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CUVEwaters integrated water resources management

CuveWaters Construction Manual # 1

Ferrocement Tank

Documentation and Work Instructions for Participants

of Training on Rainwater Harvesting Construction

SPONSORED BY THE

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Preface

„CuveWaters – Integrated Water Resources Management in central-northern Namibia" is a joint research project of German and Namibian partners funded by the German Federal Ministry of Education and Research (BMBF). Main research partners are the Institute for Social-Ecological Research (Frankfurt, Germany) and the Technische Universität Darmstadt (Darmstadt, Germany). Partners in Namibia are for example the Ministry of Agriculture, Water and Forestry (MAWF) and the Desert Research Foundation of Namibia (DRFN), the project furthermore closely cooperates with One World Consultants (OWC) from Kenya. CuveWaters has developed different technologies for water supply and sanitation in central-northern Namibia, ranging from Groundwater Desalination to Rain- and Floodwater Harvesting as well as Sanitation and Water-reuse. Between 2009 and 2013 different pilot plants were constructed at different places all over central-northern Namibia.

This Manual was developed as part of the Capacity Development measures within the technology line of rain- and floodwater harvesting. It is intended to guide you through the process of constructing rain- and floodwater harvesting infrastructure in Namibia.

This Manual is part of a series of Rain- and Floodwater Harvesting Manuals for Namibia:

Water Storage:

#1 Ferrocement Tank

#2 Rectangular Underground Tank

#3 Pond

Horticulture and related Infrastructure:

#4 Greenhouse

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For more information on organisational, institutional and other general aspects of rain- and floodwater harvesting please have a look in the “CuveWaters Rain- and Floodwater Harvesting Toolkit”.

For more information on the CuveWaters project please visit http://www.cuvewaters.net

Alexander Jokisch

Technische Universität Darmstadt

Darmstadt, 02.03.2015

About

CuveWaters Construction Manual # 1 – Ferrocement Tank

CuveWaters – Integrated Water Resources Management in Namibia

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This manual is also available on http://www.cuvewaters.net/Publications

For more information on Rainwater Harvesting in Namibia please contact

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Table of Content

1 Preliminary considerations

Before beginning with the construction work of the ferrocement tank, preliminary considerations and work instructions should be read carefully. Indication of days means working days. Days for curing / drying of concrete and mortar are mentioned separately at each part of the construction process.

The construction manual describes how to build a 30m³ ferrocement tank as conducted during the CuveWaters project for development and implementation of an Integrated Water Resources Management (IWRM) system and, as a part of this, rainwater harvesting.

1.1 Materials & Tools Preparation

Ideally, most materials (see bill of materials) should be purchased and brought on site before start of construction or at least until needed at construction site. Storage facilities for materials, especially for cement and small items as well as for tools, should be provided at or close to construction site. The materials should be stored secure against weather conditions (e.g. rain, wind, and extreme heat) and theft. Tools needed for construction of the ferrocement tank should be available for the period of construction.

Material supply

All materials needed for construction can be obtained from hardware shops that can be found all over Namibia. In central-northern Namibia you will find the necessary materials for example in the following shops:

- Oshana Build it, Ongwediva (recommended, first choice)
- Benz Building Supplies, Ongwediva (recommended, second choice)
- Pennypichers, Ongwediva
- Pupkewitz Megabuild, Oshakati
- Chico, Oshakati

Please keep in mind that prices can differ in the different shops and seasonal variations are also common. So plan your construction site and the material supply well in advance and compare the prices in the different shops. Most hardware shops offer delivery of the materials for reasonable fees.

Sand

Especially sand can in most cases also be found locally close to the Oshanas, this option is normally much cheaper. Locals normally know where sand suitable for construction purposes can be found and can also deliver the sand for reasonable prices. Always check this sand for its quality especially its salt content!

Cement

For the construction of tanks and other infrastructure we recommend the use of cement made by Ohorongo Cement Factory only! For all constructions the 32.5R cement is sufficient!

1.2 Siting recommendations

Study the building which shall be used for water collection and how water runs off from the roof. Consider where the down-pipes are and how they can be connected to the tank. Choose the site for the tank, in a way which allows that the rainwater can easily flow from the roof catchment into the tank. Also consider where the water has to be supplied to when stored in the ferrocement tank. Is water drawn of with a tap or will a pump be connected? In any case make sure that there is enough space to place the tap or pump.

Stay at least 1 m away from a building (depending on soil conditions). Usually, the lower side of the building is the best site for a tank, since the water runs off into the tank more easily.

Stay away from trees (at least 10 m) as their roots can destroy the tank, alternatively make a trench of at least 1 m depth between a tree and the tank and fill the trench with concrete or plastic sheeting.

Make sure that the overflow pipe of the ferrocement tank is guiding the overflow water away from the tank and other buildings. Otherwise, the foundation and or walls could be deteriorating over time.

1.3 Tank volume and other dimensions

This manual describes how to construct a ferrocement tank of a volume of 30 m³. The diameter of the tank is 4.4 m. The height of the tank is 2.5 m in total. The tank consists of three main parts: foundation, sidewall, and roof.

The foundation of the tank shall be 10 cm thick and have a diameter of 4.6 m. The foundation is made of concrete which is reinforced by steel welded mesh. The sidewall is made of a core out of steel welded mesh which gives strength to the construction. Several layers of mortar will be applied to the steel reinforcement. The sidewall shall have a diameter of 4.4 m and a height of 2 m. The wall is approximately 5 to 10 cm thick. The roof structure is also made of a steel welded mesh as reinforcement, which is covered by layers of mortar. The reinforcement has a diameter of 4.4 m and will be shaped to the form of a dome before mortar is applied.

For a better understanding see the following illustration of the tank and its dimensions.

