Milestone A4

Completion of three partially below ground tanks, 2 rammed earth tanks, eight cement jars and two stabilised soil block tanks.

(Originally titled 'Completion of 3 sets of 4 tanks and associated instrumentation')*

Development Technology Unit (DTU)

University of Warwick

April 2000

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Funded by the European Commission

*Please see the introductory section for an explanation of the change in the title of this report.

1. Introduction

As mentioned in the Milestone A3 Report, 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 the work was, initially, broadened to look at tank covers and reinforced brick tanks. We have since moved forward with more radical cost reduction ideas and have been experimenting with two very low cost water storage ideas: the partially below ground tank and the rammed earth tank. We also carried out some water quality experiments in Uganda to test the acceptance of water from cement lined storage vessels. For these experiments we constructed eight 400litre cement jars. Finally, through our connections with Uganda we were asked to carry out some collaborative research with Mr Moses Musaazi of Makerere University into the use of cement stabilised soil blocks for the construction of above-ground water storage tanks.

The title of this Milestone has therefore been altered to reflect the practical research work that has actually been carried out under the programme.

A brief overview of the work that has been completed for this Milestone is given in this report. A fuller report of the work that has been carried out, including the experiments carried out and results obtained for each of the pieces of work mentioned above, will be presented in Milestone A5 (Report A3 '*Performance of Tanks for DRWH'*). This report will be submitted in the near future.

2. Construction of three partially below ground tanks

As reported in Milestone A3, work was started on the design of the Partially Below Ground (PBG) tank in Uganda last year. The work has still, to date, been primarily field based and three tanks have been built until now, in the vicinity of Kyenjojo, Kabarole District in Western Uganda. The tanks have been built by our partner organisation, ARUCED. ARUCED has also received orders for a number of these tanks to be built privately and to date eight tanks in all have been built.

The aim of the design of the PBG is to minimise the amount of material used by partially submerging the tank below ground – the major benefit of sub-surface tanks. The fact that approximately 1metre of the tank protrudes above the ground helps overcome some of the drawbacks normally associated with below ground tanks (see Table 1 below). The ground conditions in this part of SW Uganda are ideally suited to this kind of tank, being lateritic and highly stable.

	Above ground tank	Below ground tank
Pros	• Above ground structure allows for easy inspection for cracks or leakage • Many existing designs to choose from • Can be easily purchased 'off-the-shelf' in most market centres • Can be manufactured from a wide variety of materials • Easy to construct for traditional materials • Water extraction can be by gravity in many cases • Can be raised above ground level to increase water pressure	• Generally cheaper due to lower material requirements • More difficult to empty by leaving tap on • Require little or no space above ground • Unobtrusive • Surrounding ground gives support allowing lower wall thickness and thus lower costs
Cons	• Require space • Generally more expensive • More easily damaged • Prone to attack from weather • Failure can be dangerous	• Water extraction is more problematic – often requiring a pump • Leaks or failures are more difficult to detect • Contamination of the tank from groundwater is more common • Tree roots can damage the structure • There is danger to children and small animals if tank is left uncovered • Flotation of the cistern may occur if groundwater level is high and cistern is empty heavy vehicles driving over a cistern can cause damage

Table 1. Pros and Cons of Tanks and Cisterns

The design also tries to minimise the amount of cement used by employing a plastic liner to form the water proof lining for the tank. Until now the plastic liner has not, however, been fitted and the water proofing has been achieved by means of cement render. Further work in Uganda in the coming months will include the manufacture of plastic liners and these will be fitted to subsequent tanks.

