FERROCEMENT

IWACO B.V.

CONSTRUCTION MANUAL FOR A 10 M^3 RAIN WATER RESERVOIR OF FERROCEMENT

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This manual has been based on the experiences of the Rural Water Supply Project West Java, a project in the framework of the Project Aid Agreement between the Governments of Indonesia and the Netherlands.

May 1982

Government of Indonesia	Government of The Netherlands
Ministry of Public Health	Ministry of Foreign Affairs
Directorate General of	Directorate of International
Communicable Diseases Control	Technical Assistance

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PREFACE

Diverse methods of rainwater harvesting (catchment, collection and storage of rainwater for drinking water) have been used all over the world since ancient times.

In many areas of the world rainwater is still an important source of drinking water today. This is the case in regions where no, or insufficient, potable water sources, such as ground water, springs or surface water, are available. Purification of non-potable water which may be available, or supply of drinking water from outside the area (through long distance pipelines), may be solutions for such areas. The necessary installations, however, are technically complex, require heavy investments and are expensive to operate and maintain. They are therefore not yet utilized in many places, particularly not in rural areas in developing countries. In these areas rainwater is often still the only source of drinking water.

A rainwater harvesting system (RHS) includes provisions for catchment, collection and storage of rainwater. This involves certain inevitable costs. Storage is needed to "tide-over" periods with insufficient rainfall (the so-called "dry periods"). Particularly in areas with long dry periods, where a large storage capacity is needed, costs may be substantially increased by the necessity for large reservoirs etc.. High costs prevent large scale application of these systems, and costs must therefore be reduced wherever possible. This is particularly important for rural areas in developing countries.

A substantial cost reduction can be realized if existing roofs (of houses, schools, etc.) are utilized as catchment areas.

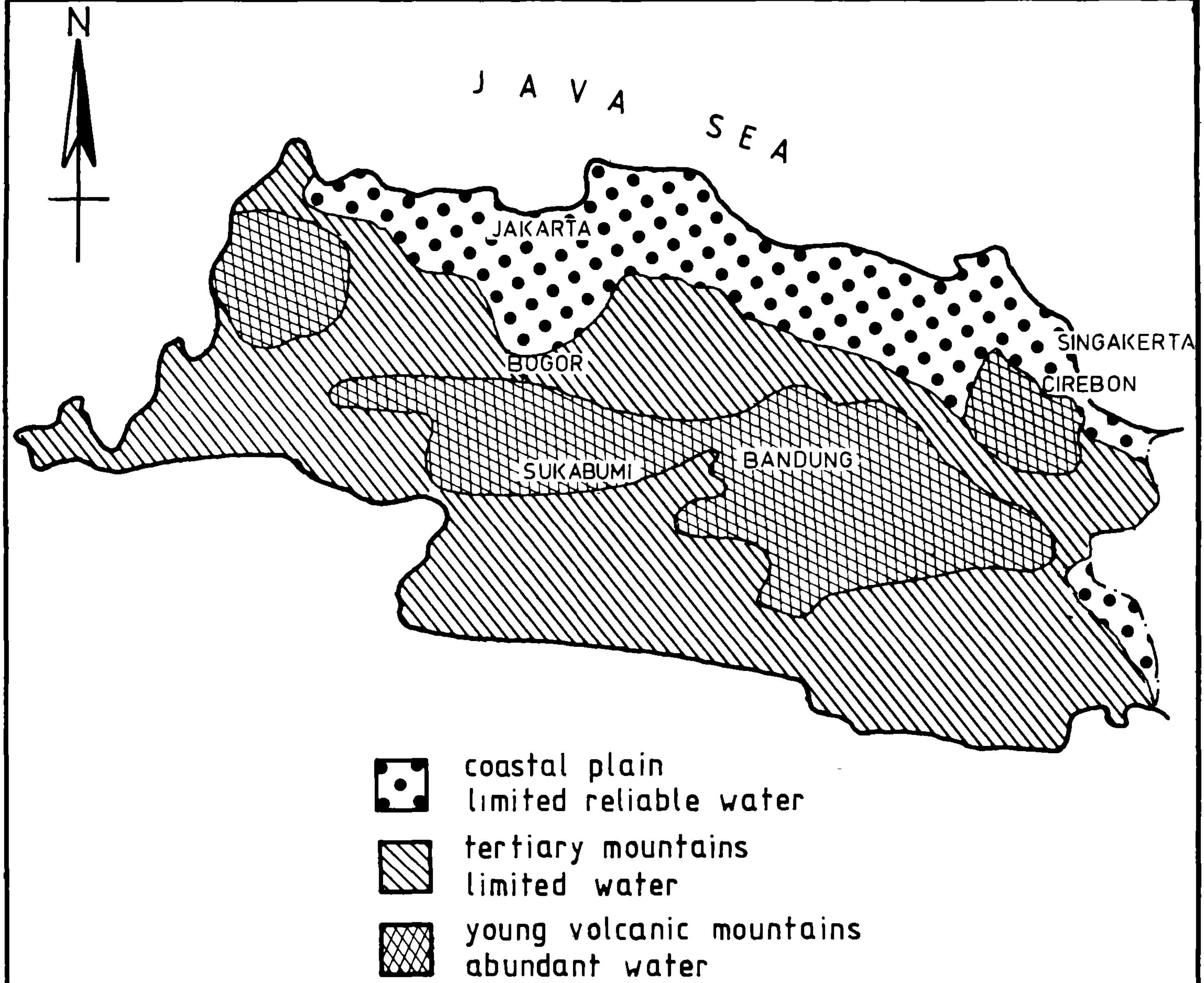
A further reduction of the cost can be obtained if an RHS is additional to other water sources. For example, in

regions with sufficient, slightly brackish groundwater or surface water not suitable for drinking without prior treatment, rainwater can be utilized for human consumption only (drinking and cooking.) Water for other purposes (washing, bathing, etc.,) which may be of a lower quality, can then be taken from the other sources . However, in areas without any other water sources, rain must serve as the source of water for all purposes.

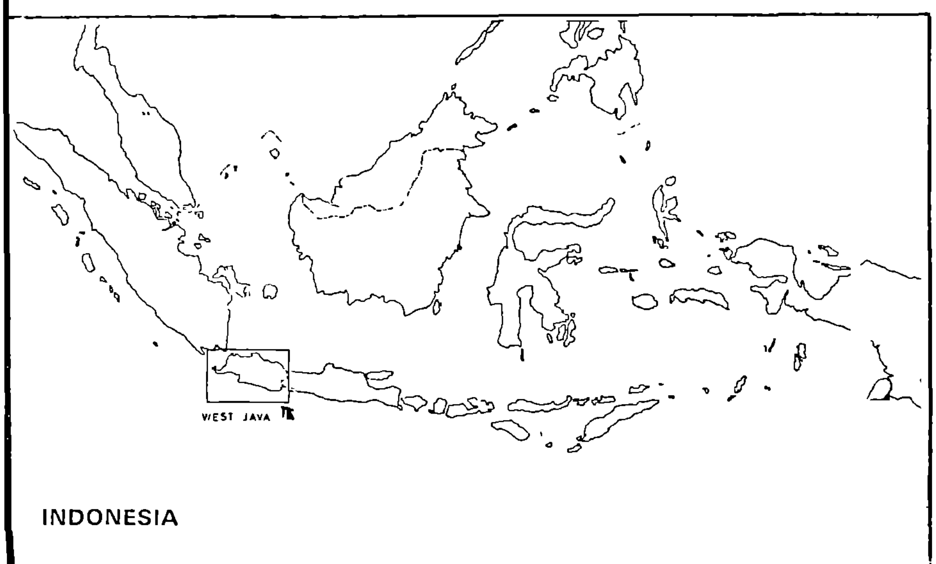
Apart from the required consumption level (litres per capita per day) and the number of consumers to be served, the sizes of the required catchment area and roof surface are heavily dependent on the rainfall pattern. Given a specific rainfall pattern, there is, however, a certain freedom of choice in selection of the size of the catchment area and storage reservoir. In the IWACO report "Rainwater harvesting for domestic and community water supply", a design method for arriving at the optimal (cheapest) combination of catchment area and reservoir capacity has been presented. The prerequisites for use of this method are a series of monthly rainfall data and a selected consumption level. When using existing roofs, the smallest reservoir will usually result in the lowest costs for the total system.

A further cost reduction can be realized by using cheap construction materials and techniques, particularly for the reservoir construction. In the framework of the IWACO Project "Rural Water Supply Project West Java", a pilot project has been carried out to investigate various construction materials and methods.

For this purpose a number of reservoirs of various sizes have been constructed in a pilot scheme in desa Singakerta (see map.) The prototypes have been tested on their mechanical-physical properties, the local availability and prices of the materials, and on the possibilities of involving the local people in the construction of the reservoir (see reference 8.)



Map of WEST JAVA



One of the materials which has been tested in this pilot scheme is ferrocement. Ferrocement is a thin-walled type of reinforced concrete in which a hydraulic mortar is reinforced with layers of small diameter mesh. The mechanical-physical properties of ferrocement make this material particularly suitable for the construction of cylindrical reservoirs. Moreover, the costs of ferrocement constructions are much lower than those of similar constructions in ordinary concrete. The method of construction of these reservoirs is simple, easy to learn, and can be carried out with simple equipment.

This instruction manual has been prepared to help stimulate the introduction of ferrocement reservoirs. The steps in the construction procedure have been presented in sequence and many figures and photographs have been provided to support the written text. However, it is felt that there will inevitably be gaps in the instructions, and it is recommended that builders build the first reservoir under the supervision of an experienced builder.

The preparation of the manual has been made possible by the co-operation of the people of Singakerta and many others. We hope that it will come up to expectations and contribute to the availability of potable water in areas where it does not yet exist.

1. INTRODUCTION.

A rainwater harvesting system includes both provisions for catchment (roof surfaces), collection and storage (reservoir) of rainwater (Chapter 2).

For the rainfall pattern in the pilot project area (desa Singakerta, Kecamatan Krangkeng, Kabupaten Indramayu, West Java, Indonesia), an RHS was designed with the design method which is presented in reference 9.
It was ascertained that for the rainfall distribution in the pilot area, a rainwater reservoir of 10 m3 and a roof surface of 40 m2 were suitable.

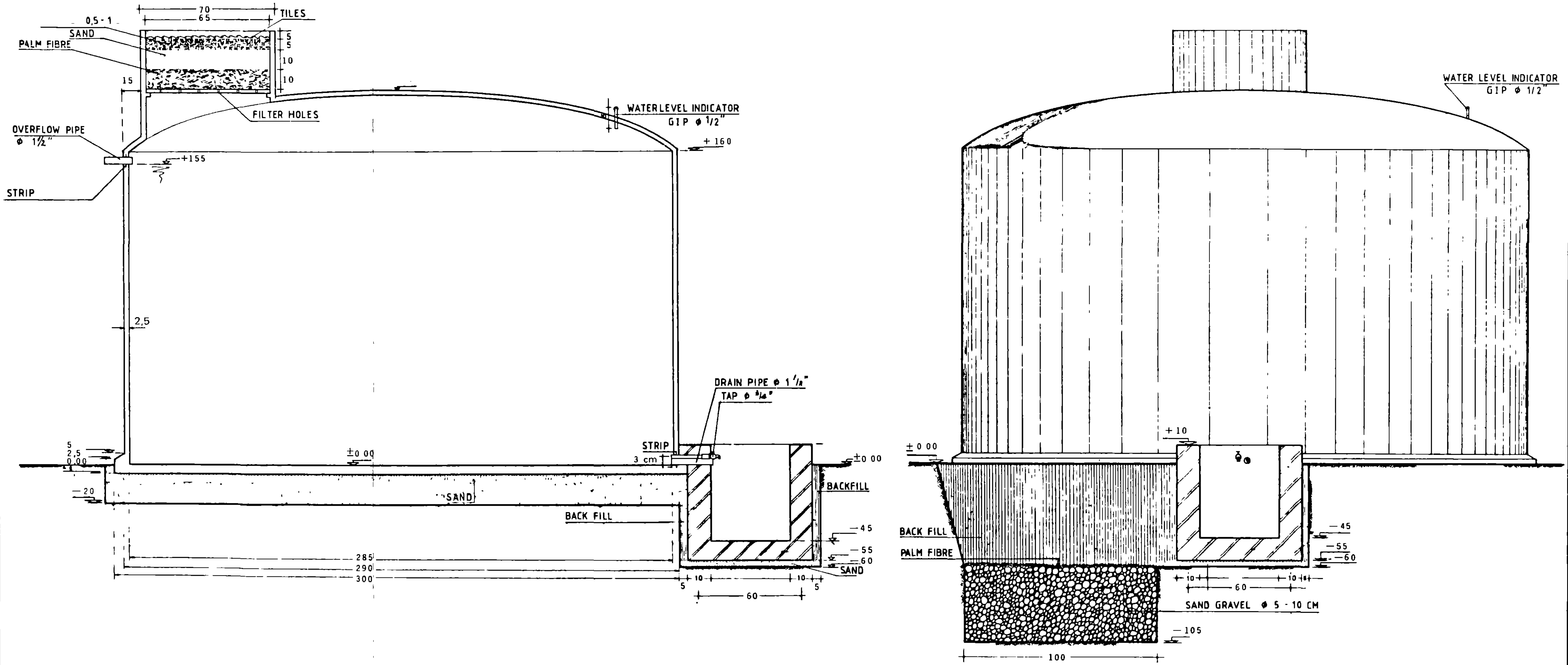
The rainwater system was constructed utilizing an existing roof and a ferrocement reservoir. This was found to be effective. About 20 people (approximately 4 families) could be supplied with at least 5 litres per person per day.

In this manual we describe the construction of the 10 m3 ferrocement reservoir, as used in the pilot scheme. The drawings for the construction of this design (figure 1) form the basis for the manual. A complete review of the construction and completion of the reservoir is given, including a survey of the materials (Chapter 5) and tools (Chapter 6) required. The sequence and duration of the various steps are schematically represented in Chapter 7.1. with reference to the chapter concerned.
Criteria for selection of a suitable roof surface and building site are also discussed (Chapters 3 and 4).

A brief consideration of the material ferrocement is given in Annex 1.

How the design of the reservoir was formulated is briefly discussed in Annex 2.

Finally a list of relevant literature about ferrocement and its applications is given in Annex 3.



NOTE.

- MEASUREMENTS IN CM

GOVERNMENT OF INDONESIA

MINISTRY OF HEALTH
DIRECTORATE OF HYGIENE AND SANITATION

WEST JAVA RURAL WATER SUPPLY PROJECT

PROJECT OFFICE JALAN SEDERHANA 7 – BANDUNG P O BOX 59

Rain water Collector
of ferrocement

DRAWN RODIONO	SCALE 1 : 10	REVISIONS	FIG NR
DATE 16 JAN 80	APPR	1	1
CONSULTANT IWACO B.V.	INTERNATIONAL WATER SUPPLY CONSULTANTS BOX 183 ROTTERDAM	2	
		3	

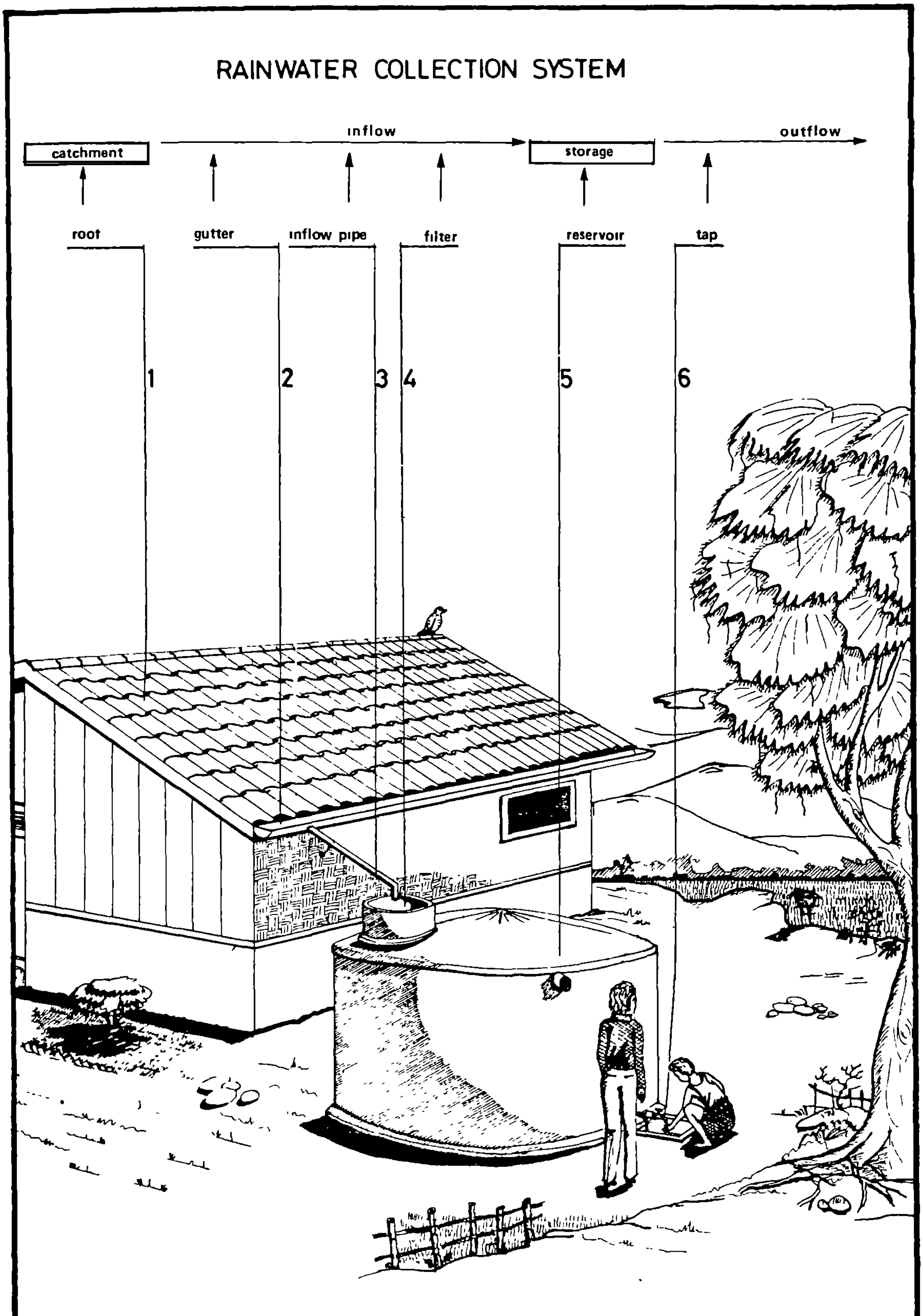


FIGURE 2.
PRINCIPLE OF A RAIN WATER HARVESTING SYSTEM.