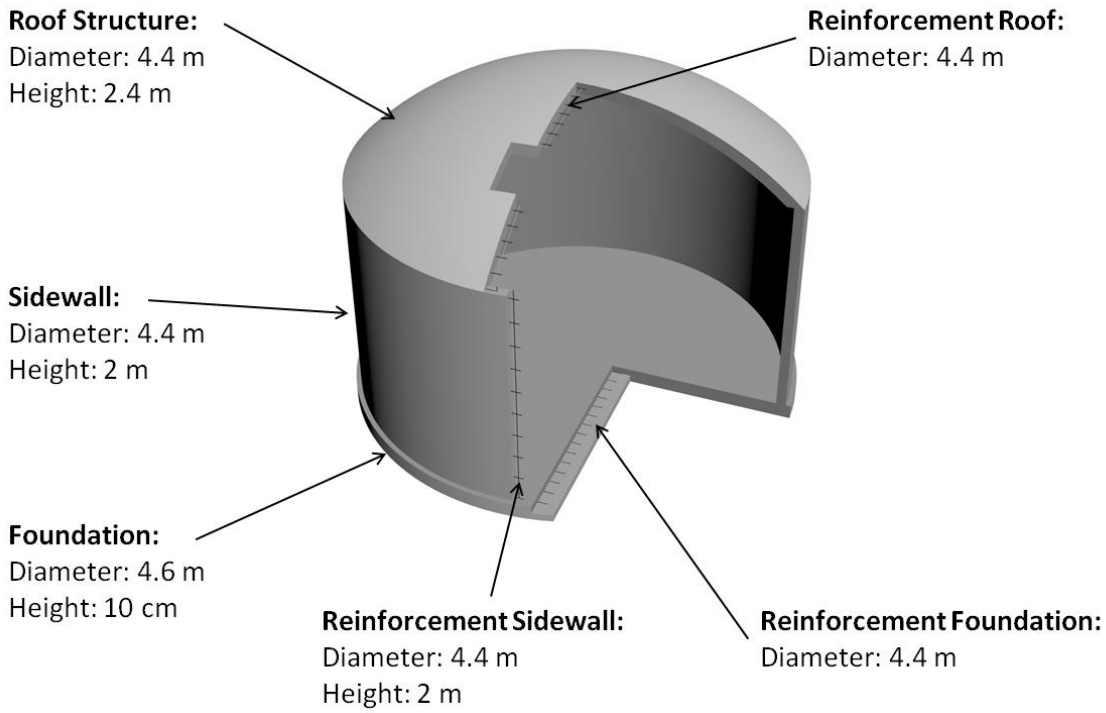

Figure 1: Illustration of ferrocement tank (section view) and description of main parts.

2 General Work Instructions

In the following chapter, actions which are to be done during the process of ferrocement tank construction will be described. These actions will be required in the detailed work instructions and therefore should be known:

2.1 How to mix and use concrete

Proper mixing of concrete is very important. The wall which will be built is not a normal house wall but of a tank that holds a big quantity of water and therefore has to withstand a much higher load.

Use concrete no longer than 45 minutes after mixing with water. In general, concreting is better to be done in the morning or late afternoon to avoid too high temperatures, which will reduce the strength of the concrete. Use water sparingly as too much water reduces the strength of the concrete. Nevertheless, make sure that the concrete does not dry before it is in place. Gravel should consist of stones of ½" to ¾" and if available, river sand should be used for mixing of concrete.

When mixing concrete, add only so much water to make the mix workable. It should not be shiny, but pasty. As a broad rule you can calculate with half the amount of water compared to the amount of cement used (for example: 10 kg cement are used for mixing concrete, then approximately 5 l water will be needed).

Mix concrete in a ratio 1 part cement, 2 parts sand, and 3 parts gravel (e.g. 4 bags of cement, 8 wheelbarrows of sand and 12 wheelbarrows of gravel). First, mix sand and cement, until the color is the same all over the mixture. Second, add gravel and mix until color again is the same all over the mixture. Third, add water until the mixture is pasty.

Keep concrete humid after being applied to ensure ideal strength after curing. If necessary cover the concrete with wet towels or plastic foils. Sprinkling water onto the concrete from time to time helps as well to achieve an ideal curing process and therefore good strength of the concrete.

2.2 How to mix and use mortar/plaster

Proper mixing of mortar and plaster is very important to achieve ideal strength and adhesion.

Use mortar/plaster no longer than 45 minutes after mixing with water. Mixing and using mortar and plaster is better to be done in the morning or late afternoon to avoid too high temperatures, which will reduce its strength. Use water sparingly as too much water reduces the strength of mortar/plaster. Nevertheless, make sure that the mortar/plaster does not dry before it is in place. For mixing mortar/plaster, gravel is not needed. If available, use river sand for mixing mortar/plaster.

Mix mortar/plaster in a ratio 1 part cement, and 3 parts sand (e.g. 1 bag of cement and 3 wheelbarrows of sand). First, mix sand and cement, until color is the same all over the mixture. Second, add water. When mixing mortar/plaster, add only so much water to make the mix workable. It should not be shiny, but pasty.

Keep mortar and plaster humid after being applied to ensure ideal strength after curing. If necessary cover with wet towels or plastic foils. Sprinkling water to the mortar or plaster from time to time helps as well to achieve an ideal curing process and therefore good strength of the mortar/plaster.

Figure 2: Mixing concrete with concrete mixer.

2.3 How to mix cement slurry

Cement slurry, which is also called NIL, is a liquid to pasty mixture of cement and water only. It is used to increase the water tightness of ferrocement and therefore avoidance of water leakages.

Mix cement with water in a proper sized can or bucket. The slurry shall not be too pasty to allow an easy application to the wall. Nevertheless, the slurry shall not be too watery to ensure its sealing function.