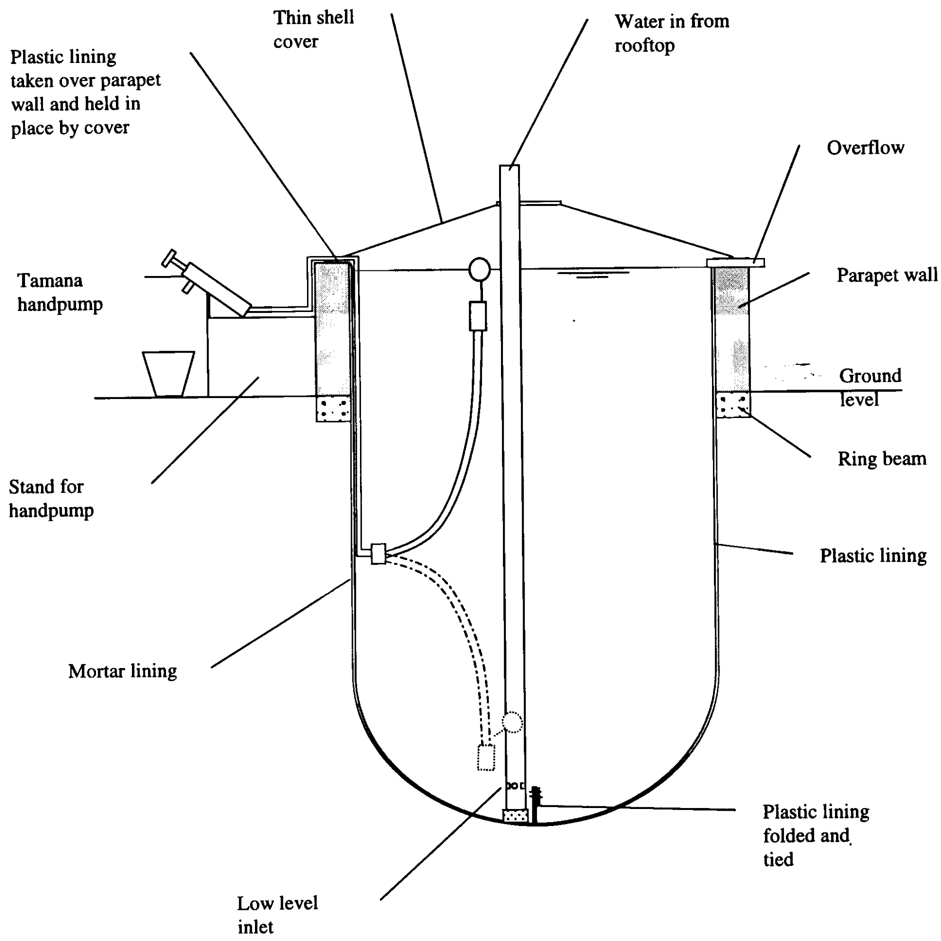

Figure 1 – Schematic drawing of the Partially Below Ground Tank

A costing exercise has been carried out to estimate the benefits of using the PBG tank against the traditional ferrocement tank (assumed to be amongst the cheapest options) and the rammed earth tank (described below). A brief summary is given Table 2.

	Ferro-cement tank	***Rammed earth tank***	***Partially below ground tank***
Material	394	179	107
Labour	81	98	90
Total cost	475	277	197

Table 2 - Comparison of costs between a ferrocement, rammed earth and PBG tank – all 11 cubic metres

Each of the PBG tanks was fitted with a thin shell ferrocement cover, described in a previous report and developed under this programme.

Figure 2 – A thin shell ferrocement cover near completion and ready for fitting to a PBG tank

Figure 3 - A completed PBG tank showing inlet pipe and handpump for extracting water

Initial leakage tests were carried out on a number of tanks using a device developed at Warwick (see Figure 4). These tests are continuing at present and will be reported later.

Figure 4 – Leakage test apparatus being tested in the field on a PBG tank

3. Construction of two rammed earth tanks

The direction of the experimental work at the University has shifted from reinforced brick tanks (reported in Milestone A3) to a more radical design of tank – the rammed earth tank. The aim is to adopt a low-cost technique commonly used for house building in areas of the world such as North Africa, North and South America and the Middle East. The technique uses a mixture of sand and clay, sometimes with a small amount of stabiliser such as cement, which is rammed, either manually or pneumatically, between wooden shutters. To use rammed earth as the structural material in a water storage vessel a waterproof liner is required. This can be provided by employing one of a number of possible options, such as cement render or a plastic sheet liner (as mentioned earlier, this latter is being developed for this application at the University). It is a technique that is relatively simple in essence and requires little in the way of imported material.

