TOOLS

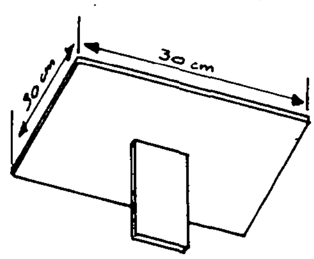
6.1. List of necessary tools

Excavation and marking out tools	- post - pegs - tape (measure) - 2 kg hammer string line - wheelbarrow - shovels - pickaxes for excavation - mattocks for groundlevelling - woodsaw - spirit level
Mixing mortar tools	- plastic sheeting - mix 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 the formwork (mould)	- depends on types of formwork

Tools for the wiremesh	-	wire snips for mesh
	-	cutter for mesh
	-	cutter for wire
	-	spanners for mesh
	-	tool for tightening by kinking
	-	crowbar, 1 meter long
Tools for bending reinforcement	-	see hereafter
Tools for placing the mortar mix	-	plasterers steel hand floats
	-	hand hawks
	-	trowelling boards
	-	wire brush
	-	trowel combform
	-	chisels
Tools for finishing	-	toe-slipper
	-	plastic sheeting or sacking for curing the mortar
	-	sponge

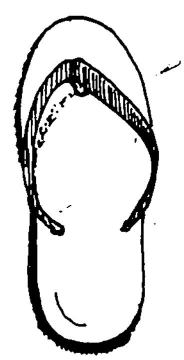


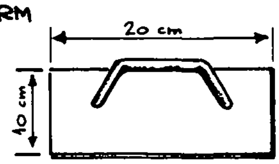
TROWEL COMBFORM



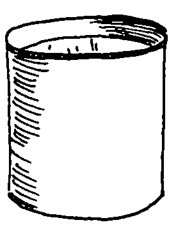
WOODEN MORTOR HOLDER (HAWK)

TOE SLIPPER

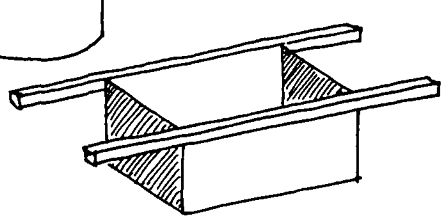




FLOAT

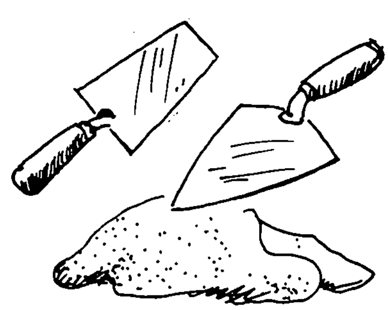


WATER BIN



MEASURING BOX 50 X 50 X 40 cm

PLASTERERS STEEL HAND



6.2. A simple tool for bending reinforcement bars

This tool consists of the two parts (part A and part B as indicated on figure 1) of T shaped iron, each with the dimensions of 30 x 30 x 3 mm and a length of 600-700 mm.
A 30 mm section is removed from both parts (see figure 1).
A tube with an inside bore of 12 mm is welded in the hole that is drilled in the L-part left from part A (figure 1).

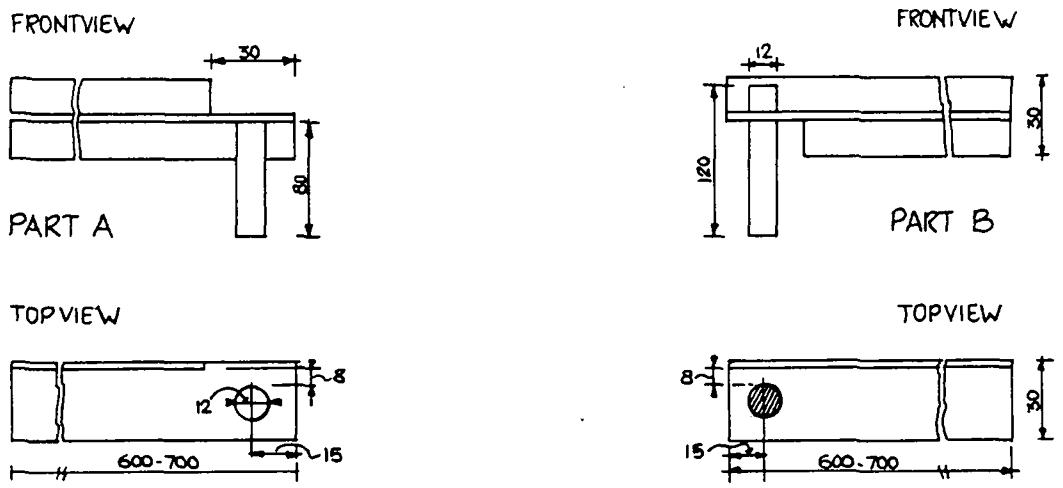


Figure 1

A bar (Ø 12 mm) is welded in the hole that is drilled in the L-part left from part B (figure 1).
Both parts are jointed like a hinge by putting the bar of part B into the tube of part A (figure 2).

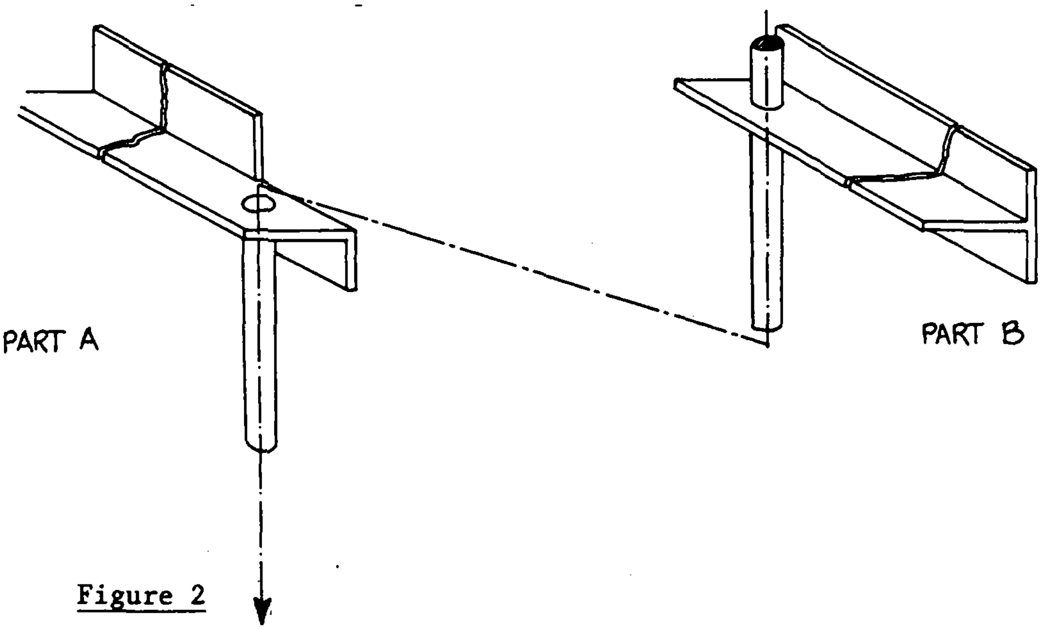


Figure 2

Operation of the tool

Put one part into a vice and join both parts as described above.

Place the concrete bar in the tool at the bending point and pull the other part towards you (figure 3).

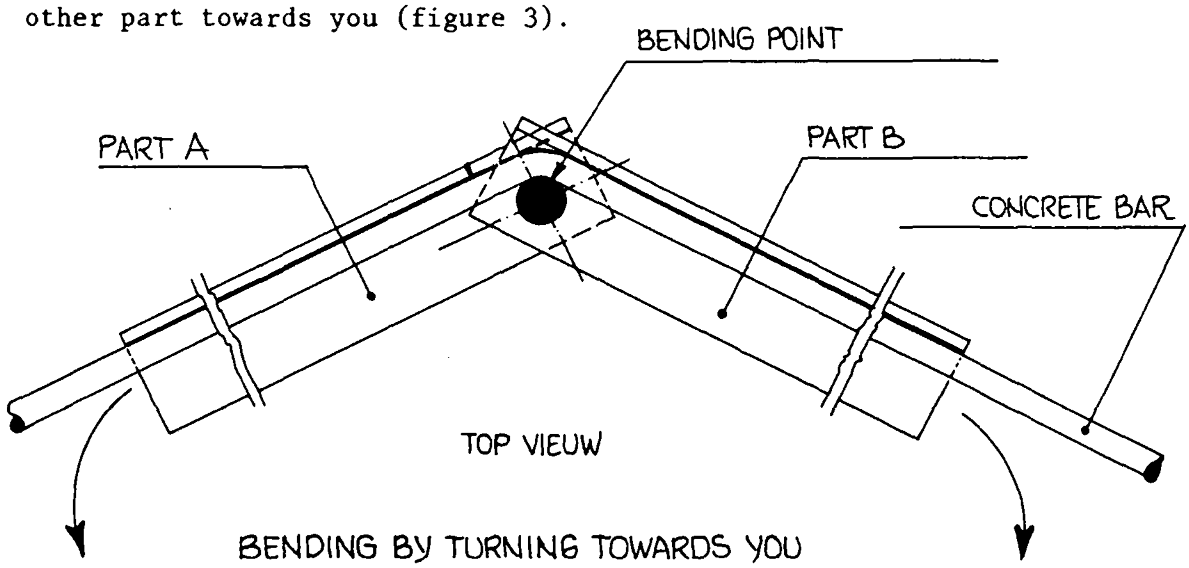


Figure 3

Now it is also possible to bend the concrete bars in the shapes as indicated in figure 4.

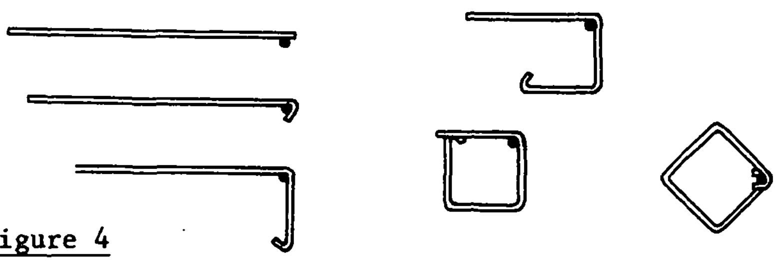
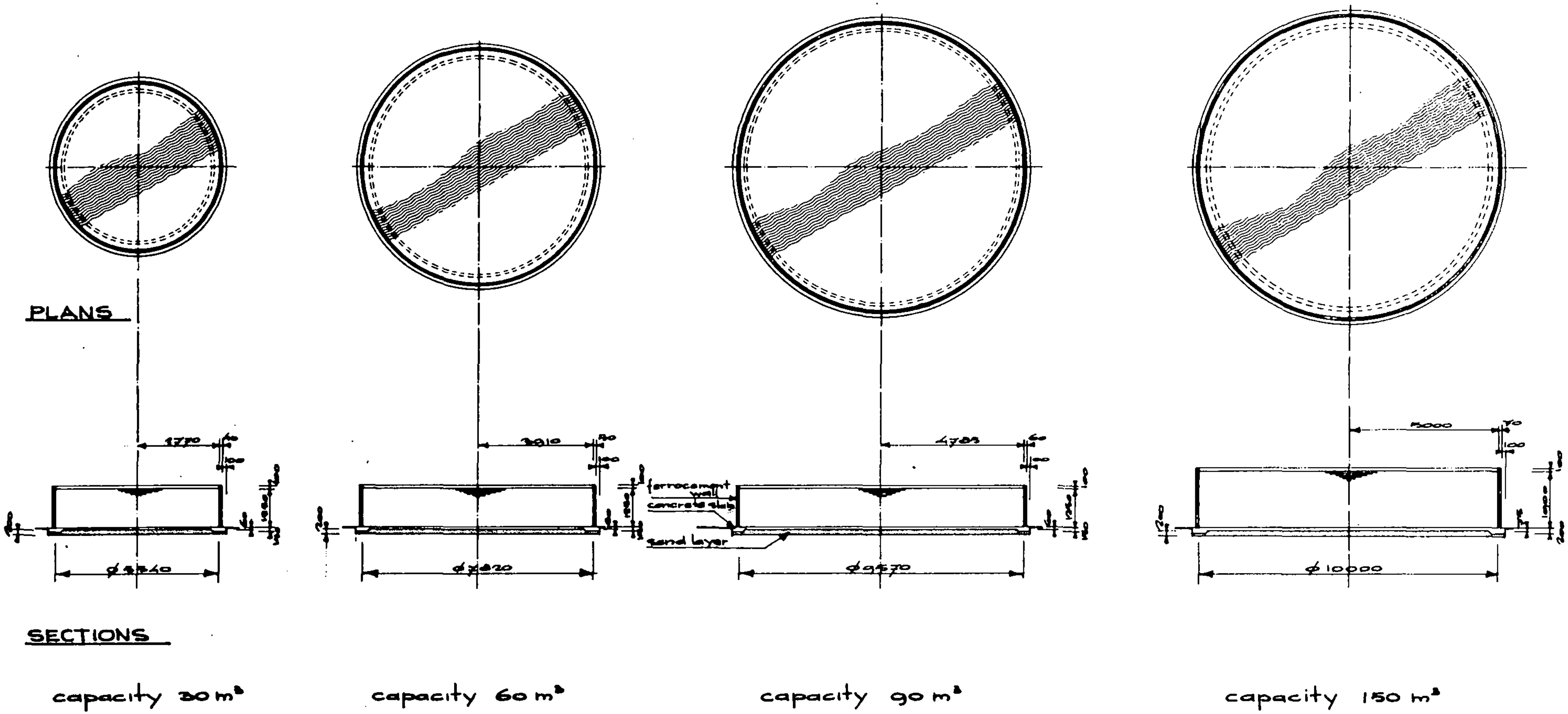


Figure 4

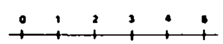
7. WORK INSTRUCTIONS
DRAWINGS
BILL OF QUANTITIES

7.1. Water tank type I PAGE

-	General layout		38
-	Work instructions		39
-	Capacity 30 m^3:	details and dimensions	43
		bill of quantities	44
-	Capacity 60 m^3:	details and dimensions	45
		bill of quantities	46
-	Capacity 90 m^3:	details and dimensions	47
		bill of quantities	48
-	Capacity 150 m^3:	details and dimensions	49
		bill of quantities	50
-	Vertical section variant A		51



TYPE I



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
FERROCEMENT CONSTRUCTION	measures in mm date 820623
TYPE I GENERAL LAY OUT	TWO DHV

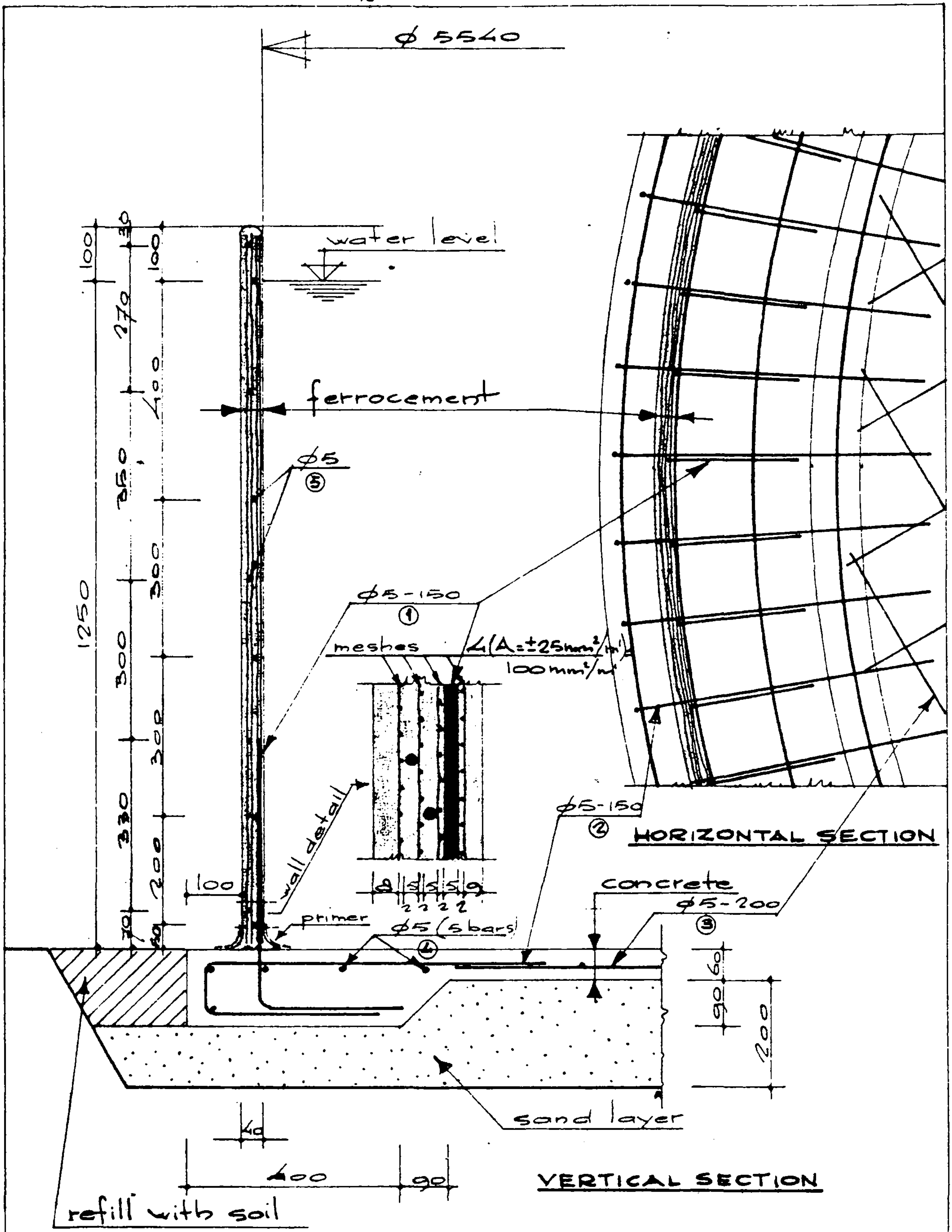
Type I

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 270 mm of the topsoil	
- refill with a sand and/or gravel layer of approx. 200 mm	
- the refill is to be compacted with tampers (own manufacture); if 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 tank slab and the ringtrench with pegs (pegs core to core 1 meter)	
- excavate the ringtrench to the proper depth and line its outer edge with formwork	- formwork can be made of: bricks, stabilised sand or plywood
- polythylene sheets are to be spread over this area	- an alternative is a layer of screed of approx. 20 mm
- place the reinforcement for the ringtrench and for the floorslab and fix the bars together with tying wire	- for bending the bars the bendingtool described on page 34 can be used
- check the circumference of the starterbars by describing a circle with a rope from the post to the centre of the proposed tank	- take special care that the bars are in the right position
- mix cement, sand and gravel to a dry mortar (1 : 2 :3)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion: cement-water: 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- cast and compact the mortar for the floorslab and ringtrench	
- level and finish the surface of the slab with a straight edged board or plywood	

work sequence and description	notes and recommendations
- immediately after casting protect the slab against weather influences by covering it with plastic sheeting or wet sacking for a week	- this is very important in tropical climates
- refill the outer circumference with soil	- using the topsoil that was removed earlier
- this refill must be compacted	
- assemble and erect the formwork (mould) on the floorslab	- some types of formwork and their construction are described in this manual (see page 20)
- re-check the right position in relation to the starterbars	
- the formwork is to be cleaned and slightly oiled to allow easy removal of the mould after plastering	- old motor oil can be used for this purpose
- wind the wire mesh around the outside surface of the formwork	- for choosing the meshes and the reinforcement see the step-by-step method on page 28 - several types of meshes and their characteristics are described in this manual (see page 16)
- in combination with the wire mesh, the reinforcing wire is to be wound around the mould at the distances indicated on the drawings; tie the wire mesh and the reinforcement firmly into place with tying wire	- the wire mesh and reinforcement should overlap by at least 500 mm
- mix cement and sand to a dry mortar (1 : 2)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion of cement : water = 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- carry the prepared mortar to the side of the wall on a trowelling board. The board prevents dirt from reaching the mortar, and any surplus mortar can be caught on it	- apply the mortar quickly; once the mortar is more than half an hour old it must be removed from site
- start plastering or trowelling: the mortar can be applied by hand to the walls with a plasterer's steel hand float and a hand hawk. The mortar is trowelled from the base of the wall upwards. Each layer of plaster should have a thickness of approx. 10 mm. Depending on the wall thickness, 4-5-6 or 7 layers are to be applied.	- tools for plastering and trowelling are described in this manual (see page 33) - it is important to trowel in an upwards direction in order to fill the corrugations and fully cover the reinforcing wire

work sequence and description	notes and recommendations
- each layer should be bonded sufficiently, but not hardened completely. After this the surface has to be roughened with a wire brush or a trowel (combform) - clean the surface and remove loose materials before applying the next layer; if joints are necessary they must be made in a horizontal line around the tank - the plastering operation is completed when the total thickness has been reached - remove the formwork/mould after hardening of the last layer of the wall - plaster the inside of the tank to the indicated thickness and until the reinforcement is fully covered - trowel both surfaces very smooth with a toe-slipper. If a rough surface is required to ensure a good bonding surface for painting, the wall should be washed down with a sponge	- if the first layer is not finished or the plastering must be interrupted for several hours, it is desirable to keep the construction joint as dust-free as possible before starting the next plastering operation the joints should be brushed with a wire brush and be coated with cement grout to give a strong bond for the fresh mortar the layers must be of uniform thickness with no gaps or weak spots especially in tropical climates the wall of the tank must be covered with black plastic or wet sacking between the application of each layer.
- IMPORTANT: cover the wall with plastic sheets or wet sacking for a week to protect the structure against weather influences.	- during the first 24 hours after plastering the surface should not be permitted to dry
(This procedure is called: "curing")	- curing is described on page 30 of this manual
- after curing and drying of the tank the joint between the tank-slab and the tankwall is to be painted twice with bituminous paint (both sides)	
- then the water tank is to be tested by filling it with water A newly built empty tank should always be filled slowly and it should be left for a week with a shallow depth of water at the bottom before filling completely.	

work sequence and description	notes and recommendations
- after testing and after drying the water tank for a week, painting can be carried out if desired	- for the application of paint or coating see page 24 in this manual



0 5 10 15
scale in centimeters

TYPE I
capacity 30 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	**SWD**
FERROCEMENT CONSTRUCTION	measures in mm date 820721
TYPE I DETAILS AND DIMENSIONS	TWO

BILL OF REINFORCEMENT

bar ref.	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	5	118	0,75	89				250 L 500	
2	floor	5	118	1,10	130				100 L 650 350	
3	floor	5			192					
4	floor/ring	5			84					
5	wall	5			175					
6										
	total length pro diameter				670					
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				103				+ →	
	total weight (kg)								103	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	104		
sand - fine	m³	0,7		
sand - coarse	m³	0,7		
gravel	m³	1,1		
brickwork				
cement	bag (40 ltr)	17		
excavation	m³	7,9		
layer (sand)	m³	5		
refill with soil	m³	0,6		
bund				
impermeable soil				
plastic foil	m²	28		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	100		
formwork/mould	m²	24		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

TYPE I
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

FERROCEMENT CONSTRUCTION

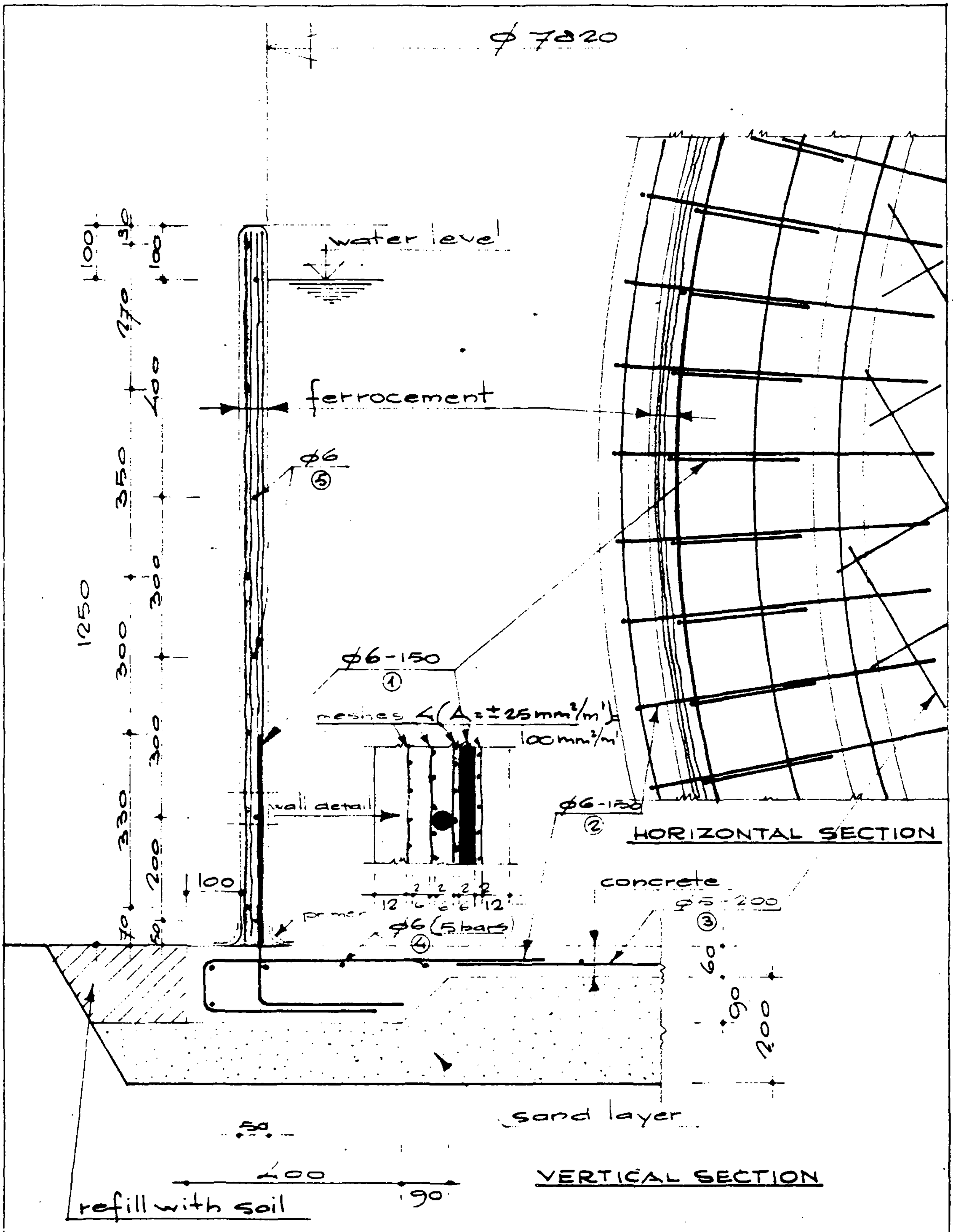
TYPE I

BILL OF QUANTITIES

SWD

measures in mm
date 820721

TWO



IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	820721
TYPE I DETAILS AND DIMENSIONS	TWO

TYPE I
capacity 60 m³

BILL OF REINFORCEMENT

nr	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	6	166	0,75		125			250 500	
2	floor	6	166	1,00		166			300 500 100	
3	floor	5			409					
4	floor/ring	6				119				
5	wall	6				247				
6										
	total length pro diameter				409	557				
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				63	124			+ →	
	total weight (kg)								187	

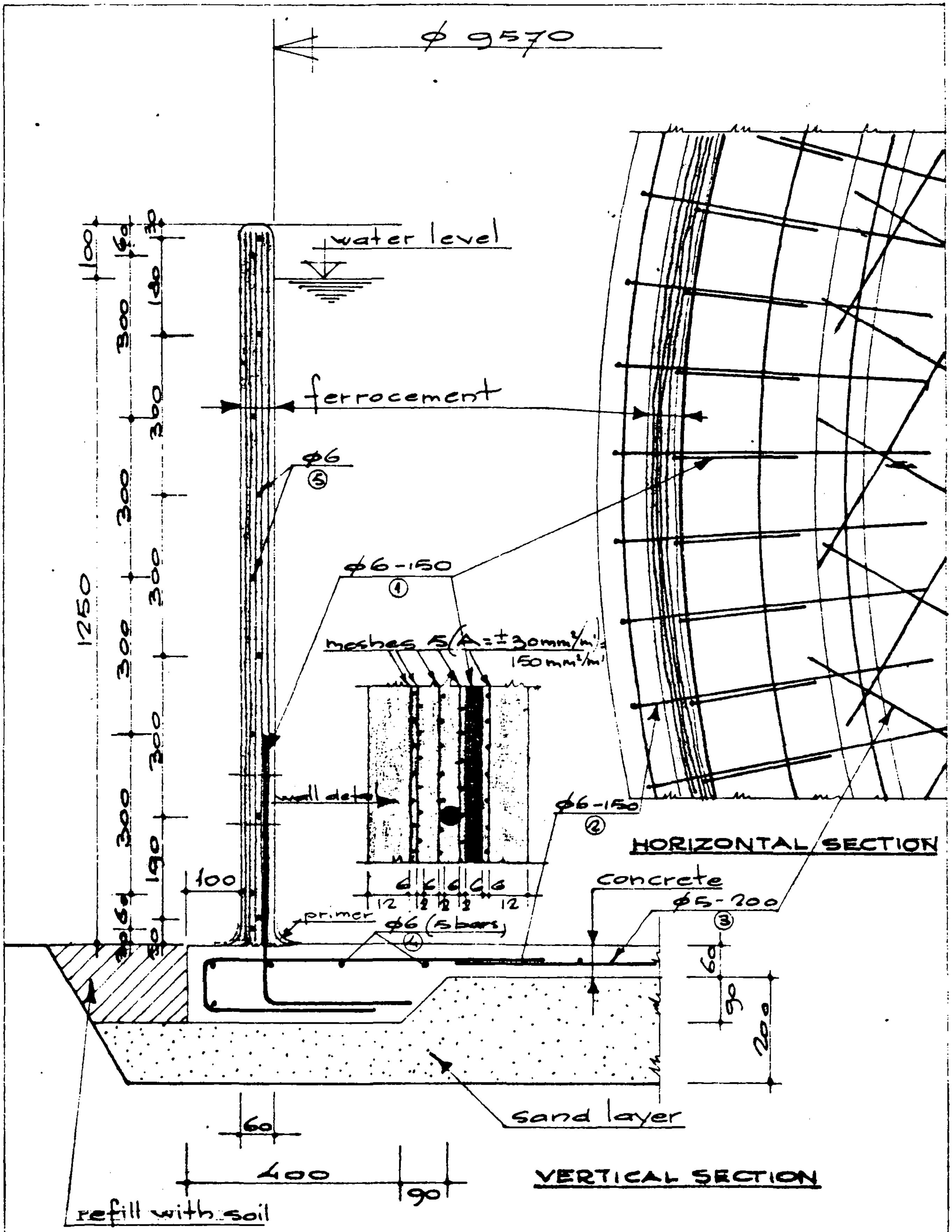
BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	146		
sand - fine	m³	1,1		
sand - coarse	m³	1,4		
gravel	m³	2		
brickwork				
cement	bag (40 ltr)	32		
excavation	m³	14,8		
layer (sand)	m³	10		
refill with soil	m³	1		
bund				
impermeable soil				
plastic foil	m²	55		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	150		
formwork/mould	m²	33		
total materials				
labour	mandays	hours	rates	
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	SWD
FERROCEMENT CONSTRUCTION	measures in mm, date 820321
TYPE I BILL OF QUANTITIES	TWO

TYPE I
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.