Radiyono

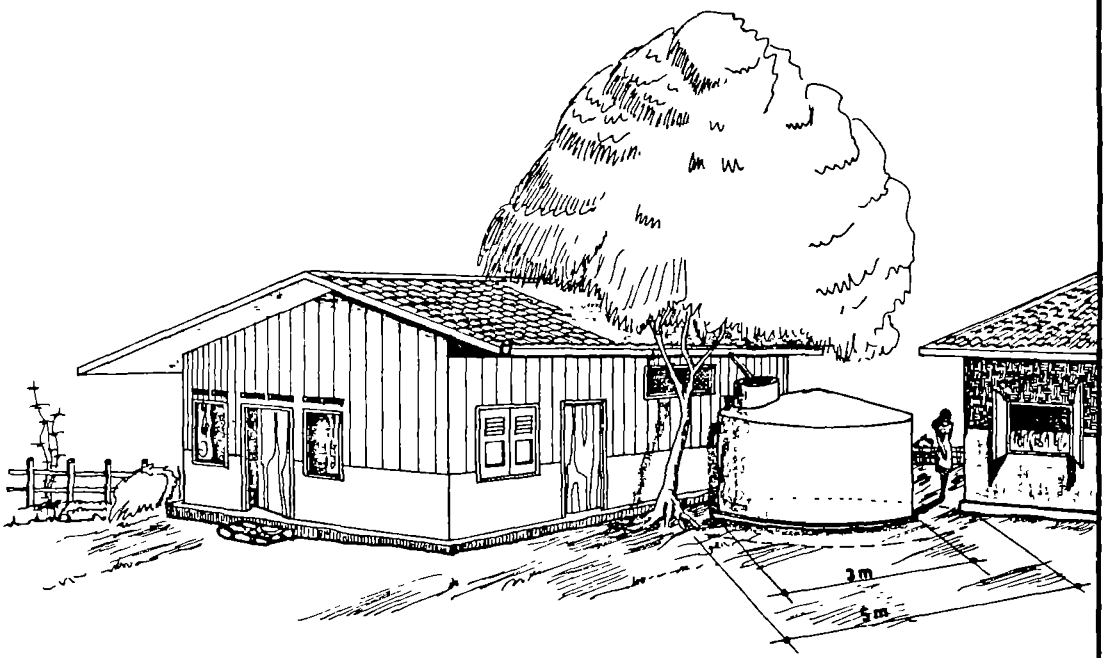
2. THE WORKING OF A RAINWATER SUPPLY SYSTEM.

The collection of rainwater for water supply involves not only the collection of rainwater, but also the storage of this water in a reservoir.

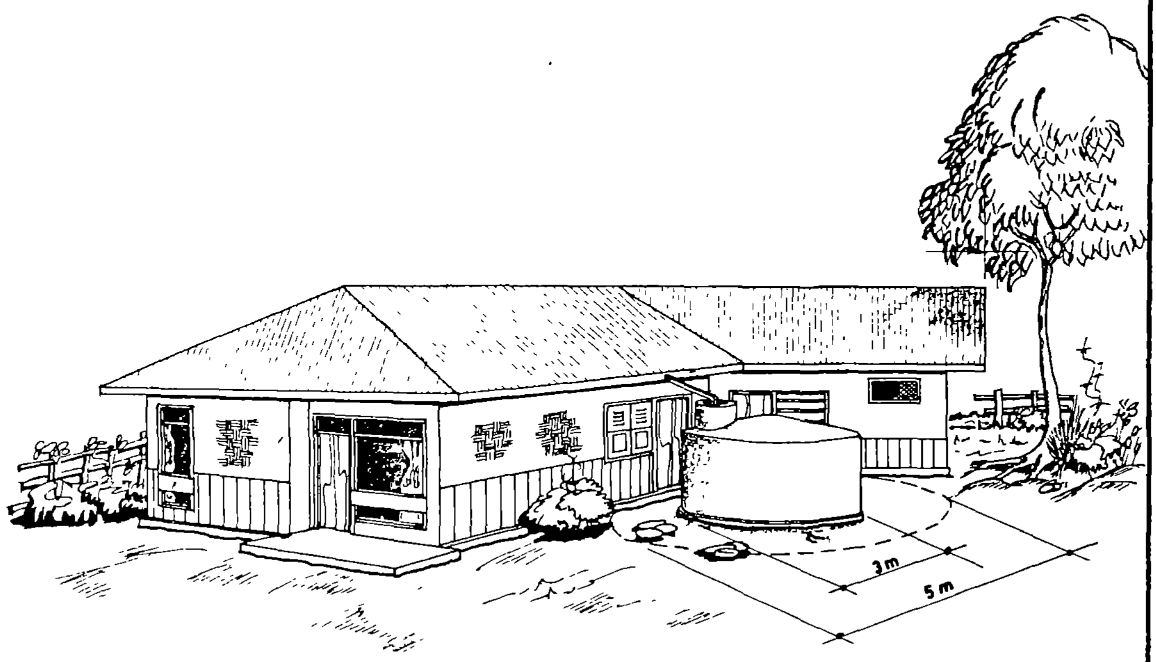
Water for consumption is then tapped from this reservoir.

A rainwater harvesting system therefore consists of the following parts (see figure 2):

1. catchment area or collection surface:	in many cases an existing roof can be used;
2. gutter or gutters:	for the collection of the rainwater;
3. inflow pipe:	for transfer of the rainwater to the reservoir;
4. filter:	for filtration to remove pollutants;
5. reservoir:	for storage during periods of insufficient rainfall;
6. tap:	for tapping of the water from the reservoir.



a) TREE OVERHANGING THE ROOF.



b)

FIGURE 3. SELECTION OF ROOF

3. CRITERIA FOR SELECTION OF A ROOF FOR USE AS A CATCHMENT AREA.

For the selection of a suitable roof as a catchment area the following criteria are of importance:

1. Approximately 40 m^2 of roof surface is required.

2. The roofing material should for preference be tile, slate or corrugated plates of aluminium or galvanized iron, preferably not asbestos cement.
   Under no circumstances may thatched roofs, or roof coverings in which lead is used, be utilized as collection surfaces.

3. The entire roof surface to be utilized should be exposed to the rain, that is, no trees or other obstacles should overhang it (see figure 3a).

4. The roof construction and roofing material should be in good condition. The roof edge should be strong enough for the attachment of gutters.

5. The roof edge should be situated at least 2.50 metres above the ground.

6. The roof surface should be and remain as free as possible from the excrement of birds or other pollutants. That is, a roof which birds regularly use for shelter at night is not suitable, although a scarecrow can be used, if necessary (see also Chapter 8).

4. THE SELECTION OF A SUITABLE LOCATION FOR THE RESERVOIR.

For the selection of a suitable location for the reservoir, the following criteria should be adopted:"

1. The external diameter of the reservoir is 3.10 m. A flat area of ground of a diameter of approximately 5 metres (see figure 3) is therefore required as a building site.

2. The distance of the reservoir from the roof gutter should be as short as possible (1 to 2 metres).

3. The reservoir should preferably not , be constructed in a place where it receives full sun.

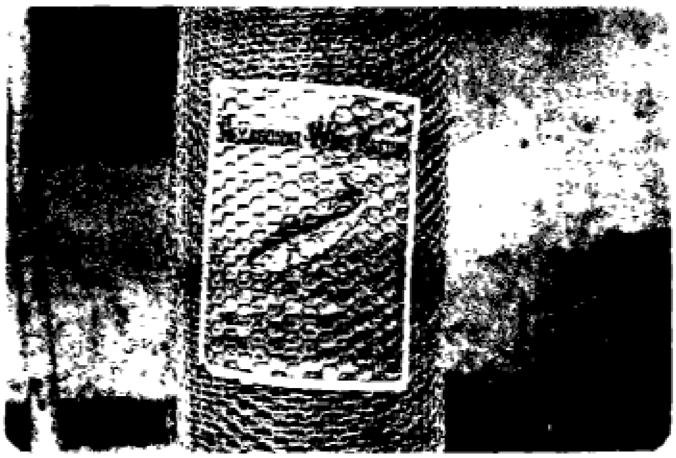


PHOTO 1: CHICKEN WIRE

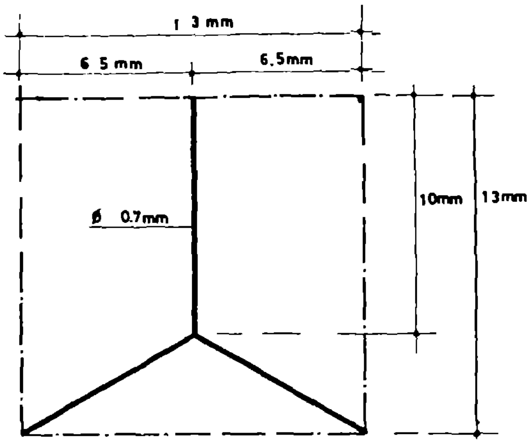


FIGURE 4:
REPEATED SECTION OF THE CHICKEN WIRE.

PHOTO 2:

IRON WIRE Ø 5 mm.

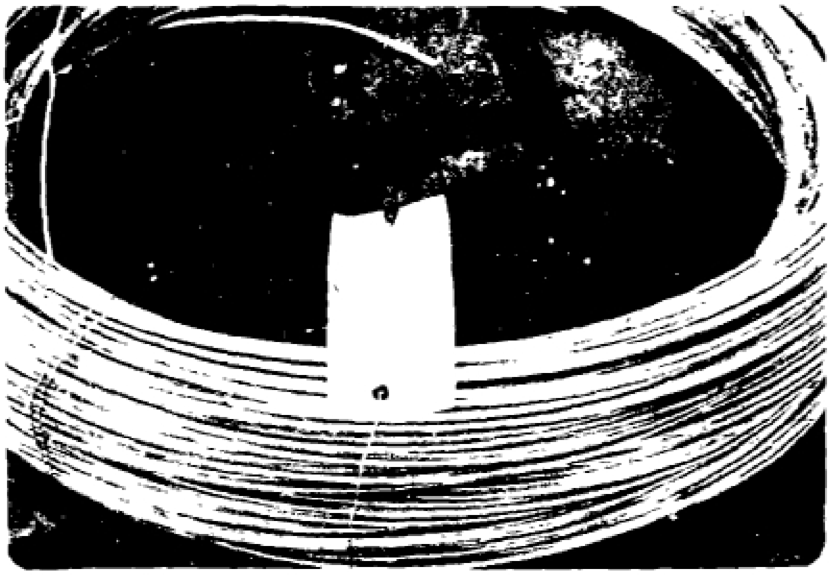
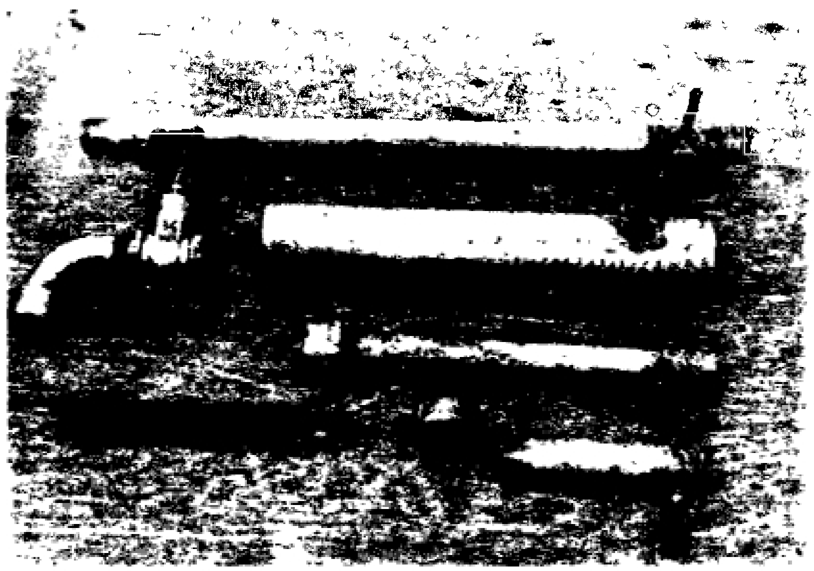


PHOTO 3:
PIPEWORK.
(Galvanized steel = G.S.)



5. LIST OF MATERIALS REQUIRED.

Nr.	Material	Unit	Quantity
01	Cement	bag(40 kg)	18
02*	Clean sand Ø 2.5 mm	m3	1.4
03	Iron-(binding) wire Ø 0,65 mm	kg	2
04*	Galvanized chicken-wire (see photo 1 and figure 4) (1,00 m wide)	m	50
05*	Iron-wire Ø 5 mm (see photo 2)	kg	74
06	Overflow pipe G.S. Ø 1½ inch (see photo 3)	m	0.20
07	Drain-pipe G.S. Ø 1½ inch length 20 cm + 1 cap (see photo 3)	set	1
08	Pipe leading to tap G.S. Ø 3/4 inch length 45 cm + 1 shut-off valve 1/4 inch + 1 G.S. bend 90" Ø 1/4 inch (see photo 3)	set	1
09	Pipe end length 10 cm Ø ½ inch with cap for measurement of the water level	set	1
10	Galvanized iron plate. (ZINC) thickness 0.65 mm (0.90 x 1.80 m)	piece	4
11	Soldering tin	kg	0.3
12	Palm fibre or similar material	kg	2.5

Important:

- * The chicken-wire and iron-wire should be free from oil and grease.
- * The sand should be free from organic and chemical components. It should be washed with clean water.(i.e. water with no impurities such as clay, loam, acids and organic substances).

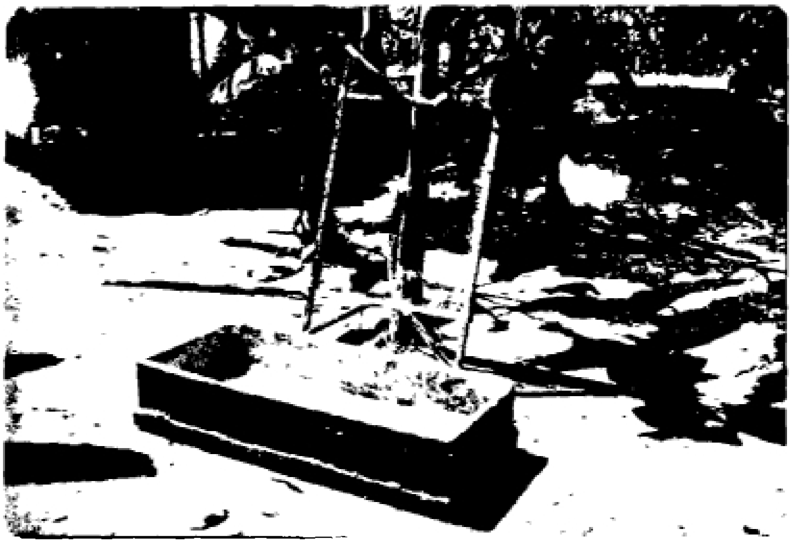
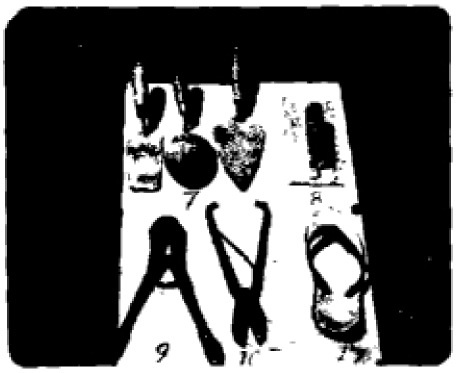


PHOTO 4:

MIX TRUNK AND SAND SCREEN.



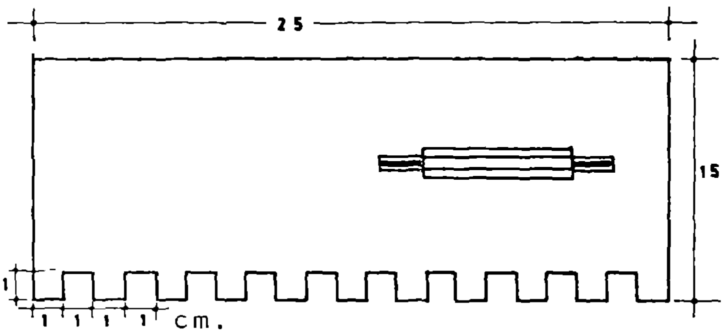


FIGURE 5: TROWEL.