Figure 5 – A section of wall rammed between the wooden shuttering shown after removal of the shuttering

So far, the work that has been done on rammed earth tanks has been experimental, and mainly focused on adapting the basic technique (generally used for construction of straight walls in the building sector), to the construction of circular walls for water storage tanks. A 0.7m inner radius quadrant shuttering (see Figure 5) was manufactured and a number of test sections were rammed using a locally excavated soil (local to the University). The soil had to be modified somewhat to make it suitable in terms of cohesion. Wall thickness was increased gradually from a starting minimum of 60mm. We eventually opted for a 100mm wall thickness although even this is unsuitable for manufacture in the field. It is ideal, however, for testing purposes.

A tank, of radius 0.7m and depth 0.7m, has been constructed in a test pit at the University, and fitted with a plastic liner. The tank has been fitted with steel straps to give added hoop strength, but these will be removed after initial tests. The straps will be fitted with strain gauges and will be linked to computer data logging equipment. Measurements of strain, water depth, and temperature will be taken during tests. It is hoped that full-scale testing will take place within the coming month (May 2000). The aim is to seal the top of the tank with a large wooden disc, which will be pierced with a header pipe. The water pressure head will be gradually increased to a maximum of 5m while logging the variation in strain and water depth. The tank has been designed to fail at about 4m, so the test should be destructive, giving valuable information on the strength of rammed earth as a possible alternative to conventional building materials.

Figure 6 – Bird's eye view of the rammed earth tank under construction in the test pit at the University

Figure 7 – Revised shuttering arrangement shown during construction of the experimental tank

4. Construction of eight cement jars for water quality experiments.

There has been much discussion about the acceptability of water that is stored in vessels lined with cement mortar. Many users complain about the taste of the water, especially in the early days when the cement is still leaching calcium. An experiment was set up in Uganda, and carried out by the DTU's partner organisation, ARUCED. Eight small jars of 400 litres each were build and cured using different methods. The aim these experiments was to try to quantify the acceptability of water from cement lined vessels that were cured in a number of different ways. The experiment was designed to determine the efficacy of 8 different curing regimes in the search to find a regime that would minimise the taste problem. The experiment was also used to look at some technical aspects of small cement jars, as well as the user aspects of small rainwater jars and their benefits to users.

The outcome of the taste experiment has been unsatisfactory. There were a number of problems with the experiment, many of which were outside the control of the people involved, but some due to poor experimental procedure. They included:

- Key staff leaving the organisation during the experiments
- Failure of equipment that had been taken to Uganda from the UK
- Curing water being taken from an unknown source
- Poor siting of tanks which meant that sampling was difficult on a daily basis