0 5 10 15

scale in centimeters

TYPE I
capacity 90m³

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm; date 820721
TYPE I DETAILS AND DIMENSIONS	TWO DHV

BILL OF REINFORCEMENT

bar	location	Ø	number bars	single length	total length mild steel m' Ø5	Ø6	Ø8	Ø10	bending details	remarks
1	floor/wall	6	204	0,75		153			250 ⌊500	
2	floor	6	204	1,00		204			300 ⌊ 600 100	
3	floor	5			631					
4	floor/ring	6				147				
5	wall	6				363				
6										
	total length pro diameter				631	867				
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				97	192			+ →	
	total weight								289	

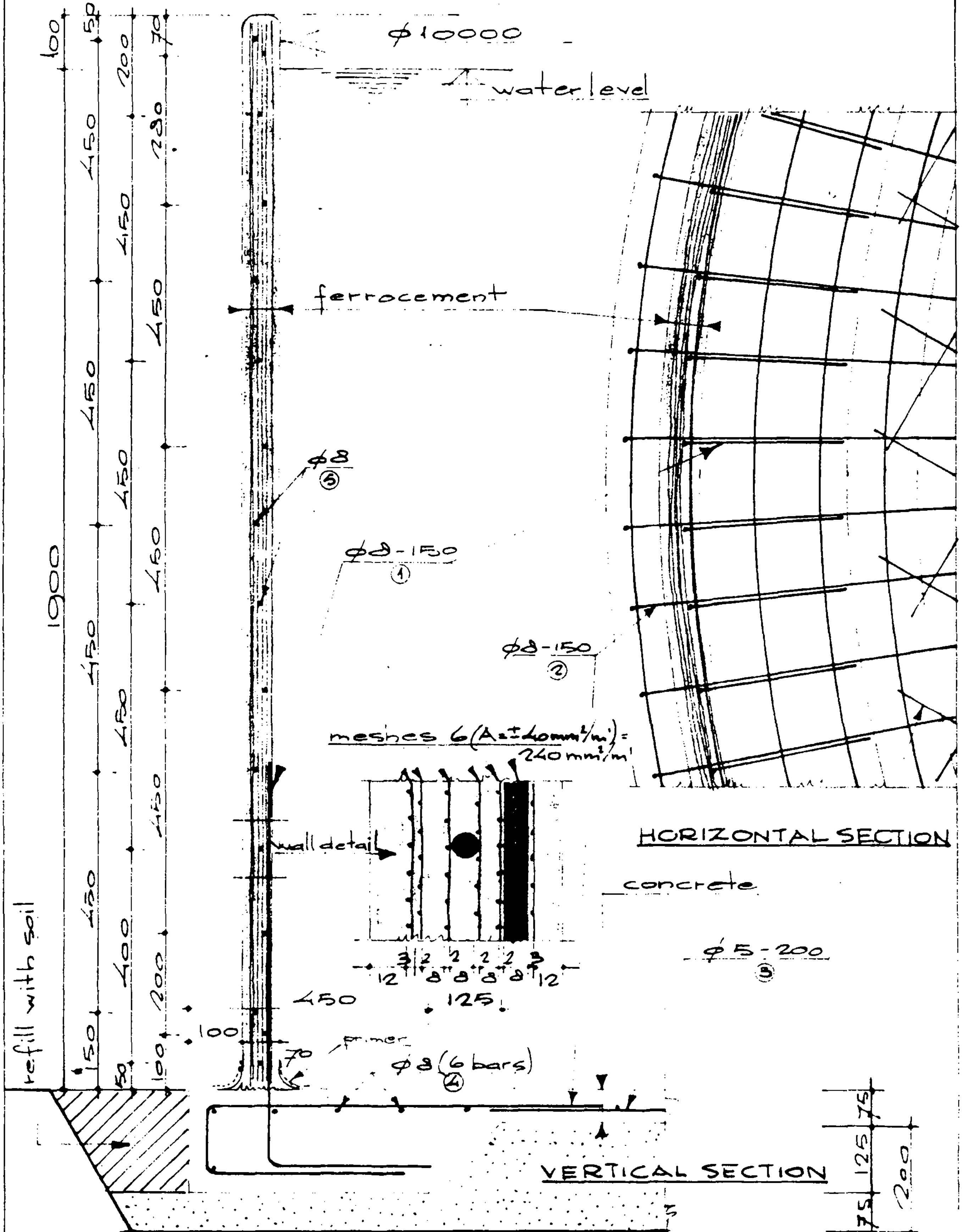
BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	225		
sand - fine	m³	1,6		
sand - coarse	m³	1,9		
gravel	m³	2,9		
brickwork				
cement	bag (40 ltr.)	45		
excavation	m³	21,6		
layer (sand)	m³	14,7		
refill with soil	m³	1		
bund				
impermeable soil				
plastic foil	m²	85		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	200		
formwork/mould	m²	41		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

TYPE I
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
FERROCEMENT CONSTRUCTION	measures in mm; date 820721
TYPE I BILL OF QUANTITIES	TWO



0 5 10 15

scale in centimeters

TYPE I
capacity 150m³

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	
TYPE I DETAILS AND DIMENSIONS	TWO

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	8	212	1,05			223		300 ⌊ 750	
2	floor	8	212	1,20			254		130 ⌊ 720, 350	
3	floor	5			694					
4	floor/ring	8					185			
5	wall	8					506			
6										
	total length pro diameter				694		1168			
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				107		461		+ →	
	total weight								568	

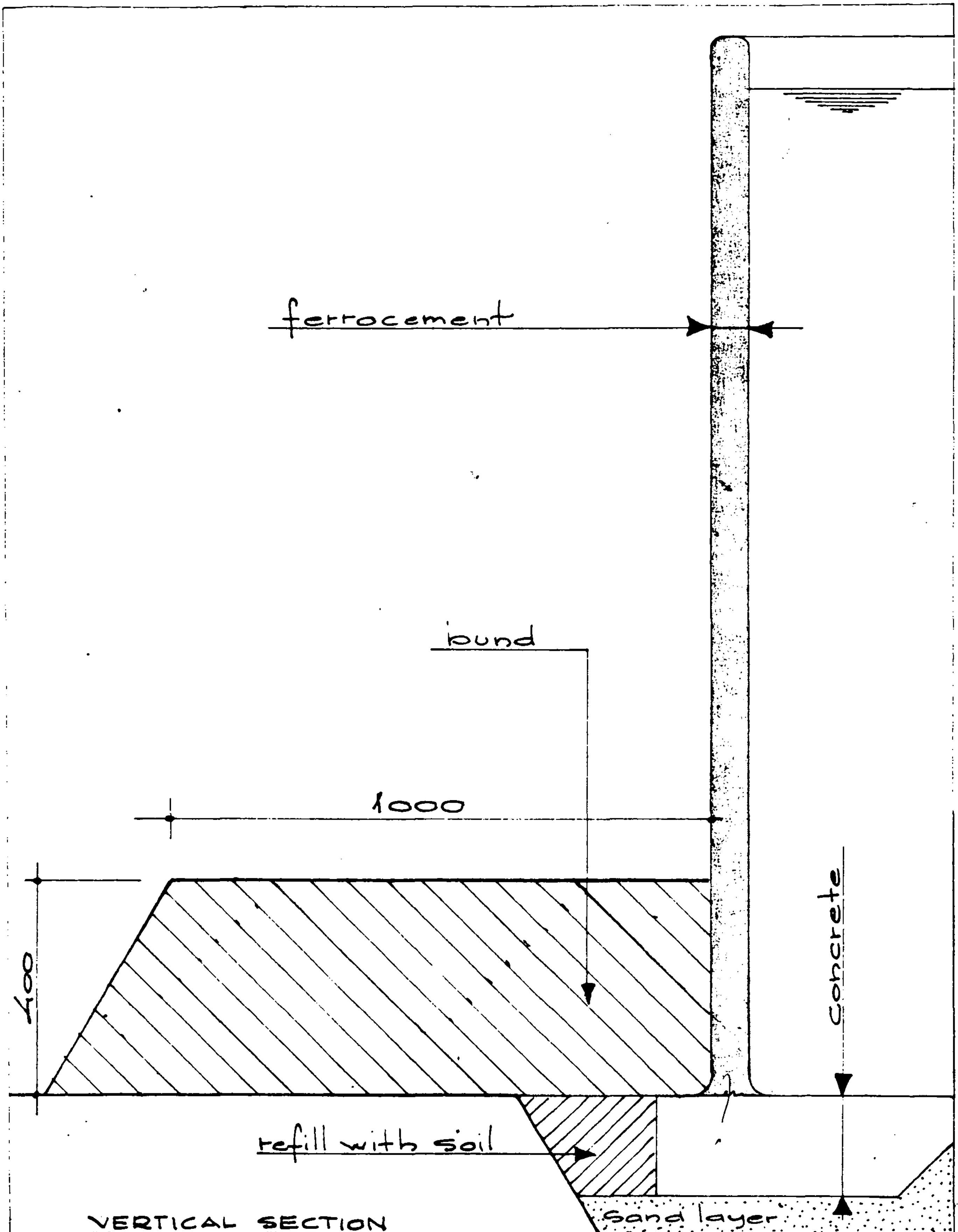
BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	416		
sand - fine	m³	3		
sand - coarse	m³	29		
gravel	m³	42		
brickwork				
cement	bag (40 ltr)	73		
excavation	m³	25,4		
layer (sand)	m³	15,2		
refill with soil	m³	1,5		
bund				
impermeable soil				
plastic foil	m²	90		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	400		
formwork/mould	m²	63		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

TYPE I
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
FERROCEMENT CONSTRUCTION	measures in mm, date 820721
TYPE I, BILL OF QUANTITIES	TWO



VERTICAL SECTION
VARIANT A

0 5 10 15
scale in centimeters

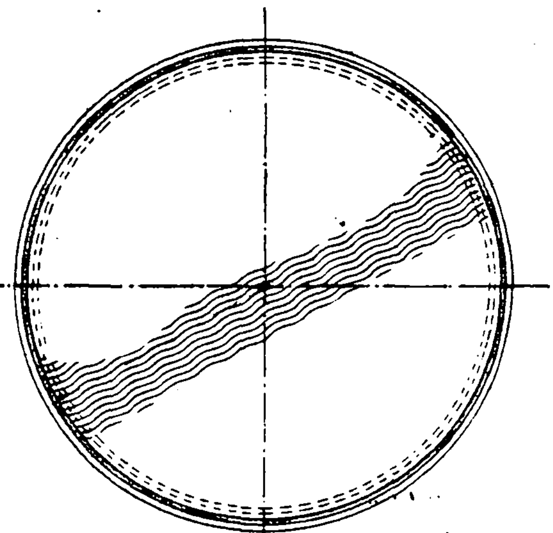
TYPE I
capacity 150 m³

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

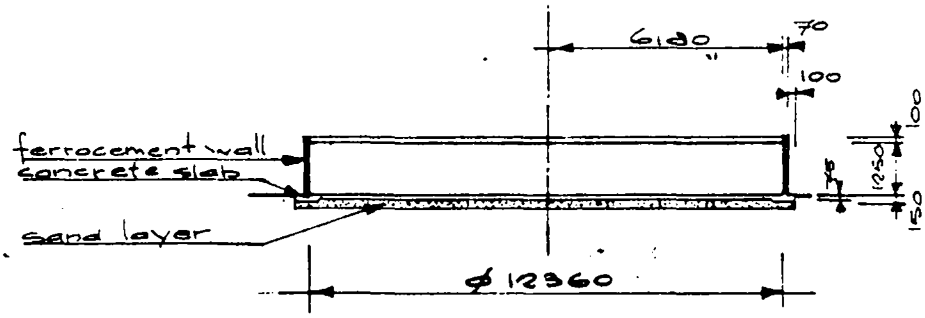
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	
TYPE I	measures in mm date 820721
DETAILS AND DIMENSIONS	TWO | DHV

6.2. Water tank type II PAGE

-	General layout		53
-	Work instructions		54
-	Capacity 150 m^3:	details and dimensions	58
		bill of quantities	59



PLAN



SECTION

capacity 150 m³

0 1 2 3
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
FERROCEMENT CONSTRUCTION	measures in mm date
TYPE II GENERAL LAY OUT	TWO

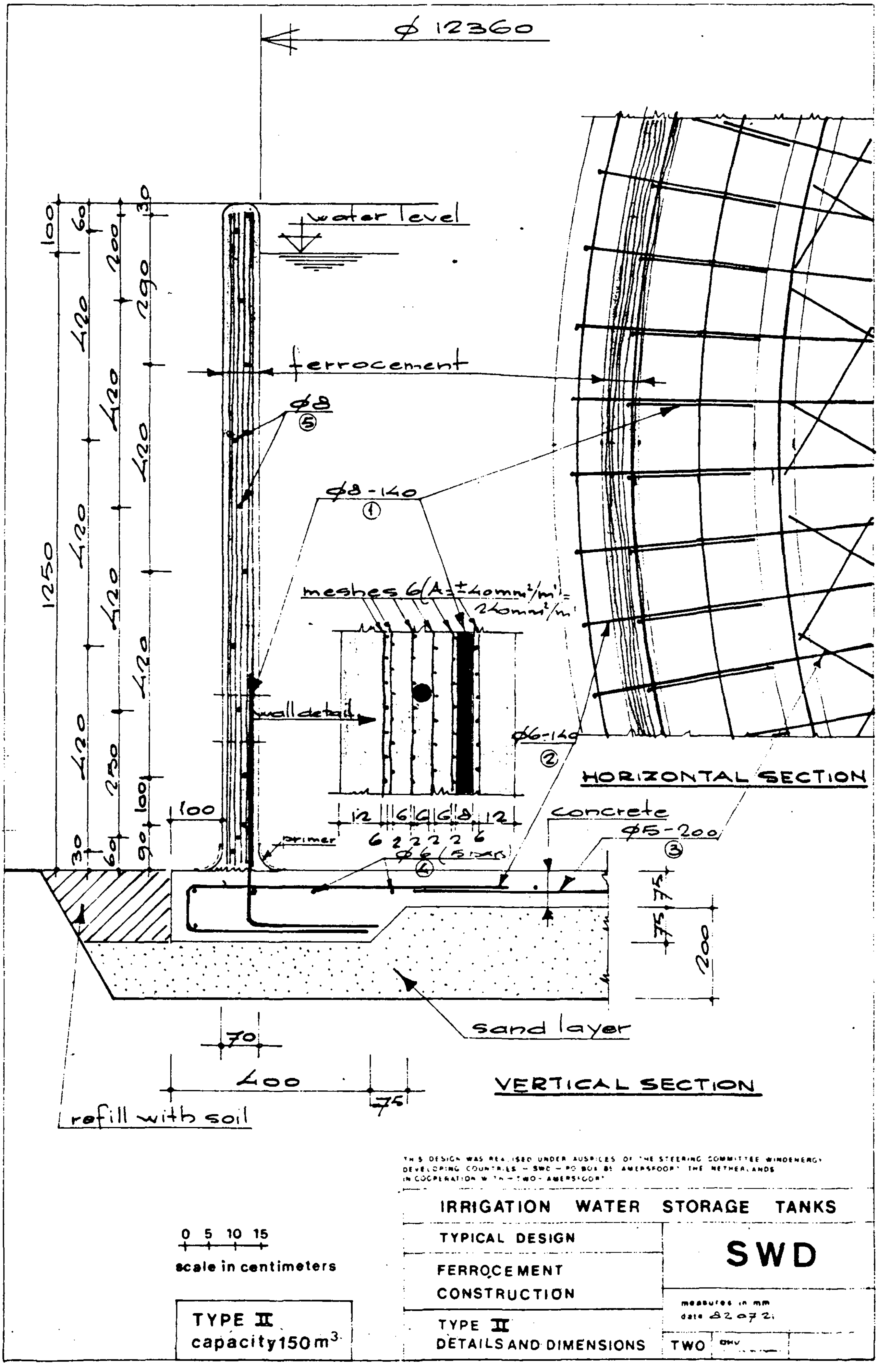
Type II

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. 270 mm of the topsoil	
- refill with a sand and/or gravel layer of approx. 200 mm	
- the refill is to be compacted with tampers (own manufacture); if 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 tank-slab and the ringtrench with pegs (pegs core to core 1 meter)	
- excavate the ringtrench to the proper depth and line its outer with formwork	- formwork can be made of: bricks, stabilised sand or plywood
- polythylene sheets are to be spread over this area	- an alternative is a layer of screed of approx. 20 mm
- place the reinforcement for the ringtrench and for the floorslab and fix the bars together with tying wire	- for bending the bars the bendingtool described on page 34 can be used
- check the circumference of the starter bars by describing a circle, with a rope from the post to the centre of the proposed tank	- take special care that the bars are in the right position
- mix cement, sand and gravel to a dry mortar (1 : 2 :3)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion: cement-water: 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- cast and compact the mortar for the floorslab and ringtrench	
- level and finish the surface of the slab with a straight edged board or plywood	

work sequence and description	notes and recommendations
- immediately after casting protect the slab against weather influences by covering it with plastic-sheeting or wet sacking for a week	- this is very important in tropical climates
- refill the outer circumference with soil	- using the topsoil that was removed earlier
- this refill must be compacted	
- assemble and erect the formwork (mould) on the floorslab	- some types of formwork and their construction are described in this manual (see page 20)
- re-check the right position in relation to the starterbars	
- the formwork is to be cleaned and slightly oiled to allow easy removal of the mould after plastering	- old motor oil can be used for this purpose
- wind the wire mesh around the outside surface of the formwork	- for choosing the meshes and the reinforcement see the step-by-step method on page 28.
	- Several types of meshes and their characteristics are described in this manual (see pages 16)
- in combination with the wire mesh, the reinforcing wire is to be wound around the mould at the distances indicated on the drawings; tie the wire mesh and the reinforcement firmly into place with tying wire	- the wire mesh and reinforcement should overlap by at least 500 mm
- mix cement and sand to a dry mortar (1 : 2)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion of cement : water = 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- carry the prepared mortar to the side of the wall on a trowelling board. The board prevents dirt from reaching the mortar, and any surplus mortar can be caught on it	- apply the mortar quickly; once the mortar is more than half an hour old it must be removed from site
- start plastering or trowelling: the mortar can be applied by hand to the walls with a plasterer's steel hand float and a hand hawk. The mortar is trowelled from the base of the wall upwards. Each layer of plaster should have a thickness of approx. 10 mm. Depending on the wall thickness, 4-5-6 or 7 layers are to be applied.	- tools for plastering and trowelling are described in this manual (see page 33) - it is important to trowel in an upwards direction in order to fill the corrugations and fully cover the reinforcing wire

work sequence and description	notes and recommendations
- each layer should be bonded sufficiently, but not hardened completely. After this the surface has to be roughened with a wire brush or a trowel (combform) - clean the surface and remove loose materials before applying the next layer; if joints are necessary they must be made in a horizontal line around the tank - the plastering operation is completed when the total thickness has been reached - remove the formwork/mould after hardening of the last layer of the wall - plaster the inside of the tank to the indicated thickness and until the reinforcement is fully covered - trowel both surfaces very smooth with a toe-slipper. If a rough surface is required to ensure a good bonding surface for painting, the wall should be washed down with a sponge	- if the first layer is not finished or the plastering must be interrupted for several hours, it is desirable to keep the construction joint as dust-free as possible before starting the next plastering operation the joints should be brushed with a wire brush and be coated with cement grout to give a strong bond for the fresh mortar the layers must be of uniform thickness with no gaps or weak spots especially in tropical climates the wall of the tank must be covered with black plastic or wet sacking between the application of each layer.
- IMPORTANT: cover the wall with plastic sheets or wet sacking for a week to protect the structure against weather influences.	- during the first 24 hours after plastering the surface should not be permitted to dry
(This procedure is called: "curing")	- curing is described on page 30 of this manual
- after curing and drying of the tank the joint between the tank-slab and the tankwall is to be painted twice with bituminous paint (both sides) - then the water tank is to be tested by filling it with water A newly built empty tank should always be filled slowly and it should be left for a week with a shallow depth of water at the bottom before filling completely.	

work sequence and description	notes and recommendations
- after testing and after drying the water tank for a week, painting can be carried out if desired	- for the application of paint or coating see page 24 in this manual


ϕ 12360
water level
ferrocement
ϕ8
5
ϕ8-140
1
meshes 6(A=±40mm²/m')=240mm²/m'
wall detail
ϕ6-140
2
HORIZONTAL SECTION
concrete
ϕ5-200
3
primer
ϕ6 (5 bars)
4
sand layer
VERTICAL SECTION
refill with soil
1250
400
0 5 10 15
scale in centimeters
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
FERROCEMENT
CONSTRUCTION
SWD
measures in mm
TYPE II
DETAILS AND DIMENSIONS
TWO

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	8	262	0,75			197		250 500	
2	floor	6	262	1,05		275			100 600 350	
3	floor	5			1086					
4	floor/ring	6				191				
5	wall	6					508			
6										
total length pro diameter					1086	466	705			
weight in kg/m'					0,154	0,222	0,395	0,617		
total weight pro diameter					167	103	278		+ →	
total weight									548	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m^2	346		
sand - fine	m^3	2,5		
sand - coarse	m^3	3,6		
gravel	m^3	5,4		
brickwork				
cement	bag (40 ltr.)	76		
excavation	m^3	38		
layer (sand)	m^3	25		
refill with soil	m^3	1,6		
bund				
impermeable soil				
plastic foil	m^2	132		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	350		
formwork/mould	m^2	52		
total materials				
labour	mandays	hours	rates	

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

FERROCEMENT CONSTRUCTION

TYPE II
BILL OF QUANTITIES

SWD

measures in mm
date 820721

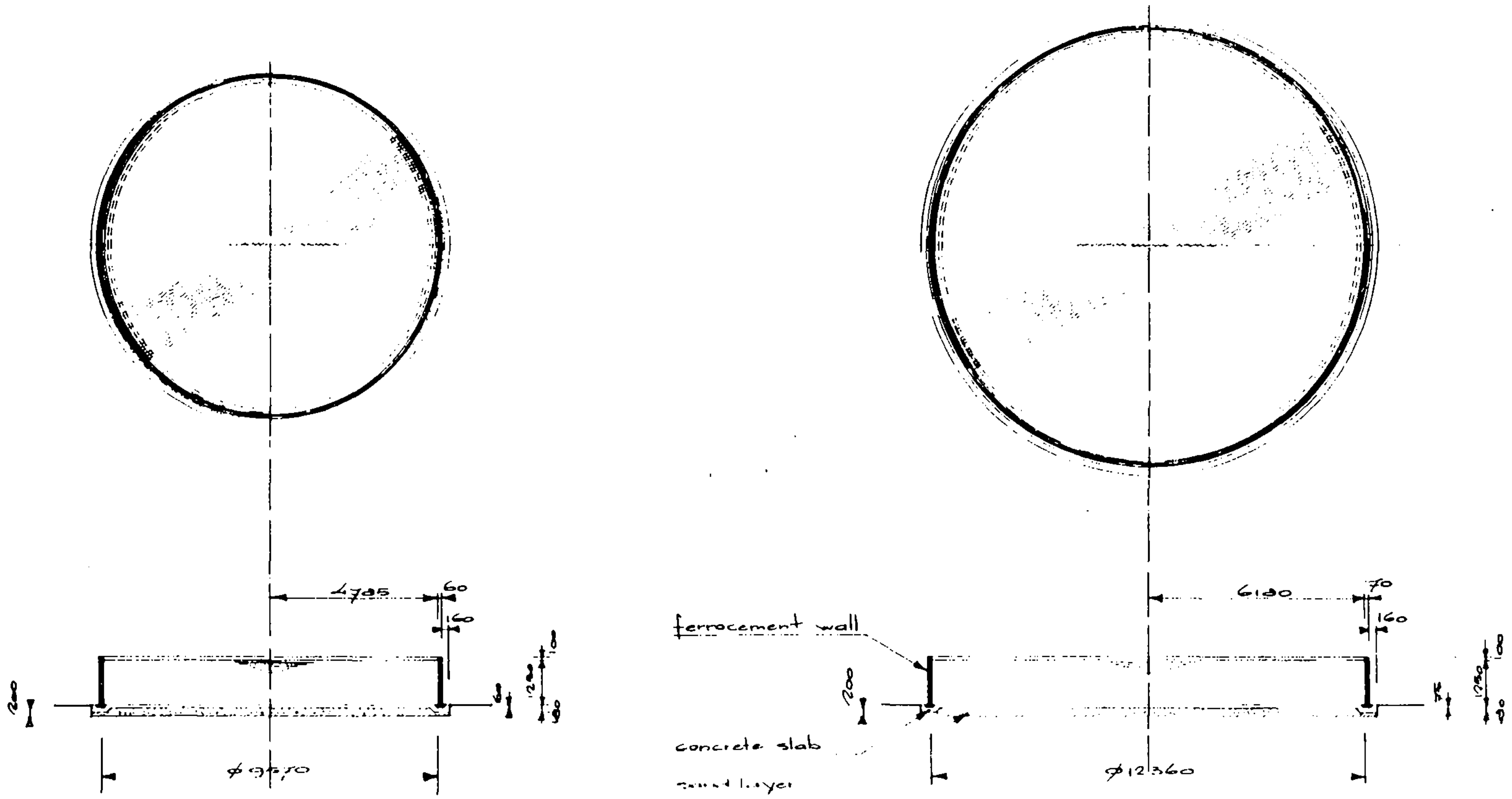
TWO

TYPE II
capacity 150m^3

7.3. <u>Water tank type III</u>		PAGE
- General layout		61
- Work instructions		62
- Capacity 90 m^3:	details and dimensions	66
	bill of quantities	67
- Capacity 150 m^3:	details and dimensions	68
	bill of quantities	69
- Vertical section variant A		70

PLANS

SECTIONS



capacity 90 m³

capacity 150 m³

TYPE III

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
FERROCEMENT CONSTRUCTION	measures in mm date 820623
TYPE III GENERAL LAY OUT	TWO DHV

