Milestone A3

‘Completion of one externally reinforced brick tank, two brick test cylinders, one partially below ground tanks and five thin-shell ferrocement tank covers’.

(Originally titled ‘Completion of 6 underground tanks with instrumentation’)*

University of Warwick

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*Early in the programme, after the initial desk study had identified the areas where further research is required, it was decided to broaden the original scope of the water storage (technology) component of the programme to include above ground, free-standing water storage tanks as well as underground tanks. The focus of this work, as reported in Milestone A2, has been primarily the research into externally reinforced, single-skin brick tanks. It was also decided that we would put some resources into developing a simple, cheap, lightweight, tank cover, as this was seen as an area where little work has been done and where there was much scope for improvement for relatively little input. The title of this Milestone has therefore been altered to reflect the practical research work that has actually been carried out under the programme.

1. Externally reinforced brick tanks

The early work on this topic was reported in Milestone A2 and covered the early tests that were carried out on brick cylinder specimens that were constructed at the University's civil engineering laboratory.

The aim of the tests were to determine the suitability of single-skin, burnt-brick, externally-reinforced (with packaging strap in this case) cylindrical tanks for water storage. The specimens were subjected to pressure forces in order to determine the hoop stresses induced in the strapping and the behaviour of the brick-strapping combination under load and at failure. The test results were then compared with a spreadsheet model that had been generated earlier.

The early results proved promising but were inconclusive due to some uncertainties in the experimental procedure. Further tests are currently underway at the University to more fully model the behaviour of the tank under load.

Figure 1 below shows one of the specimens under test, showing the internal expansion ring used to apply pressure. Figure 2 shows the steel strapping with a strain gauge that was used to measure the hoop stress generated. For fuller details of the tests, please refer to the Milestone A2 report.

Further work has since been carried out on the construction of a full-sized tank for rainwater storage at a field site in Herefordshire. The tank has a capacity of approximately six cubic metres, with a diameter of 2m and a height of 2m. The tank is at present complete, but without instrumentation as yet. The aim of the experimental tank (shown under construction in Figure 3 below), is to further investigate the behaviour of the tank with particular regard to induced stresses under real conditions and also to investigate the feasibility of a number of peripherals designs.

The tank has been built at the site of a Herefordshire based educational charity who run regular residential courses. The tank will store water captured from the roof of a large shower and toilet complex and the water is then pumped to a header tank from where it is piped to the toilets for flushing. The tank will experience regular cycling (emptying and filling) and hence will allow regular analysis of the stresses and achieve a simulation of accelerated ageing. The cost of the system was shared between the University of Warwick and the charity. The schematic diagrams for the system are shown in appendix 1.

The site will also give us a valuable UK based field testing station at which we can pre-test any idea or component before passing them on to partners or field contractors for further testing and development. The site has already been used to test plastic tank liners which are being developed at the University, as well as being fitted with a novel overflow/ washout system. The system is fitted with WISY filters, which will be tested for efficiency at a later stage.

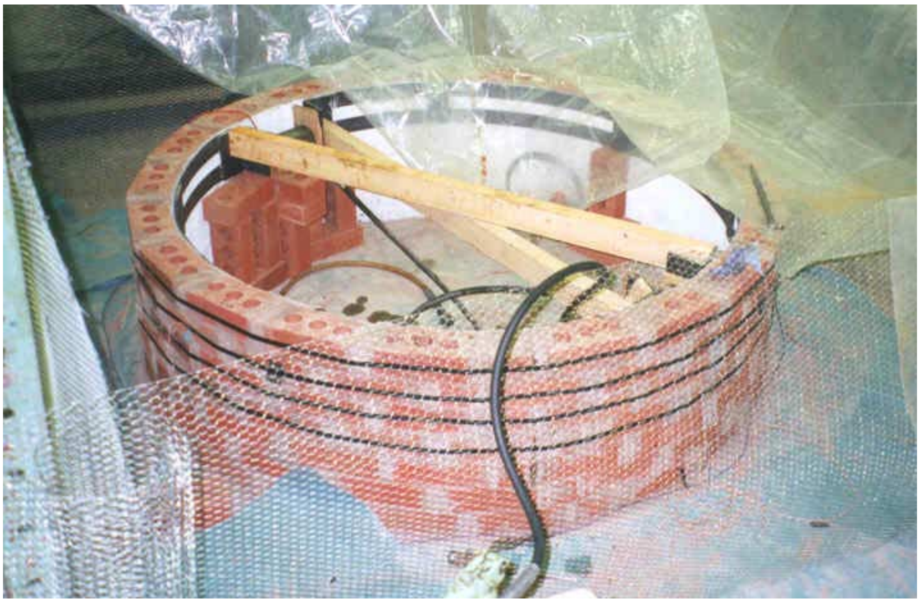
Figure 1 – Tests arrangement for externally reinforced brick cylinders