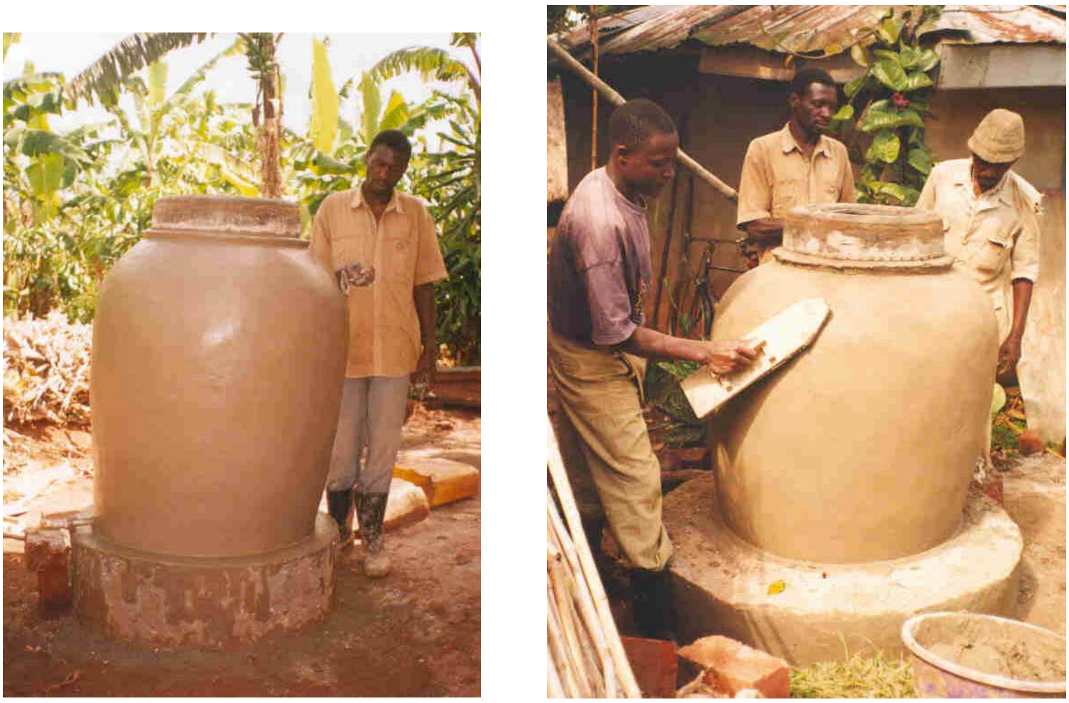

Figure 9 - 400 litre water storage jars being constructed as part of the water quality testing experiments in Uganda

A full report on the taste experiments will be presented later. The user studies are still underway. On a technical level, a number of findings have been made:

- Significant training is required to teach local masons the art of jar construction using this technique (the technique was taken directly from a classic ferrocement construction manual by S. B . Watt titled ‘Ferrocement Water Tanks’ [It Publications 1978]).
- Often the jars failed because the walls were of insufficient thickness – some method is needed of

5. Construction of two stabilised soil block tanks in Kampala, Uganda

In March 2000, two experimental cylindrical water tanks were built at Kawempwe, Kampala in collaboration with Dr Muses Musaazi, a lecturer at Makerere University. Both were built above ground of curved stabilised-soil blocks with end interlocking, 280mm x 140mm x 110mm high, made with an Approtec (Kenyan) manual block press. The soil used was a red somewhat pozzolanic local soil previously known to make strong blocks. The tanks were built on concrete plinths, lined with ‘waterproofed’ mortar (3 parts sand, 1 part cement and .02 parts ‘Leak Seal’ waterproofing compound). There was no metal reinforcing.

Figure 10 – Showing one of the stabilised soil block tanks under construction

Tank 1 is 2050mm high, has internal diameter 1300mm, wall thickness 140mm (+ 15mm render) and used 15 x 15 = 225 blocks incorporating 6% cement (100 blocks per 50kg bag). It has been filled with water and therefore has withstood a maximum head of 2.05m at the wall bottom. Volume = 2720 litres, max hoop stress = 0.19 MPa

Tank 2 is 1880mm high, has internal diameter 1000mm and the same wall thickness, but used 12 x 14 = 168 blocks with only 3% cement (180 blocks per 50 kg bag). It has been filled with water and therefore withstood a head of 1.88m at the wall bottom. Construction is continuing to extend its height up to 4m, testing its ability to resist pressure forces at both 3m and 4m head. Volume = 1476 litres, maximum hoop stress (so far) = 0.13 MPa.

Materials use included 1 packet (50kg costing $\$_{US}11$) of cement for the render, 1 packet for a conical (reinforced) lid, 1 packet for mortar between the blocks and ½ packet in the foundation. Thus only $^1/_5$ to ¼ of the cement is in the blocks themselves. Experiments to achieve curved blocks with *vertical* interlocking, if successful, will significantly reduce the quantity of mortar needed for block-laying. The lid may well be made more cheaply, as that employed was designed to carry certain testing devices.

Figure 11 – Showing the interlocking blocks used for the tanks