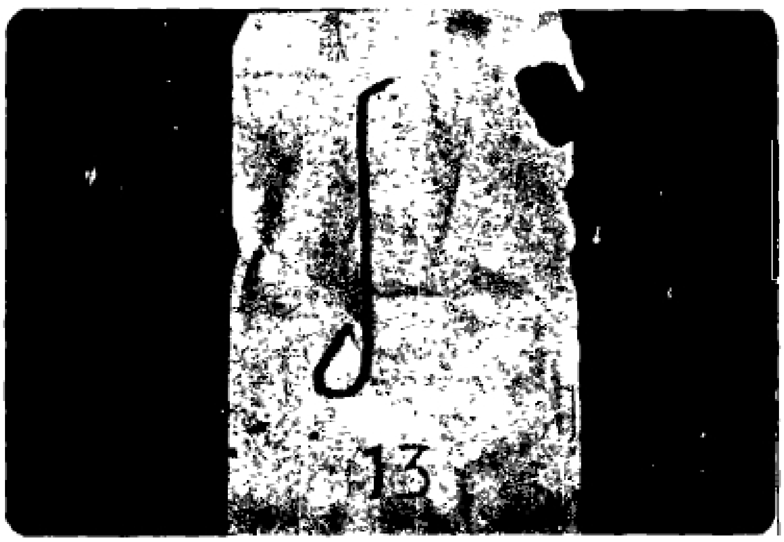


PHOTO 6:

"NUT"

6. TOOLS AND OTHER EXPEDIENTS REQUIRED.

6.1. LIST OF TOOLS AND EXPEDIENTS.

Nr.	Description	Unit	Quantity
01	Mould (see 6.3.)	piece	1
02	Sieve with a mesh size of Ø 2.5 mm (photo 4)	piece	1
03	Mixing trough for mortar (70 x 120 x 35 cm)	piece	1
04	Motor pump complete with flexible tubes (for the rinsing of sand and the filling of tanks)	piece	1
05	Spade	piece	1
06	Shovel	piece	1
07	Trowels (photo 5)	piece	3
08	Toothed scoop (photo 5 and figure 5)	piece	2
09	Iron cutters (photo 5)	piece	1
10	Galvanized iron cutters (photo 5)	piece	1
11	Bucket - galvanized iron	piece	3
	Bucket - plastic	piece	1
12	Pincers or similar	piece	3
13	Tool, (for the purposes of this manual termed a "nut") to connect the pieces of chicken-wire to each other (photo 6)	piece	3
14	Hammer	piece	1
15	Hand drilling machine	piece	1
16	Metal hack-saw	piece	1
17	Rubber slipper (photo 5)	piece	2

6.2. LIST OF MATERIALS.

Nr.	Material	Unit	Quantity
18	Clean oil drum.	piece	1
19	Plastic brush	piece	2
20	Plastic film (width 2.35 m)	m	10
21	Soldering-iron + tin	piece	3
22	Plaited bamboo mat 3 x 3 m	piece	1
23	Bamboo poles 1,85 m in length	piece	25
24	Brick 22 x 11 x 5 cm	piece	50
25	Wooden or plastic hammer	piece	2
26	Steel chisel	piece	1

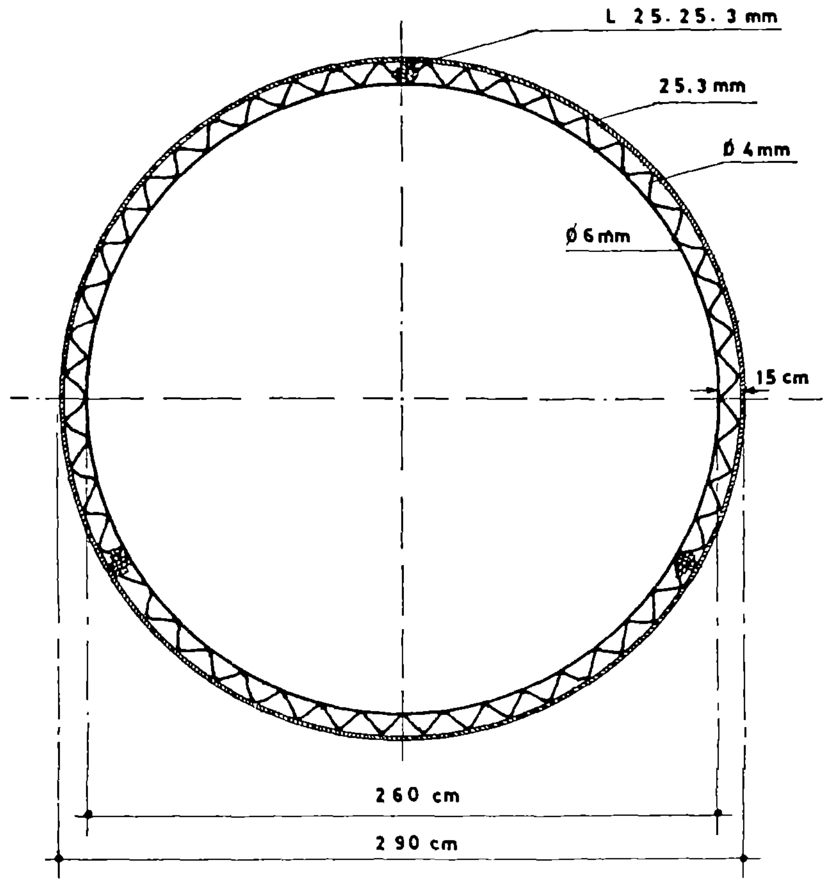


FIGURE 6: STEEL RING.

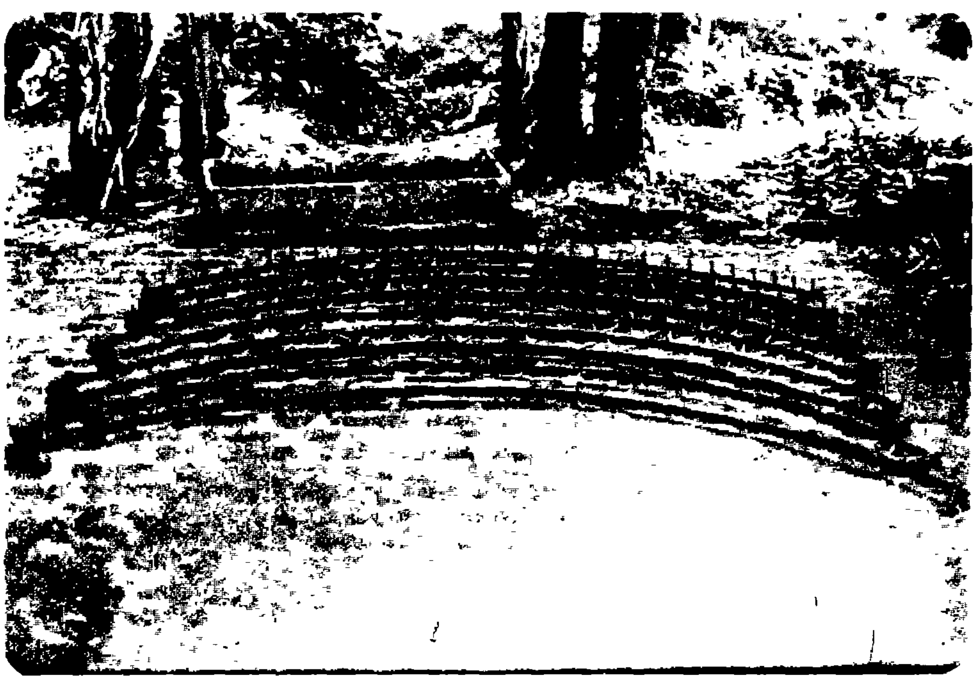


PHOTO 7: NINE RING SEGMENTS.

6.3. THE MOULD.

Photo No.

6.3.1. Description.

The mould consists of 3 steel rings (figure 6) which are covered with plates of plywood.

The steel rings are dismountable and each consists of three segments.

The ring segments are constructed in a workshop. 7

One of the rings (3 segments) is provided with steel pins, because this ring is also used for the twisting of the floor reinforcement (figure 7).

6.3.2. Materials required for the construction of the mould.

Nr.	Description	Unit	Quantity
01	Steel strip 25 x 3 cm	metre	30
02	Iron-wire Ø 4 mm	metre	72
03	Iron-wire Ø 6 mm	metre	30
04	Angle-iron 150 x 25 x 25 m thickness 3 mm	piece	18
05	Bolts and nuts Ø 6 mm length of bolt 2 cm	piece	18
06	Steel pins Ø 9 mm length 8 cm	piece	96
07	Plywood thickness 3 mm, 60 x 120 cm	piece	9

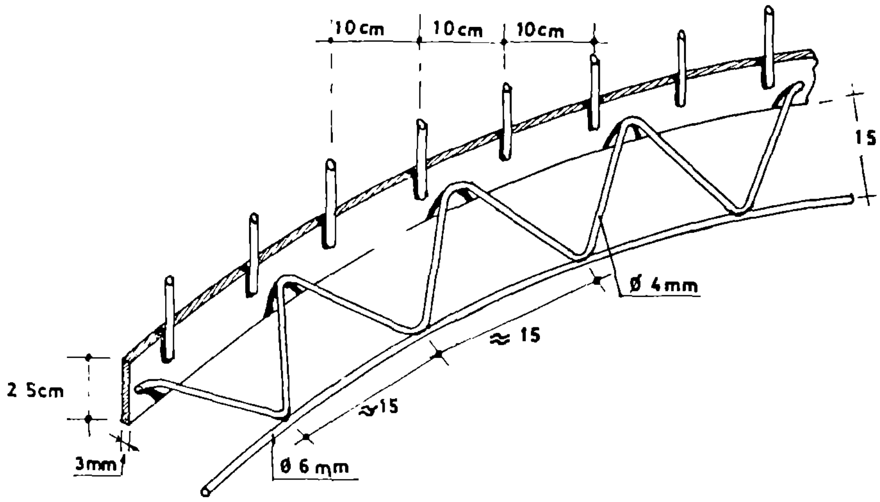


FIGURE 7: DETAIL OF RING SEGMENT WITH STEEL PINS.

PHOTO 8: PAIR OF ANGLE IRONS

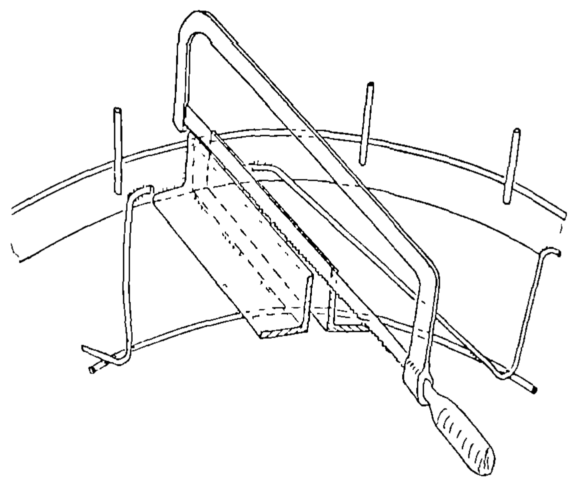


FIGURE 8: SAWING OF THE STEEL RING BETWEEN THE ANGLE IRONS.

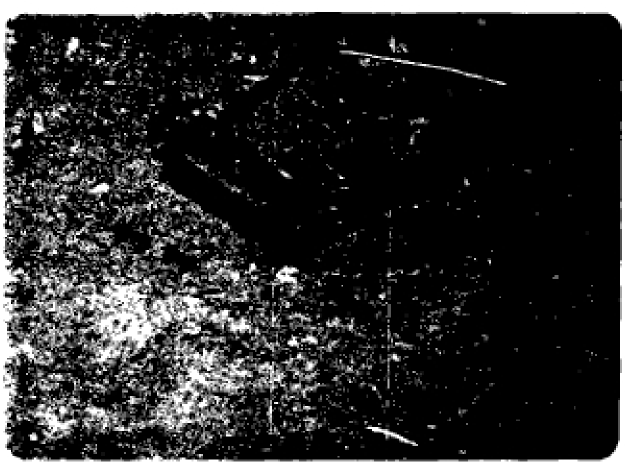


PHOTO 9: DETAIL OF FINISHED RING SEGMENT.

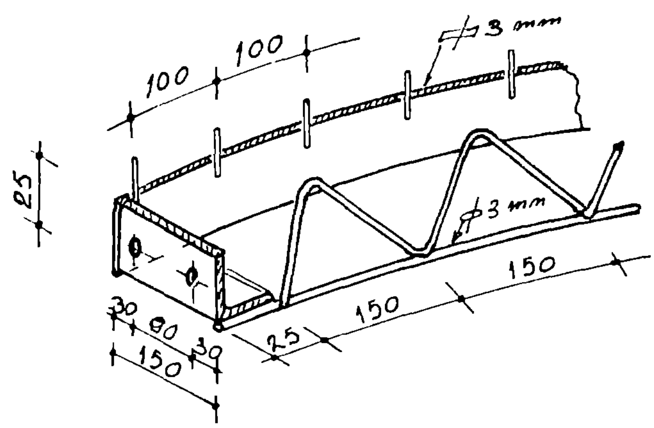


FIGURE 9

6.3.3. Construction of the steel rings for the mould.

Photo Nr.

a. The steel strip (25 x 3 mm) is bent to form a circle of diameter 2.90 cm, after which the ends are welded together.

b. A length of iron-wire (Ø 4 mm) is bent into a zigzag form (see figure 7); a length of iron-wire (Ø 6 mm) is bent to form a circle of diameter 260 cm and the ends are welded together.

c. The zigzag iron-wire (Ø 4 mm) is then welded between the circular steel strip and the circular iron-wire (Ø 6 mm) as shown in figure 7.

d. Six angle-irons (150 x 25 x 25 mm; thickness 3 mm) are attached to each other in pairs with three bolts and nuts. The three pairs of angle-irons are then placed on the iron-wire with one of the cross cut sides against the steel strip, and welded. The bolts are 8
then loosened and the steel ring (angle-iron and iron-wire) is sawn through between both angle-irons (see figure 8).

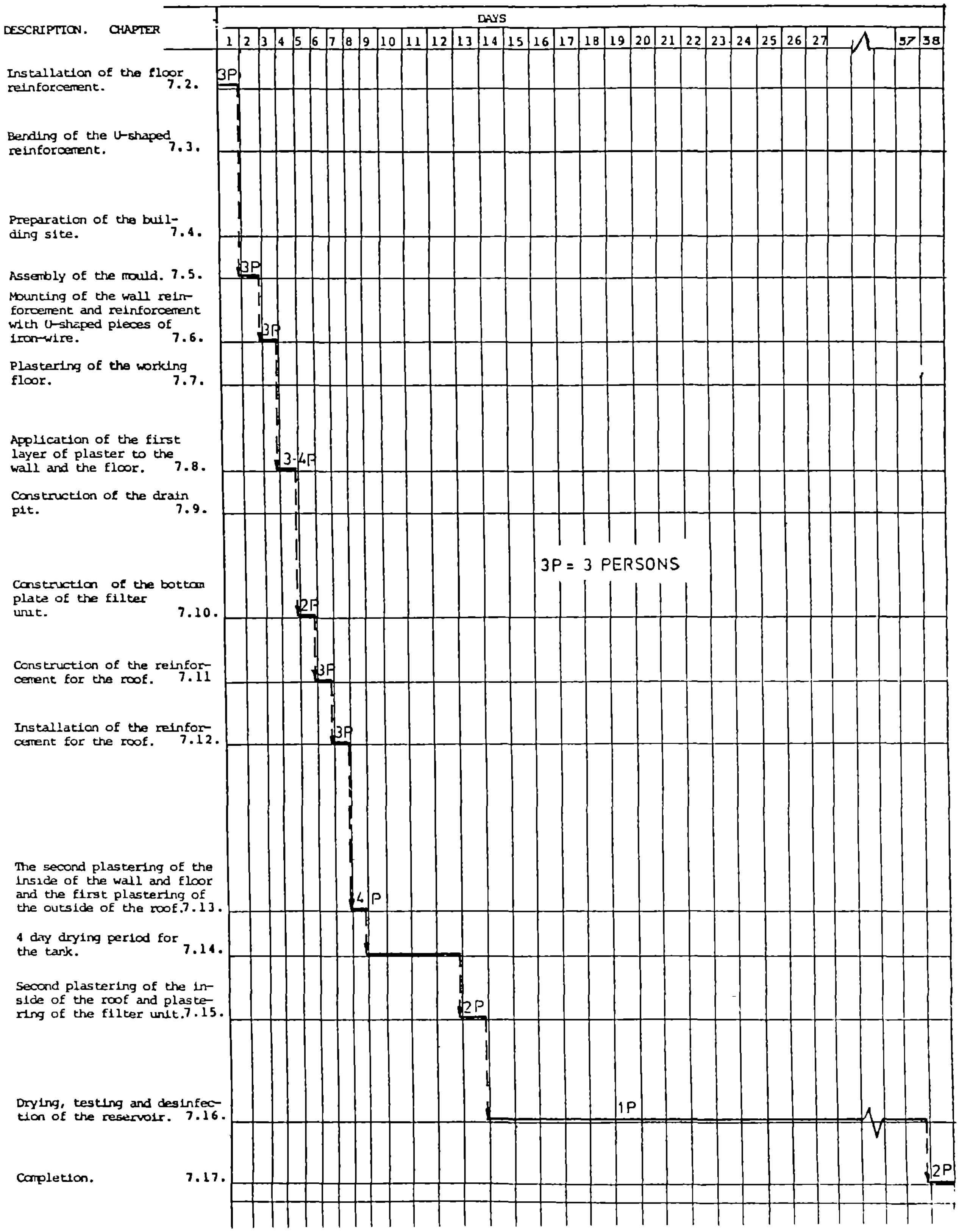
e. In this way, three segments are produced. The two angle-irons which form the connection between two segments are marked for identification and matching during mounting of the ring.

f. The rings are painted with minium (paint containing red lead) and each of them is 9
painted a different colour.