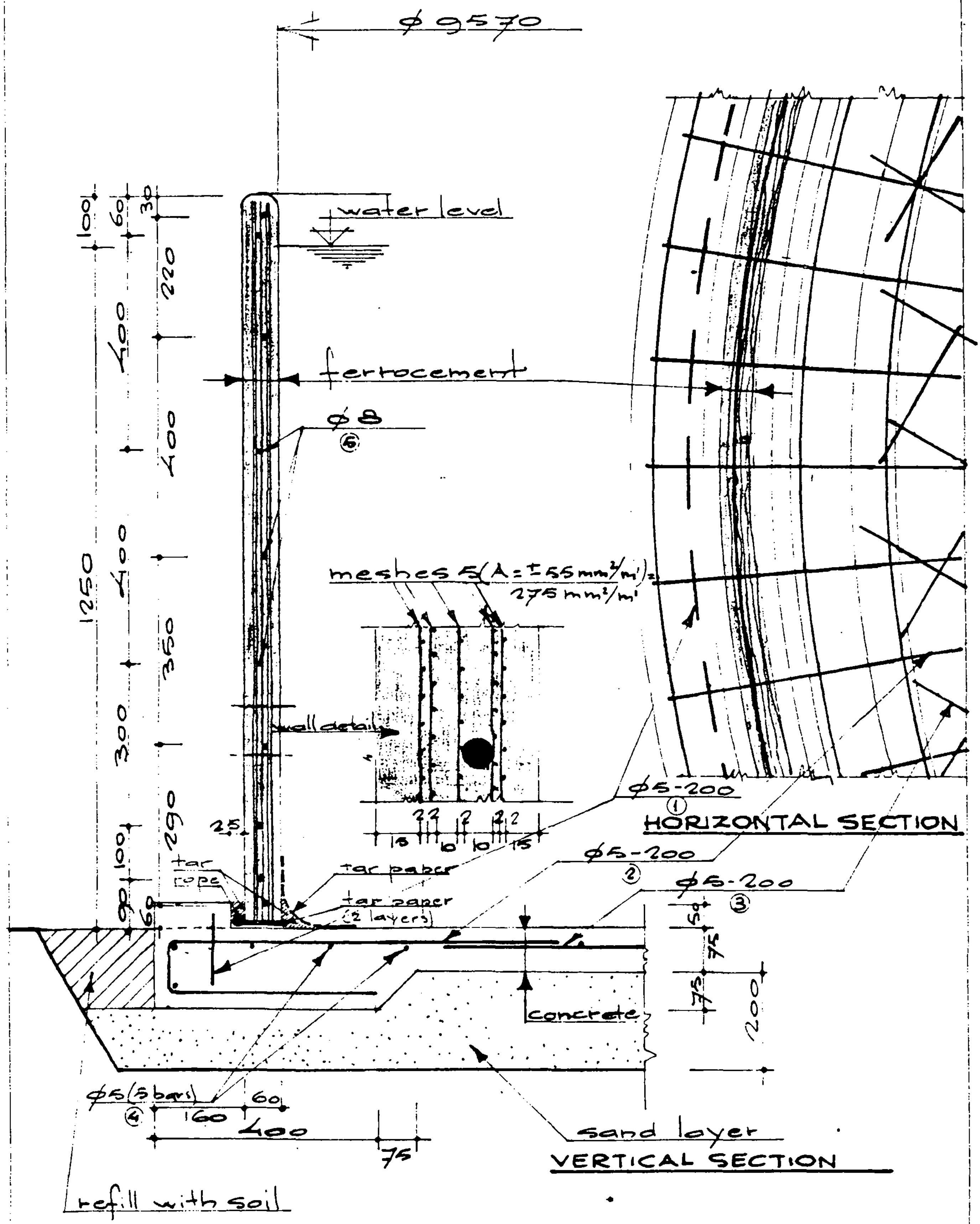
Type III

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 270 mm of the topsoil	
- refill with a sand and/or gravel layer of approx. 200 mm	
- the refill is to be compacted with tampers (own manufacture); if 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 tank slab and the ringtrench with pegs (pegs core to core 1 meter)	
- excavate the ringtrench to the proper depth and line its outer edge with formwork	- formwork can be made of: bricks, stabilised sand or plywood
- polythylene sheets are to be spread over this area	- an alternative is a layer of screed of approx. 20 mm
- place the reinforcement for the ringtrench and for the floorslab and fix the bars together with tying wire	- for bending the bars the bendingtool described on page 34 can be used
- check the circumference of the hair-pins by describing a circle with a rope from the post to the centre of the proposed tank	- take special care that the hair-pins are in the right position
- mix cement, sand and gravel to a dry mortar (1 : 2 :3)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion: cement-water: 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- cast and compact the mortar for the floorslab and ringtrench	
- level and finish the surface of the slab with a straight edged board or plywood	

work sequence and description	notes and recommendations
- immediately after casting protect the slab against weather influences by covering it with plastic sheeting or wet sacking for a week	- this is very important in tropical climates
- refill the outer circumference with soil	- using the topsoil that was removed earlier
- this refill must be compacted	
- assemble and erect the formwork (mould) on the floorslab	- some types of formwork and their construction are described in this manual (see page 20)
- Apply 2 layers of tarredpaper to the bottom of the slab, where construction of the tankwall is proposed	
- the formwork is to be cleaned and slightly oiled to allow easy removal of the mould after plastering	- old motor il can be used for this purpose
- wind the wire mesh around the outside surface of the formwork	- for choosing the meshes and the reinforcement see the step-by-step method on page 28. several types of meshes and their characteristics are described in this manual (see pages 16)
- in combination with the wire mesh, the reinforcing wire is to be wound around the mould at the distances indicated on the drawings; tie the wire mesh and the reinforcement firmly into place with tying wire	- the wire mesh and reinforcement should overlap by at least 500 mm
- mix cement and sand to a dry mortar (1 : 2)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion of cement : water = 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- carry the prepared mortar to the side of the wall on a trowelling board. The board prevents dirt from reaching the mortar, and any surplus mortar can be caught on it	- apply the mortar quickly; once the mortar is more than half an hour old it must be removed from site
- start plastering or trowelling: the mortar can be applied by hand to the walls with a plasterer's steel hand float and a hand hawk. The mortar is trowelled from the base of the wall upwards. Each layer of plaster should have a thickness of approx. 10 mm.	- tools for plastering and trowelling are described in this manual (see page 33) - it is important to trowel in an upwards direction in order to fill the corrugations and fully cover the reinforcing wire

work sequence and description	notes and recommendations
Depending on the wall thickness, 4-5-6 or 7 layers are to be applied.	
- each layer should be bonded sufficiently, but not hardened completely. After this the surface has to be roughened by a wire brush or a trowel (combform)	- if the first layer is not finished or the plastering must be interrupted for several hours, it is desirable to keep the construction joint as dust-free as possible before starting the next plastering operation the joints should be brushed with a wire brush and be coated with cement grout to give a strong bond for the fresh mortar the layers must be of uniform thickness with no gaps or weak spots especially in tropical climates the wall of the tank must be covered with black plastic or wet sacking between the application of each layer.
- clean the surface and remove loose materials before applying the next layer; if joints are necessary they must be made in a horizontal line around the tank	
- the plastering operation is completed when the total thickness has been reached	
- remove the formwork/mould after hardening of the last layer of the wall	
- plaster the inside of the tank to the indicated thickness and until the reinforcement is fully covered	
- trowel both surfaces very smooth with a toe-slipper. If a rough surface is required to ensure a good bonding surface for painting, the wall should be washed down with a sponge	
- IMPORTANT: cover the wall with plastic sheets or wet sacking for a week to protect the structure against weather influences.	- during the first 24 hours after plastering the surface should not be permitted to dry
(This procedure is called: "curing")	- curing is described on page 30 of this manual
- a concrete plinth, 50 mm high, is to be poured onto the outer circumference of the tankslab. Keep 25 mm free between this plinth and the tankwall to allow the tankwall to move	- take care that the surface around the joint is completely cleaned before the works involving the plinth, the hot bitumen and the bituminous paint are started
- seal the underneath of the joint by binding string round it	
- fill the outer sliding joint with hot bitumen	

work sequence and description	notes and recommendations
- after curing and drying of the tank the inside joint between the tankslab and the tankwall is to be painted twice with bituminous paint	
- then the water tank is to be tested by filling it with water A newly built empty tank should always be filled slowly and it should be left for a week with a shallow depth of water at the bottom before filling completely.	
- after testing and after drying the water tank for a week, painting can be carried out if desired	- for the application of paint or coating see page 24 in this manual



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

0 5 10 15

scale in centimeters

TYPE III
capacity 90 m³

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	
TYPE III DETAILS AND DIMENSIONS	measures in mm date 820721 TWO DHV

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor	5	204	0,41	84				130 ⌐150¬ 130	
2	floor	5	204	1,15	235				100 ⌊350⌋ 700	
3	floor	5			631					
4	floor/ring	5			147					
5	wall	8					302			
6										
	total length pro diameter				1097		302			
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				169		119		+ →	
	total weight								288	

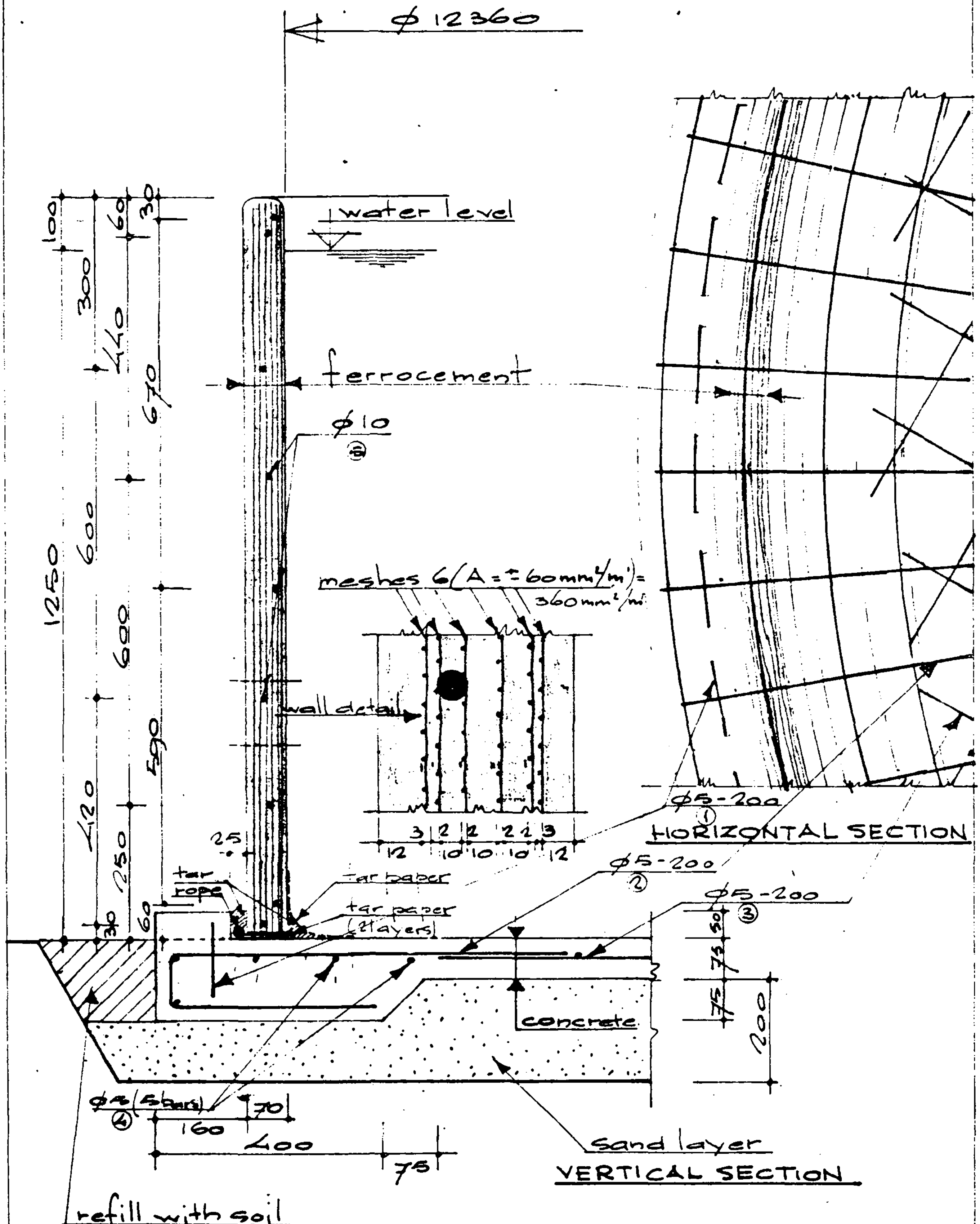
BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	225		
sand - fine	m³	1,7		
sand - coarse	m³	2,2		
gravel	m³	3,2		
brickwork				
cement	bag (40 kg)	48		
excavation	m³	23		
layer (sand)	m³	15		
refill with soil	m³	1,3		
bund				
impermeable soil				
plastic foil	m²	85		
painting/sealing				
tar paper	m²	20		
primer				
tools				
concrete mixer				
rope	m'	30		
tying wire	m'	200		
formwork/mould	m²	41		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

TYPE III
capacity 90 m³

THIS DESIGN WAS REAL... COMMITTEE WINDENERGY DEVELOPING COUNTRIES ... THE NETHERLANDS IN COOPERATION WITH TWO ...

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN FERROCEMENT CONSTRUCTION	SWD
TYPE III BILL OF QUANTITIES	measures in mm date 82072 TWO



0 5 10 15
scale in centimeters

TYPE III
capacity 150m³

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

FERROCEMENT CONSTRUCTION

TYPE III
DETAILS AND DIMENSIONS

SWD

measures in mm

TWO

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor	5	267	0,41	109				130 / 150 / 130	
2	floor	5	267	1,15	307				100 / 700 / 350	
3	floor	5			1105					
4	floor/ring	5			194					
5	wall	10						391		
6										
total length pro diameter					1715			391		
weight in kg/m'					0,154	0,222	0,395	0,617		
total weight pro diameter					264			241 + →		
total weight									505	

BILL OF QUANTITIES

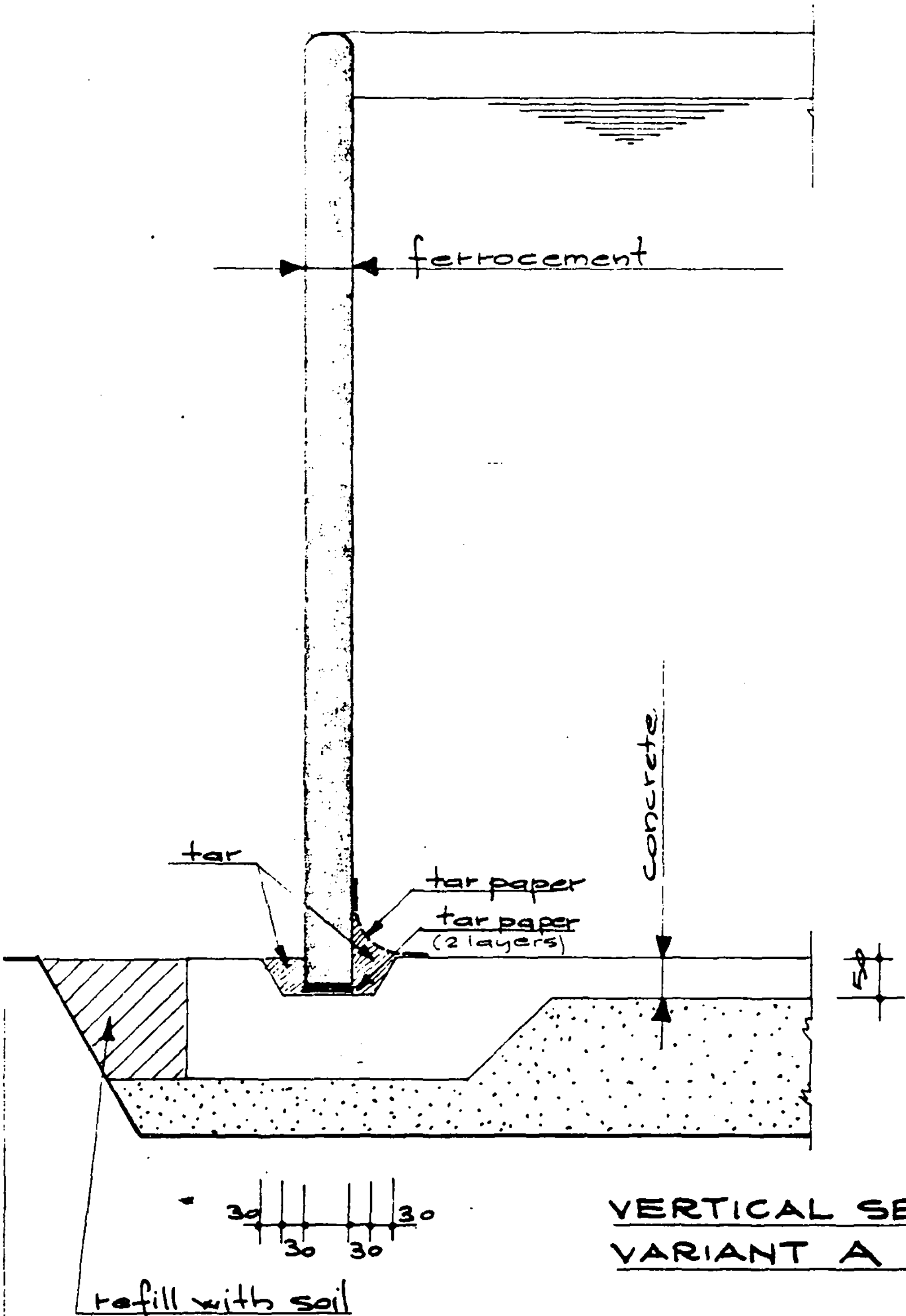
ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m^2	318		
sand - fine	m^3	2,6		
sand - coarse	m^3	3,9		
gravel	m^3	5,9		
brickwork				
cement	bag (40 ltr)	80		
excavation	m^3	39		
layer (sand)	m^3	24		
refill with soil	m^3	1,7		
bund				
impermeable soil				
plastic foil	m^2	135		
painting/sealing				
tar paper	m^2	25		
primer				
tools				
concrete mixer				
rope	m'	39		
tying wire	m'	300		
formwork/mould	m^2	53		
total materials				
labour	mandays	hours	rates	

TOTAL COST OF STORAGE TANK

TYPE III
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	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 820721
TYPE III BILL OF QUANTITIES	TWO



VERTICAL SECTION
VARIANT A

0 5 10 15
scale in centimeters

TYPE III
VARIANT A

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

FERROCEMENT
CONSTRUCTION

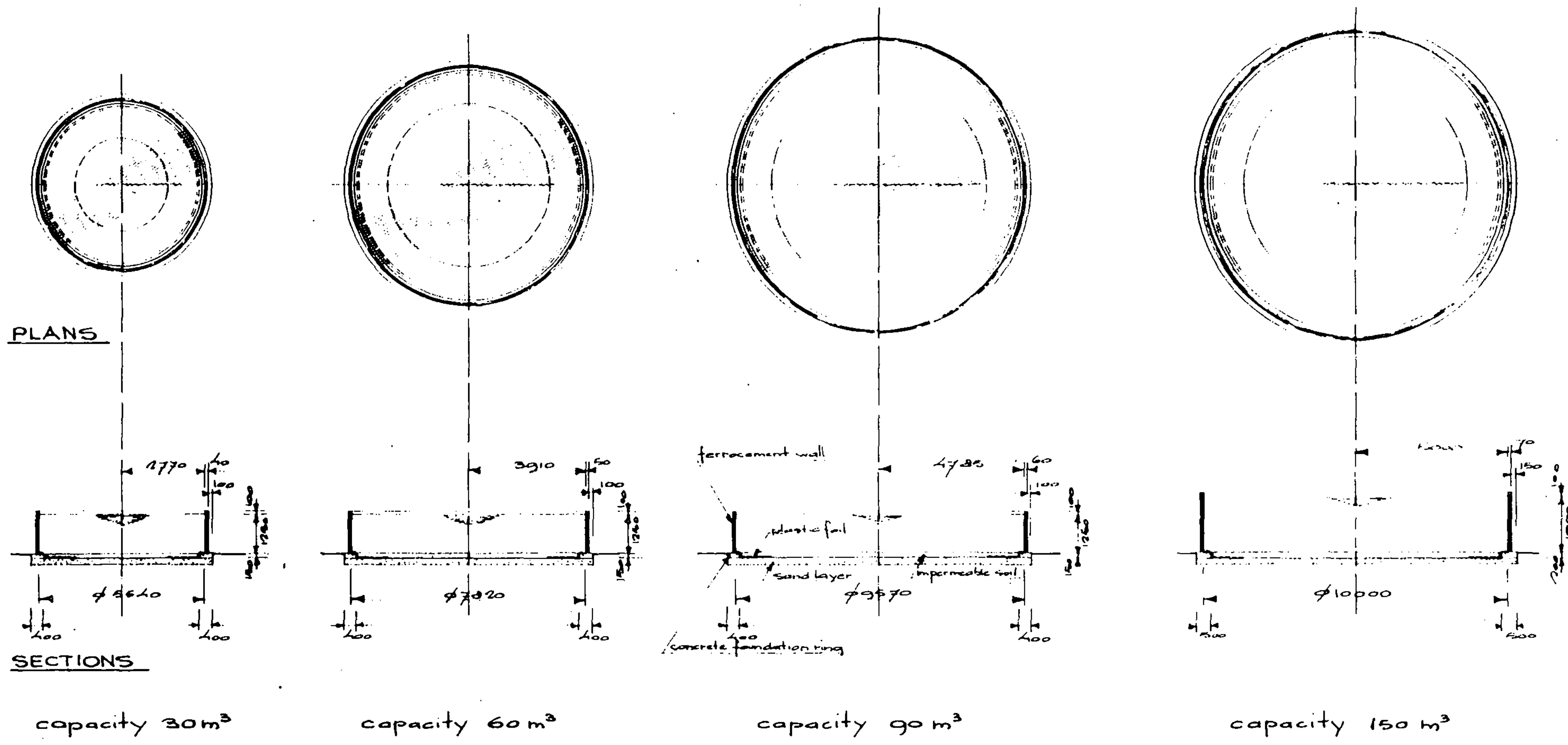
TYPE III
DETAILS AND DIMENSIONS

SWD

measures in mm
date 820721

TWO DHV

7.4.	Water tank type IV		PAGE
-	General layout		72
-	Work instructions		73
-	Capacity 30 m^3:	details and dimensions	77
		bill of quantities	78
-	Capacity 60 m^3:	details and dimensions	79
		bill of quantities	80
-	Capacity 90 m^3:	details and dimensions	81
		bill of quantities	82
-	Capacity 150 m^3:	details and dimensions	83
		bill of quantities	84
-	Vertical section variant A and B		85



TYPE IV

scale in meters

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

FERROCEMENT CONSTRUCTION

TYPE IV

GENERAL LAY OUT

SWD

measures in mm

date 820623

TWO DHV

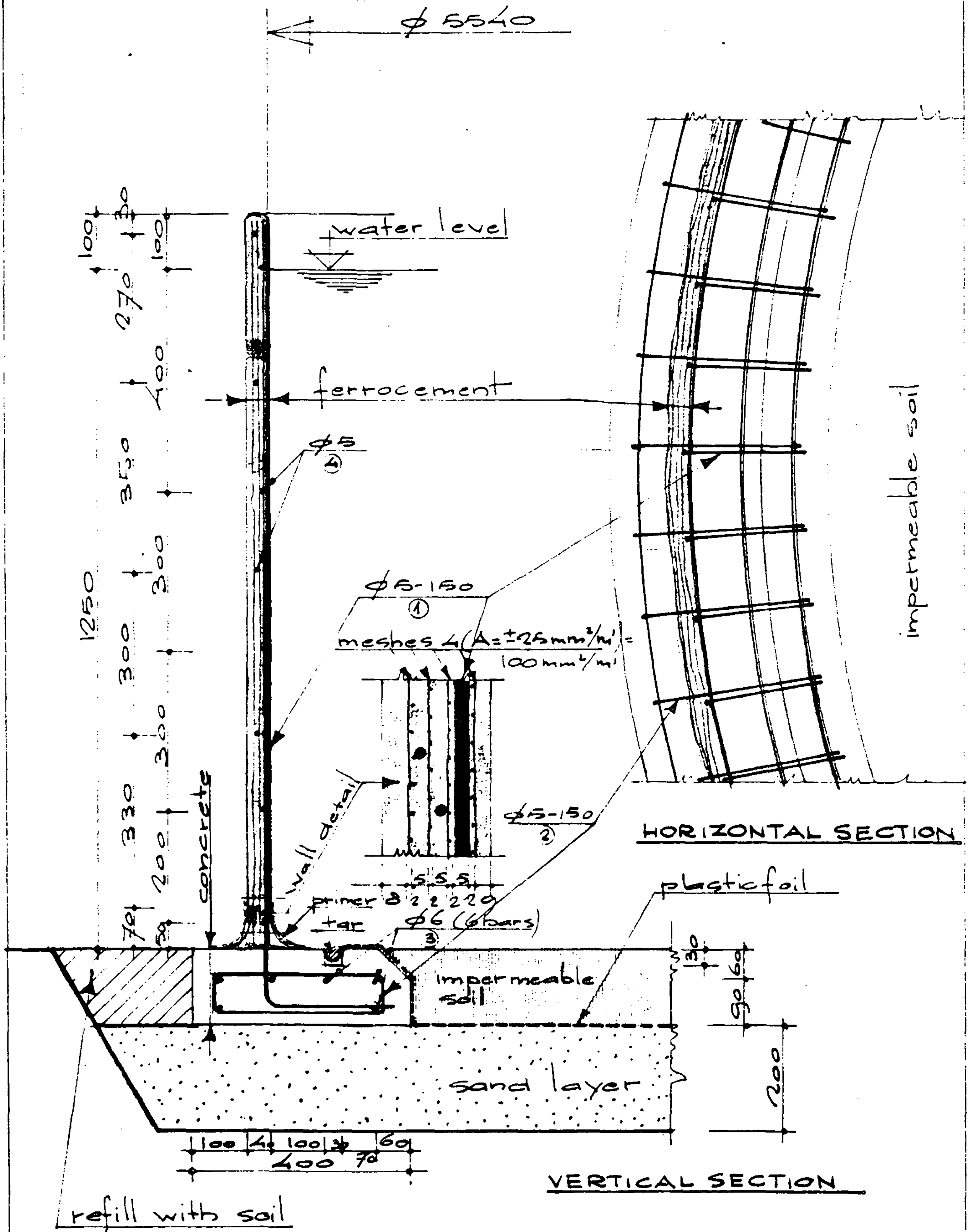
Type IV

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 270 mm of the topsoil	
- refill with a sand and/or gravel layer of approx. 200 mm	
- the refill is to be compacted with tampers (own namufacture); if 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 tank slab and the ringtrench with pegs (pegs core to core 1 meter)	
- excavate the ringtrench to the proper depth and line its outer edge with formwork	- formwork can be made of: bricks, stabilised sand or plywood
- polythylene sheets are to be spread over this area	- an alternative is a layer of screed of approx. 20 mm
- place the reinforcement for the ringbeams and fix the bars together with tying wire	- for bending the bars the bendingtool described on page 34 can be used
- check the circumference of the starterbars by describing a circle with a rope from the post to the centre of the proposed tank	- take special care that the bars are in the right position
- mix cement, sand and gravel to a dry mortar (1 : 2 :3)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion: cement-water: 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- cast and compact the mortar for the ringbeam	
- in the top of the ringbeam a circular groove of 30 * 30 mm^2 should be made	
- level and finish the surface of the ringbeam with a straight edged board or plywood	

work sequence and description	notes and recommendations
- immediately after casting protect the ringbeam against weather influences by covering it with plastic sheeting or wet sacking for a week	- this is very important in tropical climates
- refill the outer circumference with soil	- using the topsoil that was removed earlier
- this refill must be compacted	
- assemble and erect the formwork (mould) on the floorslab - re-check the right position in relation to the starterbars	- some types of formwork and their construction are described in this manual (see page 20)
- the formwork is to be cleaned and slightly oiled to allow easy removal of the mould after plastering	- old motor oil can be used for this purpose
- wind the wire mesh around the outside surface of the formwork	- for choosing the meshes and the reinforcement see the step-by-step method on page 28. several types of meshes and their characteristics are described in this manual (see page 16)
- in combination with the wire mesh, the reinforcing wire is to be wound around the mould at the distances indicated on the drawings; tie the wire mesh and the reinforcement firmly into place with tying wire	- the wire mesh and reinforcement should overlap by at least 500 mm
- mix cement and sand to a dry mortar (1 : 2)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion of cement : water = 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- carry the prepared mortar to the side of the wall on a trowelling board. The board prevents dirt from reaching the mortar, and any surplus mortar can be caught on it	- apply the mortar quickly; once the mortar is more than half an hour old it must be removed from site
- start plastering or trowelling: the mortar can be applied by hand to the walls with a plasterer's steel hand float and a hand hawk. The mortar is trowelled from the base of the wall upwards. Each layer of plaster should have a thickness of approx. 10 mm. Depending on the wall thcikness, 4-5-6 or 7 layers are to be applied.	- tools for plastering and trowelling are described in this manual (see page 33) - it is important to trowel in an upwards direction in order to fill the corrugations and fully cover the reinforcing wire

work sequence and description	notes and recommendations
- each layer should be bonded sufficiently, but not hardened completely. After this the surface has to be roughened with a wire brush or a trowel (combform)	- if the first layer is not finished or the plastering must be interrupted for several hours, it is desirable to keep the construction joint as dust-free as possible
- clean the surface and remove loose materials before applying the next layer; if joints are necessary they must be made in a horizontal line around the tank	before starting the next plastering operation the joints should be brushed with a wire brush and be coated with cement grout to give a strong bond for the fresh mortar
- the plastering operation is completed when the total thickness has been reached	
- remove the formwork/mould after hardening of the last layer of the wall	the layers must be of uniform thickness with no gaps or weak spots
- plaster the inside of the tank to the indicated thickness and until the reinforcement is fully covered	especially in tropical climates the wall of the tank must be covered with black plastic or wet sacking between the application of each layer.
- trowel both surfaces very smooth with a toe-slipper. If a rough surface is required to ensure a good bonding surface for painting, the wall should be washed down with a sponge	
- IMPORTANT: cover the wall with plastic sheets or wet sacking for a week to protect the structure against weather influences.	- during the first 24 hours after plastering the surface should not be permitted to dry
(This procedure is called: "curing")	- curing is described on page 30 of this manual
- apply polyethylene sheeting on top of the sand layer and around the inside of the tank foundation up to the groove. The joints in the plastic foil must be sealed by means of a flat or soldering iron	
- the plastic foil is to be inserted in the groove of the ringbeam as indicated on the drawing	- take special care with the insertion of the plastic foil

work sequence and description	notes and recommendations
- fill the bottom of the tank with a layer of impermeable soil, approx. 150 mm deep	- the groove should be cleaned before it can be filled
- fill the groove with hot bitumen	
- after curing and drying of the tank the joint between the tank-slab and the tankwall is to be painted twice with bituminous paint (both sides)	
- then the water tank is to be tested by filling it with water A newly built empty tank should always be filled slowly and it should be left for a week with a shallow depth of water at the bottom before filling completely.	
- after testing and after drying the water tank for a week, painting can be carried out if desired	- for the application of paint or coating see page 24 in this manual



