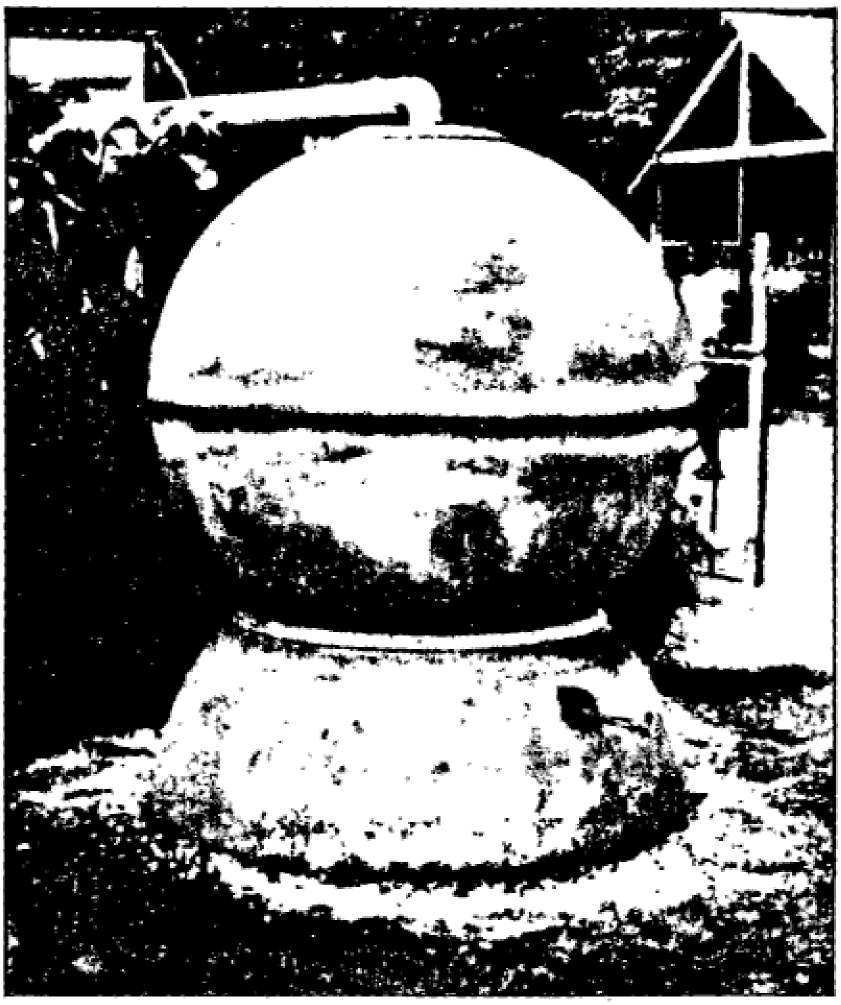
The Earth-Molded Spherical Water Tank

An Innovative Approach to Domestic Water Storage in Rural Areas



A special project description
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Abstract

The need to provide safe water in lesser developed countries is well documented. In many regions that suffer rainfall could be collected in domestic storage tanks to supplement or fulfill requirements. But costs remain high.

The earth-molded spherical tank was designed by the author for construction at the village level. The technique requires a minimum of equipment and materials, and the tank is easier to build, less expensive, and more durable than the ferrocement alternatives since no steel wire or mesh is needed.

This more ideal structural form is produced by shaping a hemispherical mold (radius = 78cm) from earth and cement slurry with a pivoting steel template. The template also defines the cross section of the cement mortar and fiber castings formed over the mold. Two castings are joined with a cement mortar seal and rested upon a third that serves as a stand.

The unimproved $2m^3$ (500 U.S. gallon) design worked well in three trials in the South Pacific in 1982 and holds promise for guided self-help projects or as a small-scale rural enterprise. The spherical water tank may also serve to show that an 'appropriate' technology can be precise and attractive.

The Need for Water Storage

There are plenty of statistics to describe the developing world's need for clean water for drinking and sanitation. Involved is one-third of the earth's population, or more than one and one-half billion people living in the developing countries of Asia, Africa, and Latin America who do not have access to a safe water supply. Of this number eighty percent are people who live in rural areas. [1]

One shocking result is that 10 to 20 million children die each year from diarrheal diseases alone. Diarrhea and other waterborne diseases are transmitted primarily by drinking or washing with contaminated water, a cycle that could be interrupted if wells were sealed and other supplies kept in enclosed tanks. Certainly, reducing the spread of disease involves a great deal more. Yet the World Health Organization reports that most of the Third World's health problems would disappear if everyone only had access to safe water. [2]

Even without the boggling health statistics, the negative social and economic effects of a community short of water are alone costly. In Fiji each year cargo ships are diverted at great expense [*] to ferry emergency supplies to remote islands where dozens of villages are helpless.