Figure 2 – Strain gauge used to measure hoop stress generated in steel strap during testing.

Future work in this area will include research into the use of cement stabilised soil blocks in place of brick, used in conjunction with a plastic tank liner, with the aim of reducing costs further.


Figure 3 – Full-size experimental tank under construction at field site.


Figure 4 – Strapping applied to experimental tank.

Results of the tests carried out at the University and at the field site will be reported in Milestone A5.

2. Partially below ground tanks

The work on partially below ground tanks is still in the very early stages and, to date, has been primarily field based. The work builds on previous DTU work in Uganda with fully below-ground tanks. Modifications were made to the original (fully below-ground) design to eliminate some of the problems commonly encountered with this type of tank, while still taking advantage of the beneficial aspects. These problems are:

- ingress of water from above ground causing contamination
- danger to children (and adults) if cover is left off the tank
- danger of collapse if driven over with a vehicle
- difficulties in excavation due to the construction process (see DTU Working Paper number 'Underground Storage of Rainwater for Domestic Use' at http://www.eng.warwick.ac.uk/DTU/workingpapers/wp49/index.html)
- no suitable overflow when tank overfills

The previous tank design is shown below in Figure 5. Approximately 15 of these tanks, which range from 8 to 10 cubic metres, have been built in western Uganda over the past 3 years with good results.