2.4 How to make the steel reinforcement for the foundation

Draw a circle of the diameter needed on the ground (for a 30 m³ ferrocement tank, the diameter is 4.4 m, i.e. 2.2 m radius). Place reinforcement steel mesh onto the ground where circle was drawn. The overlap of one mesh and another should be 20 cm. Tie overlapping meshes with binding wire at each square. Use a bolt cutter to cut steel mesh to circular form and dimension needed.

Figure 3: Tying reinforcement steel meshes together to build reinforcement for foundation.

Figure 4: Usage of binding wire to tie reinforcement steel together.

Figure 5: Cutting reinforcement mesh for foundation into circular shape.

2.5 How to make the steel reinforcement for the sidewall

Place reinforcement steel mesh onto the ground. Overlap of one mesh and another should be 20 cm. Put as many meshes in row as needed to form a 2 m width and 14 m length stripe on the ground. One side of 14 m length should have protruding steel bars of approximately 10 cm. This side will be the upper side of the wall later on.

Use a bolt cutter to cut mesh to form and dimensions needed. Tie overlapping meshes with binding wire at each square. Form a tube of 2 m height and a diameter of 4.4 m by joining the two ends of the stripe. The reinforcement steel mesh should overlap minimum 20 cm at this joint as well. Tie mesh together with binding wire.

Figure 6: Positioning and tying of steel meshes to a stripe of 14m length.

Figure 7: Forming a circular tube with the reinforcement of the sidewall.

3 Detailed Work Instructions – Construction Diary

The sequence of actions for the construction of a ferrocement tank as described below is an ideal one. Sequence may be changed depending on availability of manpower, materials and tools as well as for weather conditions or other reasons. Some of the steps should be done parallel to work efficiently.

A day of curing of concrete and each layer of mortar and plaster is advisable to increase the strength of the material and as a result make the tank more durable. The advice is given at the end of work instructions for days on which concrete, plaster or mortar were applied.

3.1 Day 1: Siting, Excavation, and Preparation of Reinforcement Mesh

Work instructions:

- Choose a site for the ferrocement tank according to the considerations above.
- Draw a circle of outer diameter 4.4 m (radius 2.2 m) for the foundation on the ground.

Figure 8: Drawing a circle where the foundation of the ferrocement tank shall be build.

- Make the reinforcement steel mesh for foundation and place it close to construction site
- Make the reinforcement steel mesh for the sidewall (can be done at the same time the foundation is done).
- Level surface. If necessary excavate a layer of soil and compact soil to achieve an even surface.
- Place a foil onto the even surface. The foil should cover a circle and have a diameter of approximately 4.6 m (a bit bigger than the tank itself).
- Mix concrete and place several heaps of concrete on the foil to pin foil down and allow leveling of reinforcement steel mesh on heaps.
- Place reinforcement steel mesh for foundation onto concrete heaps and level the steel welded mesh with a spirit level. Establish a distance of 3-5 cm between plastic foil and reinforcement. Cut overlap where necessary to fit mesh into area of foundation.

Figure 9: Plastic foil and steel reinforcement for foundation of ferrocement tank.

- Place the reinforcement steel mesh for sidewall onto reinforcement of foundation and tie both together with binding wire. Protruding steel bars on the reinforcement form the upper side of the side wall. (At least one person should stay inside the foundation site to execute following steps.)

- Place draw-off pipe for tap or pump connection radial from the close to the centre of the tank to the outside of the wall where future use is most convenient (openings of the pipe should be covered). If necessary, fix pipe to the steel welded mesh with binding wire.
- Fill foundation site with concrete to cover reinforcement mesh with a layer of concrete of approximately 5 cm. Compact concrete and even surface using straight edge and spirit level. The foundation should be around 10 cm thick.

  Approximately 4 bags of cement, 8 wheelbarrows of sand and 12 wheelbarrows of gravel are needed for the foundation of the ferrocement tank.
- Make sure that the concrete is covering all the reinforcements around the circumference and no piece is sticking out (touching the soil)

Figure 10: Sidewall reinforcement tied to foundation reinforcement and foundation filled with concrete (draw-off pipe in place).

Following steps could either be done on day 1 or 2 (whatever is preferred):

- Apply chicken mesh to the outside of the reinforcement steel of the sidewall. Overlaps should be 20 cm. Tie the chicken mesh to reinforcement with wire.
- Place sacks to the outside of the side wall reinforcement. Best is to pin on protruding steel bars on the top.

- Tie sacks to reinforcement with cord from the top edge to the bottom. Distance from one line to another should be not larger 4 cm.

Figure 11: Placing sacks to sidewall reinforcement (already covered with chicken mesh) from the outside.

- Ensure that sacks reach to the foundation. If necessary, put additional stripes of sacks to the lower part and fix them with cord.
- Excavate whole where draw-off pipe is and tap will be installed (rectangular shape, 20 cm deep, 80 x 80 cm wide)

Figure 12: Tying sacks to sidewall reinforcement with cord.

Figure 13: Excavation of future water tap pit.

3.2 Day 2: Walling of Tank (part 1) and Brick Laying for Tap

On the second day of tank construction, the first part of sidewall construction will be done. Therefore the reinforcement will be coated with plaster. If chicken mesh and sacks were not tied to the reinforcement of the sidewall on day 1, this has to be done first. If a pump will be connected to the water draw off pipe, the construction of the tap pit maybe is not necessary.

Work instructions:

- Put 8 mm steel bar to the inside of side wall reinforcement and tie it with binding wire to the reinforcement. Start approximately 30 cm from the foundation and go from bottom to top (each 30 cm one steel bar). *If the steel reinforcement of the sidewall is thicker than 4 mm, then additional 8 mm steel bars are not necessary.*

Figure 14: Tying 8mm steel bars to sidewall reinforcement from the inside (from the ground each 40 cm to the top).