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[*] reported to be over US $300,000 in 1981 by the govt.

This is all the more disturbing since rainfall is abundant in the Fiji Islands as it is in many developing countries where water problems exist. But simple, affordable tanks that could fulfill requirements, or at least supplement other supplies, have not found their way.

Instead rainwater is collected in a rusting fifty gallon drum, if at all. When they can be afforded galvanized steel tanks installed in tropical humidity and salt air last only two to five years. In Samoa a fabricator offers a 20 year guarantee, but has never had to respond since no owners had kept the agreement to clean and paint twice a year. The tanks are simply not maintained.

Ferrocement

The widespread interest in ferrocement construction methods in recent years has been due largely to this need for a durable alternative. Ferrocement combines finely divided steel (usually wires, meshes or fibers) with cement mortar in various ways to form a composite that is far cheaper than reinforced concrete. But the cost is still too high for unsubsidized villagers to afford. Or, as often, the scale of an externally formulated solution goes beyond the modest range of self-help.

In the Pacific region much effort has been made to lower the costs of construction and bring the technology to the people. The 1982 Ferrocement Demonstration and Training Activity by the World Health Organization is one example.

As the the short-term contractor charged with carrying out the construction trials and training exercises the author had the opportunity to work with the latest ferrocement techniques. An unanticipated result of this

activity was the completely new spherical tank forming method. With encouragement from the activity's supervisor this new idea for 'village level' construction was tried out alongside the ferrocement methods that were the focus of the W.H.O. training exercises.

The Spherical Tank Design

The $2m^3$ (500 US gallon) 'earth-molded' spherical water tank was conceived and designed by the author to take advantage of a structurally superior and efficient shape [*] for domestic water storage containers.

The hope was first to simplify construction from that of existing ferrocement designs (corners in cylindrical and cubical tanks require careful attention, and also a suprising percentage of the total materials to resist the stresses that concentrate there). . . and secondly to eliminate steel wire or mesh reinforcing altogether, again for simplicity, but also because steel wire or mesh is an expensive component (often imported) that is not even needed when more ideal shell or 'double curved' shapes are employed.

This has been shown by the unreinforced 'Thai water jar' a cement mortar variation of a traditional water storage vessel. A two cubic meter version of the Thai jar was also brought into the construction trials.

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[*] the surface area required to contain a given volume in a sphere is less than for a cube, cylinder, etc. The structural advantages are well known to engineers; R.B.L. Smith [3].

The spherical design followed the example of the somewhat free-formed [*] Thai water jar, but with a system that precisely controls the tank wall thickness and contour to form an even more ideal structural shape. The sphere also offers the flexibility of precasting, whereas the jar is intended for 'in-situ' construction only.

The common problem of producing a shell structure, the formwork, has been solved in this case by shaping a hemispherical mold (radius = 78cm or 31") from almost any free and available material like soil, and cement slurry with a special pivoting template. The same template is later used to define the cross section and smooth the surface of the cement mortar castings produced on top of the mold.

A cross sectional veiw of the trial design is shown on the next page. The construction procedures are then outlined on the pages that follow, with photographs and a description from the construction trials in Fiji, Western Samoa and Vanuatu.