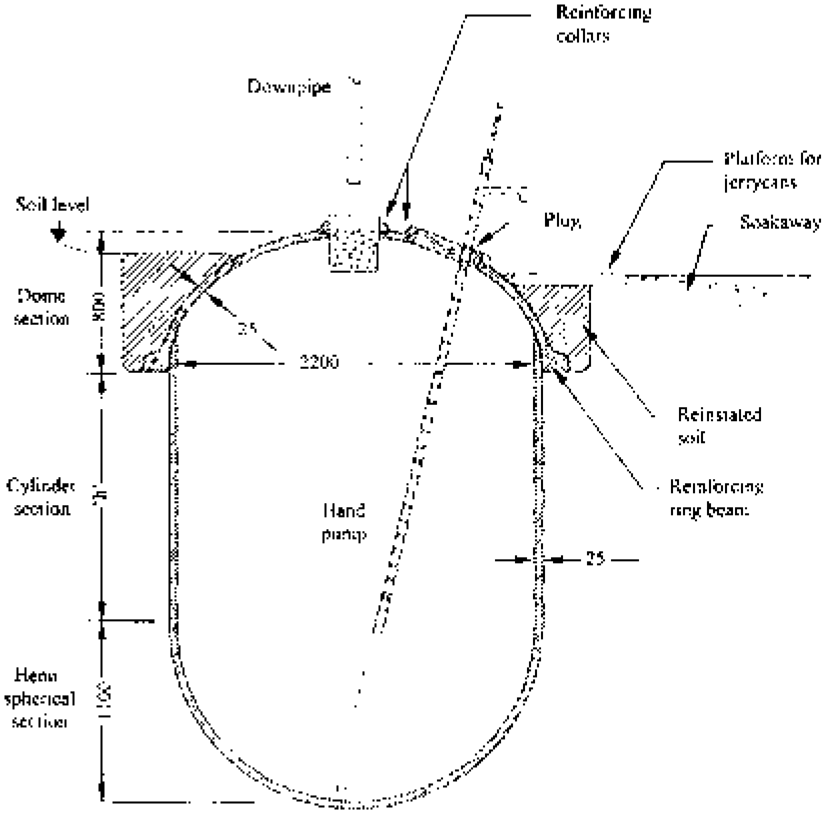

Figure 5 – DTU fully below-ground tank design

The tank is suitable only under certain soil conditions, namely where the soil is sufficiently stable to not cause any concern regarding subsidence. This is the case in many parts of Eastern Africa where the soil is lateritic.

The partially below ground tank (see Figure 6) is raised slightly above ground level in order to eliminate the problems listed above. The parapet wall sits atop a concrete ring beam through which the tank is excavated. The tank is lined with cement render and will, when the technology is sufficiently developed, be fitted with a continuous plastic lining. Water enters the tank through a pipe which directs it to the base of the tank which promotes rapid settling of sediment. The tank is fitted with an improved handpump and floating off-take. The floating off-take takes water always from slightly below the surface level of the water. These two innovations help maximise residence time in the tank, allowing full sedimentation to take place even when water is drawn off as fresh water is entering (except under conditions where the tank is almost empty).