- Put wooden sticks into the ground around the tank in a distance to the foundation of 1.5 m to 2 m. Those sticks are used for fixation of the sidewall reinforcement. *Fixation can also be done in different ways, but should be robust enough to keep sidewall in position.*

- Level sidewall reinforcement by using spirit level. Fix reinforcement in leveled condition with cord to wooden sticks around the tank.
- Mix plaster. *Approximately 3 bags of cement and 9 wheelbarrows of sand are needed. Mix inside the tank.*
- Apply a coat of plaster to the inner side of the reinforcement of the sidewall (1-2 cm thick) so that reinforcement mesh is totally covered. This can be done by hand or by use of trowel and float.
- Ensure that plaster is also applied in the edge from sidewall to foundation.
- Keep a small space (5 cm x 5 cm) without plaster at the upper edge of the sidewall, where the overflow pipe will be fitted later on.
- The coat of plaster needs 1 day of curing. During this time it should be sprinkled with water three or four times or covered to ensure ideal strength.

Figure 15: Leveling and fixing sidewall in position.

Figure 16: Applying the first layer of plaster to the sidewall from the inside.

The work for the tap pit can be done at the same time the plastering of the wall is done:

- If not done on day 1, excavate a hole where the draw-off pipe is facing out of the tank foundation and where tap will be installed (rectangular shape, 20 cm deep, 80 x 80 cm wide).
- Place bricks to the sides of the excavation (the long, slim side should face the ground to ensure sufficient space to tap water when tank is used).
- Fill gaps between bricks with mortar.
- Apply mortar to the area around the draw-off pipe and level surface.

Figure 17: Placing bricks into future water tap pit.

Day of Curing of Plaster

3.3 Day 3: Walling of Tank (part 2) and Laying Bricks to Tap Pit

On the third day of construction, sidewall as well as tap pit will be continued. Therefore, another layer of plaster has to be applied to the wall from the inside and another layer of bricks has to be put in place.

Work instructions:

- Mix plaster. *Approximately 3 bags of cement and 9 wheelbarrows of sand are needed. Mix inside the tank.*
- Apply a coat of plaster to the inner side of the sidewall (1-2 cm thick).
- Ensure that plaster is also applied in edge between sidewall to foundation.
- Keep a small space (5 cm x 5 cm) without plaster at the upper edge, where later on the overflow pipe will be fitted.
- The coat of plaster needs 1 day of curing. During this time it should be sprinkled with water three or four times or covered to ensure ideal strength.

The work for the tap pit can be done at the same time the plastering of the wall is done:

- Apply some mortar to the bricks in the tap pit.
- Lay another row of bricks on top of the bricks already positioned.
- Fill gaps between bricks with mortar.

Day of Curing of Plaster

Figure 18: Laying second layer of bricks and plastering the future water tap pit

3.4 Day 4: Walling of Tank (part 3) and Finishing of Floor.

On the fourth day of construction, the sidewall will be finished from the inside with another layer of plaster and a finishing treatment with cement slurry to improve water tightness of the wall. In addition, the floor will be finished with a layer of plaster which has to be leveled and smoothened.

Work instructions:

- Mix plaster. *Approximately 6 ½ bags of cement and 19 wheelbarrows of sand are needed during day 4. Mix only the amount of plaster you can process at a time.*
- Apply a coat of plaster to the inner side of the sidewall (1-2 cm thick).
- Use a straight edge to straighten the surface. Use a wood float to smoothen the surface.
- Clean the floor of the tank.

- Mix cement slurry (NIL) and apply to inside wall of the tank using a can or a brush. Use steel float or trowel to press NIL and plaster to get a very smooth surface.
- Apply a layer of plaster (approximately 1-2 cm thick) to the floor of the tank and straighten surface.
- Fill edge between sidewall and floor with mortar and round with trowel.
- Finishing inside of sidewall and floor of tank should be done on the same day.

Figure 19: Application of cement slurry (NIL) to sidewall from the inside (floor and edges already smoothened)

- Remove cord and sacks from the outside of the sidewall.
- Apply a coat of plaster to the outside of the sidewall (1-2 cm thick).
- The plaster (inside and outside; walls and floor) needs 1 day of curing. During this time it should be sprinkled with water three or four times to ensure ideal strength.

Day of Curing of Plaster

Figure 20: Plastering the sidewall of the ferrocement tank from the outside after removal of sacks.

3.5 Day 5: Walling of Tank (part 4) and Preparation of Roof Reinforcement.

On the fifth day of construction, the walling of the outside of the tank will be continued. This time the layer of plaster has to be smoothened after application and the wall has to be treated with cement slurry. In addition the roof will be prepared. The reinforcement has to be made from steel welded mesh, chicken mesh, as well as sacks which will be tied to the reinforcement.

Work instructions:

- Mix plaster. *Approximately 3 bags of cement and 9 wheelbarrows of sand are needed.*
- Apply a coat of plaster to the outside of the sidewall (1-2 cm thick).
- Use a straight edge to straighten the surface. Use a wood float to smoothen the surface.

Figure 21: Application of plaster to the outside wall of the ferrocement tank and smoothening of the surface.

- Mix cement slurry (NIL) and apply to outside wall of the tank using a can or a brush. Use steel float or trowel to press NIL and plaster to get a very smooth surface.
- The coat of plaster needs 1 day of curing. During this time it should be sprinkled with water three or four times to ensure ideal strength.

The preparation of the roof reinforcement can be done at the same time the plaster is applied to the outside of the sidewall:

- Make roof reinforcement the same way the reinforcement of foundation is made.
- Cut the manhole of 50 cm x 50 cm into the reinforcement at a convenient place not too far from the edge. *It is also possible to cut manhole into the reinforcement, when shaping a dome and positioning of support poles in tank is completed.*
- Put chicken mesh to the reinforcement of the roof and tie them together with binding wire.
- Place sacks on the circular steel mesh and sew them to the mesh with a thin rope and needles. The mesh must be totally covered with sacks.