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0 5 10 15

scale in centimeters

TYPE IV
capacity 30 m³

IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

FERROCEMENT CONSTRUCTION

TYPE IV
DETAILS AND DIMENSIONS

SWD

measures in mm

TWO

BILL OF REINFORCEMENT

bar ref.	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	5	118	0,75	89				250 ∟ 500	
2	floor	5	118	0,74	88				70 [300] 70, 300	
3	floor/ring	6				103				
4	wall	5			175					
5										
6										
	total length pro diameter				352	103				
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				54	23			+ →	
	total weight								77	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	107		
sand - fine	m³	0,7		
sand - coarse	m³	0,4		
gravel	m³	0,5		
brickwork				
cement	bag (50ltr.)	12		
excavation	m³	11		
layer (sand)	m³	5,9		
refill with soil	m³	0,6		
bund				
impermeable soil	m³	3		
plastic foil	m²	12		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	100		
formwork/mould	m²	24		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

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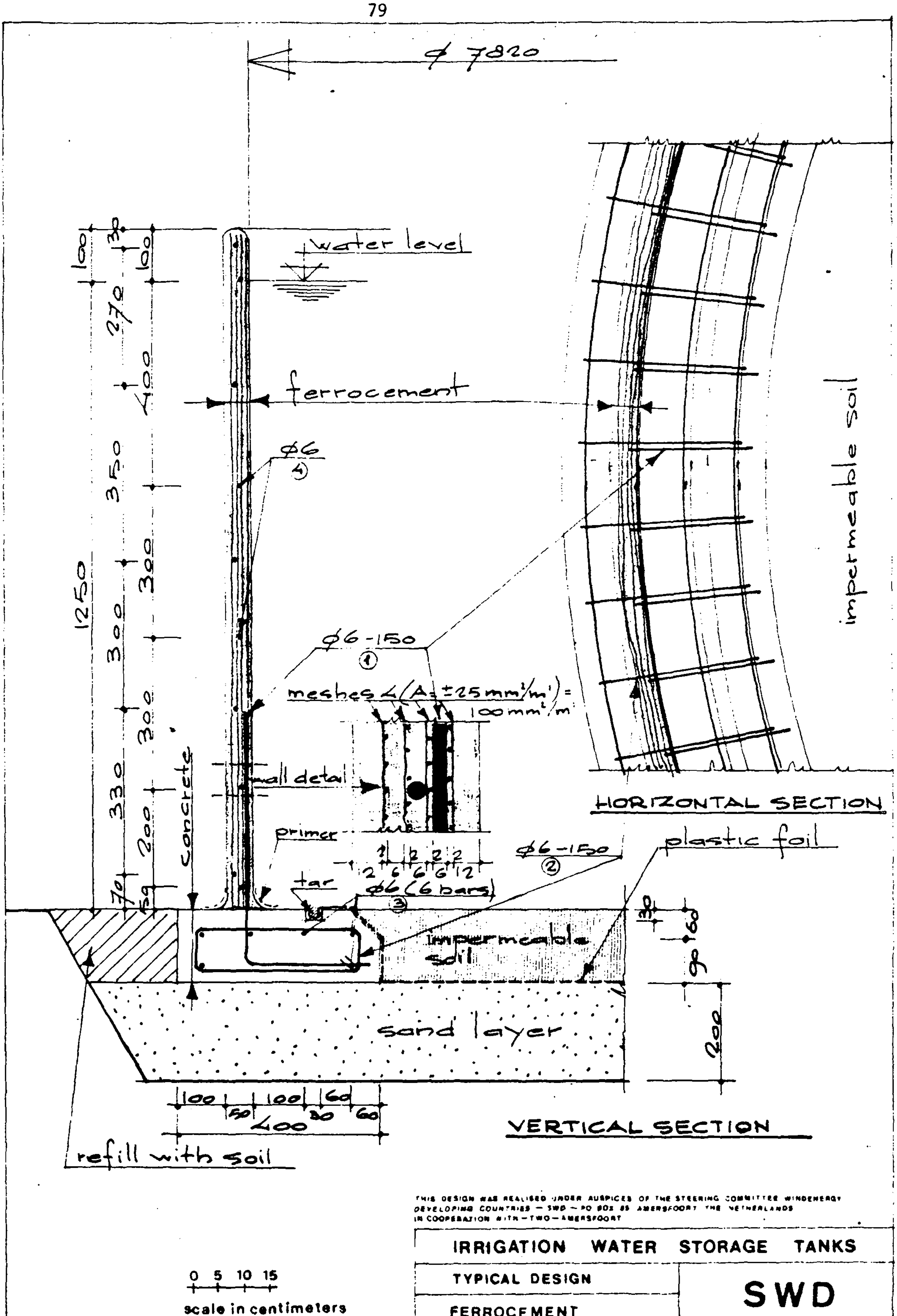
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	
TYPE IV BILL OF QUANTITIES	measures in mm date 820721
	TWO

TYPE IV
capacity 30 m³



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IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	
	measures in mm date 920,72'
TYPE IV DETAILS AND DIMENSIONS	TWO

TYPE IV
capacity 60 m³

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	6	166	0,75		125			250 └ 500	
2	floor	6	166	0,74		123			70 [300] 70, 300	
3	floor/ring	6				145				
4	wall	6				247				
5										
6										
	total length pro diameter					640				
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter					142			+ →	
	total weight								142	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	154		
sand - fine	m³	1,2		
sand - coarse	m³	0,5		
gravel	m³	0,8		
brickwork				
cement	bag (40 ltr.)	20		
excavation	m³	20		
layer (sand)	m³	11,2		
refill with soil	m³	0,9		
bund				
impermeable soil	m³	6,3		
plastic foil	m²	17		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	150		
formwork/mould	m²	34		
total materials				
labour	mandays	hours	rates	

TOTAL COST OF STORAGE TANK

TYPE IV
capacity 60 m^3

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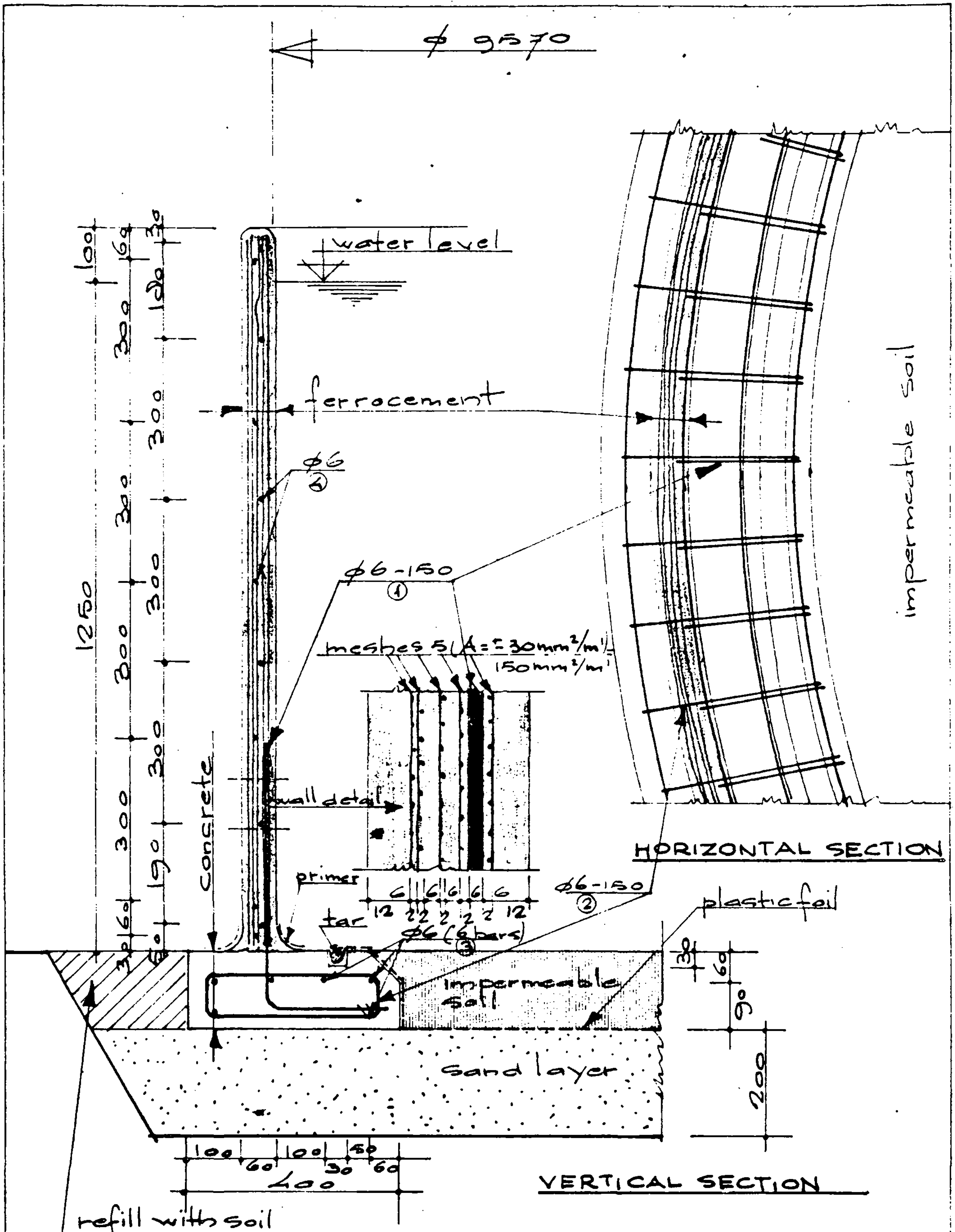
IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm, date 820781
TYPE IV BILL OF QUANTITIES	TWO



0 5 10 15
scale in centimeters

TYPE IV
capacity 90 m³

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm
TYPE IV DETAILS AND DIMENSIONS	TWO

BILL OF REINFORCEMENT

bar ref	location	⌀	number bars	single length	total length mild steel m' ⌀5	⌀6	⌀8	⌀10	bending details	remarks
1	floor/wall	6	203	0,75		153			250 ∟ 500	
2	floor	6	203	0,74		151			70 ⊔ 300 ⊔ 70; 300	
3	floor/ring	6				179				
4	wall	6				359				
5										
6										
total length pro diameter						842				
weight in kg/m'					0,154	0,222	0,395	0,617		
total weight pro diameter									+ →	
total weight						187			187	

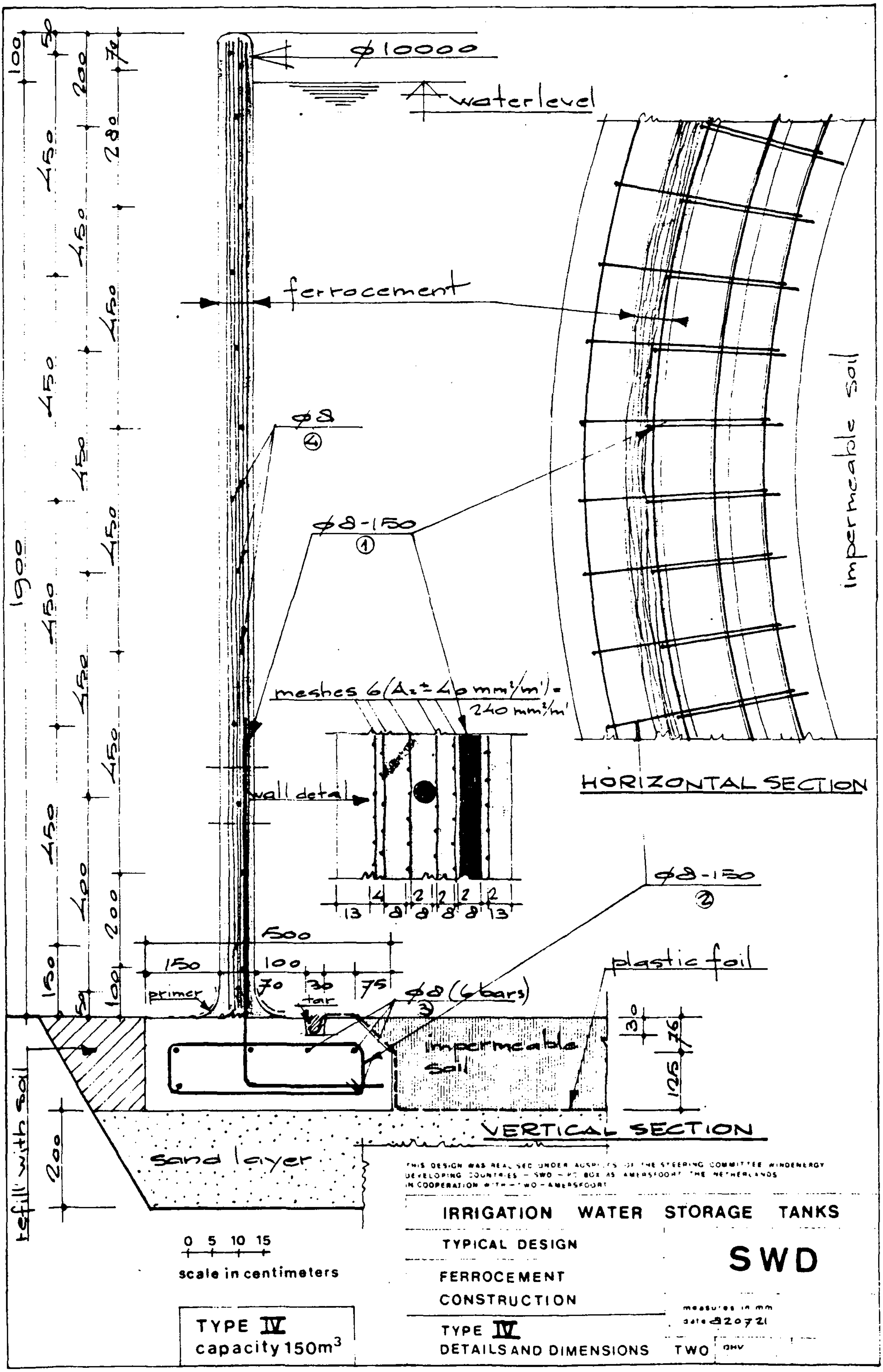
BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	232		
sand – fine	m³	1,6		
sand – coarse	m³	0,6		
gravel	m³	0,9		
brickwork				
cement	bag (40 ltr.)	28		
excavation	m³	30		
layer (sand)	m³	16		
refill with soil	m³	1,1		
bund				
impermeable soil	m³	10		
plastic foil	m²	21		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	200		
formwork/mould	m²	41		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

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
FERROCEMENT CONSTRUCTION	measures in mm; date 320721
TYPE IV BILL OF QUANTITIES	TWO



ϕ10000
waterlevel
ferrocement
ϕ8
④
ϕ8-150
①
meshes 6(A₂ ± 40 mm²/m') = 240 mm²/m'
wall detail
HORIZONTAL SECTION
impermeable soil
ϕ8-150
②
plastic foil
ϕ8 (6 bars)
③
primer
tar
impermeable soil
VERTICAL SECTION
sand layer
refill with soil
1900
500
150
100
70
30
75
0 5 10 15
scale in centimeters
TYPE IV
capacity 150m³
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
FERROCEMENT CONSTRUCTION
SWD
measures in mm
date 820721
TYPE IV
DETAILS AND DIMENSIONS
TWO

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	8	213	1,00			213		250 ⌊ 750	
2	floor	8	213	1,00			213		100 [400] 100; 400	
3	floor/ring	8					187			
4	wall	8					499			
5										
6										
	total length pro diameter						1112			
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter						440		+ →	
	total weight								440	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m^2	432		
sand - fine	m^3	3		
sand - coarse	m^3	1,1		
gravel	m^3	1,6		
brickwork				
cement	bag (40 ltr.)	50		
excavation	m^3	37		
layer (sand)	m^3	18		
refill with soil	m^3	1,2		
bund				
impermeable soil	m^3	14		
plastic foil	m^2	26		
painting/sealing				
tar paper				
primer				
tools				
concrete mixer				
tying wire	m'	400		
formwork/mould	m^2	63		

total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

TYPE IV
capacity 150 m^3

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

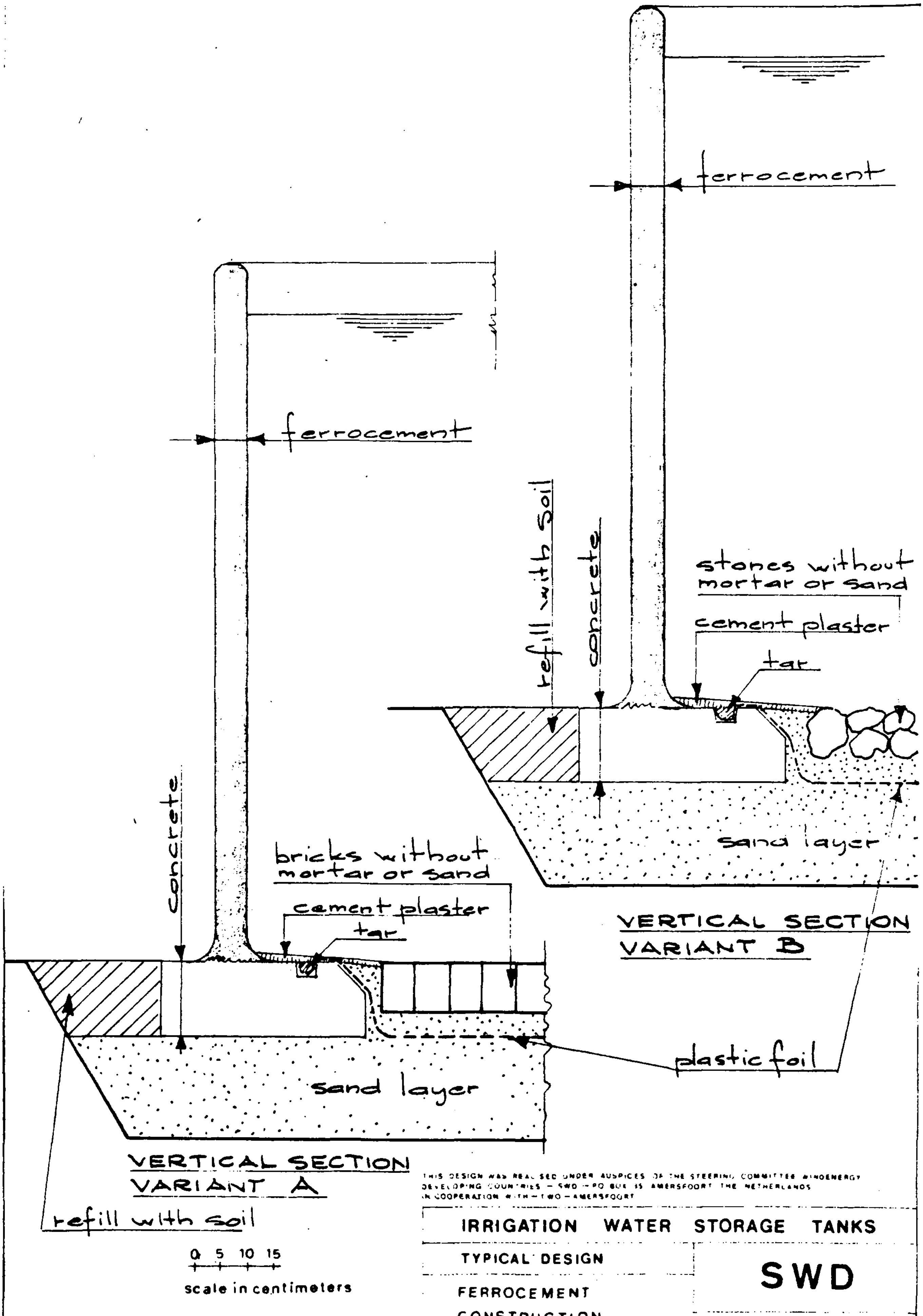
FERROCEMENT CONSTRUCTION

TYPE IV
BILL OF QUANTITIES

SWD

measures in mm
date 820721

TWO | DHV

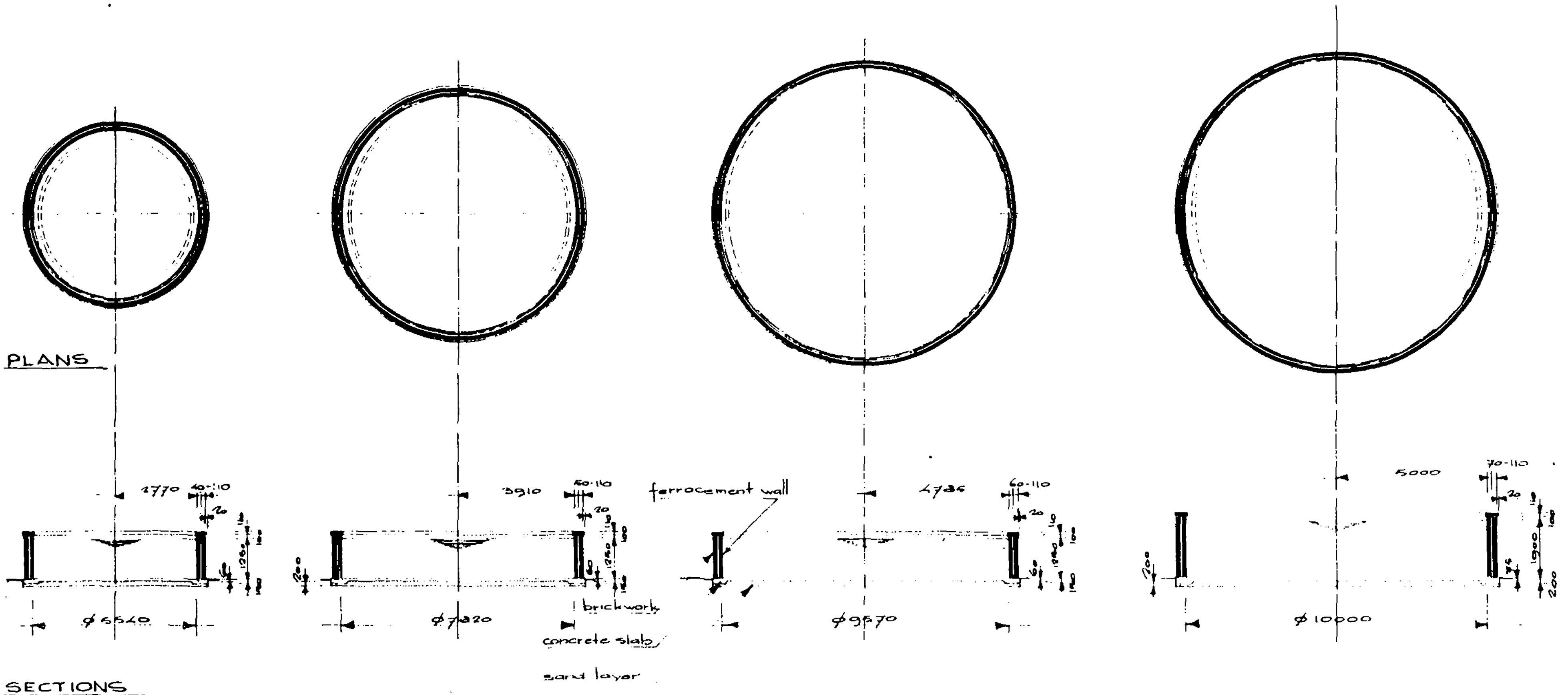


THIS DESIGN WAS REALISED UNDER AUSPICES OF THE STEERING COMMITTEE WINDENERGY DEVELOPING COUNTRIES – SWD – PO BOX 85 AMERSFOORT THE NETHERLANDS IN COOPERATION WITH – TWO – AMERSFOORT

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 82-07-21
TYPE IV DETAILS AND DIMENSIONS	TWO

TYPE IV
VARIANT A AND B

7.5.	Water tank Type V		PAGE
-	General layout		87
-	Work-instructions		88
-	Capacity 30 m^3:	Details and dimensions	92
		Bill of quantities	93
-	Capacity 60 m^3:	Details and dimensions	94
		Bill of quantities	95
-	Capacity 90 m^3:	Details and dimensions	96
		Bill of quantities	97
-	Capacity 150 m^3:	Details and dimensions	98
		Bill of quantities	99
-	Vertical section variant A		100
-	Brickwork bond		101
-	Different types of shuttering		102
-	Detail top of the wall type V		103



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

TYPE V

0 1 2 3 4 5
scale in meters

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IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN FERROCEMENT CONSTRUCTION	SWD
TYPE V GENERAL LAY OUT	measures in mm date 820628 TWO DHV