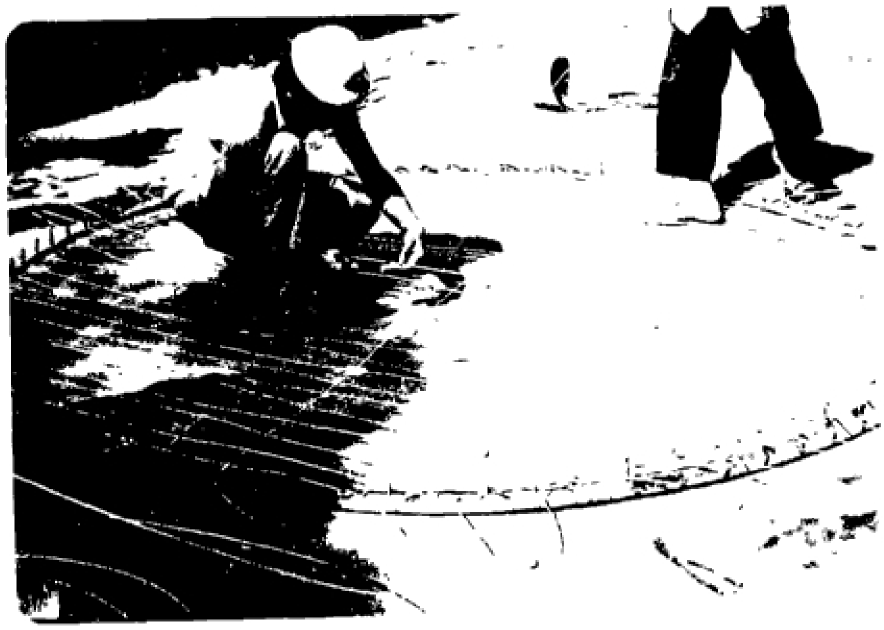
g. One of the rings is provided with steel pins (diameter 9 mm and length 8 cm), which are welded at 10 cm intervals on the inside of 8
the steel strip (see figures 7 and 9).

7. CONSTRUCTION OF THE RESERVOIR.

7.1. TIME SCHEDULE OF THE CONSTRUCTION.



INSTALLATION OF THE FLOOR REINFORCEMENT.



THE SECOND LAYER IS WOVEN BETWEEN THE FIRST LAYER.

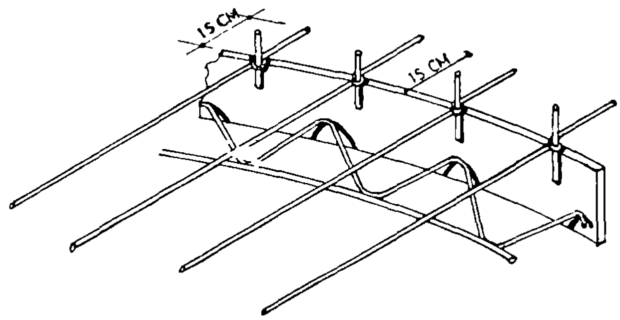


FIGURE 10: THE ENDS ARE ATTACHED AROUND THE STEEL PINS

PHOTO 12.

EVERY SECOND CROSSING IS TIED WITH IRON WIRE.

7.2. INSTALLATION OF THE FLOOR REINFORCEMENT.

		Photo Nr.
7.2.1.	The ring which has been fitted with steel pins is assembled and placed on the ground.	
7.2.2.	The first layer of reinforcement (galvanized iron-wire Ø 5 mm) has been placed in position in the ring between the steel pins, as shown in figure 10.	10,11
7.2.3.	The second layer of reinforcement is now woven between the first layer, and the ends are attached with a noose round the steel pins.	10,11
7.2.4.	At every second crossing, the reinforcement wires are tied to each other with iron-wire.	12
7.2.5.	The reinforcement net is then lifted out of the steel ring. An extra wire is intertwined at the four sides of the net.	13

INSTALLATION OF THE FLOOR REINFORCEMENT.

PHOTO 13: AN EXTRA WIRE INTERTWINED.

<u>BENDING OF THE U-SHAPED REINFORCEMENT.</u>

PHOTO 14:
EACH PIECE OF IRON WIRE IS BENT INTO A U-SHAPE.

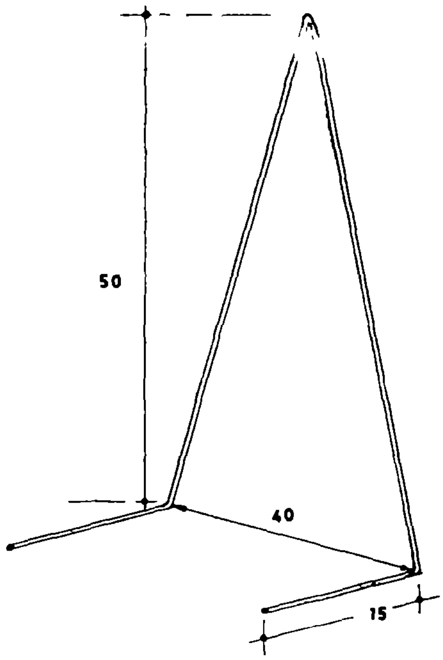


FIGURE 11:
U-SHAPED REINFORCEMENT.

7.3. BENDING OF THE U-SHAPED REINFORCEMENT.

Photo Nr.

7.3.1. 45 pieces of iron-wire Ø 5 mm are cut into 130 cm lengths.

7.3.2. Each piece of iron-wire is then bent into the shape indicated in figure 11. 14

The bending is carried out as follows:

- 3 nails are driven into a piece of plywood so as to form an isosceles triangle with a base of 40 cm and legs of 50 cm.

- The middle of the piece of iron-wire is laid against the nail which forms the top of the triangle. The iron-wire is then bent in the direction of the nails forming the base of the triangle.

- The parts of the iron-wire protruding below the base nails are bent perpendicularly upwards (see figure 11).

PREPARATION OF THE BUILDING SITE.

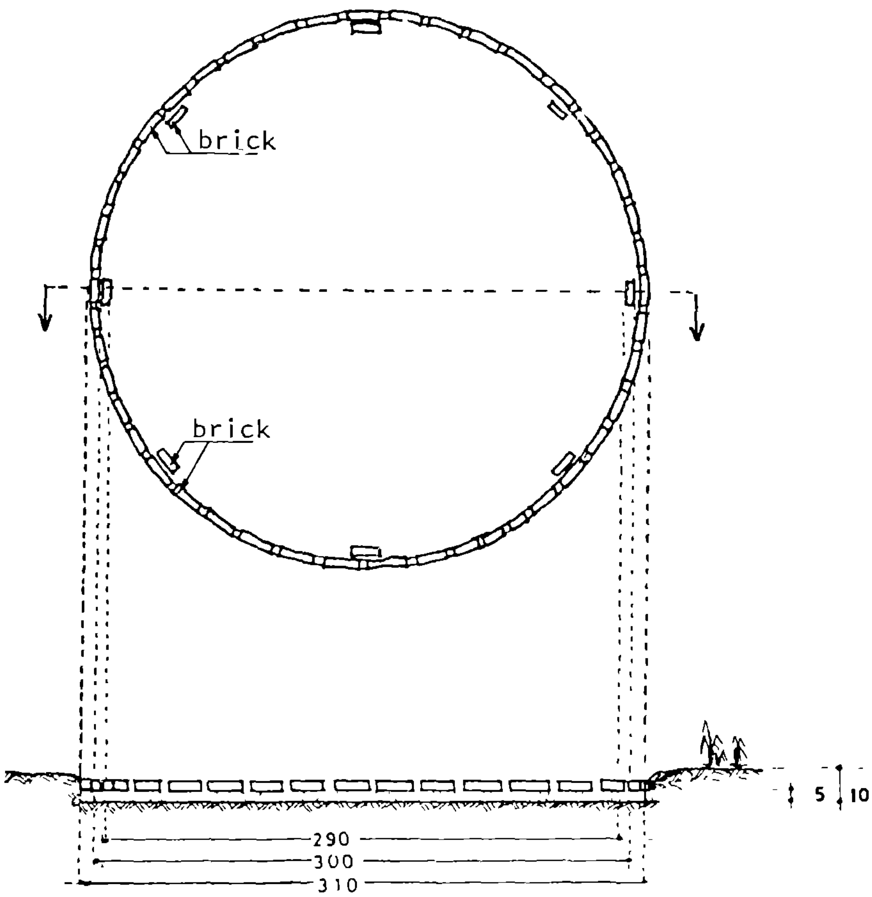


FIGURE 12:
DEMENSIONS OF THE BUILDING SITE.

PHOTO 15: THE PREPARED BUILDING SITE.

7.4. PREPARATION OF THE BUILDING SITE.

Photo Nr.

7.4.1. A flat area of ground with a diameter of 5 m is required for the location of the reservoir.

7.4.2. After the chosen area has been cleared, a circle of diameter 3,10 m is drawn on the ground as follows:

- a nail or piece of wood is driven into the ground at the approximate centre of the circle and a wire is fastened to it. A nail or a pointed piece of wood is fastened to the wire at a length of 155 cm from the centre. A circle is drawn on the ground with the nail or piece of wood.

7.4.3. The earth within this circle is then excavated to a depth of 10 cm. 15

7.4.4. Bricks, with a thickness of 5 cm, are then placed against the edge inside the excavated area (see figure 12). 15

7.4.5. Sand is then placed in the excavated area. It is spread out, rammed in and watered to give a layer of 5 cm.

7.4.6. 8 bricks are placed at equal distances from each other against the bricks previously placed in the excavated area (see figure 12). 15

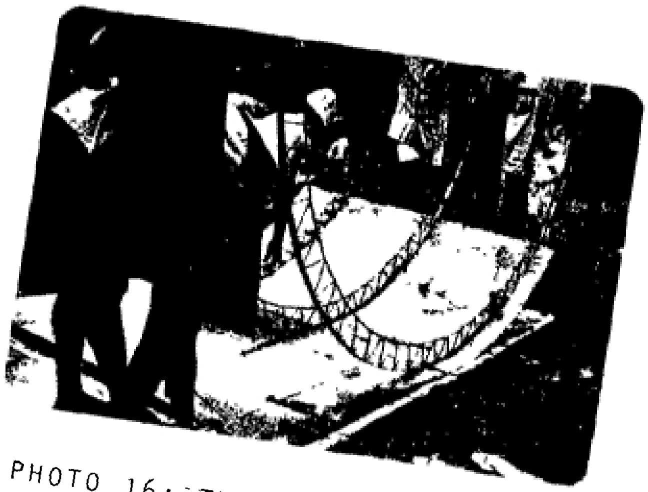


PHOTO 16: THREE STEEL RINGS ARE LAID VERTICALLY ON THE PLAYWOOD SHEET.

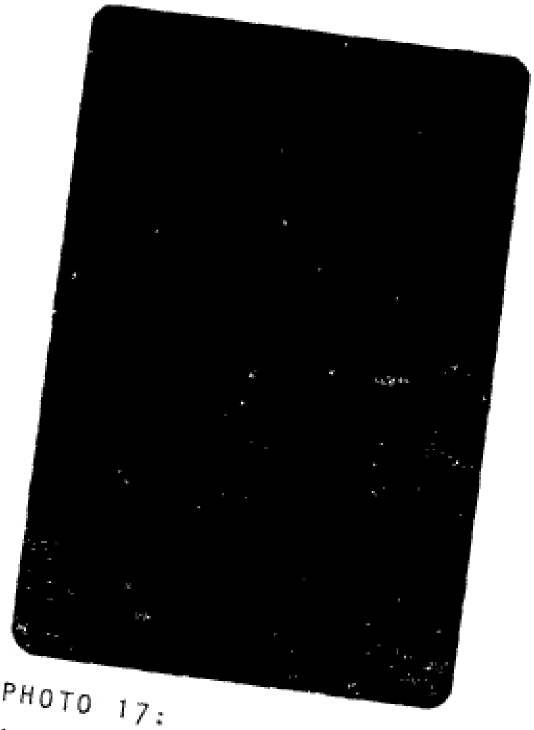


PHOTO 17:
AND FASTENED WITH IRON WIRE.

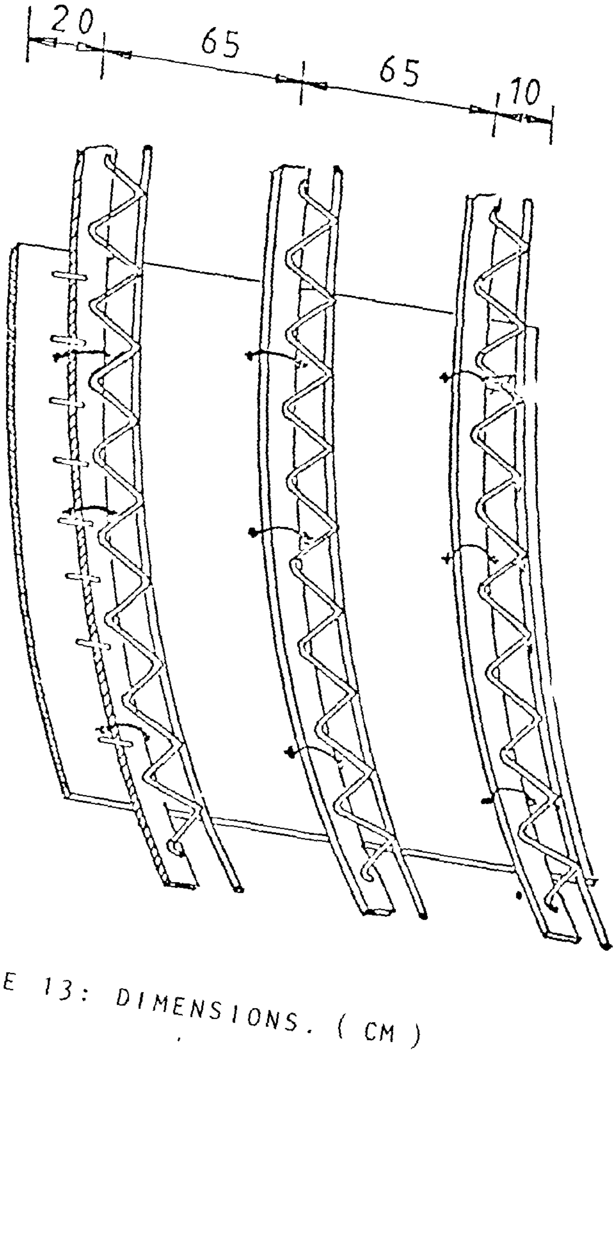


FIGURE 13: DIMENSIONS. (CM)

PHOTO 18:

EXPANSION SPACE OF 3 TO 5 mm
BETWEEN THE PLYWOOD SHEETS.

PHOTO 19:
THE THREE STEEL RING COVERED WITH PLYWOOD.

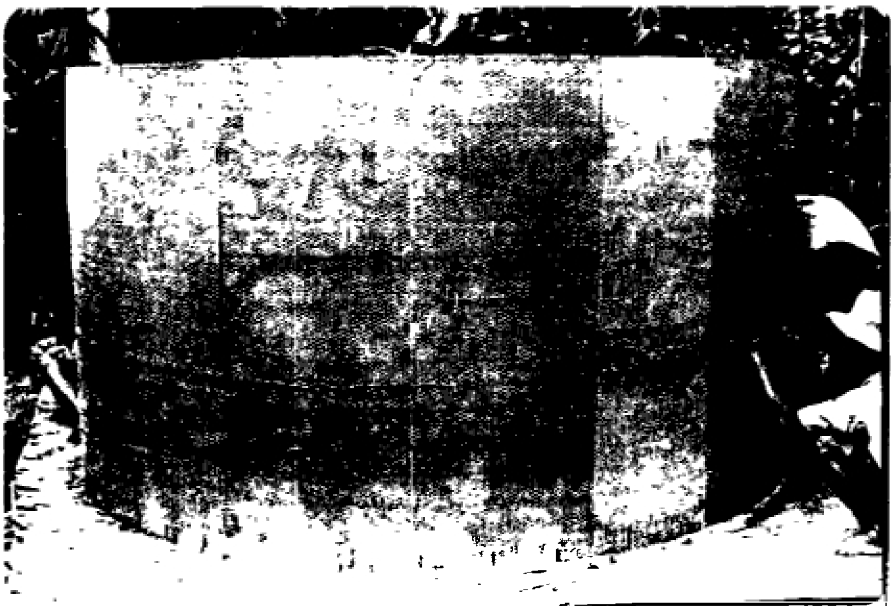
7.5. ASSEMBLY OF THE MOULD.

		Photo Nr.
7.5.1.	The ring segments are assembled to form the three rings.	
7.5.2.	The plywood sheets are laid on the ground.	16
7.5.3.	The three steel rings are laid vertically on the first plywood sheet with the ring fitted with steel pins being uppermost when the mould is later vertically placed. (see figure 13).	16,17
7.5.4.	The first plywood sheet is fastened to the three rings with iron-wire in 4 places. (see figure 13).	17
7.5.5.	After the first sheet of plywood has been attached to the rings, the rings are rolled until they come to stand on the second sheet of plywood.	16
7.5.6.	The second sheet of plywood is fastened to the rings in the same way.	
7.5.7.	This procedure is repeated until the rings are entirely covered with plywood sheets.	19
7.5.8.	<u>It is important to keep an expansion space of 3 to 5 mm between the plywood sheets.</u>	18

MOUNTING OF THE WALL REINFORCEMENT.