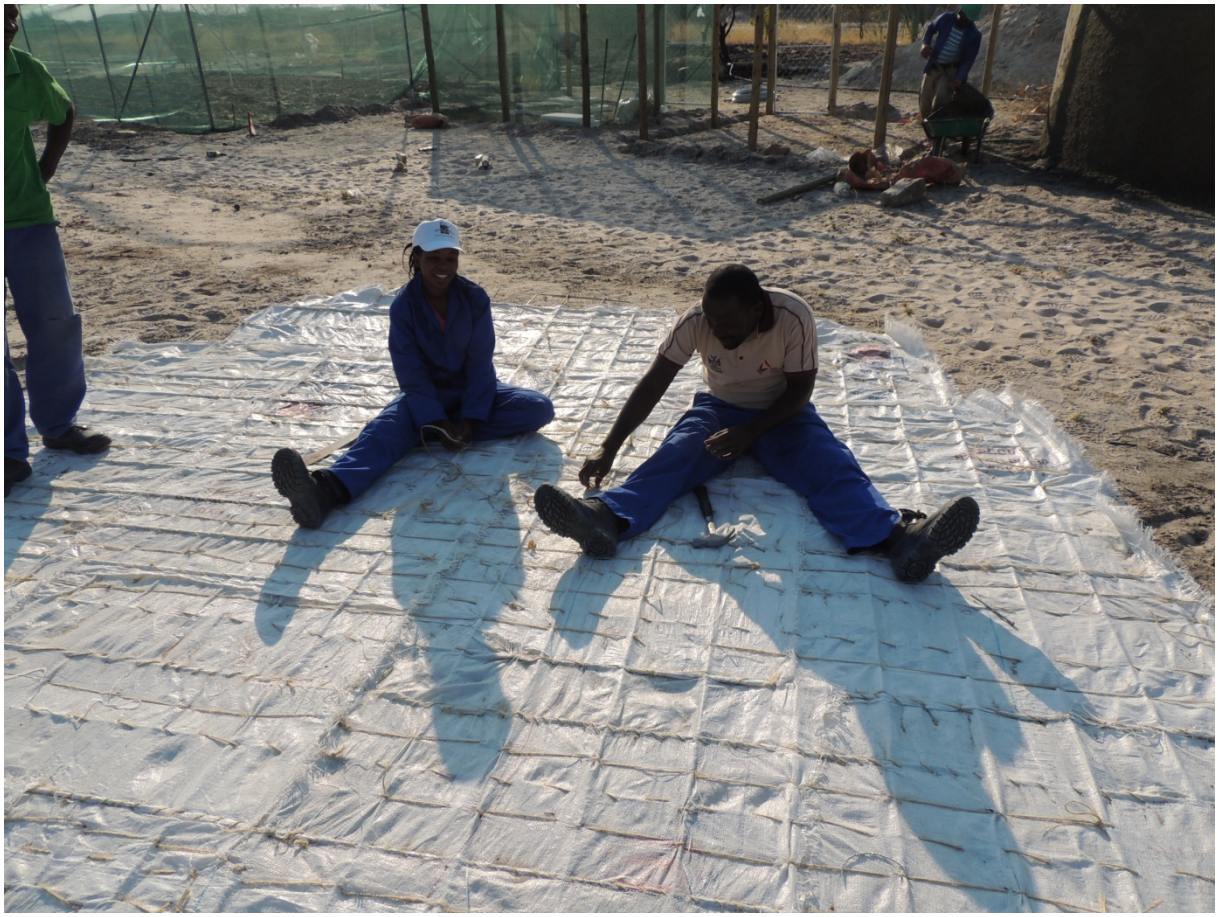

Figure 22: Tying sacks to roof reinforcement with rope and needle.

- Turn reinforcement upside down, so that sacks are facing the ground and steel mesh is on top.
- Place the roof reinforcement with sacks on downside onto the tank. The roof reinforcement now is lying loose on the tank. *In windy regions or if raining, fixation should be done on the same day (description see day 6).*

Day of Curing of Plaster

3.6 Day 6: Finishing the Wall of the Tank and the Fetching Point.

On the sixth day of construction, the sidewall of the tank and the tap pit for fetching the water will be finished. The last layer of plaster is sprayed to the wall with a plaster sprayer. Depending on availability of tools, it can also be applied by trowel.

Work instructions:

- Mix plaster. *Approximately 3 bags of cement and 9 wheelbarrows of sand are needed.*
- Apply plaster to outside of tank by use of a plaster sprayer.

Figure 23: Application of final layer of plaster with plaster sprayer. Border of foundation not leveled and smoothened yet.

- Apply plaster to outside borders of foundation.
- Level and smoothen the base with trowel or straight edge and form a proper edge with wood float.
- Apply plaster to the bricks forming the tap pit. Level and smoothen plaster with trowel or straight edge to achieve a smooth surface.
- Fill in a layer of gravel into tap pit to allow good seep away of spilled water when tank is in use.

Day of Curing of Plaster

3.7 Day 7: Construction of the Roof

On the seventh day of construction, the roof will be build. Therefore, the roof reinforcement is fixed on the top edge of the sidewall and shaped as a dome with wooden support poles from the inside of the tank. In addition a gauge is build, which acts as water level indication and support for the roof.

Please consider that a proper construction of the roof is essential for stability and long lifetime of the ferrocement tank.

Work instructions:

- Place a 2.4 m high support pole to the middle of the tank to support roof reinforcement.
- Fix the roof reinforcement to the sidewall by bending the protruding steel bars and with binding wire.
- Support roof reinforcement with more support poles of length of 2 m to 2.4 m (maximum distance of one support pole to another should be 70 cm) and shape a dome out of roof reinforcement. In total approximately 60 support poles are needed.