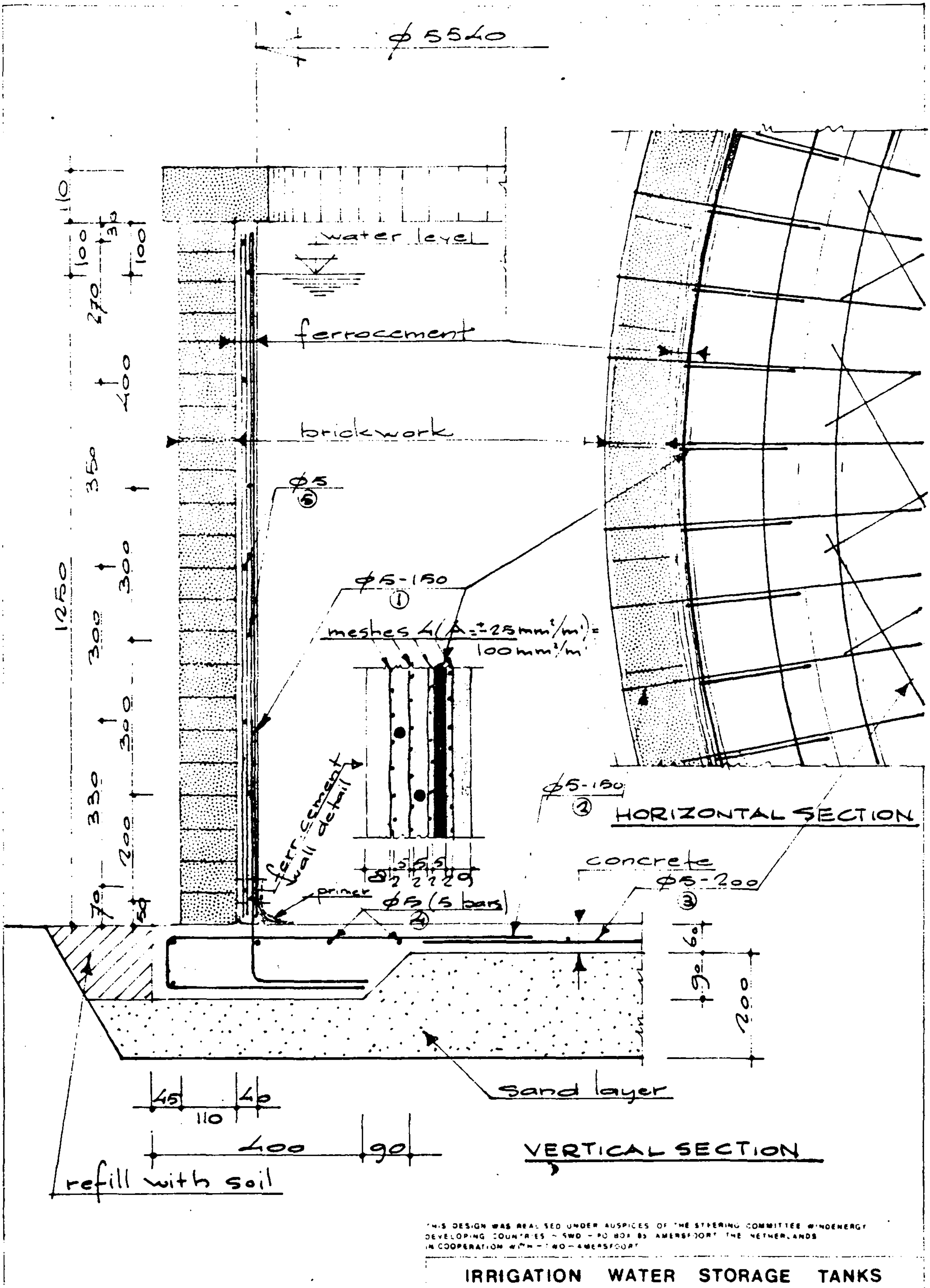
Type V

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 270 mm of the topsoil	
- refill with a sand and/or gravel layer of approx. 200 mm	
- the refill is to be compacted with tampers (own manufacture); if 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 tank slab and the ringtrench with pegs (pegs core to core 1 meter)	
- excavate the ringtrench to the proper depth and line its outer edge with formwork	- formwork can be made of: bricks, stabilised sand or plywood
- polythylene sheets are to be spread over this area	- an alternative is a layer of screed of approx. 20 mm
- place the reinforcement for the ringtrench and for the floorslab and fix the bars together with tying wire	- for bending the bars the bendingtool described on page 34 can be used
- check the circumference of the starterbars by describing a circle with a rope from the post to the centre of the proposed tank	- take especial care that the bars are in the right position
- mix cement, sand and gravel to a dry mortar (1 : 2 :3)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion: cement-water: 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- cast and compact the mortar for the floorslab and ringtrench	
- level and finish the surface of the slab with a straight edged board or plywood	

work sequence and description	notes and recommendantions
- immediately after casting protect the slab against weather influences by covering it with plastic sheeting or wet sacking for a week	- this is very important in tropical climates
- refill the outer circumference with soil	- using the topsoil that was removed earlier
- this refill must be compacted	
- re-check the right position in relation to the starterbars	
- mark the circumference of the brickwork wall with pegs (pegs core to core 1 meter)	
- mix cement and sand to a dry mortar	- mortar for brickwork is indicated on page 13.
- add water to the dry mortar until the mortar can be handled well	
- start bricklaying of the outerwall put pieces of tying wire (0.3 m lenght) in the inside joints of the wall at distances of 0.5 m in horizontal and vertical direction	- the bond is indicated in the details (see page 32) - immediately after bricklaying (at the end of each day) the finished parts of the wall are to be protected against weather influences
- the brickwork outerwall is the formwork for the inside ferrocement wall	
- wind the wire mesh around the inside surface of the brickwork wall	- for choosing the meshes and the reinforcement see the step-by-step method on page 28 described in this manual (see page 16)
- in combination with the wire mesh, the reinforcing wire is to be wound around the brickwork at the distances indicated on the drawings; tie the wire mesh and the reinforcement firmly into place with tying wire	- the wire mesh and reinforcement should overlap by at least 500 mm
- mix cement and sand to a dry mortar (1 : 2)	- volume-batching: use measuring boxes or buckets
- add water to the dry mortar in the proportion of cement : water = 1 : 0.45 (by weight)	- the mortar can be mixed by hand or by a powered concrete mixer
- carry the prepared mortar to the inside of the wall on a trowelling board. The board prevents dirt from reaching the mortar, and any surplus mortar can be caught on it	- apply the mortar quickly; once the mortar is more than half an hour old it must be removed from site

work sequence and description	notes and recommendations
- start plastering or trowelling: the mortar can be applied by hand to the brickwork with a plasterer's steel hand float and a hand hawk. The mortar is trowelled from the base of the wall upwards. Each layer of plaster should have a thickness of approx. 10 mm. Depending on the wall thickness, 4-5-6 or 7 layers are to be applied.	- tools for plastering and trowelling are described in this manual (see page 33) - it is important to trowel in an upwards direction in order to fill the corrugations and fully cover the *reinforcing wire*
- each layer should be bonded sufficiently, but not hardened completely. After this the surface has to be roughened with a wire brush or a trowel (combform) - clean the surface and remove loose materials before applying the next layer; if joints are necessary they must be made in a horizontal line around the tank - the plastering operation is completed when the total thickness has been reached	- if the first layer is not finished or the plastering must be interrupted for several hours, it is desirable to keep the construction joint as dust-free as possible before starting the next plastering operation the joints should be brushed with a wire brush and be coated with cement grout to give a strong bond for the fresh mortar the layers must be of uniform thickness with no gaps or weak spots especially in tropical climates the wall of the tank must be covered with black plastic or wet sacking between the application of each layer.
- trowel the inside surface very smooth with a toe-slipper. If a rough surface is required to ensure a good bonding surface for painting, the wall should be washed down with a sponge	
- IMPORTANT: cover the wall with plastic sheets or wet sacking for a week to protect the structure against weather influences.	- during the first 24 hours after plastering the surface should not be permitted to dry
(This procedure is called: "curing")	- curing is described on page 30 of this manual

work sequence and description	notes and recommendations
- after curing and drying of the tank the joint between the tank-slab and the tankwall is to be painted twice with bituminous paint (both sides)	
- then the water tank is to be tested by filling it with water A newly built empty tank should always be filled slowly and it should be left for a week with a shallow depth of water at the bottom before filling completely.	
- after testing and after drying the water tank for a week, painting can be carried out if desired	- for the application of paint or coating see page 24 in this manual
- on top of the tankwall a brick layer of edge coping is to be applied (see page 101);	



ϕ 5540
water level
ferrocement
brickwork
ϕ5
⑥
ϕ5-150
①
meshes 4 (A=±25mm²/m') = 100mm²/m'
ferrocement wall detail
primer
ϕ5 (5 bars)
④
ϕ5-150
②
HORIZONTAL SECTION
concrete
ϕ5-200
③
sand layer
refill with soil
VERTICAL SECTION
110
100
100
270
400
350
300
300
300
330
200
70
50
1250
60
90
200
45
40
110
400
90
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
FERROCEMENT
CONSTRUCTION
SWD
0 5 10 15
scale in centimeters
measures in mm
TYPE V
capacity 30 m³
TYPE V
DETAILS AND DIMENSIONS
TWO

BILL OF REINFORCEMENT

bar ref.	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	5	118	0,70	83				200 ⌊ 500	
2	floor	5	118	1,15	136				100 700 550	
3	floor	5			192					
4	floor/ring	5			84					
5	wall	5			175					
6										
	total length pro diameter				670					
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				103				+ →	
	total weight								103	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	104		
sand - fine	m³	0,7		
sand - coarse	m³	0,8		
gravel	m³	1,2		
brickwork 220x105x55	piece	2000		
cement	bag (40 ltr)	19		
excavation	m³	7,9		
layer (sand)	m³	5		
refill with soil	m³	0,6		
bund				
impermeable soil				
plastic foil	m²	28		
painting/sealing				
tar paper	m²	4		
primer				
tools				
concrete mixer				
tying wire		200		
formwork/mould		3		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

TYPE V
capacity 30 m³

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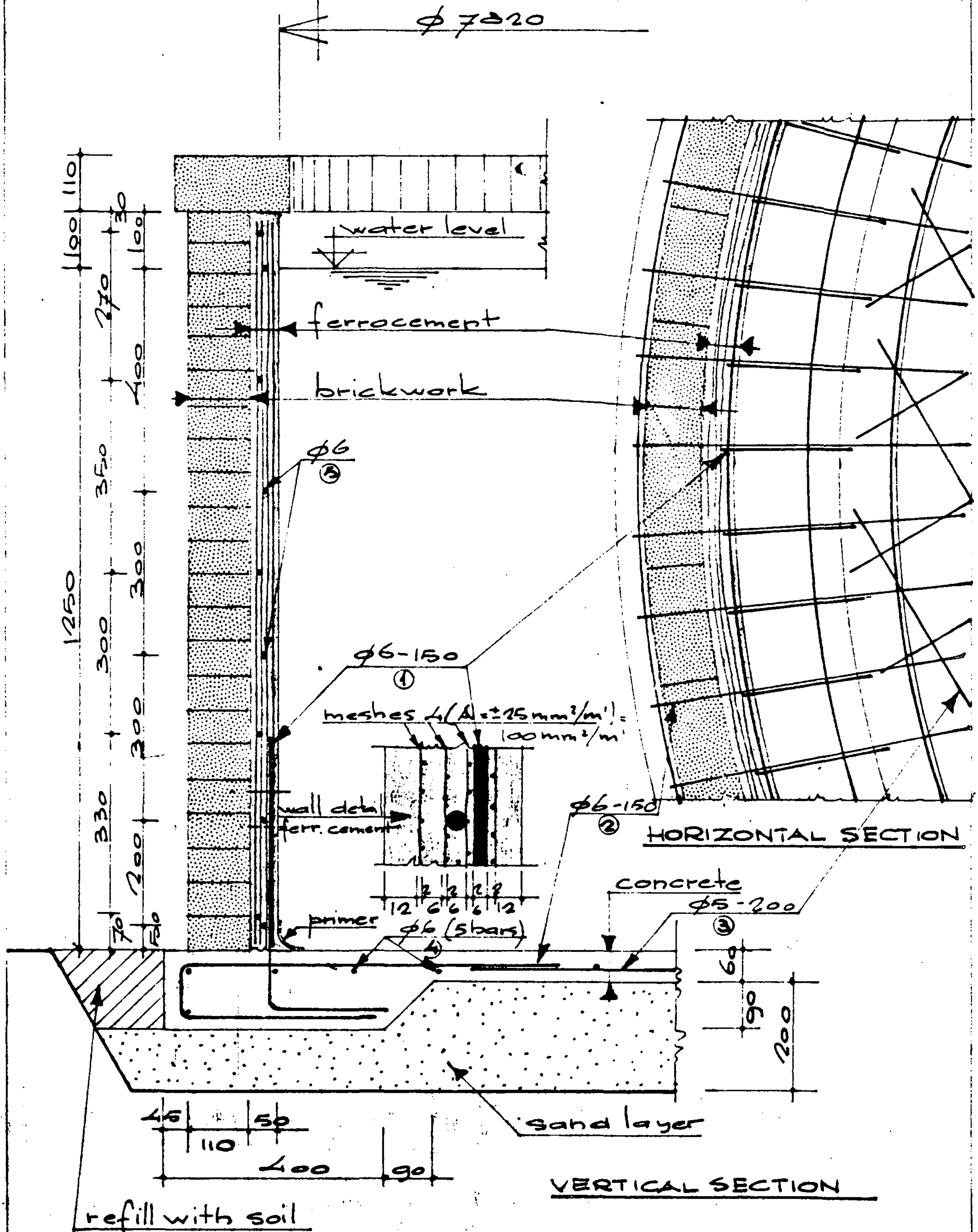
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 82 07 21
TYPE V BILL OF QUANTITIES	TWO



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0 5 10 15

scale in centimeters

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 820721
TYPE V DETAILS AND DIMENSIONS	TWO

TYPE V
capacity 60 m³

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	6	166	0,70		116			200 └ 500	
2	floor	6	166	1,15		191			100 └ 700 / 350	
3	floor	5			409					
4	floor/ring	6				119				
5	wall	6				247				
6										
total length pro diameter					409	673				
weight in kg/m'					0,154	0,222	0,395	0,617		
total weight pro diameter					63	149			+ →	
total weight									212	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	146		
sand - fine	m³	1,3		
sand - coarse	m³	1,5		
gravel	m³	2,1		
brickwork 220x110x55	piece	2800		
cement	bag (40 ltr.)	34		
excavation	m³	14,8		
layer (sand)	m³	10		
refill with soil	m³	1		
bund				
impermeable soil				
plastic foil	m²	55		
painting/sealing				
tar paper	m²	5		
primer				
tools				
concrete mixer				
tying wire	m'	300		
formwork/mould	m²	4		
total materials				
labour	~~mandays~~	hours	rates	
TOTAL COST OF STORAGE TANK				

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

FERROCEMENT CONSTRUCTION

TYPE V

BILL OF QUANTITIES

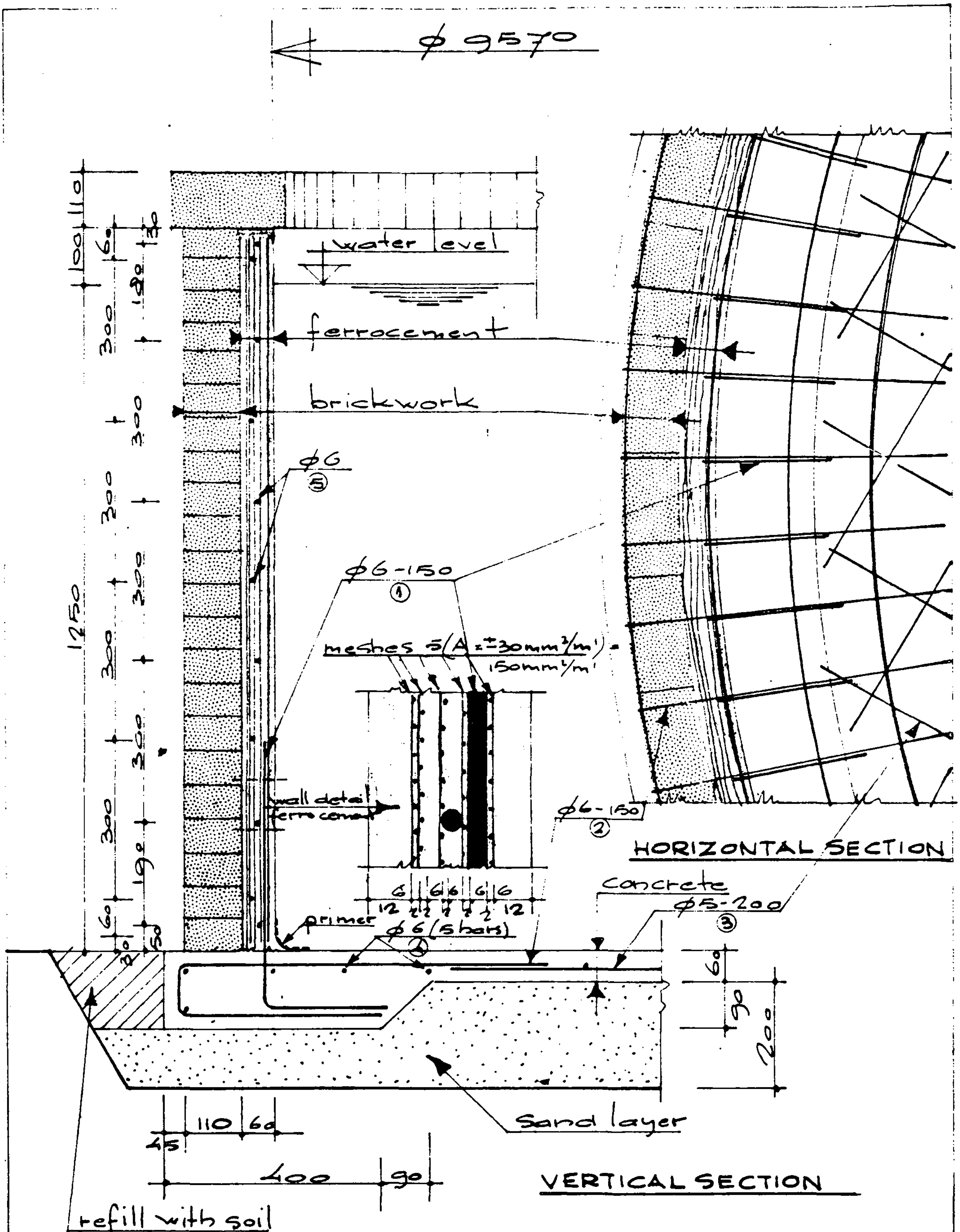
SWD

measures in mm

date 820721

TWO

TYPE V
capacity 60 m^3



0 5 10 15

scale in centimeters

TYPE V
capacity 90 m³

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IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 820721
TYPE V DETAILS AND DIMENSIONS	TWO

BILL OF REINFORCEMENT

bar ref.	location	ø	number bars	single length	total length mild steel m' ø5	ø6	ø8	ø10	bending details	remarks
1	floor/wall	6	204	0,70		143			200 ⌊ 500	
2	floor	6	204	1,15		235			100 ⌊ 700, 350	
3	floor	5			631					
4	floor/ring	6				147				
5	wall	6				363				
6										
	total length pro diameter				631	888				
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				97	197			+ →	
	total weight								294	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m^2	225		
sand - fine	m^3	1,7		
sand - coarse	m^3	2		
gravel	m^3	3		
brickwork 220x110x55	piece	3500		
cement	bag (40 ltr)	48		
excavation	m^3	21,6		
layer (sand)	m^3	14,7		
refill with soil	m^3	1		
bund				
impermeable soil				
plastic foil	m^2	85		
painting/sealing				
tar paper	m^2	10		
primer				
tools				
concrete mixer				
tying wire	m'	400		
formwork/mould	m^2	5		
total materials				
labour	mandays	hours	rates	
TOTAL COST OF STORAGE TANK				

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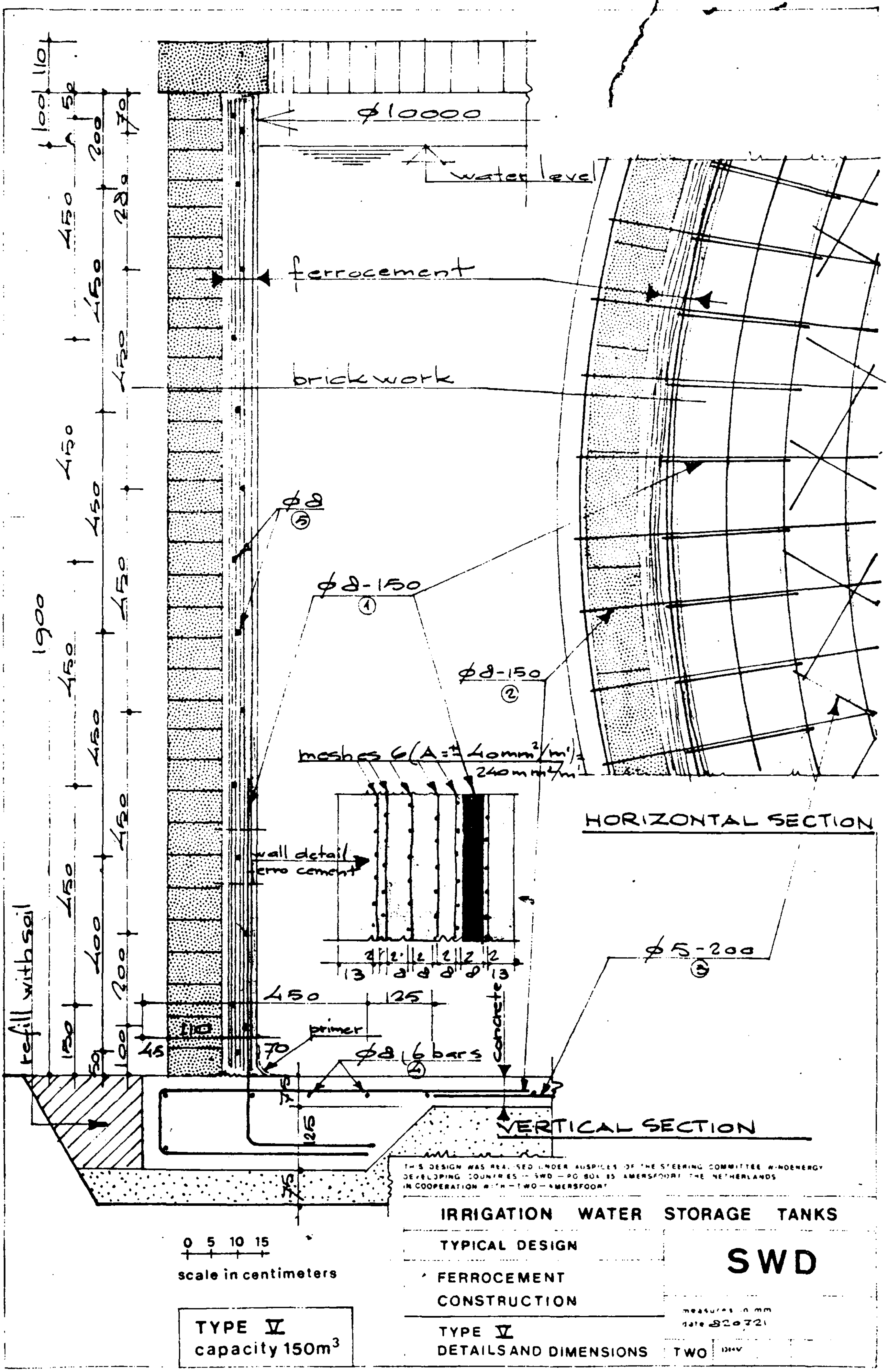
TYPE V
capacity 90 m^3

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm, date 320721
TYPE V BILL OF QUANTITIES	TWO drw.


ϕ10000
water level
ferrocement
brickwork
ϕ8
5
ϕ8-150
1
ϕ8-150
2
meshes 6(A=± 40mm²/m¹)=240mm²/m¹
HORIZONTAL SECTION
wall detail ferro cement
ϕ5-200
3
refill with soil
1900
primer
ϕ8 6 bars
4
concrete
VERTICAL SECTION
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
FERROCEMENT CONSTRUCTION
SWD
TYPE V
DETAILS AND DIMENSIONS
measures in mm
date 820721
TWO
0 5 10 15
scale in centimeters
TYPE V
capacity 150m³

BILL OF REINFORCEMENT

bar ref	location	ø	number bars	single length	total length mild steel m' ø3	ø6	ø8	ø10	bending details	remarks
1	floor/wall	8	212	1,00			212		250 ⌊ 750	
2	floor	8	212	1,30			276		130 ⌊ 750 / 420	
3	floor	3			694					
4	floor/ring	8					185			
5	wall	8					506			
6										
	total length pro diameter				694		1179			
	weight in kg/m'				0,154	0,222	0,395	0,617		
	total weight pro diameter				107		466		+ →	
	total weight								573	

BILL OF QUANTITIES

ITEM	UNIT	QUANTITY	UNIT PRICE	PRICE
mesh	m²	416		
sand - fine	m³	3,2		
sand - coarse	m³	3		
gravel	m³	4,4		
brickwork 22x110x55	piece	5000		
cement	bag (40 ltr.)	78		
excavation	m³	25,4		
layer (sand)	m³	15,2		
refill with soil	m³	1,4		
bund				
impermeable soil				
plastic foil	m²	90		
painting/sealing				
tar paper	m'	10		
primer				
tools				
concrete mixer				
tying wire	m'	800		
formwork/mould	m²	7		
total materials				

	mandays	hours	rates	
labour				

TOTAL COST OF STORAGE TANK

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IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

FERROCEMENT CONSTRUCTION

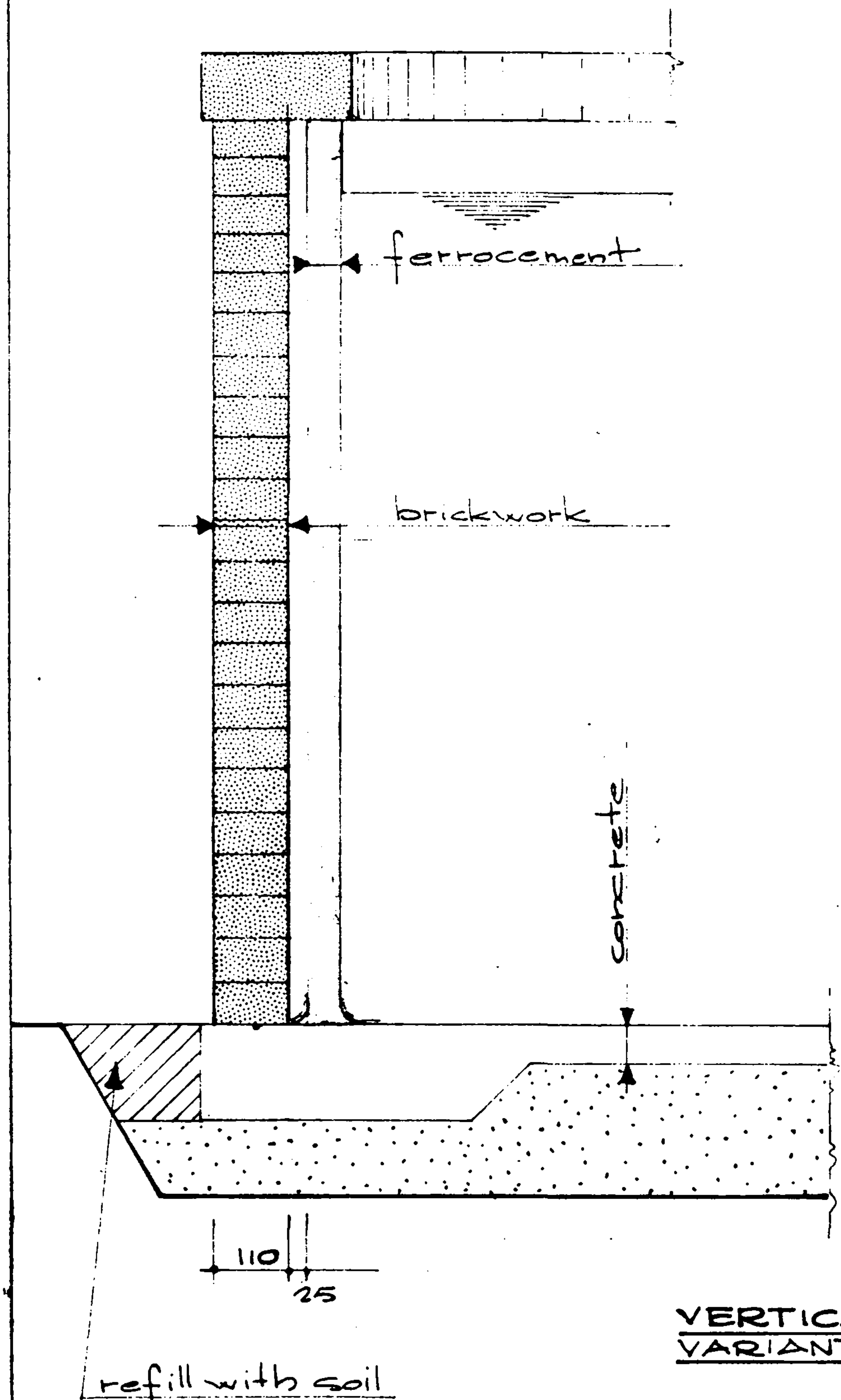
TYPE V
BILL OF QUANTITIES

SWD

measures in mm
date 820721

TWO

TYPE V
capacity 150 m^3



VERTICAL SECTION
VARIANT

0 5 10 15
scale in centimeters

TYPE V
VARIANT A

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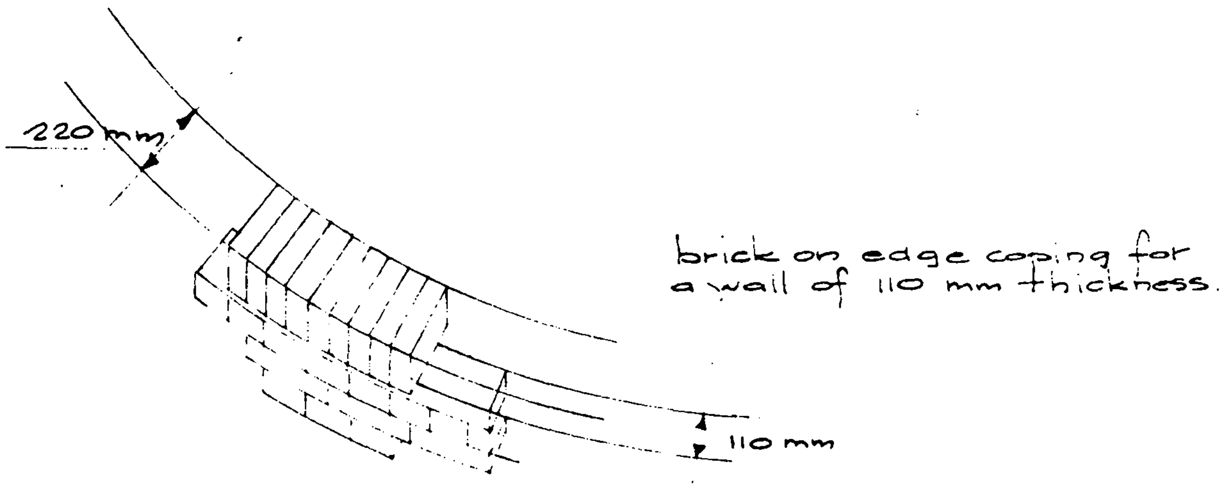
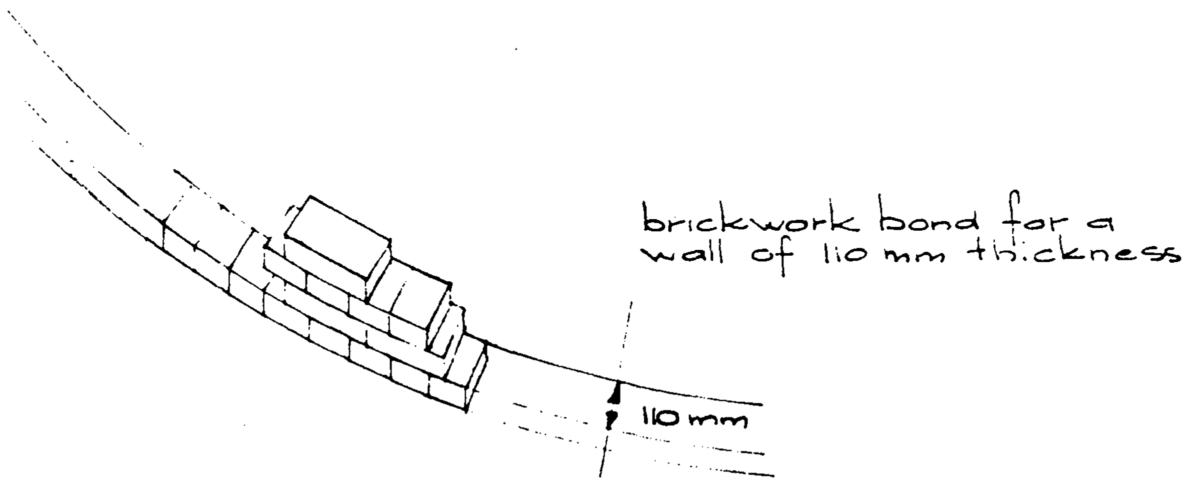
IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 821022
TYPE V DETAILS AND DIMENSIONS	TWO DHV