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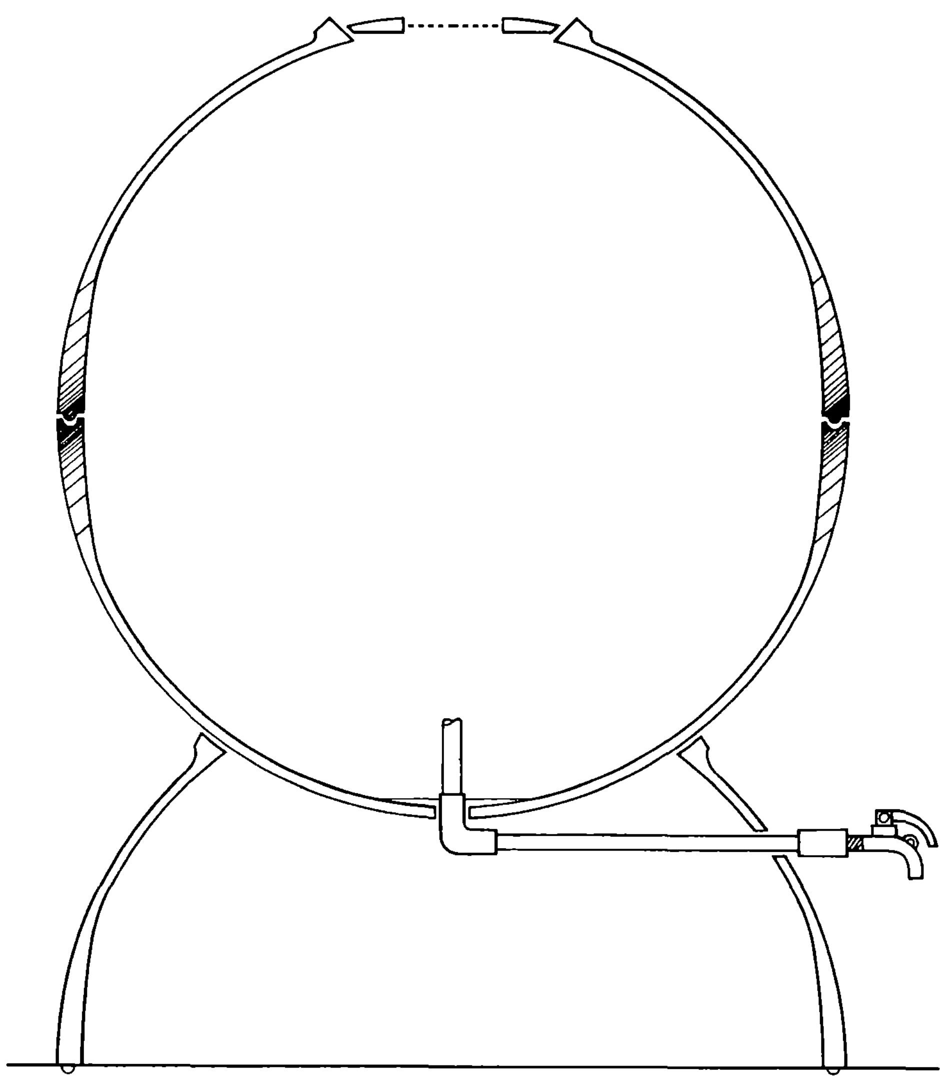
[*] the 'jar' is formed by troweling successive layers of mortar over a large sack filled with sawdust which is later removed.

CROSS SECTIONAL VIEW OF THE TRIAL DESIGN



MATERIAL . . . fiber reinforced mortar

THICKNESS . . . ~20mm . . . . . (~3/4")
~50mm . . . . . (~ 2") at mating surface

SIZE . . . . . 1.6 m diameter (63")

CAPACITY . . . 1.94 m^3 . . . . (512 US gallons)

Approximate Scale 1:15

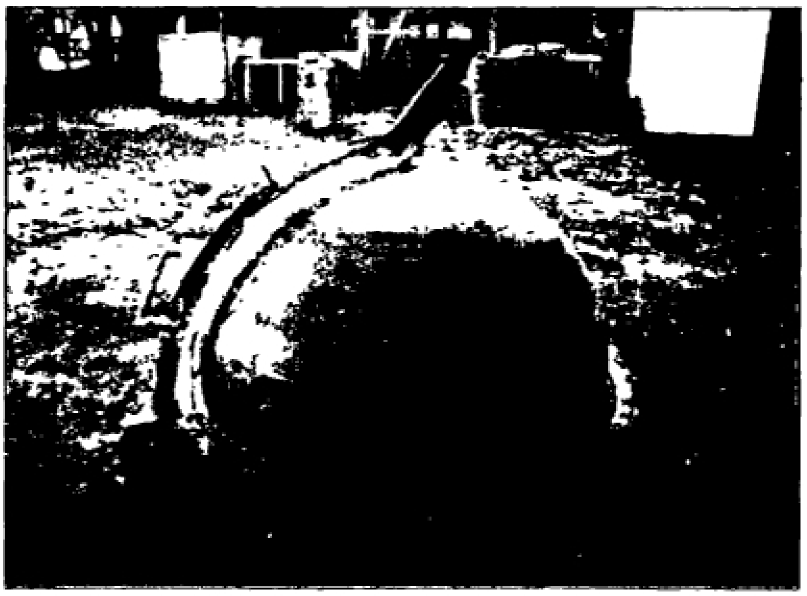
A post is buried to provide a support for the pivoting template and a hole is drilled . .

