DTU Technical Release Series TR-RWH 03

Experimental Rammed Earth Tanks - Instructions for manufacture

(based on the construction of an experimental rammed earth tank at Kyera Farm, Mbarara, Uganda)

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Content:

Introduction

The guidelines for manufacture given below are based on an experimental tank built at Kyera Farm, Mbarara, Uganda during June and July 2000. This type of tank is still at the experimental stage and is NOT recommended for manufacture as yet. The tank described below failed after being filled, but was due to a poor lining, which was the result of bad workmanship.

Tank specification

Tank internal diameter	2.0m

Tank external diameter	2.4m
Tank height	2.0m
Tank capacity	approximately 6 cubic metres
Base	100mm stone with 50mm concrete or 50mm compacted stabilised soil, 2.8m diameter
Wall	Stabilised soil, 0.2m thickness
Reinforcement	barbed wire hoops at 50-60mm spacing in rammed earth sections
Soil make-up	10% clay, 15 30% silt, 50 70% sand, 10 20% gravel, 4% cement stabilisation
Tank lining	plastic or cement render lining (latter described below)

Water extraction	by gravity or by siphonic tap (latter described below)
Cover	DTU thin-shell ferrocement cover with extended eave

Glossary

- Section A quadrant of rammed earth wall (see Figure 1)
- Lift One complete ring or 4 sections
- Pour Earth is poured to a depth of 100mm before being rammed. This is known as a pour

Figure 1 a Section of rammed earth tank wall

Tools and equipment required

- Shuttering and tie rods (see Figure 1 and Figure 4 details for manufacture

available upon request)

- Rammers (both flat and V) (see Figure 5)
- Spirit level (600mm)
- Hammer
- Spades or shovels (2)
- Buckets
- Soil preparation equipment

Soil preparation

- Find suitable soil field and lab tests are required to confirm suitable soils and some modification of the soil may be needed
- Transport soil to site. It is good to find soil as close to the site as possible.
- Prepare the soil using suitable equipment (e.g. hammers, groundnut mill, sieves or mechanised equipment). The soil needs to be made fine enough to allow good mixing.

Figure 2 A groundnut sheller fitted with 4mm sieve being used to break down soil ready for mixing

- Calculate the amount of soil required for one section using the following formulas:

Volume, $V = o\ (r_o^2\ r_i^2) \times h/4$

Weight , W = Volume x Material density

where, o = 3.142

r_o = outer radius of tank

r_I = inner radius of tank

h = height of one lift

Take material density to be 2000kg/m^3, where actual figures are not available.

- Mix soil in the correct proportions if soil modification is needed (in the case of the Mbarara tank we used 80% anthill soil, 16% coarse murram [and 4% cement]). Mix enough for one section at a time and then add cement to enough soil for one pour at a time.
- When ready to pour, add the cement to give a 4% stabilisation and mix the soil thoroughly and add enough water to satisfy the drop test.
- The soil should be kept dry if not used and soil that has had cement added should be discarded if not used.

Figure 3 Mix soils together and then add cement and water only enough for one pour at a time

Marking out the site and laying the base

- Find a suitable location for the tank enough space and close enough to the catchment area
- Level the ground to provide a circular area whose radius is at least 0.5m greater than the tank (external) radius

- Where the ground is soft, a stone base of 150mm deep is required whose surface is 50mm below the normal ground level (NGL). The diameter of the stone foundation and base is 2.5m.
- The type of base used depends on whether a plastic or render liner will be used:

  - Where a plastic liner is used, the remaining 50mm is filled with stabilised soil and rammed to provide a firm base for the tank.
  - Where a render lining is used, the base is constructed using a concrete of mix 4:2:1 to a depth of 50mm.

- Ensure that there is sufficient clear area around the base to place the shuttering

Ramming the first section of wall

- Mark out the inner and outer wall radii, using chalk or a nail scratch mark.
- Place the shuttering such that it sits in the correct position, straddling the

inner and outer marks

Figure 4 Showing the shuttering located over the marked radii with end stops and tie rods in place, ready for the soil to be poured.

Figure 5 Rammers or tamps used for compacting the soil. The V tamp is used to create the shear bond between pours.

- Ensure that the end stops are in place and that the tie rods are in place but not fully tight (Figure 4)
- Level the mould both vertically and horizontally while tightening the tie rods fully. Check well on all faces for level and plumb
- Pour the mixed soil between the shuttering to a depth of 100mm. This can be made easier by marking 100mm onto a stick and using this as a guide.
- The soil is then rammed lightly using the flat rammer (Figure 5). The ramming pattern should be kept even to ensure uniform compaction.
- The soil is then rammed again more firmly until there is a solid feel. Again the ramming pattern should be kept uniform.