IRRIGATION WATER STORAGE TANKS

TYPICAL DESIGN

EARTH BUND CONSTRUCTION

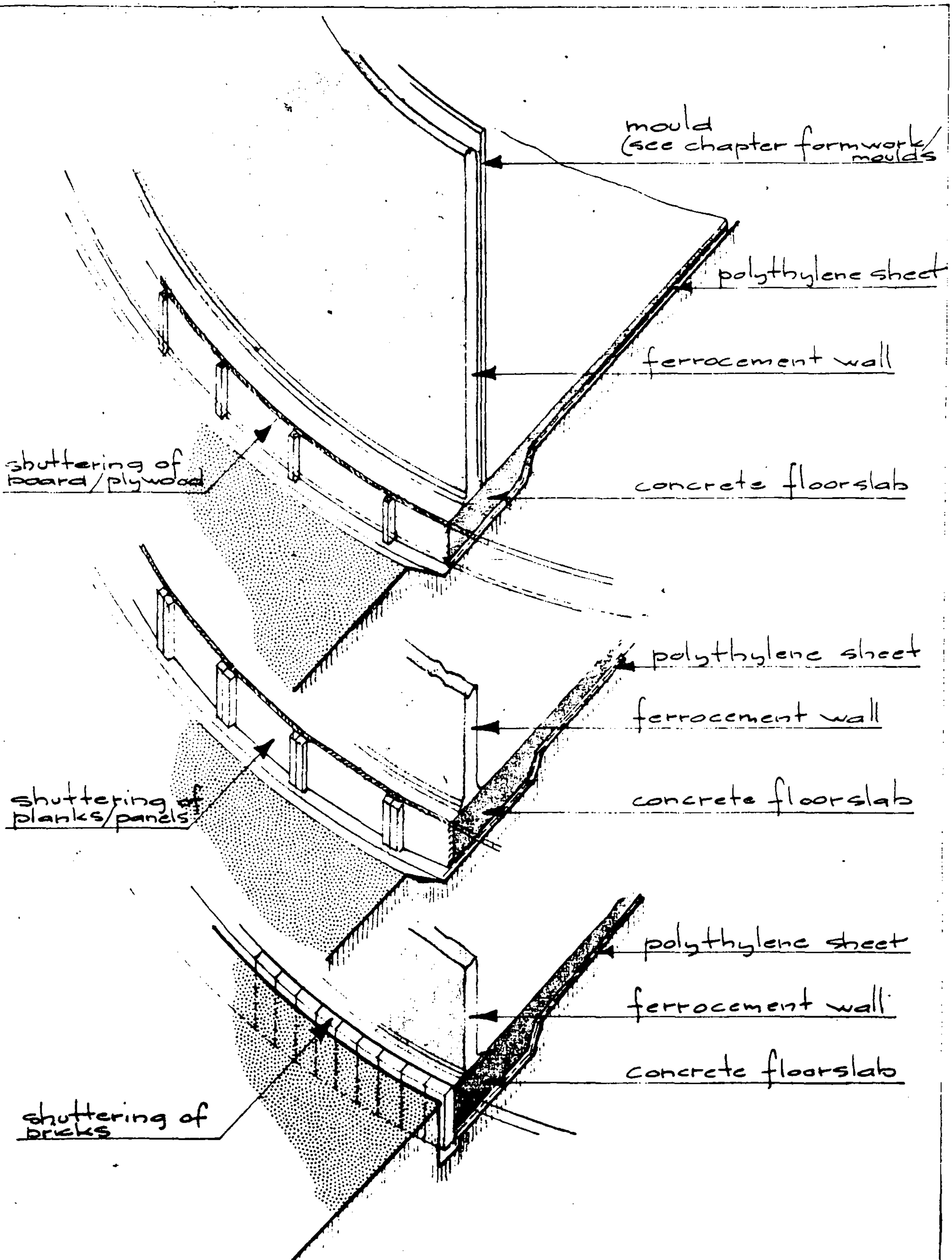
TYPE V

DETAILS AND DIMENSIONS

SWD

820721

TWO



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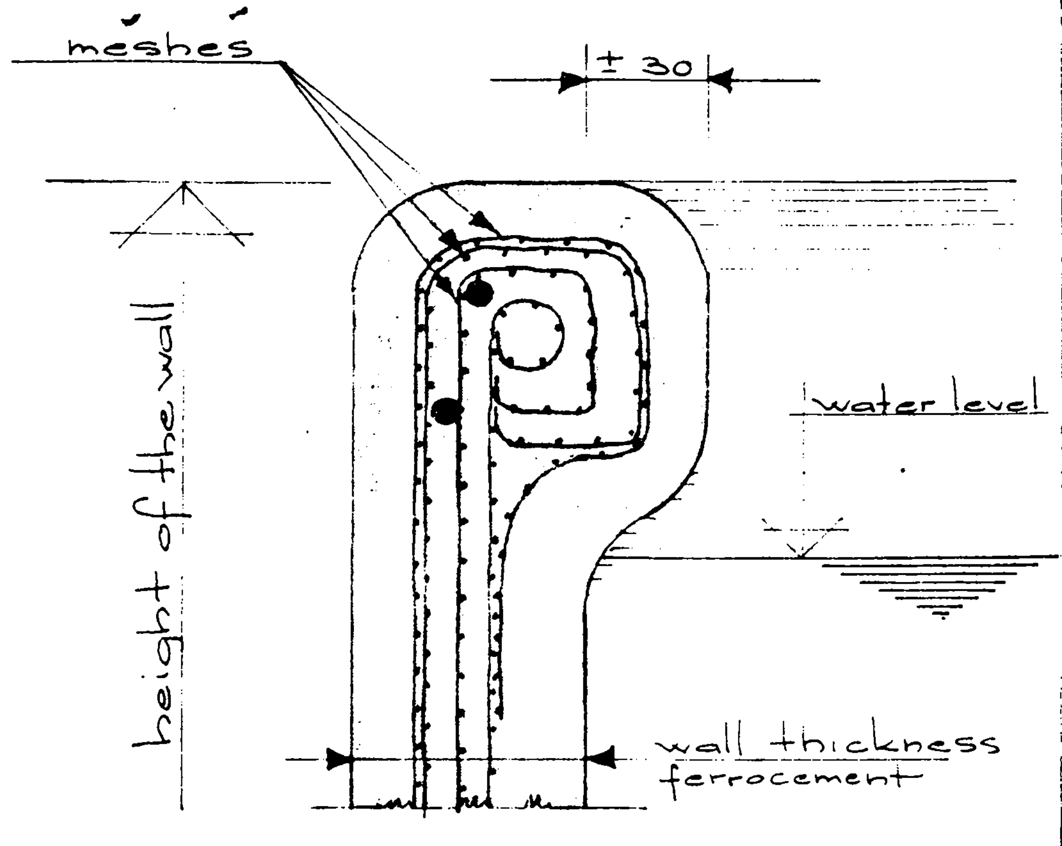
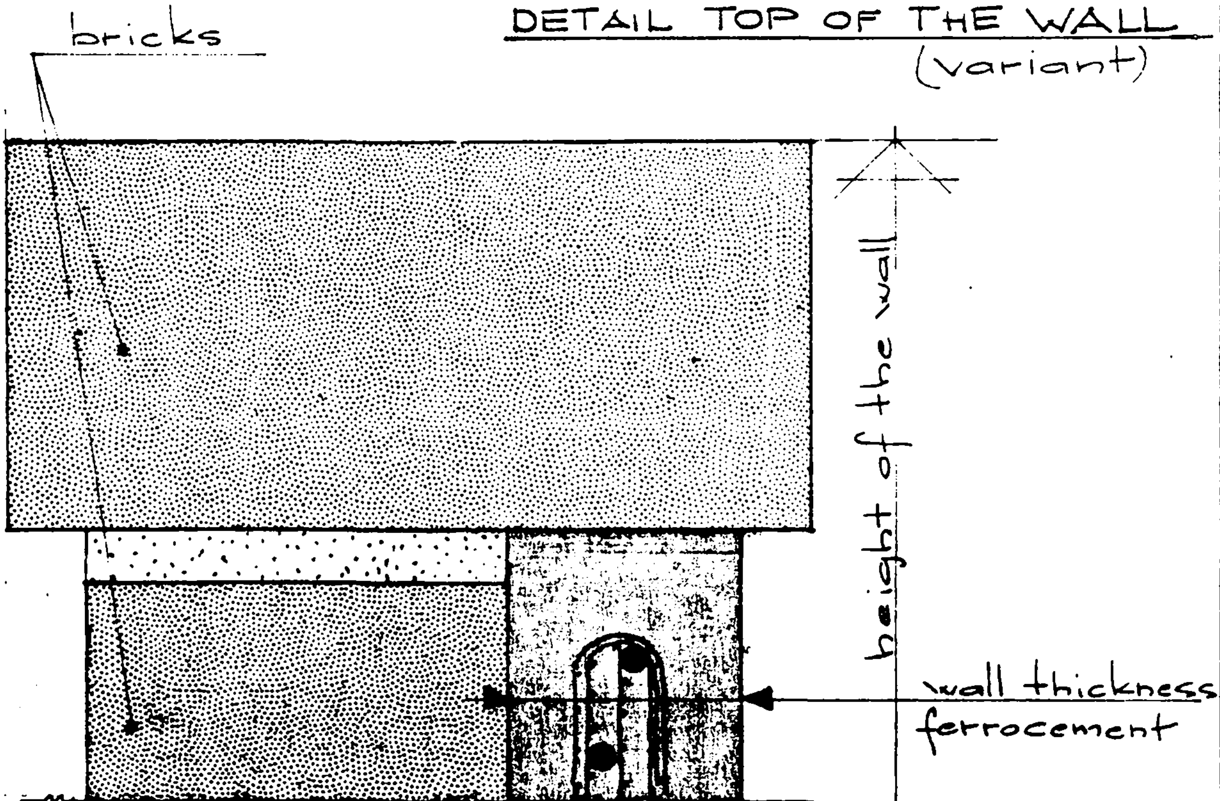
DIFFERENT TYPES OF SHUTTERING

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	measures in mm date 820721
TYPE DETAILS AND DIMENSIONS	TWO DHV



DETAIL TOP OF THE WALL
(variant)



DETAIL TOP OF THE WALL TYPE V

0 10 20 30
scale in millimeters

IRRIGATION WATER STORAGE TANKS	
TYPICAL DESIGN	SWD
FERROCEMENT CONSTRUCTION	
TYPE DETAILS AND DIMENSIONS	measures in mm date 820721 TWO

8. TESTING

8.1. Simple field identification tests for soil

Preliminary

- Look at the whole sampel.
- 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

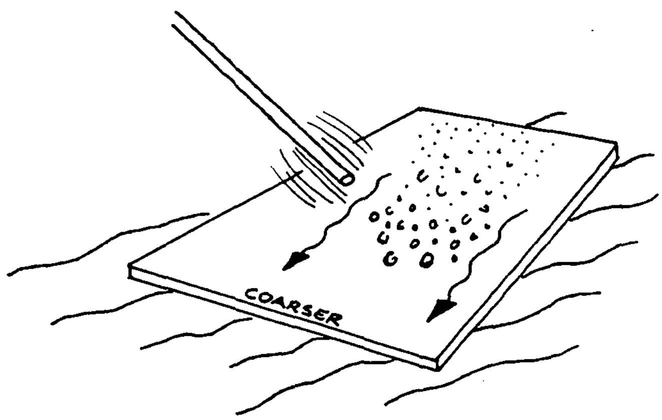
Estimate how much of each fraction is in the soil and separate coarse from fine material by hand.

d. Organic (smell) test

Take a sample of th 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.



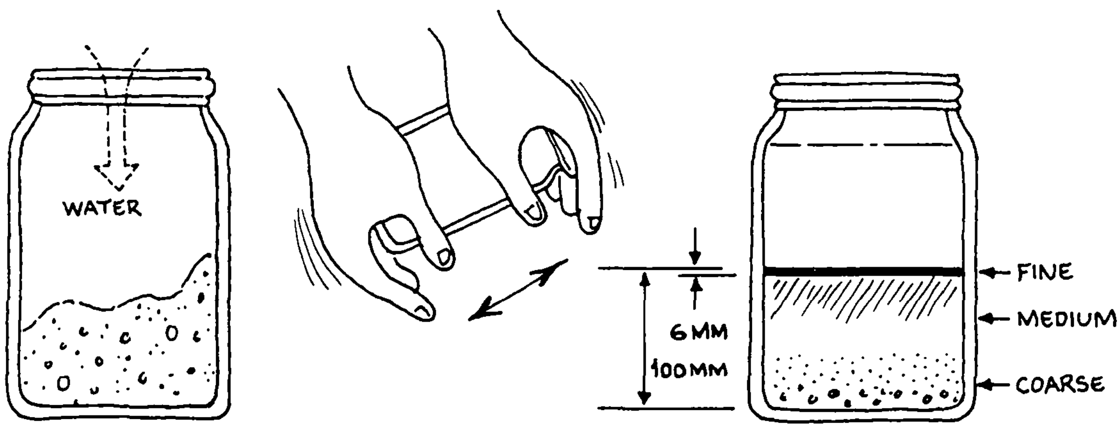
If there are many different sizes between the largest and the smallest, the sample is well-graded. This means it will compact well. If only a few sizes can be seen, then it is single-sized or poorly graded.

Settling test

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

Place a sample in a bottle or a glass jar with straight sides. Fill the bottle with 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 sample 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 toegether, even when placed on a sheet of paper, silts or clays are present, which means the material is suitable for building.

8.2. Steel bars

A simple test can be conducted as follows:

- bend the bar into a U-shape with an inside diameter of 25 times the bardiameter and then straighten it out.
- bend it into a U and if no cracks appear at the bend on re-straightening the bar is acceptable.

8.3. Testing the tank

The watertank is tested by filling it with water. A newly built empty tank should always be filled slowly and it should be left for a week with a shallow depth of water in it before filling completely.
If no seepage of water appears or only very small seepages, the ferrocement watertank may be considered acceptable.
To obtain an even more waterproof tank it may be considered to paint the inside of the tank with a thick cement slurry or a type of paint such as is described in the manual for sealing the tank.

9. CALCULATION OF THE TANKS

The great advantage of wire reinforced mortar over conventional reinforced concrete for watertank construction is its ability to resist shrinkage cracking during curing, its resistance to severe cracking under tensile load, and the need for only one set of forms for construction, whereby the mortar is applied by hand to one side. Pouring a thin shell of concrete between two closely spaced shutters - the conventional method of reinforced concrete construction - is a highly skilled and difficult task.

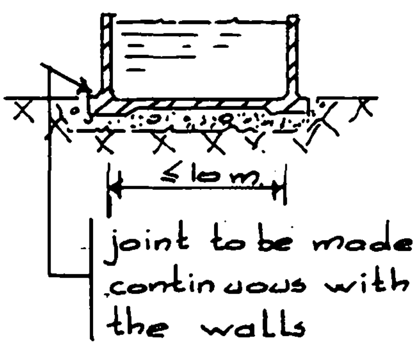
Unreinforced mortar and concrete are strong under compressive loads but very weak at resisting tensile or pulling loads; if structures made from these materials are subject to excessive tensile forces or bending, they can fracture suddenly without observable stretching and development of fine cracks.
The reason for the weakness in tension and the brittle type of failure is that, however carefully the mortar is mixed and placed, there will be always planes of weakness between the edges of discrete lumps that make up the mortar. These are exaggerated by shrinkage during curing and by imperfect bonding between each layer of mortar that is trowelled on. In compression these planes of weakness are held together by the load, but under tensile loading they will open up beyond their elastic limit coalesce with other cracks and rapidly cause the mortar to fail.
Conventional reinforced concrete is designed to overcome this characteristic by allowing the tensile loads to be taken completely on the reinforcing bars - the concrete in tension being assumed to have no strength. In reality, however, the reinforcing steel works to limit and control the tendency of the concrete to crack under tensile load.
The amount and distribution of the steel bars or wires should be in correspondence with the maximum tensile laoding.
In reinforced cement-mortar under moderate tensile loads, such as those found in the small watertanks described, the mortar may be assumed to contribute greatly to the tensile strenght of the composite layer. This occurs because the wire mesh, distributed relatively densely through the mortar, will allow the load to be taken throughout the complete layer and will prevent the early concentration of critical stresses in planes of weakness.
Any cracks that do appear under moderate loading will not be wide enough to allow water to reach the reinforcing wires and start corrosion.
The structural behaviour of a wire-reinforced mortar shell is difficult to calculate with any exactness especially if the wires, in the case of cylindrical tanks, are fixed mainly in one plane around the tank.
In addition, the mortar that is trowelled by hand onto the tank will inevitably be of varying thickness or strength.
The calculations shown, however, suggest that the smaller tanks are not highly stressed and there would seem to be a large factor of safety in most of the designs.

The succesful use of the tanks over many years may considered to confirm this supposition. The tanks described in this manual are the cylindrical with a flat floor.
Cylindrical tanks are rather simple to make. The stress at the base of the tank where the wall join the floor is comparatively large and the joint must be made strong enough.

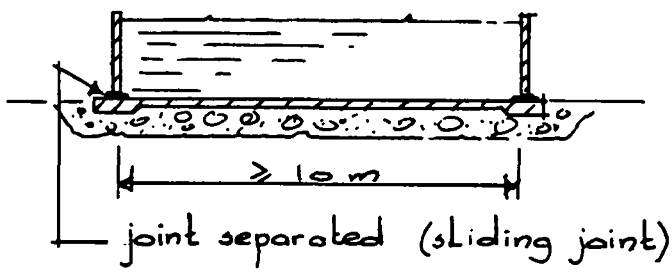
9.1. The foundation

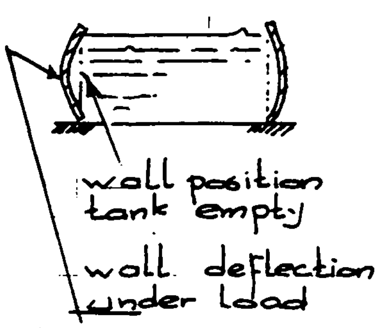
The foundation of the tanks carry the weight of both tank and water down to the ground. The floor in the smaller tanks (less than 10 m in diameter) is usually continuous with the walls; the floorslab carries the weight of the walls and the water directly onto the foundation.
The larger tanks (over 10 m in diameter) usually have the floor built seperately from the walls, and the floorslab therefore supports only the weight of water in the tank; separate foundations are needed for the walls.
Preparing the foundations is one of the most important steps in tank construction and is considered in another chapter (Chapter 5.1. Construction of the foundation).

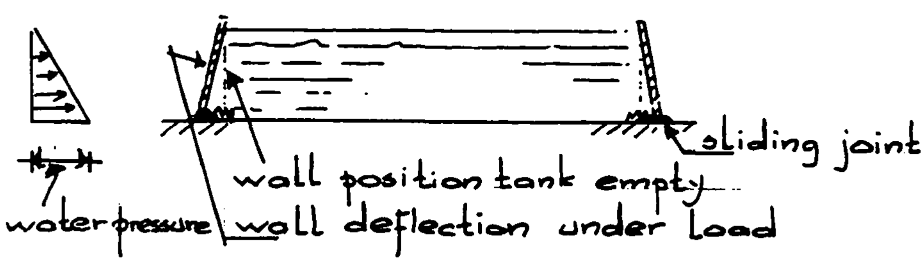
Small tanks



Large tanks







9.2. Walls

If the thin cylindrical walls were free to move at the base when the tanks were full of water, they would stretch under load to give only hoop tension forces within the walls.
To prevent leakage, however, a flexible watertight seal of some sort would then be needed between the floor and the walls.
Such a watertight seal may lead to complications in design, delivery and construction. For this reason most of the tanks described in this publication have walls built continuously with the floor or foundations.
Although this produces some design difficulties, it is an almost universally adopted technique for the relatively small shallow tanks under consideration.

In the last resort also tanks with capacities of 90 and 150 m^3 (large tanks, over 10 meter in diameter) will be designed with a "sliding joint". This type of tank avoids shrinkage-cracks due to free movement of the special joint.
A short building instruction is given for these tanks, including some characteristic properties.

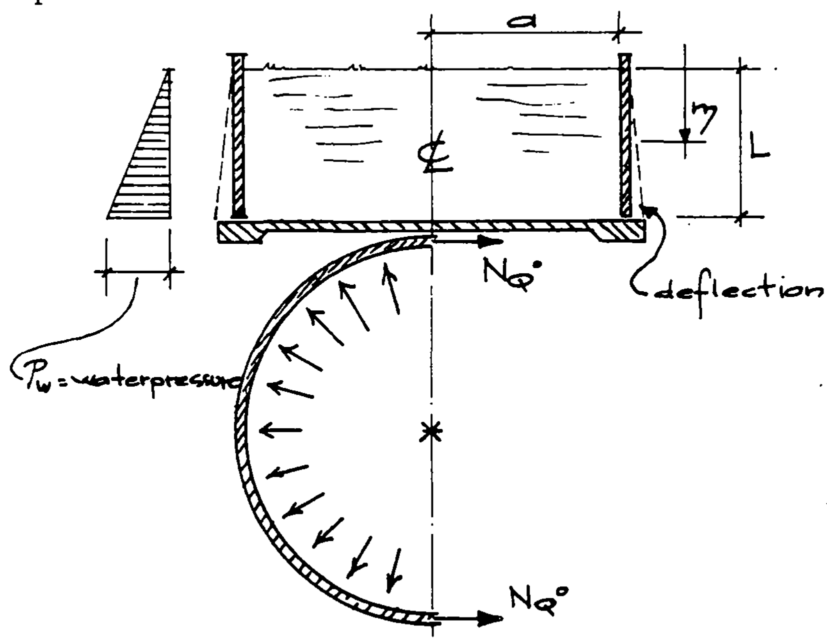
9.3. Design assumptions for calculations

- The tanks are assumed to be made of an uniform-homogeneous, elastic material. The same elastic modulus in both horizontal and vertical direction. Poissons ratio for reinforced mortar is taken to be 0.2.
- Due to the fine distribution of the reinforcement there will be very little cracking.
- A low water-cement ratio gives good water-proof structures.
- The tanks have a cylindrical wall with a flat floor. No account has been taken of creep, which would relieve some stress in the mortar.
- In publications the maximum tensile stress in the ferrocement structure occurs on the inside face at the junction of the wall and the base and is limited to approx. 2.0 N/mm^2.
- The maximum tensile stress in the reinforcement is limited to 110 N/mm^2.
- The wall of the tanks should be made not less than 40 mm thick.
- In the New Zealand standard "Code of practice for concrete structures for the storage of liquids part 1" rules are given for types of tanks described in this manual. The designs are based on "resistance to cracking".
  In this code, the following minimum wall thicknesses are given:
  - tanks up to 25 m^3: min. wall thickness 33 mm
  - tanks up to 40 m^2: min. wall thickness 44 mm
- Shrinkage and cracking can be prevented by raising the ground around the perimeter of the irrigation tank to a level of approxiamately 0.40 m above the bottom of the tank floor.
- In particular the connection between the bottom slab and the wall should be carried out very carefully; the connecting surface has to be rough and dustfree before wall trowelling can start.

For the calculation two different methodes have been taken in consideration:

1. <u>Floor and wall separated by means of a sliding joint</u>

If the thin cylindrical wall is free to move at the base when the tank is full of water, it would stretch under load to give only hoop tension forces within the wall.



On the bottom of the tank with a height "l" the water pressure will be:

p_w = 10*l

The tensile force "N_Q°" on the bottom of the tank is:

N_q° = ½ * tank diameter * water pressure = ½ * (2a) * p_w

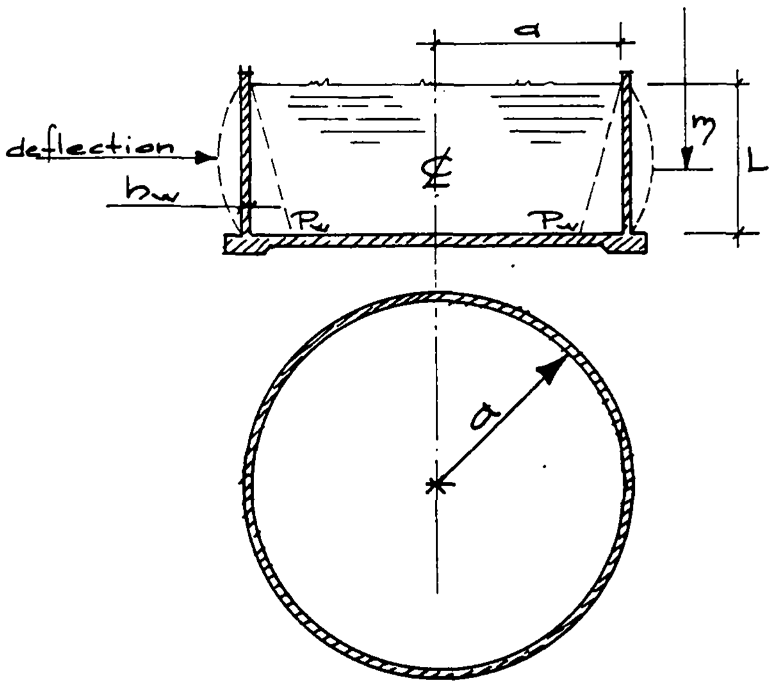
At a height "η" the tensile force will be:

N_Q^{η} = ½ * (2a) * p_w* η

According to this theory tank type III has to be calculated.

2. <u>Floor and wall connected</u>

If the thin cylindrical wall and the floor are composite and the tank is full of water, both tensile stresses and bending stresses will occur. The way how to calculate these tensile forces and bending forces is described in "Theorie und Berechnung rotationssymmetrischer Bauwerke" by Dr. Gjula Markus.
The coefficients for the forces and moments are taken from this publication.
The applicable tables are included in this manual (annex 5 and 6).
With the above theory the following formulae are used:



a = Radius of the tank (m)
h = the max. waterheight (m)
h_w = wall thickness (m)
p_w = water pressure on the bottom of the tank (kN/m^2)

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

$$N_Q = p\ a\ F_N$$

$$M_y = p\ a\ h\ \frac{F_M}{W}$$

K = the stiffness of the cylindrical wall
N_Q = ring force
M_y = bending moment in the height of the wall
F_N = coefficient for N_Q
$\frac{F_M}{W}$ = coefficient for M_y

Irrigation tanks with capacities of 30, 60, 90 and 150 m^3 have been calculated in five types:

<u>Type I</u> <u>Range of preference</u>

Ferrocement tank, wall and slab connected, for the following capacities and heights:

- capacity 30 m^3 height 1.25 m
- capacity 60 m^3 height 1.25 m
- capacity 90 m^3 height 1.25 m
- capacity 150 m^3 height 1.90 m

<u>Type II</u> Ferrocement tank, wall and slab connected, with a capacity of 150 m^3 and a height of 1.25 m.