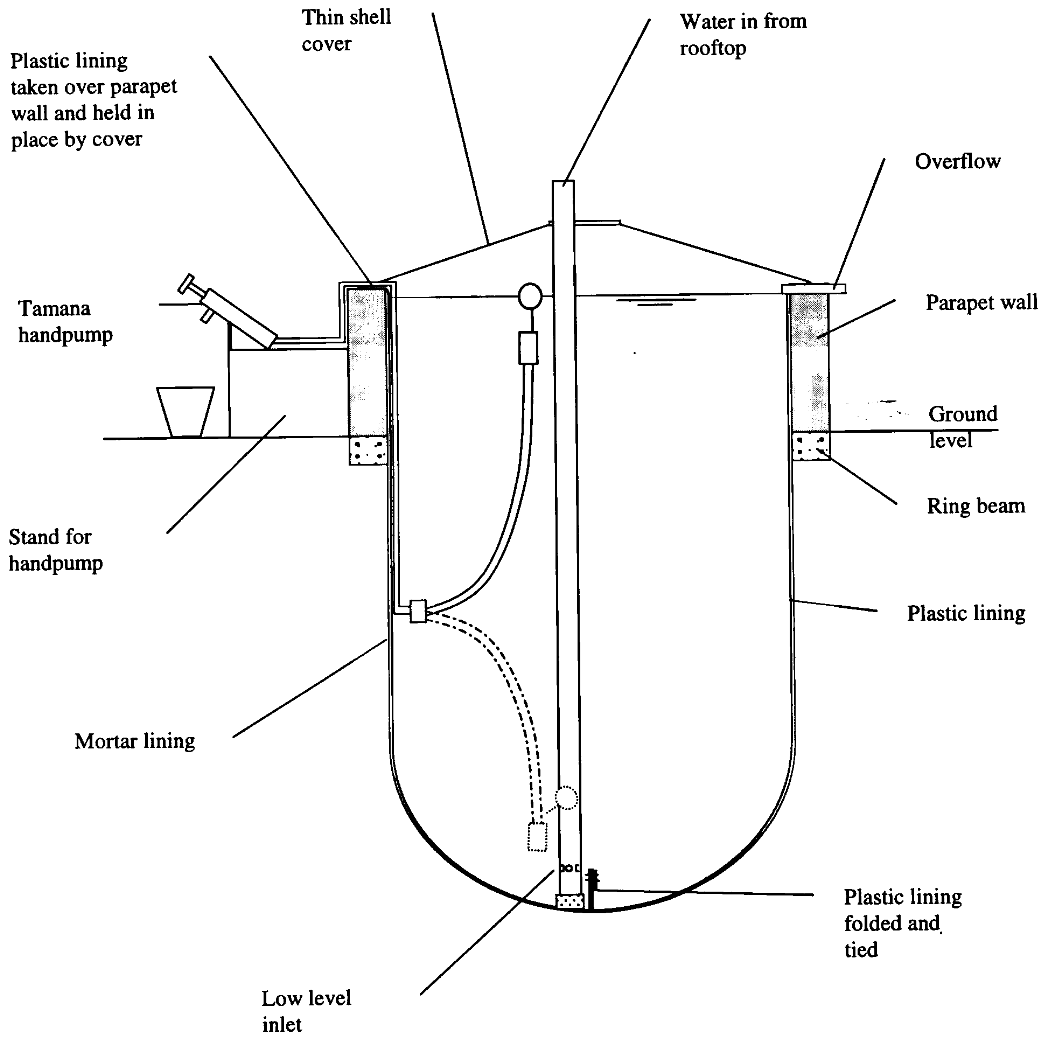

Figure 6 – Schematic representation of the cylindrical, partially below-ground tank

One partially below ground tank has been built in western Uganda. It was hoped that a number of tests would have been carried out by the time of writing this report, but due to logistical problems (funds transfer to Uganda which took 3 months), the tank has not yet been tested.

Figures 7, and 8 below, show the partially below ground tank under construction, while Figure 9 shows the thin shell ferrocement cover being manufactured.

Figure 7 – Bird's eye view of the partially below-ground tank under construction.

Figure 8 – Partially below ground tank under construction in western Uganda, showing parapet wall.

Figure 9 – Thin-shell ferrocement cover being manufacture for partially below-ground tank in western Uganda

Further information and test results form this work will be included in Milestone A5 report.

3. Thin-shell ferrocement tank covers

Milestone A2 report included documentation regarding the instructions for manufacturing a thin-shell ferrocement cover (TSF cover).

The thin-shell ferrocement tank cover is designed in such a way that it can be manufactured without the use of a mould or shuttering. It can also be manufactured remote from the tank to which it is to be fitted and moved into place once complete. The aim is to reduce the cost of the tank (cover) by eliminating costly shuttering or moulds and by reducing the quantity of material used to manufacture the cover. It also means that the cover can be removed at a later date for maintenance, refurbishment or cleaning. The cover can be manufactured by two persons (one skilled and one unskilled) in a single day (with some time required after that for curing) using tools required for the construction of a simple cylindrical ferrocement tank.

The design is based on a frame known as a reciprocal frame, that has spokes that, when loaded, put little radial loading onto the structure on which it sits. The frame is covered with a wire mesh that is then rendered with a sand cement mix.

Details of the construction process are given in Milestone A2 for a 2.0m diameter cover that has an inspection chamber opening of 0.5m.

Benefits of the thin-shell ferrocement tank

- low cost – reduced use of materials
- no shuttering or mould required
- strong and lightweight – the tank cover is designed to be strong (through good quality control) and light at the same time
- good quality control can be achieved through easy working environment
- can be manufactured by two people in a single day (one skilled and one unskilled)
- no clambering on top of tanks required during construction
- can be cured easily – in the shade and at ground level
- can be batch produced at one site

Five of these covers have been produced to date, 3 for testing purposes and two that have been fitted to tanks. One has been made in Uganda by local masons (see Figure 9 above and Figures 10 and 11 below) with no complications.

Figure 10 – 6mm steel framework being formed by local masons in western Uganda for the TSF tank cover.

Figure 11 – TSF cover being completed by local mason in western Uganda. This cover was fitted to a partially below-ground tank.

Tests have been carried out on the cover to determine its strength and the results are shown in appendix 2.

4. Appendices

Appendix 1 – Schematic representations of RWH system at field station in Herefordshire. (2 pages)

Appendix 2 – Test results for Thin-shell ferrocement tank cover. (2 pages)