Figure 24: Roof reinforcement fixed tot he sidewall by bending the steel bars and usage of binding wire.

Figure 25: Placing support poles into the tank to support the roof reinforcement and form a dome shape.

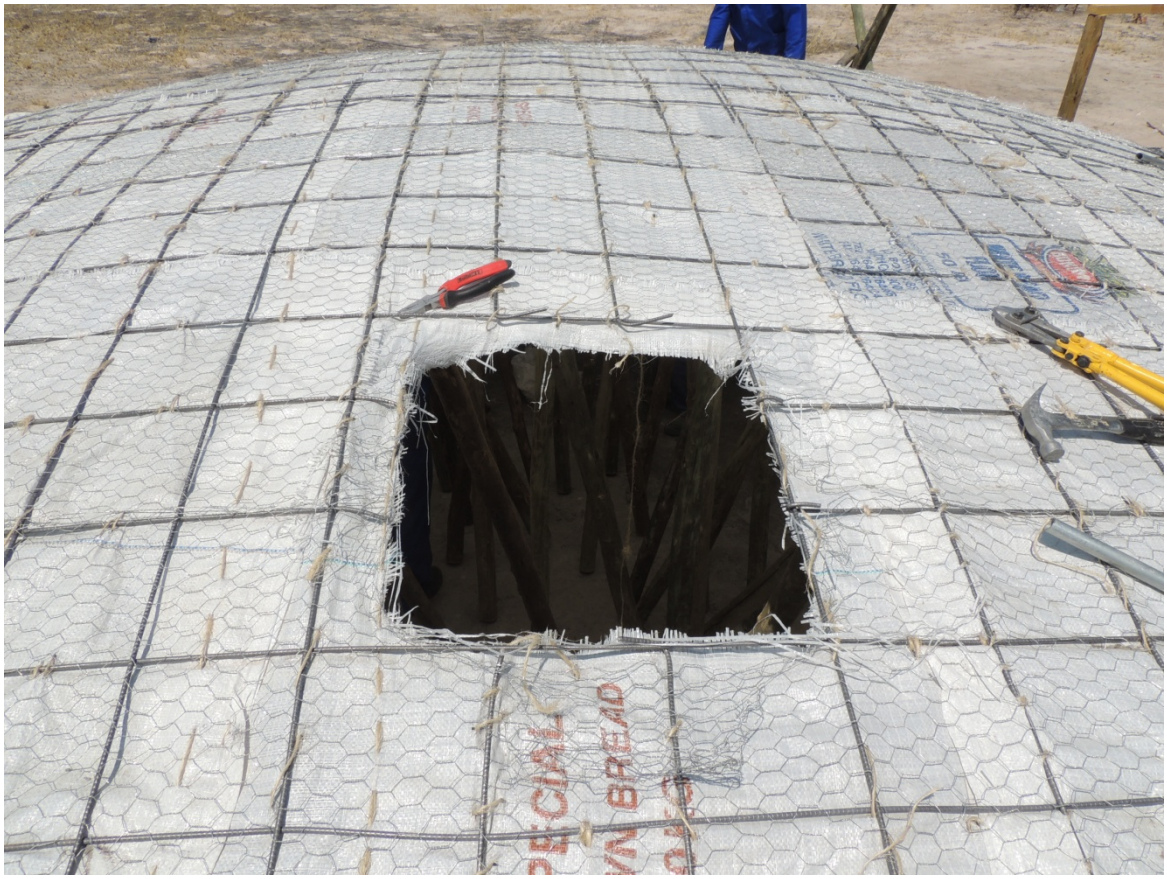

Figure 26: Roof with good dome shape and manhole cut into reinforcement.

- Fit manhole cover (50 cm x 50 cm) into roof reinforcement and fix it to reinforcement steel mesh with binding wire.
- Check stability of roof reinforcement by stepping on. If reinforcement is bouncing, more support poles are needed inside the tank.

- Cut a 4" PVC pipe to a length of approximately 2.3 m.
- Mark the PVC pipe every 33 cm beginning from one end. 5 marks are needed in total.
- Cut opposing holes to PVC pipes at each mark. Holes should be aligned to same direction from one mark to another since the pole shall serve as ladder and water level indication.
- Cut aluminum or steel pipe to a length of 25-30 cm and put them into the holes that were cut into the PVC pipe. 5 aluminum/steel pieces are to be placed in the PVC pipe.

Figure 27: 4“ PVC pipe with aluminum pipes assembled to it. Pipe has to be fixed to roof reinforcement near manhole and has to be filled with concrete.

- Place the PVC pipe inside the tank close to the manhole. The pipe later on will be gauge and ladder at the same time.

- Place 3 reinforcement steel bars inside the pipe, fix them to the roof reinforcement by bending and with binding wire and pour concrete inside the PVC pipe (ratio of concrete: 1 part cement, 2 parts sand, 3 parts gravel).
- Compact concrete from above with an iron bar.
- Mix mortar and apply it onto roof until all reinforcement steel is covered with a layer of mortar of 3-5 cm thickness. *Approximately 8 bags of cement and 24 wheelbarrows of sand will be needed.*
- Keep an opening of 20 cm x 20 cm free from mortar. This is where the roof water will enter the tank. Insert a fine mesh (the same as for sieving sand) and put mortar around to fix it to the roof.

  Instead of this opening, a PVC pipe can be installed, which can be connected to the rainwater downpipes and gutters later on.
- Fit the overflow pipe (2" plastic pipe, 40 cm length) to the space which was left free from plaster on the top edge of the sidewall and apply plaster to fix it in position.
- Use trowels, a straight edge, and wood float to smoothen the mortar, form a good dome shape, and ensure proper edges from roof to sidewall

Figure 28: Application of mortar to the roof reinforcement and smoothening of the surface with wood float.