. . for a specially made socket which is threaded into the hole.

The first sockets of this type were made for about US$ 5 each.

The template was found to be useful in aligning the post. If the axis is not exactly vertical it will not matter.

In the Fiji trial clay soil stabilized with old cement was shaped with the template which pivots <u>and</u> hinges vertically.



After smoothing with soil, sand and cement mixtures a cement and water 'slurry' was added . . .

. . . until the shape became smooth and accurate.

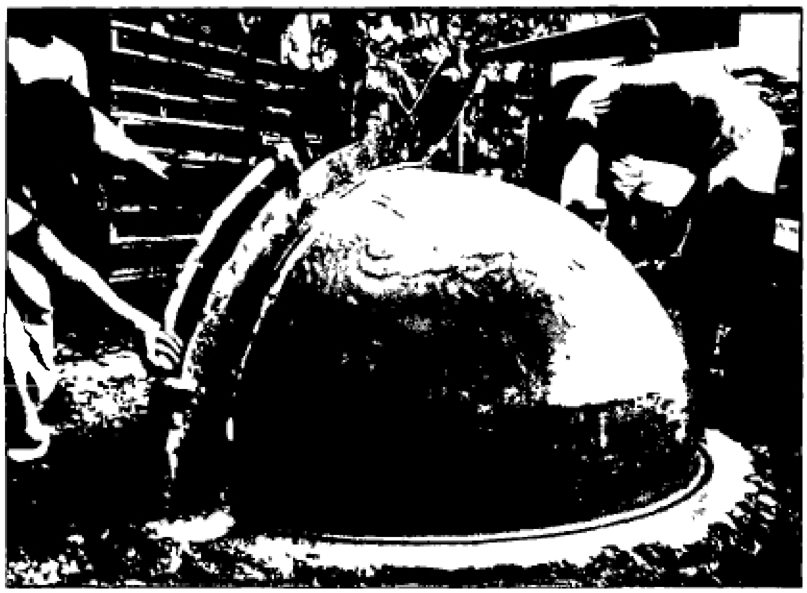
The mold is ready to use after one or two days. It is permanent and reusable.

In both the Samoa and Vanuatu trials the mold was constructed of rocks and coral piled on top old tires found nearby.

The mound was then covered with a weak mixture of concrete using stocks of cement from old or broken bags.

The build-up was accomplished in stages and allowed to set overnight when it reached the stage shown.

The template's removable insert that determines the cross section of the casting is clearly visible in this photograph.



The following day a cement, water and fine sand mixture was used to finish the mold.

At this point (photograph) it was found to be important to give the surface a chance to set before polishing it smooth.

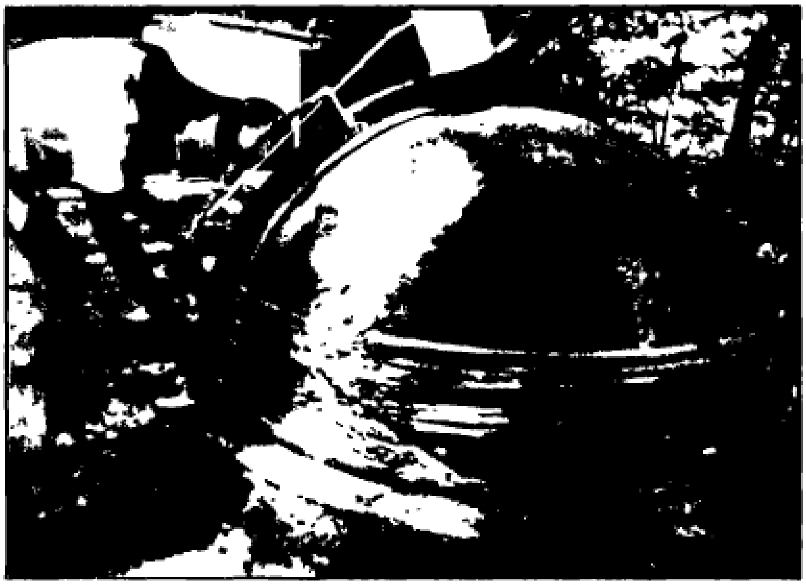
The prepared mold is covered with a double layer of wet newspapers.