PHOTO 20:

THE CHICKEN WIRE IS CUT INTO 2 PIECES.



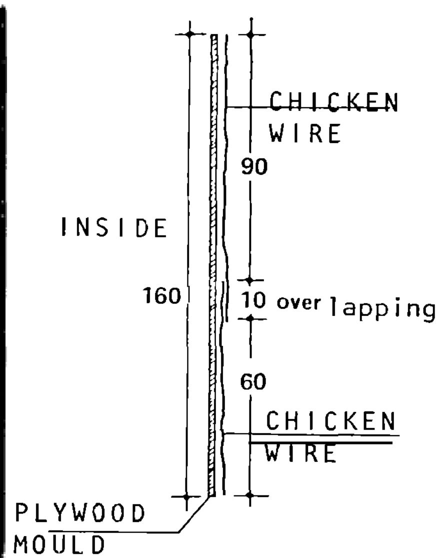


FIGURE 14
DIMENSIONS (CM)

PHOTO 21: THE LAYER OF CHICKEN-WIRE IS ATTACHED TO THE MOULD.

7.6. MOUNTING OF THE WALL REINFORCEMENT AND REINFORCEMENT WITH U-SHAPED PIECES OF IRON-WIRE.

		Photo Nr.
7.6.1.	Four pieces of chicken-wire are cut to size 9.70 x 1.00 m.	
7.6.2.	One of the pieces is cut longitudinally into 2 pieces of 9.70 x 0.70 m and 9.70 x 0.30 m respectively.	20
7.6.3.	The piece of chicken-wire cut to 9.70 x 0.70 m is wound around the mould at the bottom, to give the first reinforcement layer. The piece of chicken-wire cut to 9.70 x 1.00 m is attached to the upper part of the mould in such a way as to give an overlap of 5-10 cm with the first layer of chicken-wire below (see figure 14).	21
	The overlap is repeatedly intertwisted using tool no.13. (see photograph 6).	28,29 30,31
7.6.4.	The mould is then lifted and placed on the floor reinforcement by 4 people.	
7.6.5.	The protruding ends are bent in curved shapes.	22
7.6.6.	The horizontal parts of the U-shaped pieces of iron-wire are intertwisted between the floor reinforcement and fastened to each other with iron-wire. This can be carried out by one person standing inside the mould.	

PHOTO 22: THE PROTRUDING ENDS ARE BENT IN CURVED SHAPES.

PHOTO 23: THE U-SHAPED REINFORCEMENT IS APPLIED AROUND THE MOULD.

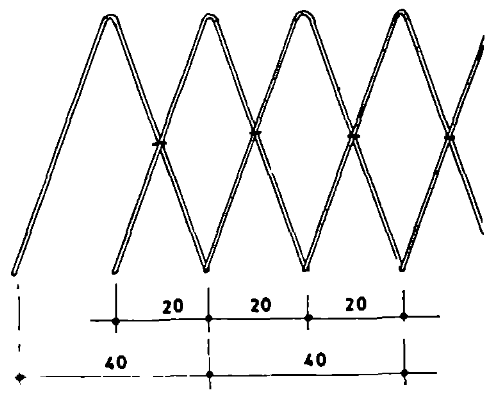


FIGURE 16. DIMENSIONS (CM)

PHOTO 24: AND THE CROSSINGS ARE FASTENED TO THE CHICKEN WIRE.

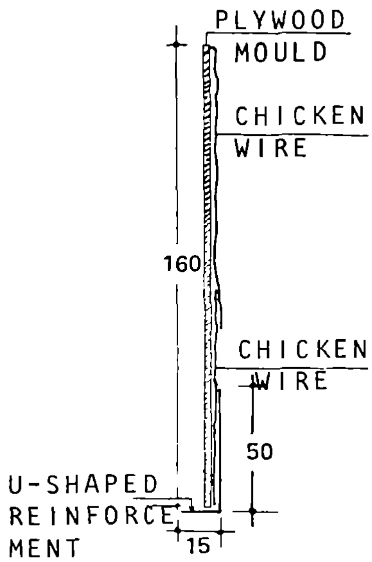


FIGURE 15 DIMENSIONS (CM)

PHOTO 25: THE FIRST LAYER OF IRON-WIRE IS POSITIONED.

PHOTO 26:
THE IRON-WIRE IS STRETCHED AROUND THE WALL.

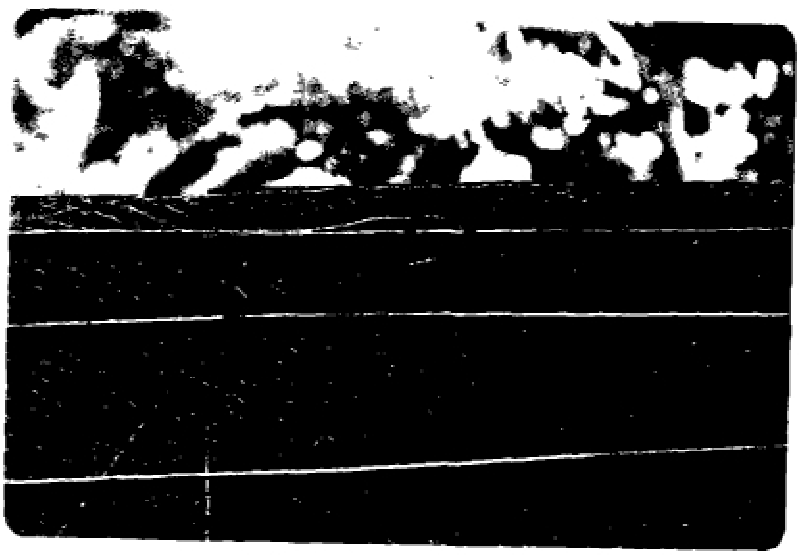


PHOTO 27:

THE ENT IS BEND OVER AND FASTENED TO THE CHICKEN-WIRE

Photo Nr.

7.6.7. The U-shaped pieces are now applied around the mould with a distance of 20 cm between centre-lines (see figures 15 and 16). It is advisable to draw these dimensions on the mould to facilitate this procedure. The procedure can best be carried out by 2 people, one inside and one outside the mould. On the outside of the mould, the crossings of the pieces are fastened to the chicken-wire (see figure 16). On the inside of the mould, the pieces are fastened to the floor reinforcement. 23,24

7.6.8. The positioning of the first layer of iron-wire Ø 5 mm is carried out as follows:
The starting point of the iron-wire is fastened to a U-shaped piece at the bottom. The iron-wire is then fastened in spirals around the mould,starting from the bottom, at distances of 5-10-15-30-30-30-20-15-5 cm. 25

7.6.9. Starting from below, the iron-wire is now stretched so that the whole is solidly positioned around the mould. The upper 3-5 cm at the end of the wire is bent over and fastened to the chicken-wire. The iron-wire is fastened to the chicken-wire at certain places to prevent it from becoming loose. 26,27

7.6.10. For the second layer of chicken-wire, two pieces of netting are used. The dimensions 9.70 x 1.00 m are used. The lower half is first positioned to give an overlap of 10 cm with the upper half. The upper half protrudes 30 cm above the mould (see figure 18). 32

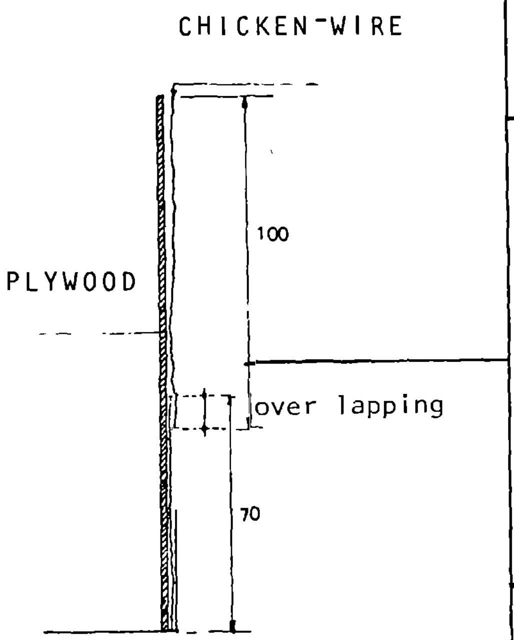


FIGURE 17.

INTERTWISTING OF OVERLAPPING LAYERS
OF CHICKEN-WIRE WITH TOOL NR. 13
(THE "NUT").

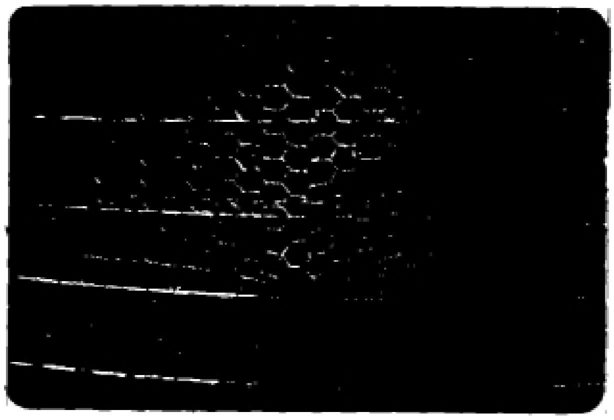


PHOTO 28

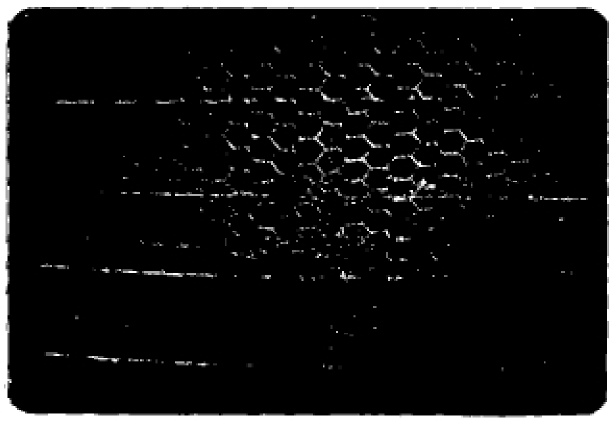


PHOTO 29

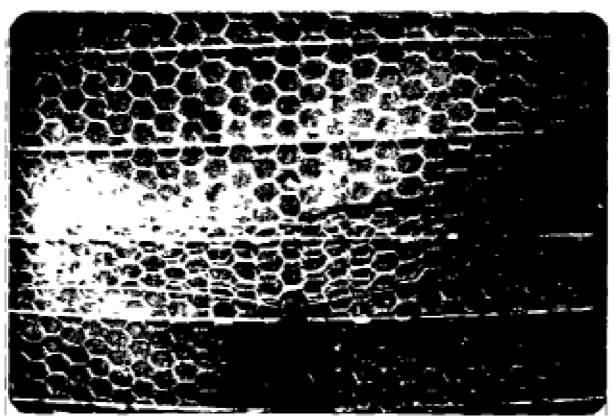


PHOTO 30

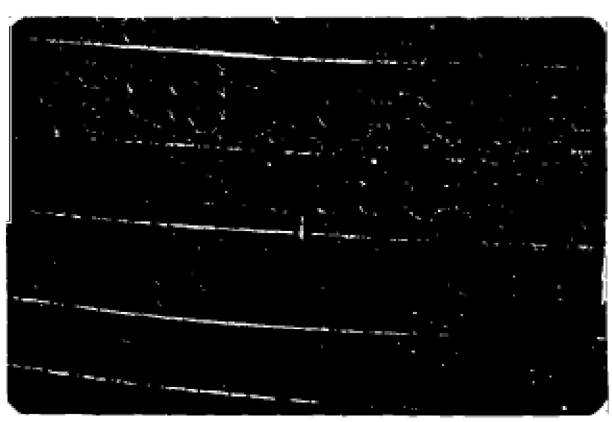


PHOTO 31

PHOTO 32: THE SECOND LAYER OF CHICKEN WIRE IS ATTACHED WITH A 30cm OVERLAP ABOVE THE MOULD.

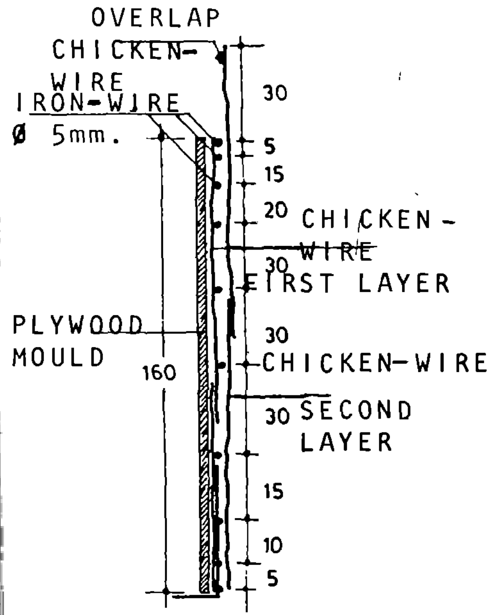


FIGURE 18

DIMENSIONS (CM)

PHOTO 33: THE SECOND LAYER OF IRON WIRE IS WOUND AROUND.

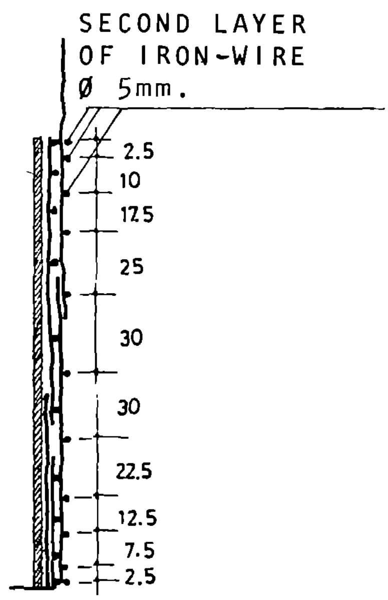


FIGURE 19

DIMENSIONS (CM)

Photo Nr.

7.6.11.	The overlap (see figure 17) is repeatedly intertwisted in the same way as the first layer.	28,29 30,31
7.6.12.	The beginning of the second layer of iron-wire is also fastened to the bottom of the mould, as closely as possible to the beginning of the iron-wire of the first layer. The iron-wire is then wound upwards in spirals in between the wires of the first layer (see figure 19).	33
7.6.13.	The second layer of iron-wire is finished on top of the mould, as closely as possible to the wire of the first layer.	
7.6.14.	The second layer of iron-wire is also pulled round the mould, starting from below, and fastened to it.	
7.6.15.	The iron-wire is then fastened to the chicken-wire with iron-wire every 75 cm. This should be carried out starting from the bottom.	
7.6.16.	All fastening (particularly the overlaps of the chicken-wire) should be tight with a flat finish.	

It is important that the chicken-wire is tight and flat around the mould.

The iron-wire should be tightly stretched and securely fixed, as this is imperative for a sturdy construction.

PLASTERING THE WORKING FLOOR.

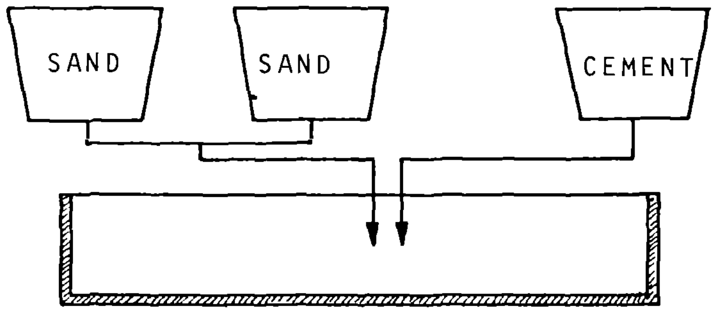


FIGURE 20: CEMENT AND SAND ARE MIXED IN A RATIO 1:2 (BY VOLUME)

PHOTO 34:
THE PROPER WATER CEMENT FACTOR IS ACHIEVED WHEN A GROOVE DRAWN WITH THE FINGER JUST STAYS OPEN;

PHOTO 35:
A WORKING FLOOR OF 2 CM THICKNESS IS LAID.

Photo Nr.

7.7. PLASTERING OF THE WORKING FLOOR.

7.7.1. The mould, with reinforcement, is cleaned with water.

7.7.2. The sand is washed and sieved using a screen with a mesh size of 2.5 mm.

7.7.3. Cement and sand are mixed in the proportion 1 : 2 parts by volume (see figure 20).

7.7.4. Water is carefully added to the cement/sand mixture until a cement/water factor of 0,4 is reached. This is achieved when a groove drawn with the finger just stays open. 34

7.7.5. The sand in the foundation circle is flattened, rammed in and soaked with water.

7.7.6. A working floor of the cement/sand mixture of 2 cm depth is laid while the sand is still wet. The depth of the layer can be checked with small boards with a thickness of 2 cm. 35

It is important that the sand is clean and that the correct water/cement factor is obtained. In this way, good quality ferrocement can be produced.

APPLICATION OF THE FIRST LAYER OF PLASTER.

PHOTO 36:

THE MOULD IS PLACED ON THE WORKING FLOOR.