- The finished ferrocement tank needs minimum 21 days of curing before commissioning. During this time it should be sprinkled with water several times to ensure ideal strength.

- To support curing and keeping the tank surface moist, hessian sacks can be put on the tank after completion.
- The manhole shall be covered either by fixing sheet metal to the frame of the manhole cover either by welding or tying. The second method is tying sacks to the fram of the manhole cover and pouring concrete into it. A piece of reinforcement steel bar can be bent into the shape of a handle and placed into the concrete.
- Before commissioning of the tank, place filters in front of ventilation and overflow pipes. These will prevent insects from entering the tank. Fine mesh, net or cloth can be used.

Figure 29: Nearly finished ferrocement tank with overflow pipe (left), manhole cover (centre), and opening for water inlet (upper right side). (The base of the tank is not yet plastered on this picture.)

4 Estimated Bill of Material

	Material	Quantity	Approximate Amount in N$
1	Cement	42	4000
2	Weld Mesh 2.4m x 6m x 8mm	6	4700
3	Binding Wire 2mm x 200m	15 kg	300
4	Chicken Mesh 25mm x 1.2m x 50m	1 roll	830
5	Steel Deformed Bars 8mm x 6m	3	95
6	Bib Tap Garden 20mm	1	120
7	Galv. Elbow 20mm	1	6
8	Galv. Plug 20mm	1	3
9	Galv. Standpipe 20mm x 600mm	2	60
10	Galv. Standpipe 20mm x 750 mm	1	50
11	Galv. Socket 20mm	1	5
12	Galv. Tee 20mm	1	7
13	Manhole Cover 50cm x 50cm	1	150
14	PVC Pipe 4” (110mm) x 6m	1	190
15	PVC sheeting 0.15mm x 4m x 10m	1	200
16	Gravel / Concrete stone (½” to ¾”)	2.5 m^3	2750
17	Clean River Sand	10 m^3	750
18	Sisal Rope 1 Ply 500 gr.	4 kg	210
19	Assorted Nails Wire 100mm x 4mm	1kg	20
20	Empty Sacks	60	125
21	Water		
22			
	Total Materials		**14571**
23	Proposed labor	40	4000
	Grand Total		**185716**

Material needed for gutters and downpipes depends on circumstances of roof catchment and tank position. This material is not listed in the bill of materials and should be considered when planning a roof water harvesting facility with ferrocement tank. Material for gutters will cost around 2500-3000 N$.

5 Bill of Tools

	Tools	Quantity	Approximate Amount in N$
1	Spade	1	105
2	Shovel Round Nose	1	100
3	Wheelbarrow	1	420
4	Bolt Cutter 600mm	1	210
5	Plastering Trowel 280mm	3	110
6	Plastering Float, Wooden 280mm	2	60
7	Hand Saw 550mm	1	105
8	Hammer Claw 500gr	1	170
9	Seewing Needles	4	15
10	Spirit Level, Aluminum 600mm	1	80
11	Bucket, builders 12l	2	90
12	Gloves, builders PVC	1	16
13	Gloves, leather	3	60
14	Rake, garden medium duty	1	75
15	Plier, combination	2	100
16	Hacksaw Frame	1	44
17	Blades, Hacksaw 32TPI HSS	1	20
18	Roof Support Poles (Gum Poles)	70	2745
19	Plaster Sprayer		
	Grand Total		**4525**

Amount of tools needed depends on number of workers supporting the construction of the ferrocement tank. Tools and quantity listed above is suitable for 5-8 workers.

6 Construction Procedure Table

Day of preparation and days for curing of concrete and mortar were not counted in the detailed work instruction, but are counted in the table below.

Day	Activity	Materials used	Remarks
Day 1	Purchase and supply of materials.		
Day 2	Site selection and start of construction. Foundation setting and reinforcement fixing	2 steel mesh for foundation, 3 steel mesh for wall 4 bags cement 8 wheelbarrows gravel 12 wheelbarrows gravel plastic foil water draw-off pipe binding wire water	
Day 3	Chicken mesh and sacks application. Reinforcing and leveling sidewall. Tank smearing (application of mortar). Tap pit excavation and brick-laying.	3 rolls chicken mesh and 30 empty sacks of 50kgs 4 bags cement 12 wheelbarrows sand 8 mm steel bars binding wire cord 4-8 bricks water	"Empty sacks" to fix at sidewall reinforcement 8mm steel bars not needed if reinforcement steel mesh is more than 4mm. Amount of bricks depends on size of tap pit.

Day	Activity	Materials used	Remarks
Day 4	Curing of mortar.	water	Keep surface of mortar humid.
Day 5	2nd layer of mortar to sidewall from inside. Brick-laying in tap pit.	4 bags cement 12 wheelbarrows of sand 4-8 bricks water	Amount of bricks depends on size of tap pit.
Day 6	Curing of mortar.	water	Keep surface of mortar humid.
Day 7	Final layer of plaster to sidewall from inside, and NIL application. Final layer of plaster of the floor. Application of first layer plaster from the outside.	2 bags cement 6 wheelbarrows of sand water	
Day 8	Curing of plaster.	water	Keep surface humid.
Day 9	Application of plaster and NIL to the sidewall from the outside. Preparation of roof reinforcement.	6 ½ bags cement 19 wheelbarrows of sand water 2 steel mesh for roof reinforcement 1 roll chicken mesh binding wire 10-15 sacks Sisal rope	
Day 10	Curing of plaster.	water	Keep surface humid.