- The rammed pour is then finished with the V rammer. This aids bonding between the rammed pours and helps prevent shear (Figure 5).
- A 2.3m length of barbed wire is cut and placed in the V trough. This should give an overlap of 300mm at either end which is used for tying the wire to the next length. The end of the wire is folded upward so that it can be pulled out easily later (Figure 6).

Figure 6 shows the tails of the barbed wire that has been rammed into the earth wall. These tails are tied to next piece of wire to form a continuous loop within the cylindrical wall.

- A further 100mm is poured into the mould and rammed in the same way as described above.
- This is continued until the section is complete.
- The tie rods are removed (they will be tight due to the compaction pressure) and the shuttering moved very carefully away from the wall section.

Figure 7 The shuttering is removed to reveal the first completed section of

rammed earth wall.

Completing the first ring

- The shuttering is moved around and replaced in such a way that the part of the shutting beyond the tie rod holes clamp lightly onto the finished section of wall. The tie rods are butted against the end of the completed wall section. The two end stops are both inserted in the open end.
- The section is then rammed in the same way as the first section.
- Barbed wire is tied to the tails as required and rammed into the wall, as with the first section.

Figure 8 - The first ring is complete and the shuttering is lifted up to start the next lift.

- When the second section is complete, the third is rammed in the same way.

- Finally the fourth section is rammed. The shuttering overlaps both the third and the first sections now and no end stops are required.
- Usually, it is possible to complete one ring per day. Cover each section with polythene sheet, weighed down with stone, to prevent rapid moisture loss. Remember that the cement has to be cured, just like concrete.

Ramming subsequent lifts

- The subsequent lifts are rammed in the same way as the first.
- The shuttering is now, however, clamped onto the previous lift and the tie rods rest on top of the soil wall of the lower sections
- The sections are built 45^{o} out of phase with the section below (as with brick wall building), to obtain a well-bonded structure.
- Where the geometry of the tank is lost slightly and the shuttering no longer fits properly (this sometimes happens due to poor levelling), the soil can be cut away carefully with a machete.

Figure 9 The fifth lift is being rammed here and scaffolding is being used to allow the workers easy access to the work

- Scaffolding is used to access the work once it becomes difficult to do so without.
- The overflow pipe is cut in during the last lift keep the pipe invert at 100mm below the top wall level. Give the pipe a slight gradient outward.
- If a siphonic water extraction system is being used (see later), provision should be made for a " pipe to be brought out at the top of the tank.
- The tank should be cured for 2 weeks under plastic before the next stage.

Rendering the tank

- The tank is rendered internally with a cement mortar. The mortar is a 1:4 mix with waterproofing agent. Two coats are applied, approximately 10mm each coat.
- Firstly the walls are cleaned to remove any loose material and then

scratched with a nail brush (or similar) to provide a key for the render. The walls are damped before the render is applied to prevent the walls sucking the moisture out of the render.

Figure 10 The tank is internally rendered with 1:4 mix sand cement mortar. Ensure a good joint between the wall and the base as this can be a point of weakness

- The waterproofing agent usually comes in powder form in 1kg bags. 1kg is added for every 50kg of OPC.
- Ensure a very good bond between the render and the floor of the tank and use a good fillet to seal the joint well. This is a point of weakness.

Fitting the cover

- For this tank, a thin-shell, ferrocement cover is used. The construction of

this cover is dealt with in another DTU Technical Paper. The cover is altered slightly to give overhanging eaves, which help to protect the tank from rain.

- When complete the cover is lifted into place by about 6 people and the joint between the wall and cover rendered to make a good seal.
- A basin is used as the cover hatch and this is also used a filter. The basin is filled with coarse gravel and cloth is tied over the top, which prevents any organic matter or larger debris from entering the tank.

Figure 11 Technical drawing of the RE tank

Water extraction

- There are two methods described here for water extraction; one is the siphonic system and the other the gravity system.

Figure 12 Showing the overflow and the overhanging eaves of the thin-shell, ferrocement cover

- The siphonic system is shown in Figure 11. It works as a simple siphon, which once started, is controlled by the outlet tap. The floating off-take shown in Figure 12 helps ensure that only the cleaner water at the surface is drawn off first more detail of the floating off-take is given another DTU Technical Paper titled A Manual for the Construction of Direct Action Handpumps for use with Rainwater Harvesting Tanks. The benefit of the siphonic system is that the tank wall need not be pierced.
- The gravity system is the type more commonly fitted to rainwater tanks. This type of system can also be used but then the outlet pipe needs to be incorporated during the ramming of the first ring.

External finish

- The tank can be finished externally using cement render if required. Figure 13 below shows a tank finished with rough cast (a cheap option) and fitted wiwth a gravity water extraction system.

Figure 13 Showing the completed tank

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