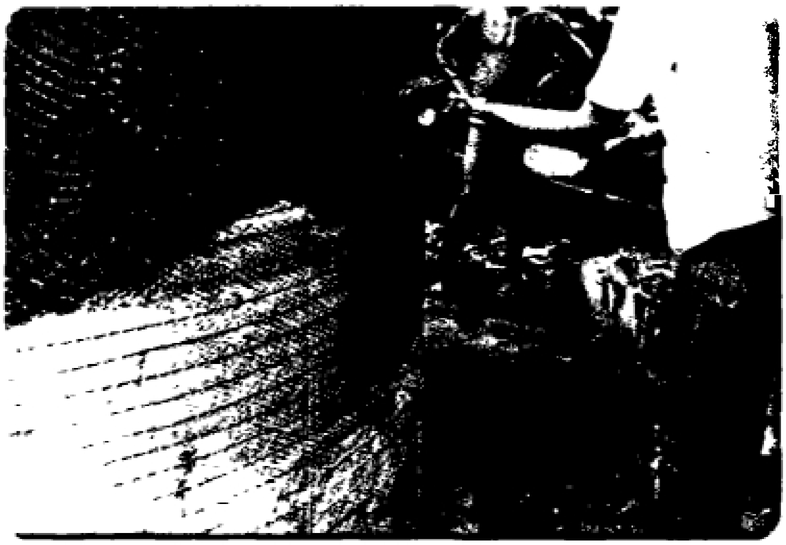


PHOTO 37:

THE OUTSIDE OF THE WALL IS PLASTERED WITH 1,5 cm LAYER

PHOTO 38:

THE SURFACE IS SMOOTHED OFF WITH A SANDAL.

Photo Nr.

7.8. APPLICATION OF THE FIRST LAYER OF PLASTER TO THE WALL AND THE FLOOR.

7.8.1. After the mould and reinforcement have been cleaned, they are placed on the working floor by 4 people. 36

7.8.2. The mortar (cement/sand mixture) is prepared as described in points 7.7.2. to 7.7.4.

7.8.3. A 3 cm layer of mortar is laid on the floor, the thickness being checked by small boards. A space of 1 cm should be left between the layer of mortar and the plywood of the mould. This facilitates removal of the mould later. Scratches of 5 mm are made in the surface of the floor to ensure good bonding with the final layer.

7.8.4. The outside of the wall is plastered with a 1.5 cm layer (measured from the plywood).
The upper surface of the mould may, at this stage, only be plastered to a height of 5 mm. 37
A toothed scoop (see figure 5) is used to apply the plaster layer. 5,37
Three openings are left in the plaster layer. The two lower openings are used for the tap and drain, and the upper opening for the overflow. The overflow opening should be located slightly to one side of the tap opening, not directly above it. This is to enable water which overflows to be caught in the drain pit and then to seep away in the seepage pit. 39

		Photo Nr.
7.8.5.	The surface of the wall is then smoothed off with, for example, a sandal.	5,38
7.8.6.	If chicken-wire, iron-wire, etc. can be seen after plastering, they must not be disturbed (see point 7.18).	
7.8.7.	After the wall has been plastered, it is covered with plastic film in order to prevent rapid drying.	

CONSTRUCTION OF THE DRAINPIT.

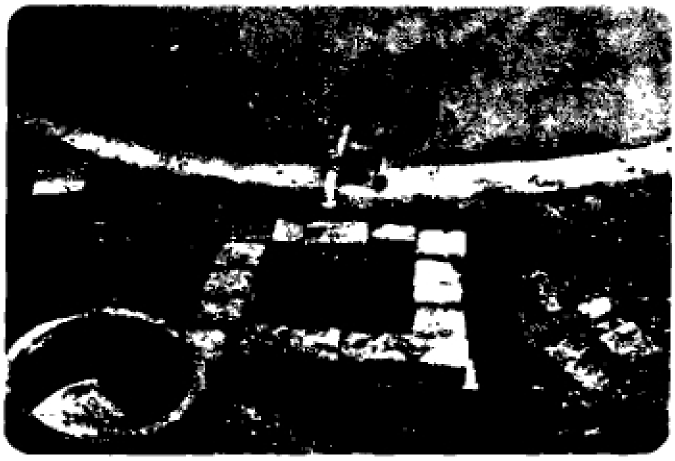


PHOTO 39:

A PIT OF BRICKS OF 60 x 60 cm IS LAID ON THE BOTTOM PLATE.

PHOTO 40:

BOTTOM AND WALL ARE FINISHED WITH A LAYER OF PLASTER.

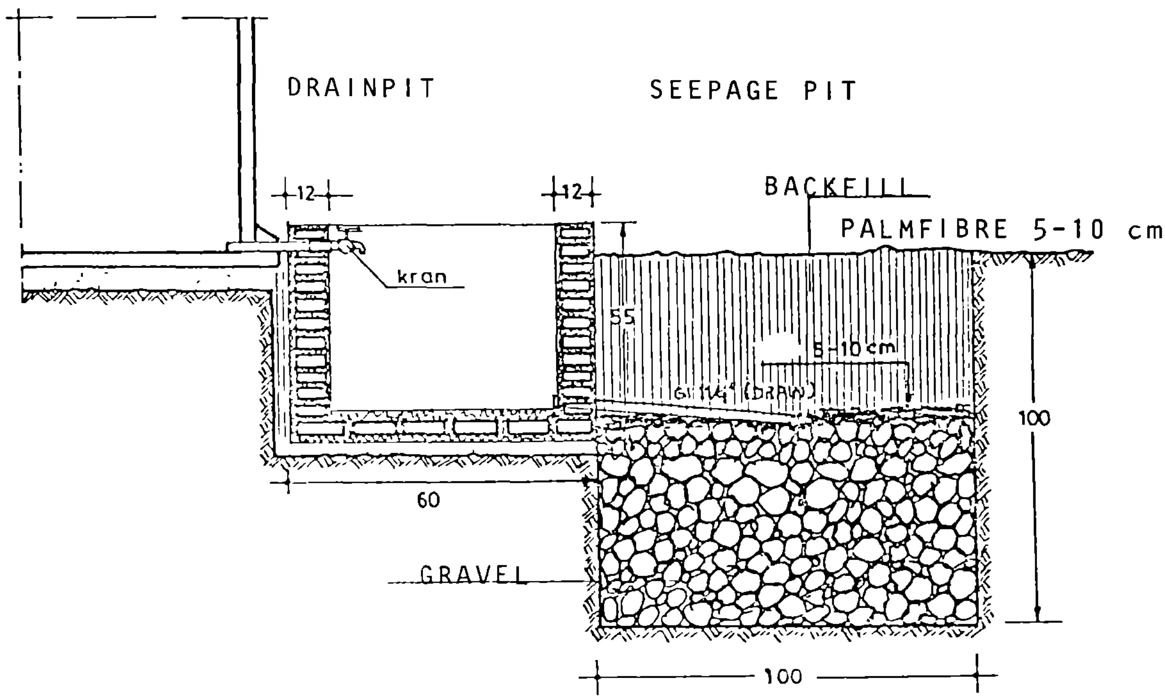


FIGURE 21:
DIMENSIONS OF DRAIN PIT AND SEEPAGE PIT.

Photo Nr.

7.9. CONSTRUCTION OF THE DRAIN PIT.

7.9.1. A drain pit of 90 x 90 cm and 60 cm deep is dug in the ground under the holes which have been left in the reservoir walls for the tap and overflow pipe.

7.9.2. The bottom place is covered with a layer of bricks. A pit of bricks of 60 x 60 cm is then laid on the bottom plate (see figure 21). 39

7.9.3. The bottom plate and wall are finished with a layer of plaster of composition 1 : 4 parts by volume cement to sand.

7.9.4. The space between the tank and the excavation is filled with the excavated earth. 40

7.9.5. A seepage area to allow unwanted or dirty water which has collected in the drain pit to seep away is constructed as follows:
A hole of 100 x 100 x 100 cm is dug at the front of the drain pit. A drain-pipe is mounted from the bottom of the drain pit running to the hole. The hole is then filled with gravel and stones to a depth of 50 cm and further excavated earth is added (see figure 21).

CONSTRUCTION OF THE BOTTOM PLATE OF THE FILTER UNIT.

PHOTO 41: A FRAMEWORK OF CHICKEN WIRE AND IRON WIRE IS MADE.

PHOTO 42: THE WET MORTAR IS PERFORATED.

Photo Nr.

7.10.	THE CONSTRUCTION OF THE BOTTOM PLATE OF THE FILTER UNIT.	
7.10.1.	A piece of iron-wire Ø 5 mm of length 215 cm is cut.	
7.10.2.	A circle of diameter 65 cm is formed and the ends are securely fastened to each other.	
7.10.3.	4 pieces of iron-wire Ø 5 mm of length 80 cm are cut.	
7.10.4.	A framework of this iron-wire and a piece of chicken-wire is made.	41
7.10.5.	A rectangular handle of iron-wire Ø 10 mm is fastened to the two crossbars to facilitate lifting of the bottom plate.	41
7.10.6.	A 5 cm layer of mortar (sand/cement in a proportion of 2 : 1 parts by volume) is placed on a plywood sheet covered with plastic. The mortar layer must be the approximate size and shape of the framework. The framework is laid on the layer of mortar and is then covered with another layer of mortar, also 5 cm thick. The surface is then finished off smoothly.	
7.10.7.	Before the layer of mortar has completely dried, the surface is perforated with about 150 holes of 1 cm diameter.	42

CONSTRUCTION OF THE REINFORCEMENT OF THE ROOF.

PHOTO 43: REINFORCEMENT FOR THE ROOF.

Photo Nr.

7.11. THE CONSTRUCTION OF THE REINFORCEMENT FOR THE ROOF.

7.11.1. The ring with steel pins is removed from the mould and placed on the ground.

7.11.2. The reinforcement for the roof is stretched in the same way as carried out for the floor (see section 7.2.). 43

INSTALLATION OF THE REINFORCEMENT OF THE ROOF.

PHOTO 44:

THE CHICKEN-WIRE THAT IS PROTRUDING ABOVE THE WALL IS CUT AND BENT AWAY.

PHOTO 45:

ROOF REINFORCEMENT IS PLACE ON THE RESERVOIR AND SUPPORTED BY BAMBOO POLES, THE REINFORCEMENT IS CUT THROUGH AND BENT TO SERVE AS REINFORCEMENT FOR THE FILTER/MANHOLE UNIT.

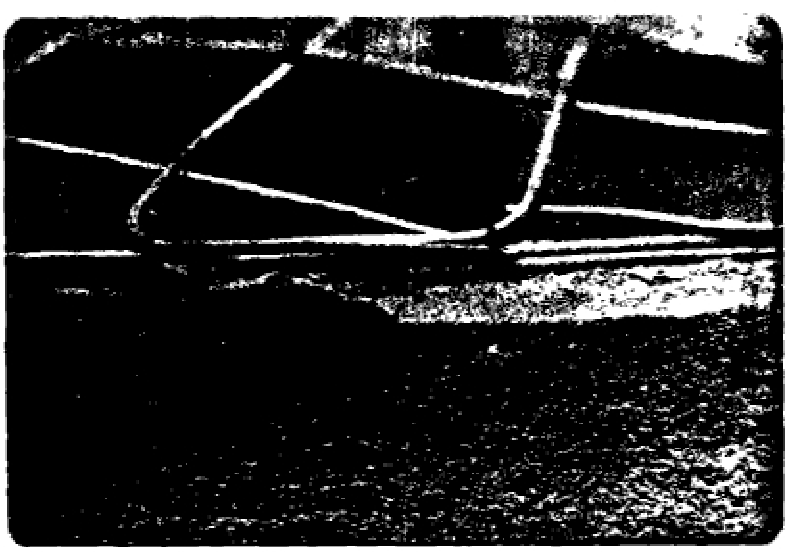


PHOTO 46:

THE PROTRUDING ENDS OF THE IRON WIRE ARE BENT AND FASTENED.

Photo Nr.

7.12. INSTALLATION OF THE REINFORCEMENT FOR THE ROOF.

7.12.1. The plastic is removed. The mould is taken out of the reservoir.

7.12.2. The chicken-wire that is protruding above the wall is cut in various places and bent away from the mould. 44

7.12.3. The reinforcement for the roof is placed on the reservoir supported in the middle by a bamboo pole of height 1.90 m. 45

7.12.4. 5 bamboo poles of length 1,85 m are then erected at a distance of 0.80 m from the central pole. 45

7.12.5. The ends of iron-wire protruding from the wall are bent sideways and put on the horizontal wall reinforcement, after which both are fastened with iron-wire. 46

7.12.6. The location of the filter unit/manhole of diameter 70 cm is determined by marking it on the reinforcement net or by using a steel gauge of Ø 70 cm. 45

7.12.7. After the location of the manhole has been determined, the reinforcement is cut through and bent vertically upwards. These ends serve as reinforcement for the wall of the filter unit/manhole. 45

7.12.8. A layer of chicken-wire is placed round the filter unit/manhole on the reinforcement net and then fastened with iron-wire in various places. 47

PHOTO 47:

A LAYER OF CHICKEN WIRE IS PLACED ON THE REINFORCEMENT AND FASTENED TO IT.

PHOTO 48:

THE REINFORCEMENT FRAME OF THE FILTER/MANHOLE UNIT IS ENVELOPED WITH A LAYER OF CHICKEN-WIRE.

PHOTO 49:

A PIECE OF ZIG-ZAG IRON WIRE IS INSTALLED.

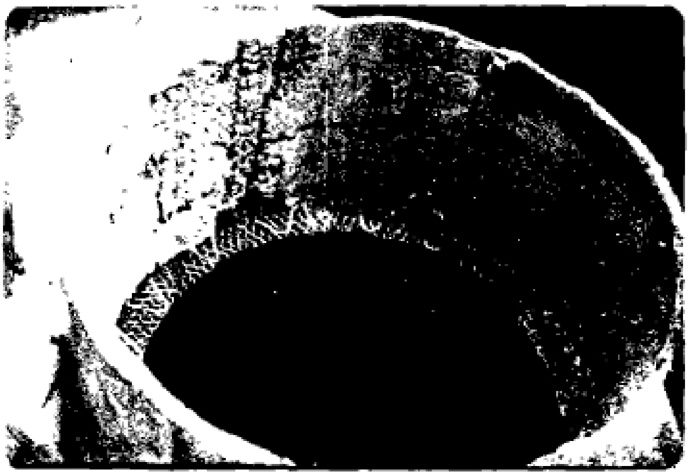


PHOTO 50:
THE ZIG-ZAG IRON WIRE IS ENVELOPED WITH CHICKEN WIRE.

Photo Nr.

7.12.9. The 30 cm of chicken-wire that is protruding from the wall is bent against the reinforcement net and then fastened to the chicken-wire of the reinforcement net with iron-wire.

7.12.10. The whole reservoir is then covered with plastic.

7.12.11. Horizontal reinforcement is placed at 6 cm intervals up to a height of 35 cm above the roof on the vertical reinforcement of the filter unit/manhole. The 35 cm is to be measured 47
on the side of the filter unit/manhole which is nearest to the centre of the roof.
The horizontal reinforcement is attached to the vertical reinforcement with iron-wire. 49

7.12.12. If the vertical reinforcement is too long, it may be trimmed. Too short a vertical reinforcement must be lengthened with pieces of iron-wire of a minimum of 15 cm in length.

7.12.13. The frame is then enveloped with chicken-wire and this is fastened with iron-wire. 48

7.12.14. A piece of iron-wire Ø 5 mm, bent into zigzag form, is fixed to the reinforcement of the roof on the inside of the filter to give an upstanding edge on the bottom plate. 49

7.12.15. Chicken-wire is wound around the zigzag iron-wire and attached to the vertical reinforcement of the filter unit wall with iron-wire. 50

SECOND PLASTERING OF THE WALL AND FLOOR.

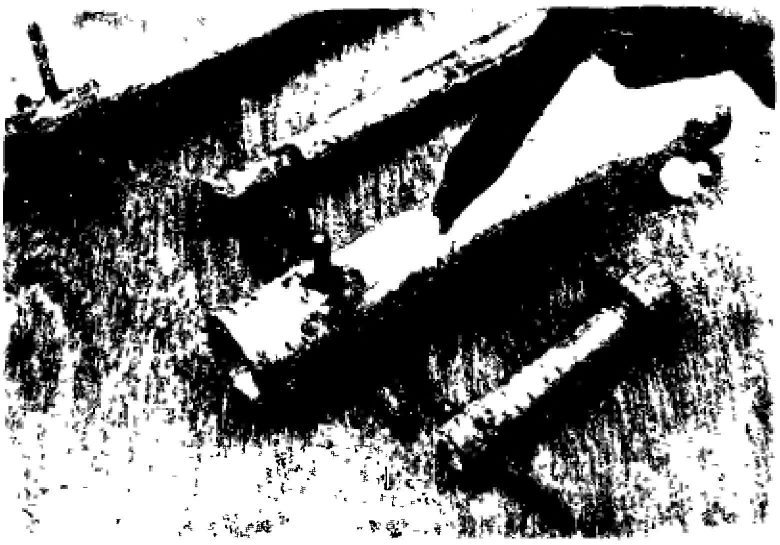


PHOTO 51:

THE SURFACE OF THE PIPEWORK IS ROUGHENED

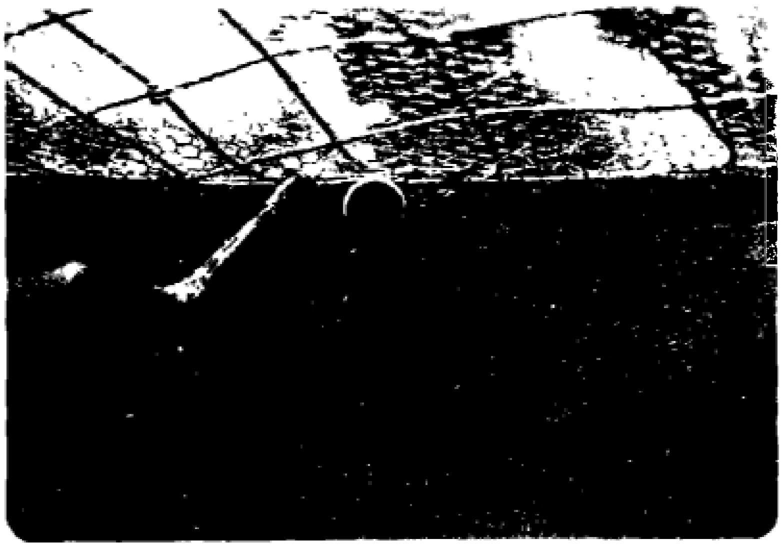


PHOTO 52:

THE INSIDE OF THE WALL IS FIRST WETTED WITH A WATER/CEMENT SLURRY.