Day	Activity	Materials used	Remarks
Day 11	Finishing sidewall and water tap pit.	3 bags cement 9 wheelbarrows of sand water	
Day 12	Curing of plaster.	water	Keep surface humid.
Day 13	Construction of the roof.	60-70 support poles binding wire manhole cove 4” PVC pipe Steel pipe 3 round steel bars 8mm of 2.4 m length 12 bags cement 32 wheelbarrows of sand 11 wheelbarrows of gravel 2” PVC pipe mesh	 as water level indication and ladder as overflow pipe as filter for rainwater
Days 14 to 35	Curing of plaster. Finishing manhole cover and placing filters to opening.	Water Sheet metal or concrete Net, mesh, or cloth	Keep surface humid.

7 Maintenance of the Ferrocement Tank

If the ferrocement tank is properly constructed and cured it should last at least 30 years. Maintenance of the tank is of low effort, but nevertheless it has to be done regularly. In this chapter easy but important instructions for cleaning and repairing the tank will be given.

7.1 Visual inspections

The condition of the tank shall be monitored continuously. Check if roof, side walls, and foundation, as well as other parts of the tank are in a good shape (from outside and inside). No cracks and no wet areas should be visible. If any crack was observed, it should be evaluated how long and deep it is. In addition the position of the crack is important. Small cracks, which only affect the surface, in general do not harm function and safety of the tank. They may be repaired within the next annual maintenance activity. Cracks in the sidewall which go along with wet surface of the tank, can lead to increasing leakage in a short period of time. Repair works should be planned as soon as possible. Deep and long cracks in the roof do not show wet area and do not lead to a leakage (since the water level is below the roof). Nevertheless, the stability and security of the tank can be at risk. Repair works should be initiated soon. In addition, it should be ensured, that no one is stepping on the roof of the tank until the crack is repaired.

During the visual inspections, it shall also be checked, whether the gutters are in good condition. In addition, filters to avoid insects and dirt from entering the tank should be checked. In case of damages filters shall be repaired or exchanged.

7.2 Cleaning the tank

Once every year the tank should be drained completely and all accumulated soil and dirt shall be removed. Best time for cleaning is directly before start of the wet season, when the tank is already empty or close to be empty. To drain the tank, open the water tap and let run-off the water. If water shall be used for irrigation or other purposes, use bucket, can or other objects to collect water from the tap. Then, climb inside the tank and remove the rest of the water with a bucket and sheets or a sponge. When the floor of the ferrocement tank is dry, remove the soil remaining on the tank floor by use of a waste cloth. The cleaning procedure will assure that water stored in the tank during the next wet season will be as clean as possible.

7.3 Repair of cracks

Repair of cracks can require different amount of effort. Small cracks without influence on function and water tightness shall be repaired by applying a thin layer of mortar to the crack. This is a cosmetic repair only.

Cracks on the sidewall that go along with wet areas due to leakage, need some more effort. First, water level shall be below the position of the crack. This ensures, the surface around the crack is dry and repair work can be done in good quality. One attempt to repair a crack going along with leakage is to fill the crack with mortar. This shall be done from inside and outside the tank if crack is visible on both sides of the sidewall. Mortar should be kept humid to allow gentle shrinking. Mortar should be applied to the cracks in two or three layers, depending on the length and deepness of the crack. Finally a layer of cement slurry shall be applied to the repaired area and the area around.

If filling the crack with mortar does not help or seems not sufficient for a very long or deep crack, another method has to be used. Use hammer and chisel to remove mortar around the crack until reinforcement of the sidewall is visible. Clean the area from dust before going on with the repair. Apply a thin layer of mortar on to the reinforcement of the sidewall. Place chicken mesh on top of the first layer of mortar and cover with another thin layer of mortar. Depending on the dimensions of the spot to be repaired, two or more layers of mortar, chicken mesh, and mortar shall be applied. Keep humid to ensure gentle shrinkage of mortar while drying. The area which was repaired shall be finished with a layer of cement slurry and cover of plaster. If the crack was inside and outside the tank, start and finish one side before continuing with the next one.

In addition, bituminous paint can be used to seal the surface of the tank and avoid leakage.

Fact sheet on CuveWaters „Ferrocement Tank“

Within the Integrated Water Resource Management project CuveWaters, different water supply and sanitation techniques are implemented in central northern Namibia as part of a multi-resource mix. One of these options is Rainwater Harvesting. Rainwater Harvesting is a technology that is very well-known all over the world as a means of providing good quality water on a small scale. Rainwater is generally collected from roofs or on non-permeable surfaces on the ground and stored in tanks below or above ground. In 2009 and 2010, four different tank systems were implemented in the pilot village Epyeshona (Okatana constituency, Oshana region), three single household systems and one community catchment. The harvested water in these tanks is mainly used for micro-scale gardening purposes by the users. In the following years further tanks were constructed in Iipopo and Ongwediva.

From the present knowledge, it is obvious that the single household tank constructed of Ferrocement is the cheapest, the easiest to construct, and the most sustainable. We propose to construct Ferrocement Tanks in central northern Namibia. During the pilot plant building phase, people were trained in constructing Rainwater Harvesting tanks and adjoining infrastructure. These people are now ready to construct further tanks in central northern Namibia.

CuveWaters Ferrocement tank facts:

Basic information

- Needed infrastructure: Roof catchment area of at least 100 m², made of corrugated iron or comparable material
- Tank storage volume: 30 m³
- Tank life time: 30 years (if maintained properly)
- Maintenance costs per year: 100 N$

Costs for construction and duration of construction

- Material costs: 20,000 N$
- Overhead costs (transport, labour etc.): 21,250 N$
- Duration of construction: 10 working days

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Benefits for the users

Self sufficiency: The harvested rainwater is mainly intended for micro-scale gardening purposes. Products from gardening can help rural inhabitants of central northern Namibia in improving their diet and generating a small income.

Security: Through diversifying the water supply households are better adapted to environmental changes and water supply system failures.

Figure 1: Ferrocement Tank in the village of Epyeshona

Figure 2: A garden attached to the Rainwater Harvesting Tank can improve self-sufficiency and generate a small income