<u>Type III</u> Ferrocement tank, wall and slab constructed with a sliding joint, for the following capacities and heights:
- capacity 90 m^3 height 1.25 m
- capacity 150 m^3 height 1.25 m

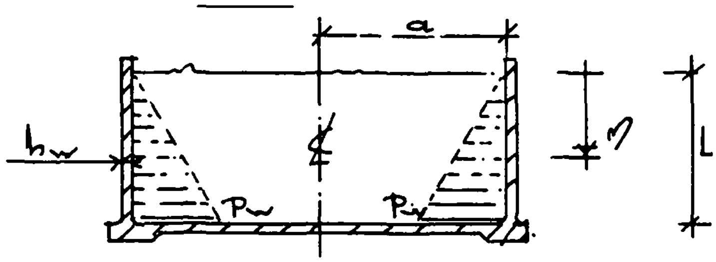
<u>Type IV</u> Ferrocement tank, wall and "foundation ring" (trench beam) connected, but with a separate bottom slab consisting of concrete or impermeable soil
Furthermore as type I

<u>Type V</u> As type I but with an extra outer brickwork wall.

9.4. Calculation of the tanks

9.4.1. Types III Ferrocement tank; wall and slab constructed with a sliding joint

<u>Scheme</u>



Formula:
$N_Q° = a.pw\mu$

$p_w = 1 * p * \gamma$
$p = 10$ kN/m^3
$\gamma = 1$

<u>Exemple for a 60 m³ tank</u>

l = 1.25 m   a = 3,91 m h_w = 0.05 m
On the bottom of the tank with a height of 1.25 m the water pressure will be:
$p = 10 * 1.25 = 12.50$ kN/m^2(m')
The tensile force "$N_Q° = \frac{1}{2} * (2 * 3.91) * 12.5 = 48.87$ kN/m'
The hoop stress with $N_Q°$ = 48.87 kN will be:

$$\sigma_{h.s} = \frac{N_Q° * 10^3}{1000 * h_w} = \frac{48.87*10^3}{1000*50} = 0.98 \text{ N/mm}^2$$

The reinforcement with $N_Q°$ = 48.87 kN will be:

$$A = \frac{48.87*10^3}{Fy} = \frac{48.87*10^3}{110} = 444 \text{ mm}^2/\text{m}'$$

On the basis of the above exemple the reinforcement for the other capacities can be calculated as follows:

capacity m^3	l (m)	a (m)	hw (m)	pw	N ° (μ=1)	max.hoop stress N/mm^2	reinforcement for hoop stress (A) mm^2/m'
30	1.25	2.77	0.04	12.5	34.63	0.87	315
60	1.25	3.91	0.05	12.5	48.87	0.98	444
90	1.25	4.79	0.06	12.5	59.87	1.00	544
150	1.25	6.18	0.07	12.5	77.25	1.10	702 D > 10 m
150	1.50	5.64	0.07	15.0	84.60	1.21	769*
150	1.75	5.22	0.07	17.5	91.35	1.31	830*

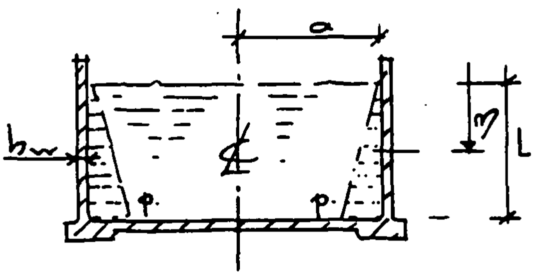
* Uneconomical solution

9.4.2. Types I - II - IV and V; Ferrocement tank
Wall and slab connected

9.4.2.1. Tank capacity of 30 m3

With a waterheight in the tank of 1.25 m the tank diameter will be:

$$(2a)^2 = \frac{30*4}{1.25*\pi} \rightarrow \quad a = 2.77 \text{ m}, \quad D = 5.54 \text{ m}$$



h_w = 40 mm
μ = 0.2

Calculation example for a 30 m^3 tank

Without reduction the water pressure on the bottom of the tank will be:
$p_w = 10 * 1.25 = 12.50 \text{ kN/m}^2 \text{ (m')}$
and the tensile force:
$N_Q Z = p_w * a = 12.5*2.77 = 34.6 \text{ kN/m'}$
However, reductions must be introduced since the wall and slab are composite.

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

$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{2.77*0.04}} = 3.91$$

Kl = 3.91*1.25 = 4.89

$p_w a h_w$ = 34.6*0.04 = 1.384 kNm/m'

Since there is no certainty whether the joint is "plastic" or "rigid" both tables, annex 5 and 6, are used to find the least favourable stresses.

- With Annex 5 "joint plastic"

Kl = 4.89, by μ = 0.7

→ F_N = 0.67 and $N_Q^{(0.7)}$ = 0.67*34.6 = 23.18 kN/m'

→ $\frac{F_M}{W}$ = 0.067 and $M_y^{(0.7)}$ = 0.067*1.384 = 0.091 kNm/m'

- With Annex 6 "joint rigid"

Kl = 4.89 by μ = 0.6

→ F_N = 0.55 and $N_Q^{(0.6)}$ = 0.55*34.6 = 19.0 kN/m'

→ $\frac{F_M}{W}$ = -0.048 and $M_y^{(0.6)}$ = 0.048*1.284 = 0.066 kNm/m'

All tensile forces and bending moments in the height of the wall are worked out in graphs.
For this case see page .
From these graphs the maximum tensile forces and bending moments will be taken to find the max. reinforcement (A) in cross and longuatudinal directions of the wall.
For calculation of the stresses and the reinforcement the following formulae have been used:

- hoop stress $\sigma_{h.s} = \frac{N_Q \eta * 10^3}{h_w * 1000}$

$\sigma_{h.s} = \frac{23.18*10^3}{40*1000} = 0,58 \text{ N/mm}^2$

- r.f. due to hoop stress $A_{h.s} = \frac{N_Q 10^3}{Fy}$

$A_{h.s} = \frac{23.18*10^3}{110} = 211 \text{ mm}^2/\text{m}'$

Use (Ø5-150+meshes 3*30 mm²)

- bending stress $\sigma_{b.s} = \frac{My*10^6*6}{1000*h_w^2}$

with joint plastic: $\sigma_{b.s} = \frac{0.16*10^6*6}{1000*40^2} = 0.6 \text{ N/mm}^2$ (m')

with joint rigid: $\sigma_{b.s} = \frac{0.33*10^6*6}{1000*40^2} = 1.24 \text{ N/mm}^2$ (m')

- r.f due to bending moments

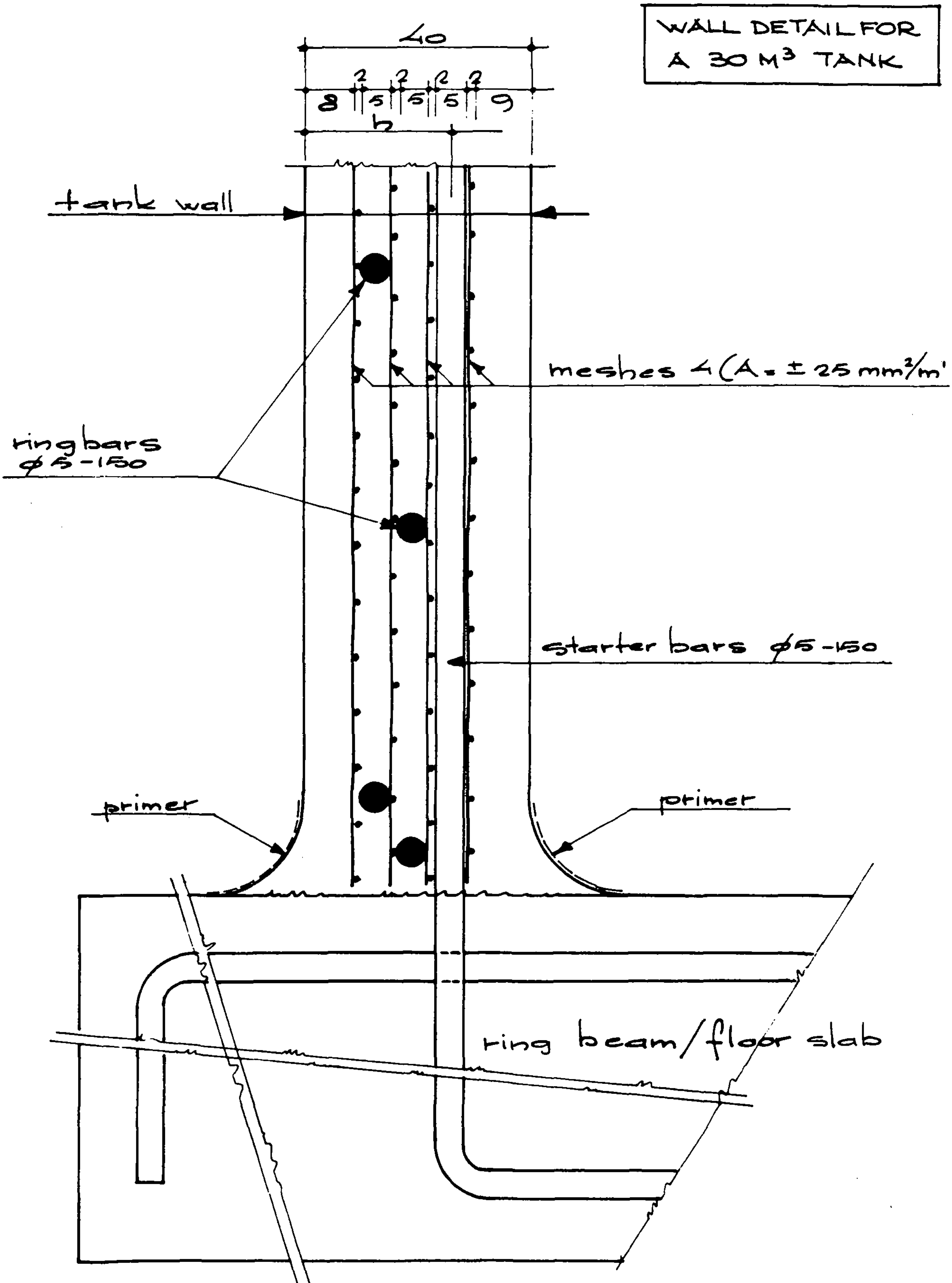
$$A_{b.m} = \frac{My*10^6}{h*0.85*Fy} \quad \text{(h = lever arm)}$$

with joint plastic: $A_{b.m} = \frac{0.16*10^6}{25*0.85*110} = 68 \text{ mm}^2/\text{m}'$

with joint rigid: $A_{b.m} = \frac{0.33*10^6}{25*0.85*110} = 141 \text{ mm}^2/\text{m}'$

use (starterbars Ø5-150).

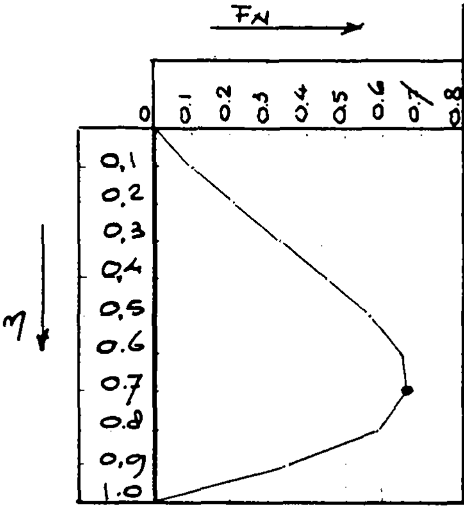
On the basis of the above calculation the tank wall for a 30 m^3 tank can be reinforced as follows:



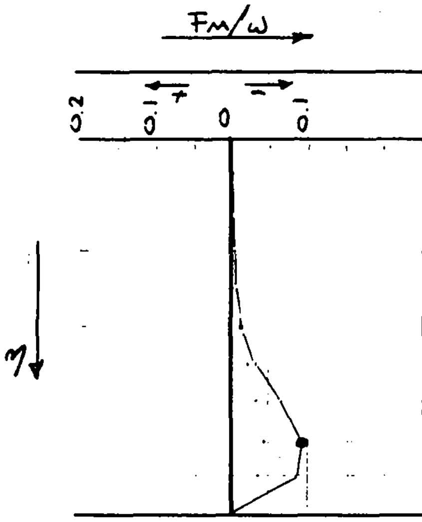
h = lever arm ≈ 25mm (for design h = 27,5 - 2,5 = 25mm)
with this example the reinforcement for the other capacities can be calculated easily.

Tank capacity 30 m^3 l = 1.25 m

$n_Q = pa \frac{F}{N}$ (kN/m') $M_y = pah \frac{F_M}{W}$ (kNm/m')



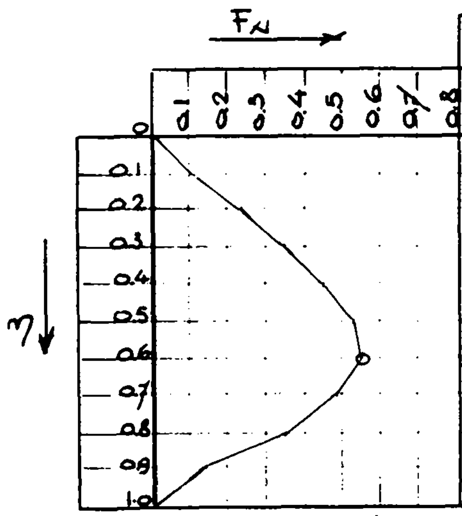
η	F_N	N_Q
0	-0.077	-0.27
0.1	+0.10	+3.46
0.2	+0.21	+7.27
0.3	+0.33	+11.42
0.4	+0.45	+15.57
0.5	+0.57	+19.7
0.6	+0.65	+22.49
0.7	+0.67	+23.18
0.8	+0.59	+20.41
0.9	+0.36	+12.46
1.0	0	0



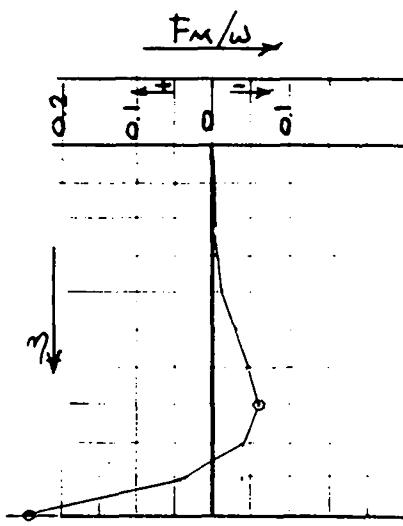
η	F_M/ω	M_y
0	0	0
0.1	0	0
0.2	+0.0018	0
0.3	+0.001	+0.001
0.4	-0.004	-0.006
0.5	-0.017	-0.02
0.6	-0.039	-0.05
0.7	-0.067	-0.09
0.8	-0.091	-0.16
0.9	-0.084	-0.12
1.0	0	0

coefficients in accordance with design tabel 1 (Annex 5)

JOINT PLASTIC



η	F_N	N_Q
0	+0.012	+0.4
0.1	+0.11	+3.8
0.2	+0.23	+8.0
0.3	+0.34	+11.8
0.4	+0.44	+15.2
0.5	+0.52	+18.0
0.6	+0.55	+19.0
0.7	+0.49	+17.0
0.8	+0.34	+11.7
0.9	+0.13	+4.5
1.0	0	0



η	F_M/ω	M_y
0	0	0
0.1	0	0
0.2	-0.0012	-0.002
0.3	-0.006	-0.008
0.4	-0.016	-0.02
0.5	-0.034	-0.05
0.6	-0.048	-0.07
0.7	-0.061	-0.08
0.8	-0.042	-0.06
0.9	+0.041	+0.06
1.0	+0.233	+0.33

Coefficients in accordance with design tabel 2 (Annex 6)

JOINT RIGID

<u>Tank capacity of 30 m³</u> $l = 1.50$ m

a = 2.52 m
D = 5.04 m

p.a. = 10 * 1.5 * 2.52 = 37.8
$p.ah_w$ = 37.8 * 0.04 = 1.512

$K = \sqrt{\frac{\sqrt{3(10.2^2)}}{2.52*0.04}} = 4.10$ $Kl = 4.10 * 1.5 = 6.15$

	F_N		N_{Q}(kN/m')	F_M/W		M_y(kNm/m')
		position η			position η	
joint plastic	0,7412	0.7	28.02	0.0938	0.9	0.142
joint rigid	0.620	0.6	23.44	-0.0564 +0.2450	0.8 1.0	0.085 0.37

<u>Tank capacity of 30 m³</u> $l = 1.75$ m

a = 2.34 m
D = 4.68 m

p.a. = 10 * 1.75 * 2.34 = 40.95
$p.ah_w$ = 40.95 * 0.05 = 2.048

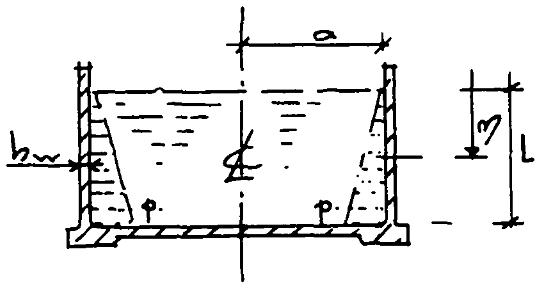
$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{2.34*0.04}} = 4.26$ $Kl = 4.26 * 1.75 = 7.45$

	F_N		N_{Q}(kN/m')	F_M/W		M_y(kNm(m')
		position η			position η	
joint plastic	0.780	0.8	31.9	0.0940	0.9	0.15
joint rigid	0.69	0.7	28.26	-0.0606 +0.2533	0.8 1.0	0.10 0.42

9.4.2.2. Tank capacity of 60 m³

With a water height in the tank of 1.25 m the tank diameter will be:

$$(2a)^2 = \frac{60 * 4}{1.25*\pi} = \rightarrow a = 3.91 \text{ m}$$
$$D = 7.82 \text{ m}$$



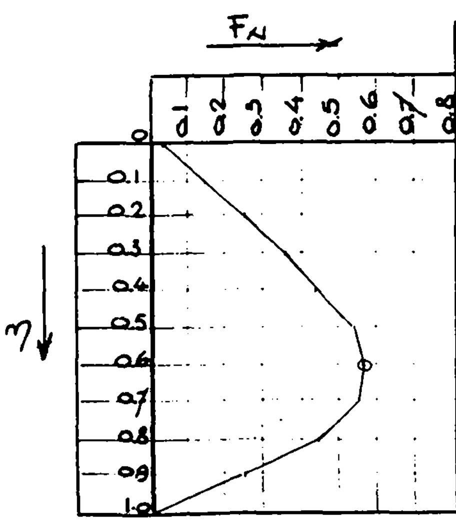
$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{3.91*0.05}} = 2.95$$

$$Kl = 2.95 * 1.25 = 3.68$$

h_w = 50 mm
μ = 0.2
p.a. = 10 * 1.25 * 3.91 = 48.88

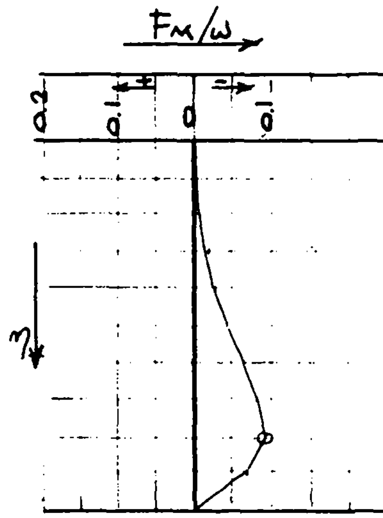
pah_w = 48.88 * 0.05 = 2.44

$N_Q = p.a.F_N$ (kN/m')



η	F_N	N_Q
0	+0.0334	+1.63
0.1	+0.1457	+7.12
0.2	+0.2571	+12.57
0.3	+0.3646	+17.82
0.4	+0.4236	+20.71
0.5	+0.5349	+26.15
0.6	+0.5694	+27.83
0.7	+0.5546	+26.62
0.8	+0.4417	+21.59
0.9	+0.2533	+12.38
1.0	0	0

$M_y = p.ah.\frac{F_M}{W}$ (kNm/m')

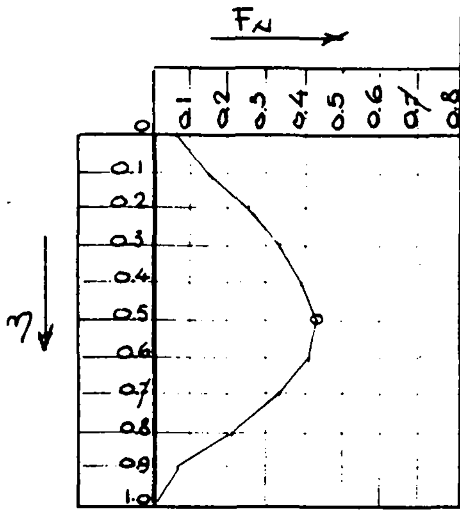


η	F_M/ω	M_y
0	0	0
0.1	-0.0009	-0.002
0.2	-0.005	-0.012
0.3	-0.0131	-0.032
0.4	-0.0258	-0.062
0.5	-0.0442	-0.108
0.6	-0.0655	-0.160
0.7	-0.0850	-0.207
0.8	-0.0927	-0.226
0.9	-0.0722	-0.176
1.0	0	0

coefficients in accordance with design table 1 (Annex 5)

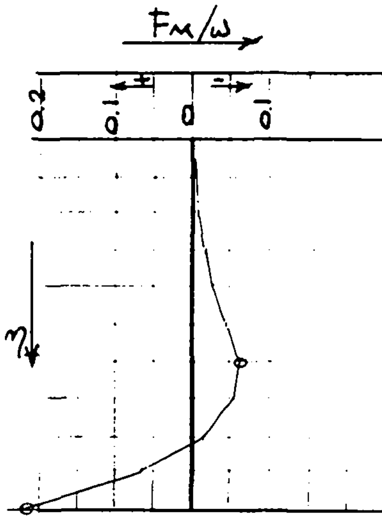
JOINT PLASTIC

$N_Q = p.a.F_N$ (kN/m')



η	F_N	N_Q
0	+0.0772	+3.78
0.1	+0.1673	+8.18
0.2	+0.2550	+12.46
0.3	+0.3340	+16.33
0.4	+0.3940	+19.26
0.5	+0.4218	+20.62
0.6	+0.4039	+19.74
0.7	+0.3817	+16.21
0.8	+0.2104	+10.28
0.9	+0.0734	+3.59
1.0	0	0

$M_y = p.ah.\frac{F_M}{W}$ (kNm/m')



η	F_M/ω	M_y
0	0	0
0.1	-0.0025	-0.006
0.2	-0.0097	-0.002
0.3	-0.0211	-0.05
0.4	-0.0354	-0.086
0.5	-0.0497	-0.121
0.6	-0.0586	-0.143
0.7	-0.0527	-0.1286
0.8	-0.0181	-0.044
0.9	+0.0682	+0.154
1.0	+0.2103	+0.513

coefficients in accordance with design tabel 2 (Annex 6)

JOINT RIGID

Tank capacity of 60 m³ $\qquad$ l = 1.50 m

a = 3.57 m
D = 7.14 m

p.a. = 10 * 1.5 * 3.57 = 53.55
$p.ah_w$ = 53.55 * 0.05 = 2.68

$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{3.57*0.05}} = 3.08$ $\qquad$ K1 = 4.63

	F_N		N_Q (kN/m')	F_M/W		M_y (kNm/m')
		position η			position η	
joint plastic	0,65	0.7	34.81	0.0919	0.8	0.25
joint rigid	0.52	0.6	27.85	-0.06 +0.223	0.7 1.0	0.16 0.60

Tank capacity of 60 m³   l = 1.75 m

a = 3.305 m
D = 6.61 m

p.a. = 10 * 1.75 * 3.305 = 57.84
$p.ah_w$ = 57.84 * 0.05 = 2.89

K = 3.205   K1 = 5.6

	F_N		N Q(kN/m')	F_M/W		M_y(kNm/m')
		position η			position η	
joint plastic	0.7164	0.7	41.44	0.0885	0.9	0.26
joint rigid	0.593	0.6	34.3	-0.0583 +0.24	0.7 1.0	0.17 0.69

9.4.2.3. Tank capacity of 90 m^3

With a water height in the tank of 1.25 m the tank diameter will be:

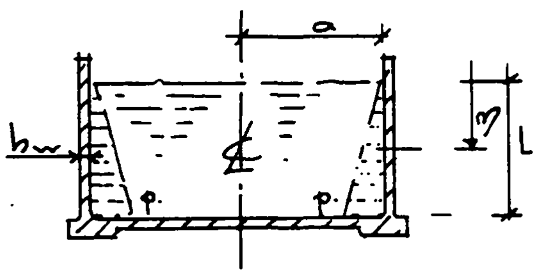
$$(2a)^2 = \frac{90 * 4}{1.25 * \pi} = 4.78 \text{ m} \quad \rightarrow \quad a = 4.785 \text{ m}, \quad D = 9.57 \text{ m}$$

With this diameter the limit of a tank in which the wall and floorslab are connected has been reached.

An alternative is to raise the waterheight in order to reduce the diameter.

Calculations are made for waterheights of both 1.25 m and 1.50 m

waterheight l = 1.25 m



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

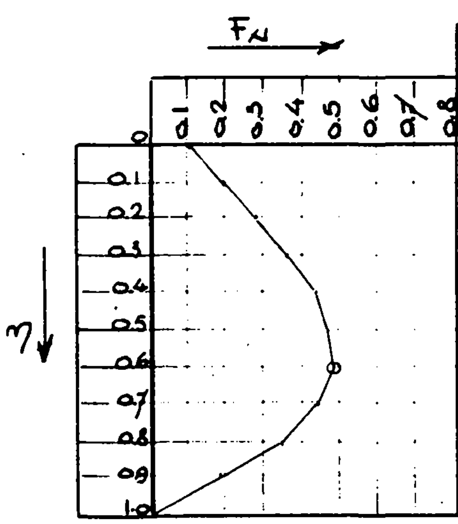
$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{4.785*06}} = 2.43$$

$$Kl = 2.43 * 1.25 = 3.04$$

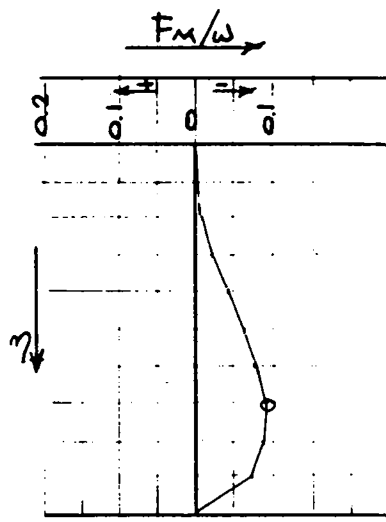
h_w = 60 mm
μ = 0.2
a = 4.785 m
p.a. = 10 * 1.25 * 4.785 = 59.81
pah_w = 59.81 * 0.06 = 3.59

$N_Q = p.a.\ F_M$ (kN/m')

$M_y = p.a.h.\frac{F_M}{W}$ (kNm/m')



η	F_N	N_Q
0	+0.108	+6.46
0.1	+0.200	+11.96
0.2	+0.291	+17.40
0.3	+0.375	+22.43
0.4	+0.444	+26.56
0.5	+0.487	+29.13
0.6	+0.493	+29.49
0.7	+0.449	+26.86
0.8	+0.350	+20.93
0.9	+0.194	+11.60
1.0	0	0



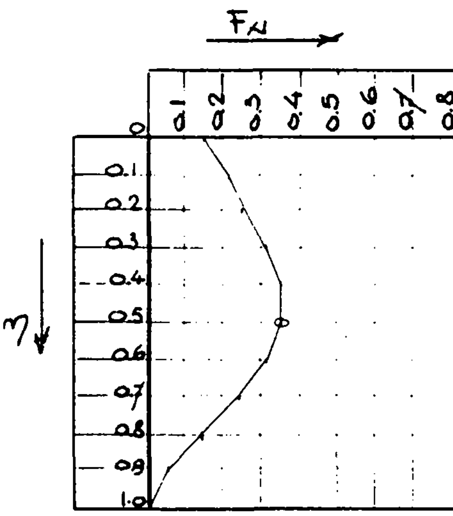
η	F_M/ω	M_y
0	0	0
0.1	-0.0028	-0.01
0.2	-0.011	-0.04
0.3	-0.0237	-0.09
0.4	-0.0406	-0.15
0.5	-0.0598	-0.21
0.6	-0.0782	-0.28
0.7	-0.0907	-0.33
0.8	-0.0896	-0.32
0.9	-0.0768	-0.28
1.0	0	0

coefficients in accordance with design table 1 (annex 5).