PHOTO 53:

A MAT OF PLAITED BAMBOO IS PLACED IN THE RESERVOIR.

Photo Nr.

7.13. THE SECOND PLASTERING OF THE INSIDE OF THE WALL AND FLOOR AND THE FIRST PLASTERING OF THE OUTSIDE OF THE ROOF.

7.13.1. The plastic is removed.

7.13.2. The six bamboo poles are removed from the reservoir through the manhole.

7.13.3. The tap, drain and overflow are placed in the openings left for them. The surface of the pipes that come into contact with the plaster-work must be roughned to assure good contact and attachment. 51

7.13.4. The inside of the wall is first wetted with a cement/water slurry (proportions 1 : 2 parts by volume). 52

7.13.5. The floor and the wall are plastered with a 1 cm layer of mortar compound as used in point 7.7.
Plastering around the tap, overflow and drain is carried out before plastering of the wall is begun.
Once the inside of the wall has been plastered, the plastering around the tap, overflow and drain can be completed; the layer of plaster should be rather thicker here. 52

7.13.6. A waiting period of 2 hours is allowed for drying of the plaster.

Photo Nr.

7.13.7. After two hours, a mat of plaited bamboo of diameter 3.10 m is placed in the reservoir via the manhole. In the position of the manhole, a hole of the same size and shape as the manhole is made in the mat. This serves as boarding for the outer plasterwork of the roof. The side where the bamboo mat is placed against the roof reinforcement is covered with plastic or paper (empty cement bags) to prevent sticking of the plaster to the bamboo mat. 53

7.13.8. The mat is supported by 25 bamboo poles which are regularly distributed over the surface. Good support can be obtained by wooden wedges or wedge-shaped stones under the poles.

7.13.9. A 2.5 cm thick layer of plaster (as used in section 7.7.) is now placed on the outside of the roof. An opening is left in the plaster layer for the pipe for measurement of the water level.

7.13.10. A ½ inch galvanized iron pipe is mounted in the roof for measurement of the water level. The surface of the pipe is roughened for good contact with the plaster. 51

7.13.11. The plasterwork around the tap, overflow and drain on the outside of the wall is finished off as follows:
The plaster work is first wetted with a cement/water slurry of proportions of 1 : 2 parts by volume. It is then plastered with mortar compound as used in section 7.7.

7.13.12. The whole reservoir is now covered with plastic. 54

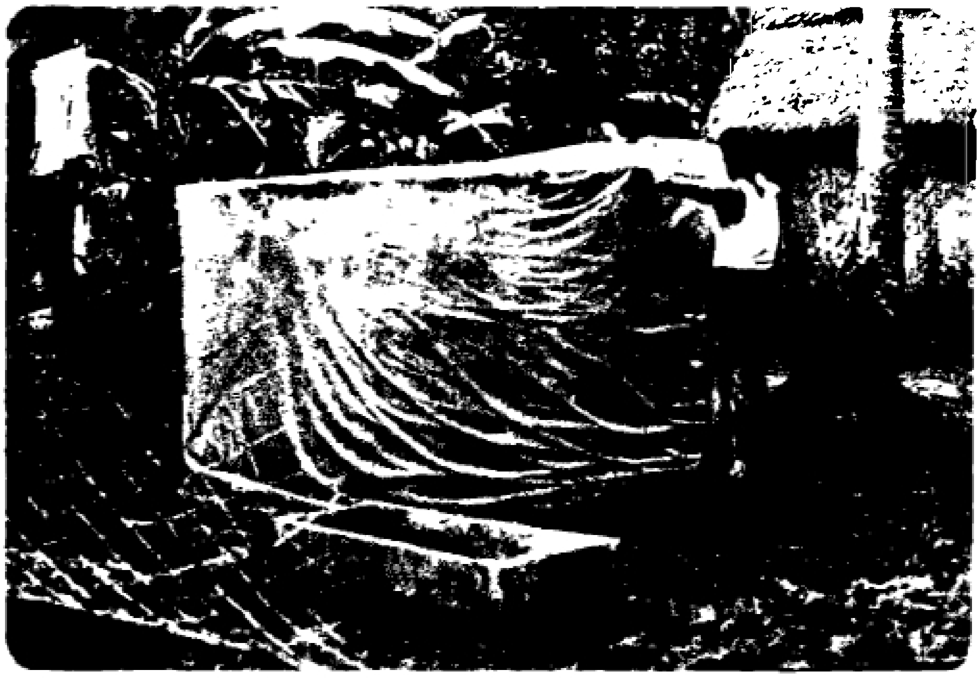


PHOTO 54:

THE WHOLF RESERVOIR IS COVERED.

Photo Nr.

7.14 4 DAY DRYING PERIOD FOR THE TANK.

7.14.1. The tank is to remain entirely covered with plastic for 4 days. 54

7.14.2. The reservoir is to be protected from direct sunshine.

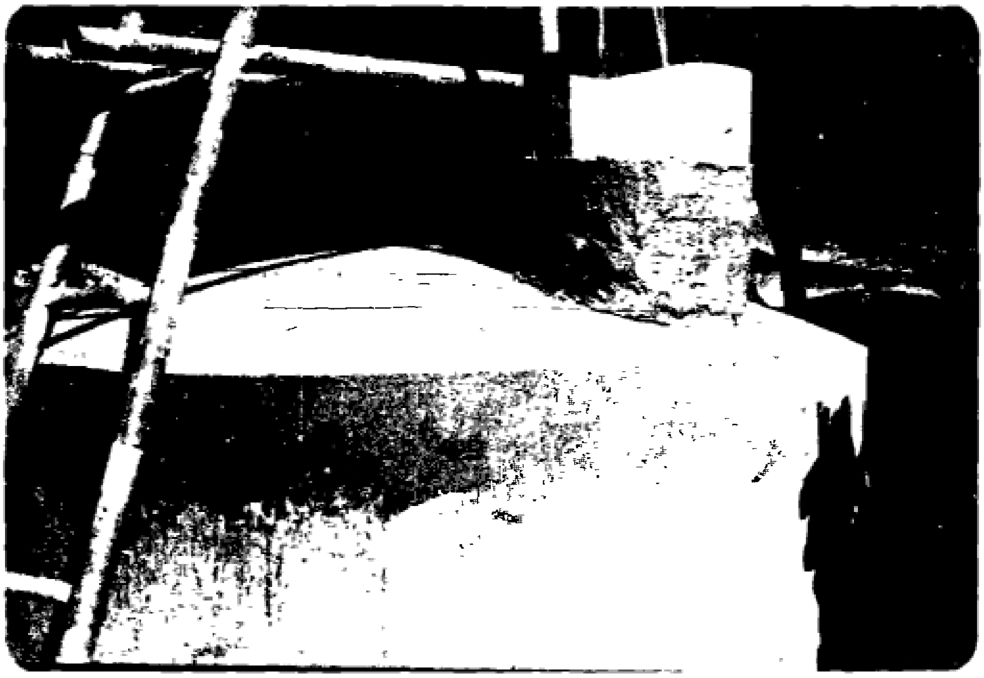


PHOTO 55:

THE FILTER UNIT IS PLASTERED WITH A 1.5 cm LAYER OF MORTAR.

Photo Nr.

7.15. SECOND PLASTERING OF THE INSIDE OF THE ROOF AND PLASTERING OF THE FILTER UNIT.

7.15.1. After 4 days the plastic, the boarding of mats and the poles are removed from the reservoir.

7.15.2. The floor and the inside of the wall are wetted with a cement/water mixture of proportions 1 : 2 parts by volume.

7.15.3. Galvanized iron sheets are placed on the inside of the filter unit and the outside is plastered with a 1.5 cm layer of mortar compound, as used in section 7.7. 55

7.15.4. The inside of the roof is checked for particles of the bamboo boarding which may remain, and, if necessary, is cleaned. The roof and the inside of the filter are then smeared with cement/water mixture, as given in point 7.15.2.

7.15.5. Half an hour after the application of the cement/water mixture, the roof and the filter are plastered to give an overall thickness of 2.5 cm.

7.15.6. The layer of plaster is then checked and touched up where necessary.

7.15.7. After the roof and the filter have been plastered and finished off, the reservoir is entirely covered with plastic.

Photo Nr.

7.16 DRYING, TESTING AND DISINFECTION OF THE RESERVOIR.

7.16.1. The reservoir must be protected from direct solar radiation during drying.

7.16.2. The outside of the overflow is covered with mosquito-net.

7.16.3. The reservoir is fed daily with 40 cm of water until it is full and the water flows out of the overflow.

7.16.4. An amount of 10 gram /m3 water of free chlorine and mixed thoroughly with the water in the reservoir.

7.16.5. The water level is measured with respect to a fixed point every day for 20 days. The measurements are recorded to check losses by absorption or leaking (water tightness test).

<u>It is important that the reservoir remains covered with plastic and protected from direct sunshine during the drying period.</u>

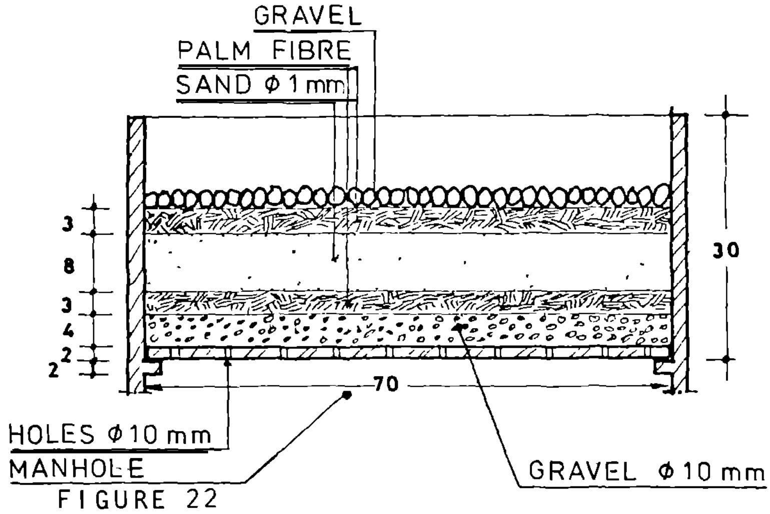


FIGURE 22

FILTER BED

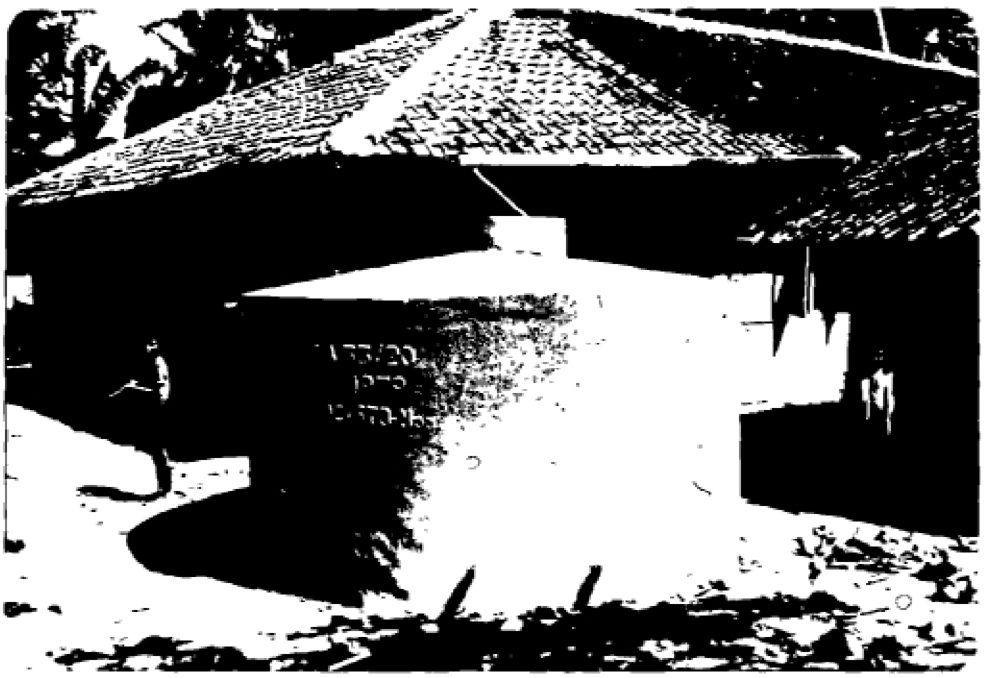


PHOTO 56:

RESERVOIR READY FOR USE.

Photo Nr.

7.17 COMPLETION.

7.17.1. The plastic is removed after the 37th day and the reservoir is emptied through the drain pipe.

7.17.2. Leaks (wet spots on the outside of the reservoir wall) are repaired by covering that spot at both sides with a cement/water mixture and finising off with a layer of mortar.
If leakage through the floor is suspected, it should be treated with a mixture of cement and water (see point 7.13.4.) and finished off with a layer of plaster.

7.17.3. If the water level falls by more than 5 cm during the 20 day water tightness test, a second test is carried out after repairs.

7.17.4. Any protruding wire or chicken-wire is carefully broken off with a small sharp chisel (pincers must not be used). The reservoir wall in that place should then be smeared with cement/water mixture and finished with mortar.

7.17.5. The inside of the reservoir is to be scrubbed with soap and then thoroughly rinsed until clean.

7.17.6. The perforated filter bottom is put into place in the filter unit and then filled with filter material (see figure 22).

7.17.7. The reservoir is now ready for use. 56

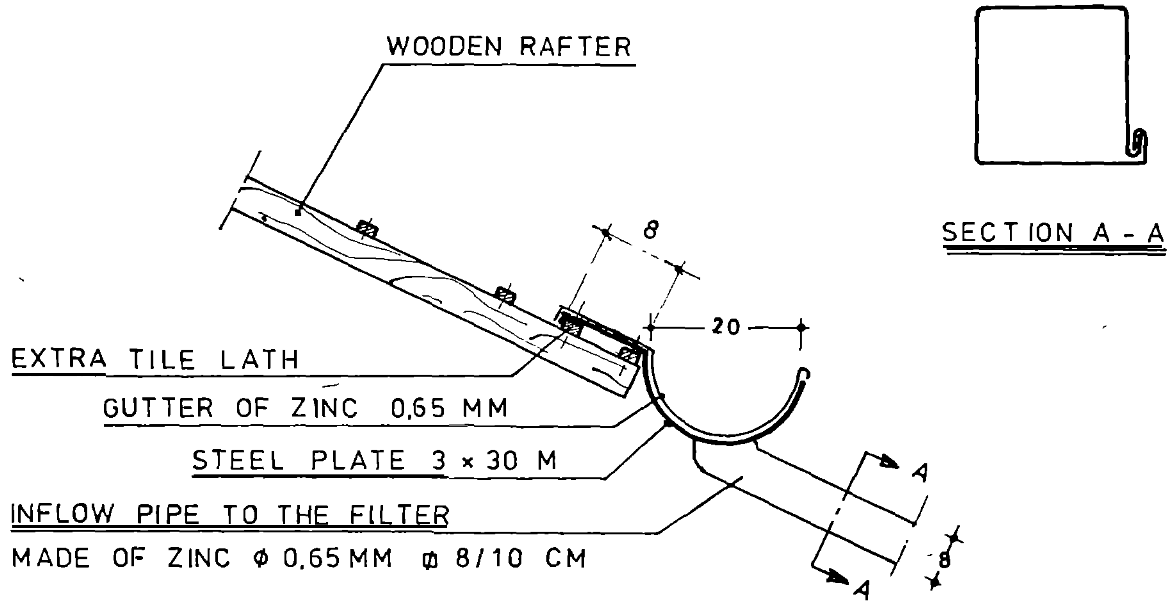

WOODEN RAFTER
SECTION A - A
8
20
EXTRA TILE LATH
GUTTER OF ZINC 0,65 MM
STEEL PLATE 3 × 30 M
INFLOW PIPE TO THE FILTER
MADE OF ZINC Φ 0,65 MM Ø 8/10 CM
A
A
8

Fig. 23

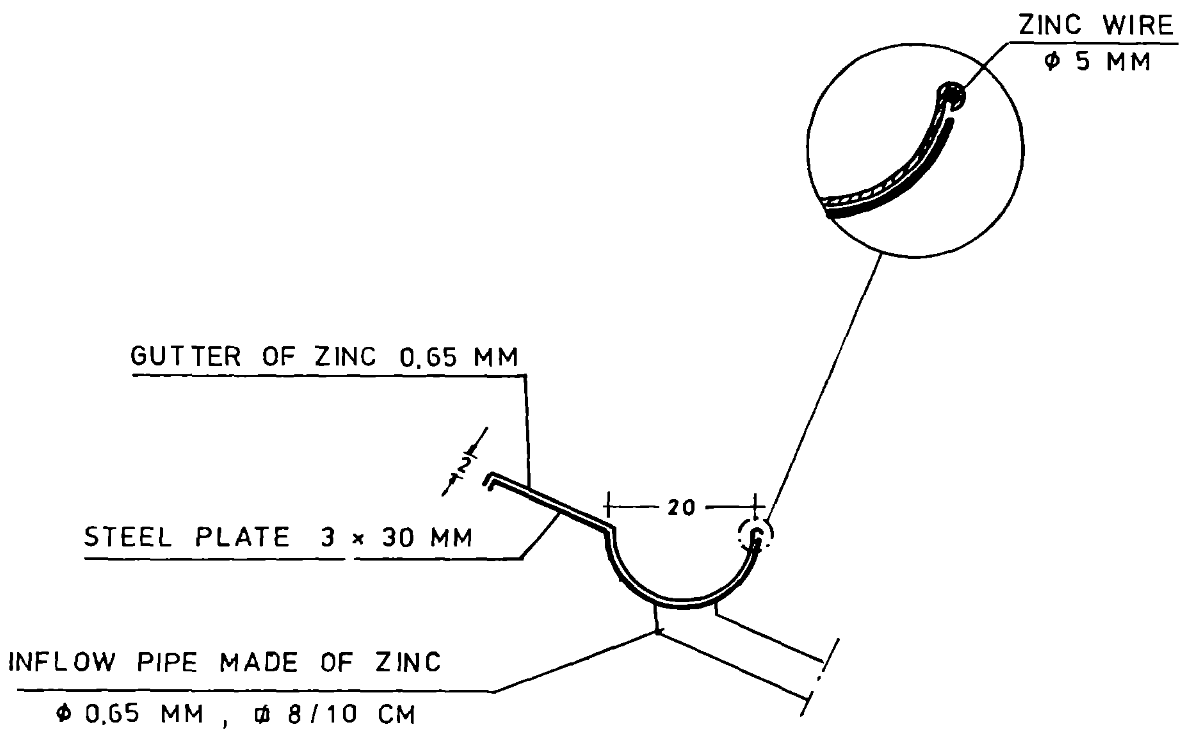

ZINC WIRE
Φ 5 MM
GUTTER OF ZINC 0,65 MM
STEEL PLATE 3 × 30 MM
20
INFLOW PIPE MADE OF ZINC
Φ 0,65 MM , Ø 8/10 CM

Fig. 24

8. CONSTRUCTION OF THE GUTTER AND SUSPENSION HOOKS.

8.1. INTRODUCTION.

The gutter construction proposed here is intended for roofs with wooden rafters. Recommendations for other types of roofs are given in points 8.6. and 8.7.