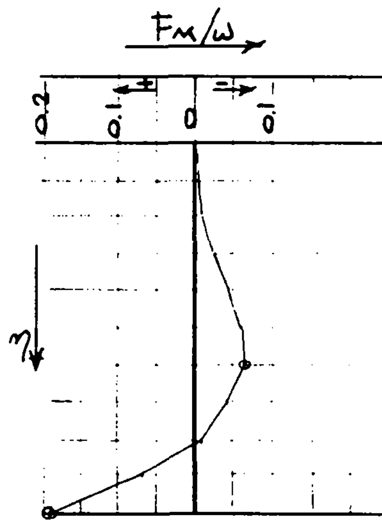
JOINT PLASTIC

$N_Q = p.a.\ F_M$ (kN/m')

$M_y = p.a.h.\frac{F_M}{W}$ (kNm/m')



F_N	N_Q
+0.162	+9.69
+0.217	+12.98
+0.269	+16.09
+0.312	+18.66
+0.338	+20.22
+0.338	+20.22
+0.304	+18.18
+0.235	+14.06
+0.141	+8.43
+0.047	+2.81
0	0



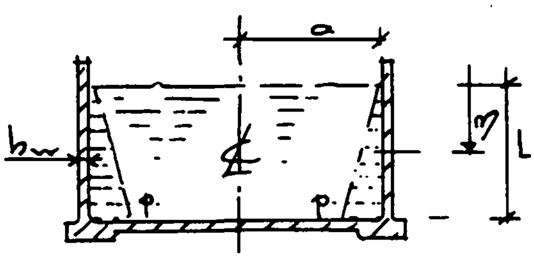
F_M/W	M_y
–	–
-0.004	-0.01
-0.014	-0.05
-0.028	-0.10
-0.042	-0.15
-0.053	-0.19
-0.056	-0.20
-0.042	-0.15
-0.003	-0.01
+0.071	+0.25
+0.192	+0.69

coefficients in accordance with design table 1 (Annex 6)

JOINT RIGID
===========

<u>Tank capacity of 90 m³</u>

waterheight l = 1.50 m



$$K = \sqrt{\frac{\sqrt{3(1 - 0.2^2)}}{4.37*0.06}} = 2.54$$

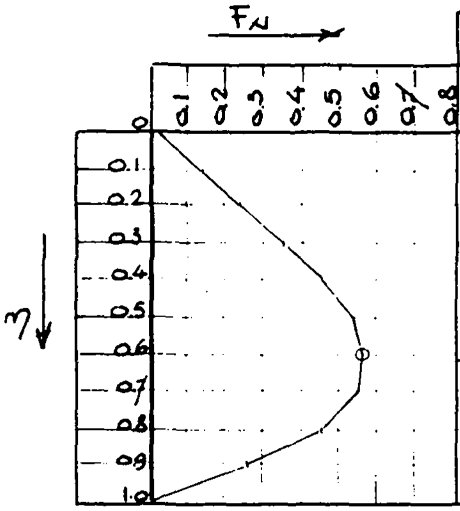
$$Kl = 2.54 * 1.5 = 3.82$$

h_w = 60 mm
μ = 0.2

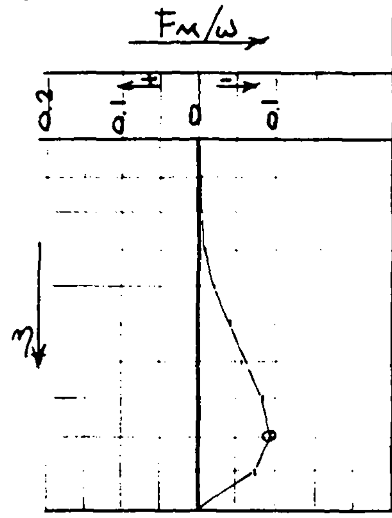
$$(2a)^2 = \frac{90 * 4}{1.5 * \pi} \quad \rightarrow a = 4.37 \text{ m}, \quad D = 8.74 \text{ m}$$

p.a. = 10 * 1.5 * 4.37 = 65.55
pah_w = 65.55 * 0.06 = 3.93

$N_Q = p.a.\ F_N (kN/m')$ $\qquad$ $M_y = p.a.h \frac{F_M}{W}$ (kNm/m')



η	F_N	N_Q
0	+0.0171	+1.12
0.1	+0.134	+8.78
0.2	+0.250	+16.39
0.3	+0.362	+23.73
0.4	+0.465	+30.48
0.5	+0.545	+35.73
0.6	+0.586	+38.41
0.7	+0.565	+37.04
0.8	+0.462	+30.28
0.9	+0.266	+17.44
1.0	0	0



η	F_M/ω	M_y
0	0	0
0.1	0.0005	-0.002
0.2	-0.0037	-0.015
0.3	-0.011	-0.043
0.4	-0.022	-0.087
0.5	-0.041	-0.161
0.6	-0.063	-0.248
0.7	-0.084	-0.330
0.8	-0.093	-0.366
0.9	-0.074	-0.291
1.0	0	0

coefficients in accordance with design table 1 (Annex 5)

JOINT PLASTIC
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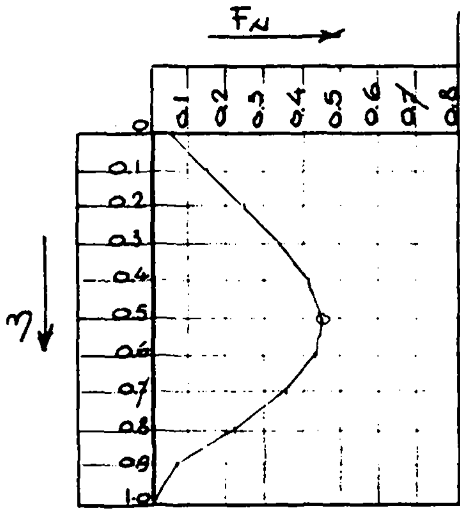
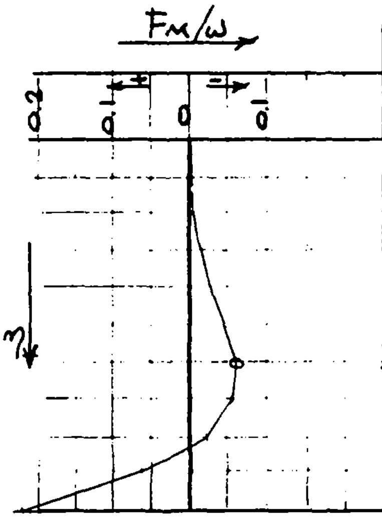


η	F_N	N_Q
0	+0.059	+3.87
0.1	+0.157	+10.29
0.2	+0.252	+16.52
0.3	+0.339	+22.22
0.4	+0.406	+26.61
0.5	+0.440	+28.84
0.6	+0.426	+27.92
0.7	+0.353	+23.14
0.8	+0.226	+14.81
0.9	+0.079	+5.18
1.0	0	0



η	F_M/ω	M_y
0	0	0
0.1	-0.0022	-0.009
0.2	-0.0087	-0.034
0.3	-0.020	-0.079
0.4	-0.034	-0.134
0.5	-0.049	-0.193
0.6	-0.059	-0.232
0.7	-0.055	-0.216
0.8	-0.0214	-0.084
0.9	+0.061	+0.240
1.0	+0.214	+0.841

coefficients in accordance with design table 2 (Annex 6)

JOINT RIGID
==========

Tank capacity of 90 m³ $\qquad$ l = 1.75 m

$$(2a)^2 = \frac{90 * 4}{1.75 * \pi} = 4.05 \text{ m} \quad \rightarrow \quad a = 4.05 \text{ m}, \; D = 8.10 \text{ m}$$

p.a. = 10 * 1.75 * 4.05 = 70.8
$p.ah_w$ = 70.8 * 0.06 = 4.25

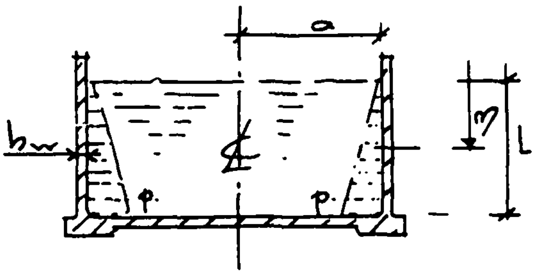
$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{4.05*0.06}} = 2.64 \qquad Kl = 4.63$$

	F_N		N_{Q}(kN/m')	F_M/W		M_y(kNm/m')
		position η			position η	
joint plastic	0.65	0.7	46.0	0.0919	0.8	0.39
joint rigid	0.52	0.6	36.8	-0.06 +0.223	0.7 1.0	0.26 0.95

9.4.2.4. Tank capacity of 150 m³

With a limited diameter of 10 m the waterheight for a tank of 150 m^3 will be:

$$(2 * 5)^2 = \frac{150*4}{l * \pi} \quad \rightarrow \quad l = 1.90 \text{ m}$$



$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{5 * 0.07}} = 2.20$$

$$K1 = 4.18$$

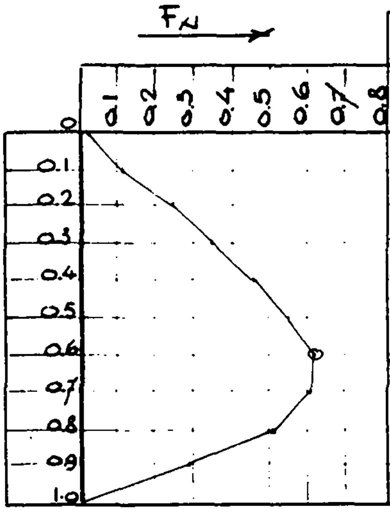
h =70 mm

μ = 0.2

p.a. = 10 * 1.9 * 5 = 95

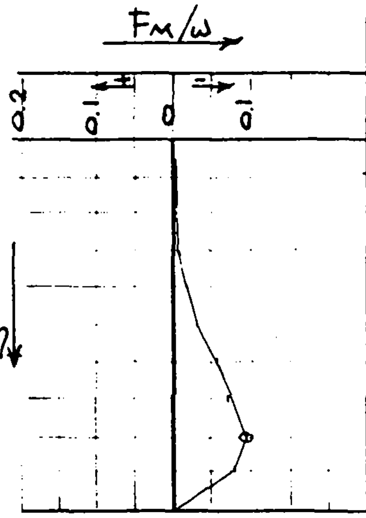
pah_w = 95 * 0.07 = 6.65

$N_Q = p.a.\ F_N$ (kN/m')



η	F_N	N_Q
0	+0.002	+0.19
0.1	+0.114	+10.83
0.2	+0.235	+22.33
0.3	+0.354	+33.63
0.4	+0.466	+44.27
0.5	+0.561	+53.30
0.6	+0.617	+58.62
0.7	+0.609	+57.86
0.8	+0.508	+48.26
0.9	+0.298	+28.31
1.0	0	0

$M_y = p.a.h\ \frac{F_M}{W}$ (kNm/m')



η	F_M/ω	M_y
0	0	0
0.1	-0.0002	-0.001
0.2	-0.0013	-0.009
0.3	-0.006	-0.04
0.4	-0.015	-0.10
0.5	-0.033	-0.22
0.6	-0.055	-0.37
0.7	-0.079	-0.53
0.8	-0.094	-0.63
0.9	-0.078	-0.52
1.0	0	0

coefficients in accordance with design table 1 (Annex 5)

JOINT PLASTIC
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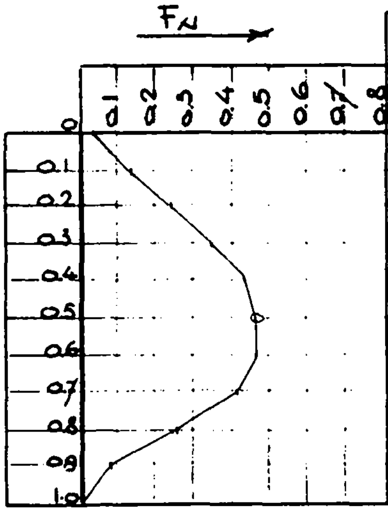
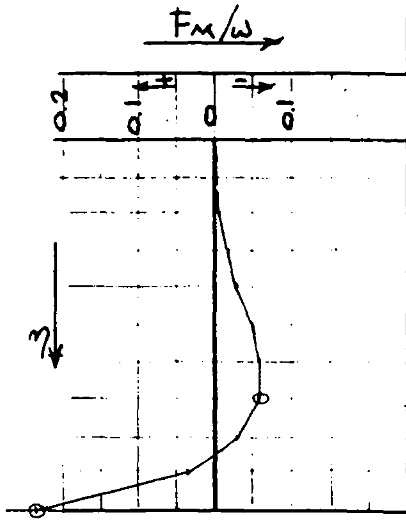


η	F_N	N_Q
0	+0.027	+2.57
0.1	+0.136	+12.92
0.2	+0.244	+23.18
0.3	+0.344	+32.68
0.4	+0.426	+40.47
0.5	+0.478	+45.41
0.6	+0.473	+44.94
0.7	+0.403	+38.29
0.8	+0.265	+25.18
0.9	+0.095	+9.03
1.0	0	0



η	F_M/ω	M_y
0	0	0
0.1	-0.0014	-0.01
0.2	-0.0062	-0.04
0.3	-0.0153	-0.10
0.4	-0.0287	-0.19
0.5	-0.045	-0.30
0.6	-0.058	-0.39
0.7	-0.059	-0.39
0.8	-0.029	-0.19
0.9	+0.036	+0.24
1.0	+0.222	+1.48

coefficients in accordance with design table 2 (Annex 6)

JOINT RIGID
==========

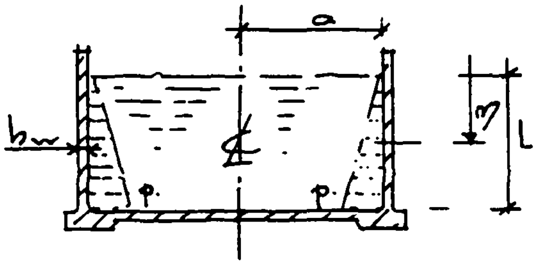
Tank capacity of 150 m^3

With a waterheight in the tank of 1.25 m the tank diameter will be:

$$(2a)^2 = \frac{150 * 4}{1.25 * \pi} \rightarrow \quad a = 6.18 \text{ m}, \quad D = 12.36 \text{ m}$$

In publications this is called a large tank (over 10 m in diameter) and usually the floor has been built separately from the walls.
If the floor and the wall is continuous, special attention should be paid to the joint, and additional reinforcement is required to protect the tankwall against crecking due to shrinkage and termperature differences.

Furthermore it is advisable only to build this kind of tank where skilled labour, good materials and good workmanship is available.



$$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{6.18 * 0.07}} = 1.98$$

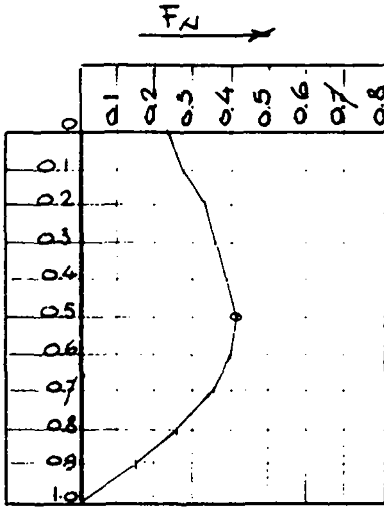
$$K1 = 1.98 * 1.25 = 2.48$$

h = 70 mm
μ = 0.2

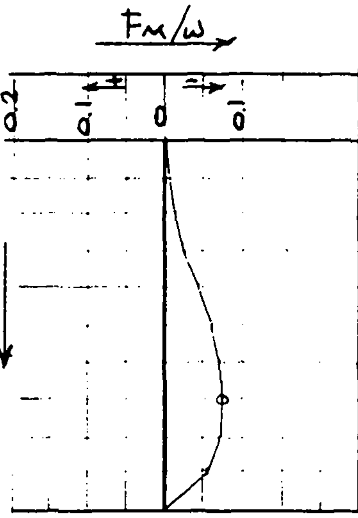
p.a. = 10 * 1.25 * 6.18 = 77.25
pah_w = 77.25 * 0.07 = 5.41

$N_Q = p.a.F_N$ (kN/m')

$M_y = pa.h \frac{F_M}{W}$ (kNm/m')



η	F_N	N_Q
0	+0.237	+18.31
0.1	+0.284	+21.94
0.2	+0.329	+25.42
0.3	+0.357	+27.58
0.4	+0.398	+30.75
0.5	+0.408	+31.52
0.6	+0.393	+30.36
0.7	+0.345	+26.65
0.8	+0.261	+20.16
0.9	+0.142	+10.97
1.0	0	0



η	F_M/ω	M_y
0	0	0
0.1	-0.0034	-0.018
0.2	-0.012	-0.065
0.3	-0.021	-0.114
0.4	-0.042	-0.227
0.5	-0.058	-0.314
0.6	-0.072	-0.390
0.7	-0.080	-0.433
0.8	-0.075	-0.406
0.9	-0.052	-0.281
1.0	0	0

coefficients in accordance with design table 1 (Annex 5)

JOINT PLASTIC
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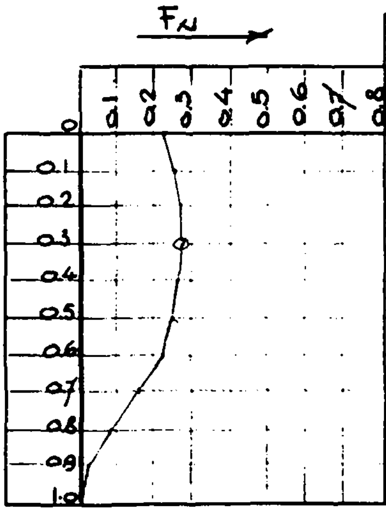
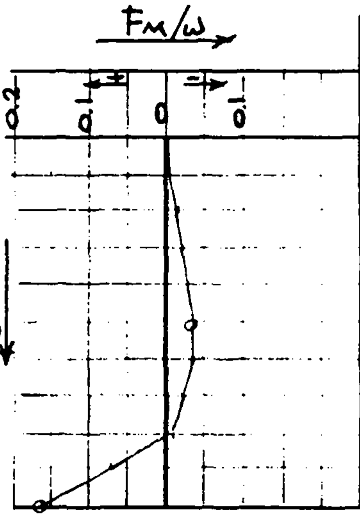


η	F_N	N_Q
0	+0.229	+17.69
0.1	+0.246	+19.00
0.2	+0.261	+20.16
0.3	+0.271	+20.93
0.4	+0.269	+20.78
0.5	+0.252	+19.47
0.6	+0.216	+16.69
0.7	+0.161	+12.44
0.8	+0.093	+7.18
0.9	+0.030	+2.32
1.0	0	0



η	F_M/ω	M_y
0	0	0
0.1	-0.0034	-0.018
0.2	-0.0119	-0.064
0.3	-0.0228	-0.123
0.4	-0.0331	-0.179
0.5	-0.040	-0.216
0.6	-0.039	-0.211
0.7	-0.0221	-0.120
0.8	-0.0125	-0.068
0.9	+0.0729	+0.394
1.0	+0.1657	-0.896

coefficients in accordance with design table 2 (Annex 6)

JOINT RIGID
===========

<u>Tank capacity of 150 m³</u> l = 1.50 m

$(2a)^2 = \frac{150 * 4}{1.5 * \pi}$ → a = 5.64 m
D = 11.28 m

pa = 10 * 1.5 * 5.64 = 84.6
pah_w = 84.6 * 0.07 = 5.92

$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{5.64 * 0.07}} = 2.07$ Kl = 2.07 * 1.5 = 3.11

	F_N		N_Q	F_M/W		M_y (kNm/m')
		position η	(kN/m')		position η	
joint plastic	0.501	0.6	42.38	0.09	0.7	0.533
joint rigid	0.347	0.5	29.36	-0.056 +0.194	-0.6 1.0	0.332 1.149

<u>Tank capacity of 150 m³</u> l = 1.75 m

$(2a)^2 = \frac{150 * 4}{1.75 * \pi}$ → a = 5.22 m
D = 10.44 m

p.a. = 10 * 1.75 * 5.22 = 91.35
$p.a.h_w$ = 91.35 * 0.07 = 6.39

$K = \sqrt{\frac{\sqrt{3(1-0.2^2)}}{5.22 * 0.07}} = 2.16$ Kl = 2.16 * 1.75 = 3.77

	F_N		N_Q	F_M/W		M_y (kNm/m')
		position η	(kN/m')		position η	
joint plastic	0.58	0.6	52.98	0.0842	0.7	0.538
joint rigid	0.4337	0.5	39.62	-0.059 +0.212	0.6 1.0	0.377 1.360

TABLES

Calculated stresses and reinforcement with a continuous wall/slab structure in thin walled cylindrical tanks

	wall thickness (mm)	maximum hoop stress N/mm²	position of max. hoop stress η	reinforcement for hoop stress mm²/m'	max. bending stress on inside face N/mm²	position of max. bending stress η	reinforcement for bending stress N/mm²
		30 m³		l = 1.25 m		a = 2.77 m	
joint plastic	40	0.58	0.7	210	-0.60	0.8	h=25 mm 68
joint rigid	40	0.48	0.6	173	-0.30 +1.24	0.7 1.0	34 141
		60 m³		l = 1.25 m		a = 3.91 m	
joint plastic	50	0.56	0.6	253	-0.54	0.8	h = 33 mm 73
joint rigid	50	0.41	0.5	187	-0.34 +1.23	0.6 1.0	46 166
		90 m³		l = 1.25 m		a = 4.785 m	
joint plastic	60	0.492	0.6	268	-0.55	0.7	h = 40 mm 88
joint rigid	60	0.34	0.5	184	-0.33 +1.15	0.6 1.0	53 184

	wall thickness (mm)	maximum hoop stress N/mm²	position of max. hoop stress m	reinforcement for hoop stress mm²/m'	max. bending stress on inside face N/mm²	position of max. bending stress m	reinforcement for bending stress N/mm²
		90 m^3		l = 1.50 m		a = 4.37 m	
							h = 40 mm
joint plastic	60	0.64	0.6	349	-0.61	0.8	98
joint rigid	60	0.48	0.5	262	-0.39 +1.40	0.6 1.0	62 225
		150 m^3		l = 1.90 m		a = 5.00 m	
							h = 50 mm
joint plastic	70	0.84	0.6	533	-0.77	0.8	135
joint rigid	60	0.65	0.5	413	-0.48 +1,81	0.7 1.0	83 317
		150 m^3		l = 1.25 m		a = 6.18 m	
							h = 50 mm
joint plastic	70	0.45	0.5	287	-0.53	0.7	93
joint rigid	70	0.30	0.3	191	-0.26 -1.10	0.5 1.0	46 192

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	(milimeter)
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)	=	47.8803 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

List of symbols

A_{hs}	=	reinforcement for the ring forces (hoop forces)
A_{bm}	=	reinforcement for the bending moments
a	=	radius of a tank
D	=	tank diameter
$\frac{F_M}{W}$	=	coefficient for My
F_N	=	coefficient for N_Q
f_y	=	yiels stress of the steelbars
h_w	=	wall thickness
h^w	=	leverarm
K	=	the stiffness of the cylindrical wall
K_N	=	kilo Newton
l	=	the max. waterheight in a tank
M	=	bending moment (general)
M_y	=	bending moment in the height of the wall
m	=	meter
N_Q	=	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_{bs}	=	bending stress in N/mm^2
σ_{hs}	=	tensile stress in N/mm^2 (hoop stress)
μ	=	poisson ration
η	=	coefficient of the height
Ø	=	diameter, wire mesh or reinforcement

ANNEX 4

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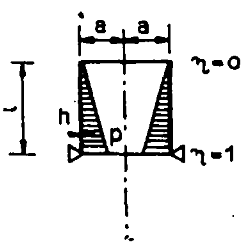
ANNEX 5

Design tabel 1: for "Joint plastic"

In acoordance with:

Markus, "Theorie und Berechnung rotationssymmetrischer Bauwerke by Dr. Gyula Markus"



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

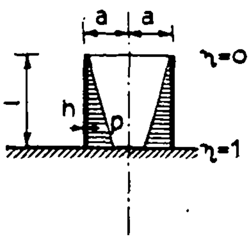
	kl \ η	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
F_N	1	+0,4883	+0,4427	+0,3971	+0,3511	+0,3045	+0,2569	+0,2082	+0,1580	+0,1064	+0,0536	0
	2	+0,3516	+0,3574	+0,3621	+0,3630	+0,3565	+0,3384	+0,3052	+0,2540	+0,1840	+0,0973	0
	3	+0,1123	+0,2037	+0,2931	+0,3754	+0,4424	+0,4837	+0,4877	+0,4435	+0,3439	+0,1905	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

ANNEX 6

Design tabel 2: for "Joint Rigid"

In accordance with:

Markus "Theorie und Berechnung rotationssymmetrischer Bauwerke
by Dr. Gyula Markus



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

	kl \ 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	+0,0995	+0,0875	+0,0754	+0,0634	+0,0514	+0,0395	+0,0281	+0,0176	+0,0087	+0,0024	0
	2	+0,2853	+0,2694	+0,2527	+0,2332	+0,2090	+0,1782	+0,1403	+0,0970	+0,0528	+0,0161	0
	3	+0,1671	+0,2199	+0,2699	+0,3110	+0,3346	+0,3322	+0,2973	+0.2292	+0,1370	+0,0452	0
	4	+0,0349	+0,1426	+0,2480	+0,3448	+0,4219	+0,4640	+0,4541	+0,3799	+0,2449	+0,0867	0
	5	−0,0095	+0,1066	+0,2230	+0,3383	+0,4454	+0,5277	+0,5586	+0,5065	+0,3537	+0,1351	0
	6	−0,0090	+0,0976	+0,2061	+0,3189	+0,4352	+0,5438	+0,6160	+0,6035	+0,4570	+0,1888	0
	7	−0,0024	+0,0987	+0,1991	+0,3050	+0,4186	+0,5374	+0,6398	+0,6712	+0,5498	+0,2460	0
	8	+0,0003	+0,0991	+0,1981	+0,2991	+0,4064	+0,5241	+0,6428	+0,7133	+0,6293	+0,3049	0
$\frac{F_M}{\omega}$	1	0	−0,0002	−0,0008	+0,0003	+0,0023	+0,0064	+0,0131	+0,0232	+0,0373	+0,0560	+0,0800
	2	0	−0,0029	−0,0097	−0,0178	−0,0243	−0,0264	−0,0238	−0,0045	+0,0259	+0,0738	+0,1424
	3	0	−0,0040	−0,0143	−0,0282	−0,0427	−0,0536	−0,0555	−0,0412	−0,0021	+0,0719	+0,1909
	4	0	−0,0018	−0,0075	−0,0177	−0,0319	−0,0478	−0,0600	−0,0581	−0,0256	+0,0591	+0,2194
	5	0	+0,0003	−0,0004	−0,0044	−0,0139	−0,0298	−0,0462	−0,0614	−0,0440	+0,0396	+0,2342
	6	0	+0,0007	+0,0019	+0,0017	−0,0026	−0,0141	−0,0342	−0,0563	−0,0556	+0,0198	+0,2439
	7	0	+0,0003	+0,0013	+0,0025	+0,0020	−0,0040	−0,0203	−0,0465	−0,0606	+0,0017	+0,2509
	8	0	0	+0,0004	+0,0014	+0,0026	+0,0010	−0,0097	−0,0351	−0,0606	−0,0142	+0,2562

ANNEX 7

Steel area and weight reinforcement bars.

bar diameter mm^2	distance c.t.c. in mm							Ø	KG per m'
	50	75	100	150	200	225	250		
Ø 4	250	168	126	84	63	56	50	4	0.009
Ø 4^5	319	213	160	106	80	71	64	4^5	0.125
Ø 5	394	262	196	131	98	88	79	5	0.154
Ø 5^5	475	318	237	159	119	106	95	5^5	0.187
Ø 6	567	377	283	188	141	126	113	6	0.222
Ø 6^5	666	444	333	222	166	148	133	6^5	0.261
Ø 7	772	515	386	258	193	172	155	7	0.303
Ø 7^5	885	592	442	296	221	197	177	7^5	0.348
Ø 8	1004	672	502	336	251	224	201	8	0.395
Ø 8^5	1139	760	569	380	285	254	228	8^5	0.445
Ø 9	1272	850	636	425	318	284	256	9	0.500
Ø 9^5	1423	950	712	475	356	316	285	9^5	0.558
Ø 10	1577	1050	789	525	394	350	315	10	0.617
Ø 10^5	1733	1157	867	578	434	386	348	10^5	0.680
Ø 11	1900	1271	950	635	475	424	382	11	0.746
Ø 11^5	2080	1385	1040	692	520	462	417	11^5	0.815
Ø 12	2262	1509	1131	754	566	504	454	12	0.888
	Steel area reinforcement bars in mm^2								