8.2. CONSTRUCTION OF THE SUSPENSION HOOK.

A piece of sheet iron of 3 x 10 cm is bent on one side to form a semicircle of a diameter of 20 cm. 2cm at the other end is bent to give a right angle. This hook can now be hooked over and fixed to a tile lath (wooden structure upon which the tiles are laid). Nail holes are made in the flat part of the suspension hook (see figures 23 and 24).

8.3. CONSTRUCTION OF THE GUTTER.

8.3.1. A piece of galvanized iron (the same length as the gutter x 46.5 cm) is bent broadwise into a circle with a diameter of 20 cm. The edge of the gutter is reinforced by bending a piece of iron-wire Ø 5 mm around it and nailing this wire down (see figure 23). The other end of the iron is bent over to form a right angle about 2 cm from the end (see figure 23).

8.4. CONSTRUCTION OF THE INFLOW PIPE.

8.4.1. An inflow pipe is required to feed water from the gutter into the reservoir (see figure 24).

8.4.2. The inflow pipe has a cross section of 8 x 10 cm and is constructed of the same galvanized iron material as the gutter. The two sides are hooked into each other (see figure 23) and then soldered.

EXTRA TILE LATH

BAMBOO RAFTER

WOODEN PLUG

GUTTER OF ZINC 0,65

STEEL PLATE 3×30 MM

Fig. 25

gutter construction for roofs with bamboo rafters

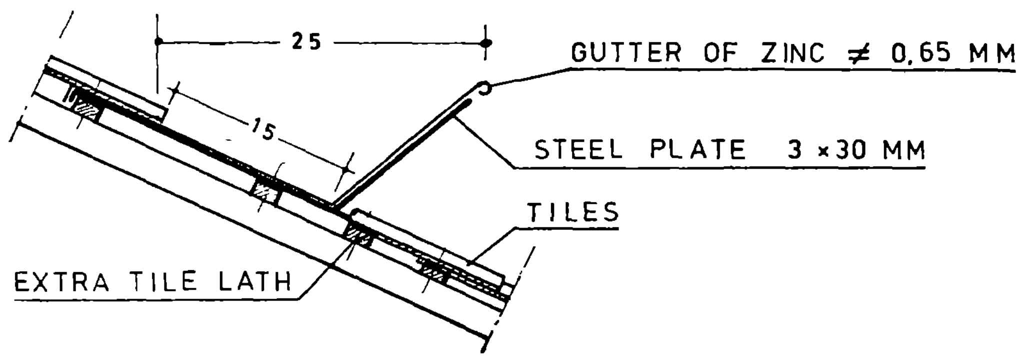


Fig. 26
gutter construction for low roofs

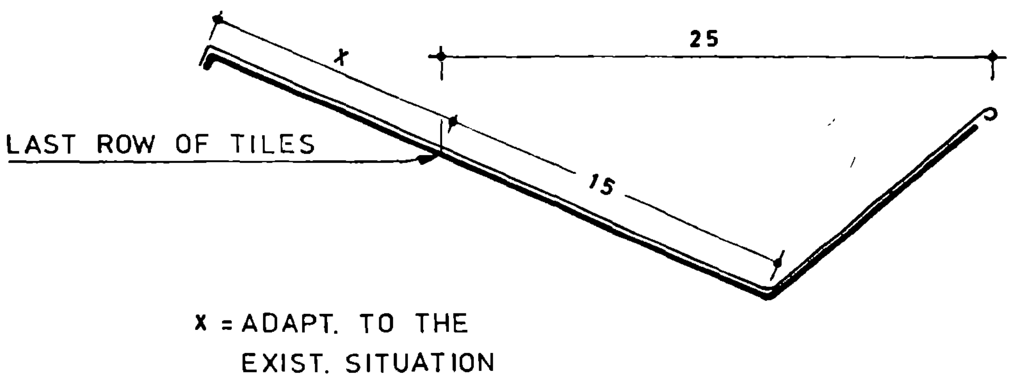


Fig. 27
gutter construction for low roofs (detail)

8.5. MOUNTING OF THE GUTTER.

The lowest row of tiles is temporarily removed before mounting the gutter. 8 cm from the lowest tile lath is measured and an extra lath is attached in this position. The hooks are placed on the two lowest laths with a maximum of 1 m between them (this distance is measured between centrelines). The gutter is then obliquely placed on the hooks in such a way as to have the gutter lying obliquely in the direction of the inflow pipe, and the whole is attached to the laths. The tiles previously removed can now be replaced.

8.6. GUTTER CONSTRUCTION FOR ROOFS WITH BAMBOO RAFTERS.

8.6.1. The gutter construction can be carried out as given in points 8.2. - 8.4.

8.6.2. 15 cm long wooden plugs are inserted into the rafters before the extra laths are attached (see figure 25).

8.7. GUTTER CONSTRUCTION FOR LOW ROOFS.

Ideally, the roof, on which the gutter is to be attached, should be higher than the reservoir filter. If there is no other building in the area which satisfies the criteria for a catchment arrea and a low building has to be used, the following recommendations are given:

The hook for the gutter must be made according to figure 27.

A row of tiles that is situated a minimum of 2.40 m above ground level are temporarily removed from the roof. The row of tiles lying beneath this row is pushed down slightly. The hooks are then attached, with a distance between centrelines of 1.00 m, to the uncovered laths. The gutter is placed on the hooks in such a way as to have the gutter lying obliquely in the direction of the inflow pipe.

The inflow pipe to the filter is fixed to the gutter as given in point 8.

9. USE AND MAINTENANCE.

9.1. USE.

9.1.1. The roof surface and the gutters must be kept free from the excrement of birds and other animals.

9.1.2. The gutters and inflow pipe must be regularly cleaned of leaves and other rubbish which may collect in them.

9.1.3. If there has been no rain for 2 or more days, the inflow pipe should be placed so that it is not leading into the reservoir, but hanging beside it. 5-10 minutes after rain begins, the inflow pipe can be connected to the reservoir again.

9.1.4. The filter must be kept free from contaminants and in good condition.

9.1.5. The mosquito-net on the overflow pipe must be checked regularly and, if necessary, renewed.

9.1.6. To keep the water consumption under control the spindle of the tap can be removed and kept elsewhere.

9.1.7. The water level in the tank should be measured and noted once a week using the same graduated stick (which is not to be used for any other purpose).

9.1.8. A drop of 1 cm in the water level corresponds to 70 litres consumption.
During dry periods, the drop in water level should correspond approximately with consumption. If this is not the case, the reservoir is leaking, and wet spots will be visible (see point 9.2.2.).

9.1.9. The draining tank should remain clean and dry.

9.1.10. The water must be boiled before drinking.

9.2. ANNUAL MAINTENANCE.

9.2.1. Annual maintenance* is carried out at the end of the dry period, when the reservoir is empty.

9.2.2. Any leaks that have been noticed during the preceding wet season must be repaired. Wet spots on the wall are treated on the inside with a cement/water mixture and finished off with a layer of plaster(see point 7.13.4.). If a leakage is evident but no wet patches have been discovered in the walls of the reservoir, the floor of the reservoir must be treated with a cement/water mixture and then finished off with a layer of plaster.

9.2.3. The interior of the reservoir is cleaned by removing deposits from the bottom and scrubbing the bottom and walls with clean water. The water used is discharged through the drain.

9.2.4. The filter is removed. The filter sand is washed with clean water or renewed. The filter receptacle is cleaned on the inside with clean water and then refilled.

9.2.5. The roof surface, gutters, suspending hooks and the inflow pipe are checked and, if necessary, repaired.

ANNEX 1.

THE MATERIAL FERROCEMENT.

The American Concrete Institute defines ferrocement as follows :

"Ferrocement is a type of thin wall reinforced concrete construction where(usually)a hydraulic cement is reinforced with layers of continuous and relatively small mesh. The mesh may be metallic material or other suitable materials".

The reinforcement (usually chicken-wire and small diameter iron-wire) is attached on a light weight mould after which the first layer of mortar is plastered. After removal of the mould a second layer is plastered.

The above mentioned definition, and others , do have a meaning from a descriptive point of view, but do not give a technical definition of the material. A code of practise (as exists for ordinary reinforced concrete) has not yet been formulated for ferrocement.
However, the A.C.I. and other institutes are working on this.

These institutes have also undertaken numerous theoretical and experimental studies to investigate the properties of ferrocement and explore its potential applications.
The activities of the International Ferrocement Information Institute (IFIC) of the Asian Institute of Technology (AIT) in Bangkok should be mentioned in this connection.

Essentially a form of reinforced concrete, ferrocement has a number of significant characteristics which distinguish this material from reinforced concrete.

1. Its thin wall and small mesh reinforcement create a high specific surface (cm^2/cm^3) of the reinforcement. Because of this high specific surface ferrocement acts as a homogeneous material within wider limits than ordinary reinforced concrete and therefore resist higher tensions before cracking occurs;

2. Ferrocement has a higher impact resistance than ordinary reinforced concrete because of its high energic absorption capacity. Moreover, damages can be easily repaired by replastering;

3. Ferrocement reinforcement is assembled over a light framework into the desired shape after which the mortar is directly plastered. The shape of the framework (mould) can be easily chosen such that a strong and rigid structure is formed;

4. The basic materials are cheap, well known in most countries and usually locally available.

5. The construction method is simple and easy to learn, while only simple equipment and tools are required;

6. Ferrocement constructions are usually cheaper than similar constructions in ordinary reinforced concrete.

The latter three properties make the application of ferrocement particularly suitable for use in low income rural areas in developing countries.

For watertight constructions (like watertanks) the aplication of ferrocement is of particular interest because of its high resistance to cracking, its ease of manipulation (circular tanks can be easily constructed) and the ease with which repairs can be made.

For more detailed information about ferrocement and its field of potential applications the reader is referred to the attached list of references (Annex 3).

ANNEX 2.

HOW THE DESIGN OF THE 10 M3 FERROCEMENT WAS FORMULATED.

The vital dimensions of the reservoir are the internal diameter, effective height and thickness of the floor, the wall and the roof.

Initially the technical design includes the dimensions of the required reinforcement and, based on this the thickness of the floor, wall and roof. However, first the internal diameter and effective height of the reservoir should be determined.

The internal diameter and effective height together determine the effective capacity, which should be 10 m3. From a cost point of view, the optimal diameter and height can be roughly calculated from the (estimated) unit prices per m3 of the various construction parts (floor, wall, roof).

For the 10 m3 ferrocement reservoir in the pilot scheme an optimal diameter of 2.30 m and a height of 2.40 meter have been calculated based on the estimated unit-prices for the 1979 price level in West Java, Indonesia.

In practice, however, an effective height of 2.35 m will generally be too high (for above ground reservoirs) to allow the rainwater from existing roofs to flow freely into the reservoir. For the situation in the pilot scheme village (Singakerta) an effective height of 1.55 m appeared to be practical in respect to the average height of the roof edges. The internal diameter corresponding to this is 2.90 m (see figure 1).

An above ground reservoir has been preferred to an underground or partially underground reservoir. This is to avoid forcing up of the construction (ferrocement constructions are relatively light) and to make tapping from the reservoir possible by means of a simple tap (instead of a handpump).

The design of the wall reinforcement and thickness is based on the assumption that the maximum loop stress in the cylindrical wall is the governing factor rather than the compressive strength or bending moment at the base of the tank (reference 7). This maximum loop stress shall not exceed the first crack tensile stress of the ferrocement composit taking into account a safety factor of 2.0. Below this first crack tensile stress, ferrocement acts as a homogeneous material in the elastic range.
Based on these principles a reinforcement has been calculated consisting of 2 layers of chicken-wire and two layers of iron -wire. The total wall thickness then amounts to 25 mm requiring about 5 mm cover at both sides of the reinforcement.

The reinforcement and thickness of the floor has been determined based on considerations used for ordinary reinforced concrete. Since the floor is always under compression, reinforcement is only placed in the bottom part of the floor.

The reinforcement and thickness of the roof are mainly determined on practical considerations and construction experiences. The starting point in these considerations is the requirement that the roof should easily resist the weight of two adults without visible deflection or cracking.

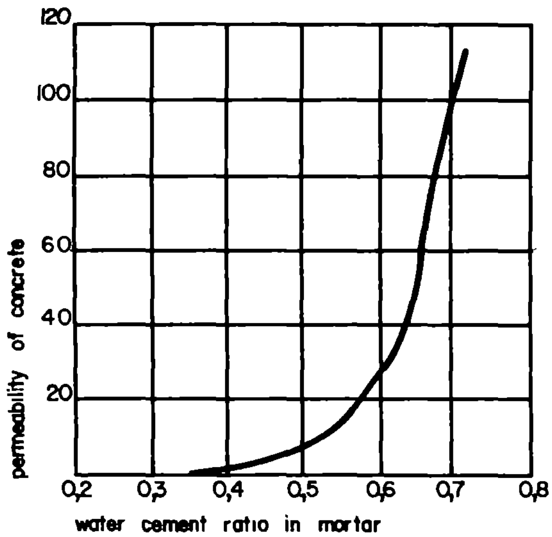


Figure 28

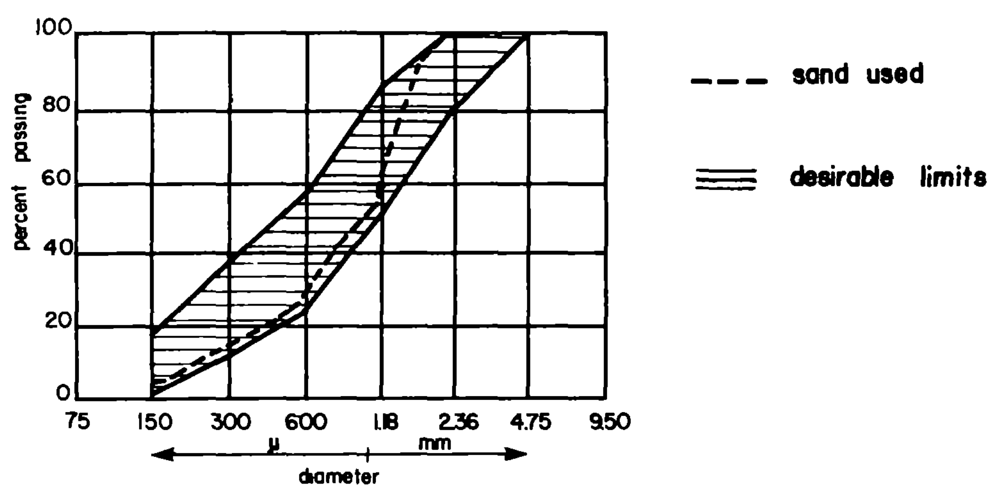


Figure 29

Extra attention has been paid to the joint between the wall and the floor because this joint is a critical part of the construction. Extra strength has been given by applying additional pieces of U-shaped iron-wire.

For the quality of the construction it is important that a mortar of the following composition is applied :

proportion cement-sand = 1 : 2 (volume units)
proportion water-cement = 0,4 : 1 (weight units)

Figure 3 shows the great influence of the water-cement factor on the watertightness of the hardened concrete.
The diameter of the sand must be between 0.015 mm and 2.5 mm. An example of the proper sieve analyses is given on figure 4.
Other requirements that are imposed upon the materials to be used are included in the text.

The purpose of the filter construction is to remove dust, leaves and other dirt. A filter rate of 5m/hour (usual for rapid sand filters), is adapted. To allow an extremely high rainfall of 50 mm/hour to pass through the filter, a filter diameter of 0.70 m2 is required. The desired filter construction has been determined based on practical tests (see figure 22).

ANNEX 3.

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