Cement mortar is then applied by hand using the pivoting template as a guide. Various mixtures were tried but 2:1 (sand: cement by weight) was used most often. Steel fibers (14.5mm or 0.57" straight lengths) were added for reinforcement.

A slump test value of 25mm (1") would describe the mortar -fiber mixture that worked best.

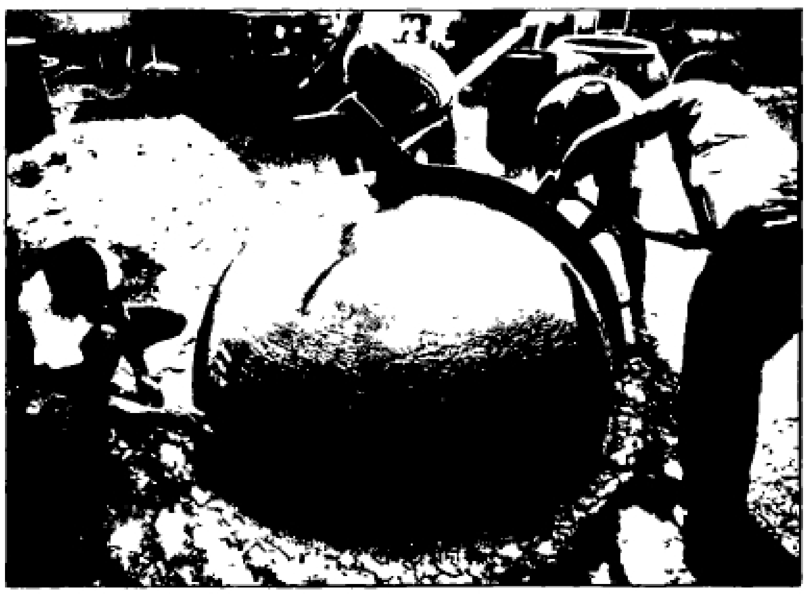
While still soft the casting is roughened to provide 'tooth' for the finish coat of mortar.

The template will just clear this rough coat as it swings around.



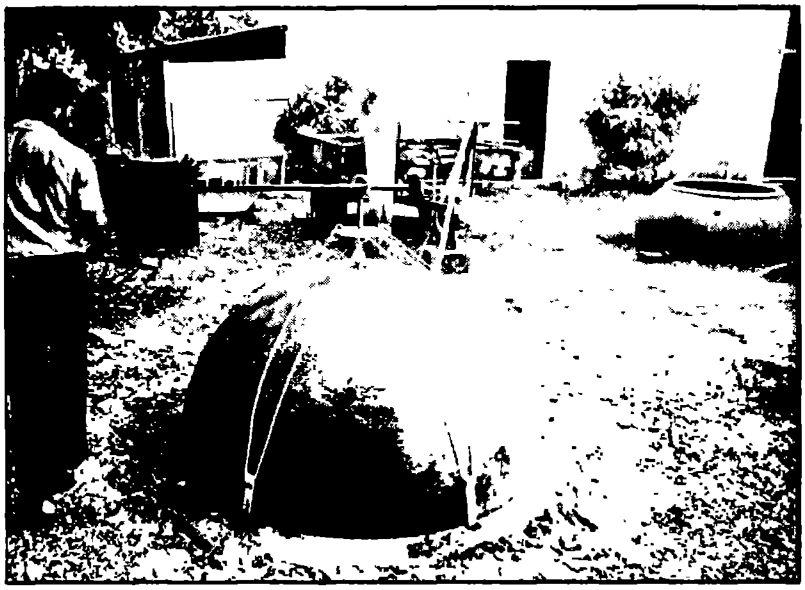
In the Fiji trial only, polypropylene filaments (manufactured locally for the making of ropes) were stretched tightly around the rough casting, left.

The unspun filaments are very strong and cheap. About US $3 (1 kg) worth of plastic fiber per tank might substitute for the steel fibers used.



The casting was normally finished after a few hours (or the next day) with a mixture of plain mortar (no fibers) to bring the final thickness to about 20mm (3/4").

Too much 'polishing' by going round and round will cause slumping. Though after 30 minutes to one hour a smooth finish can be added if desired using only the pivoting template.



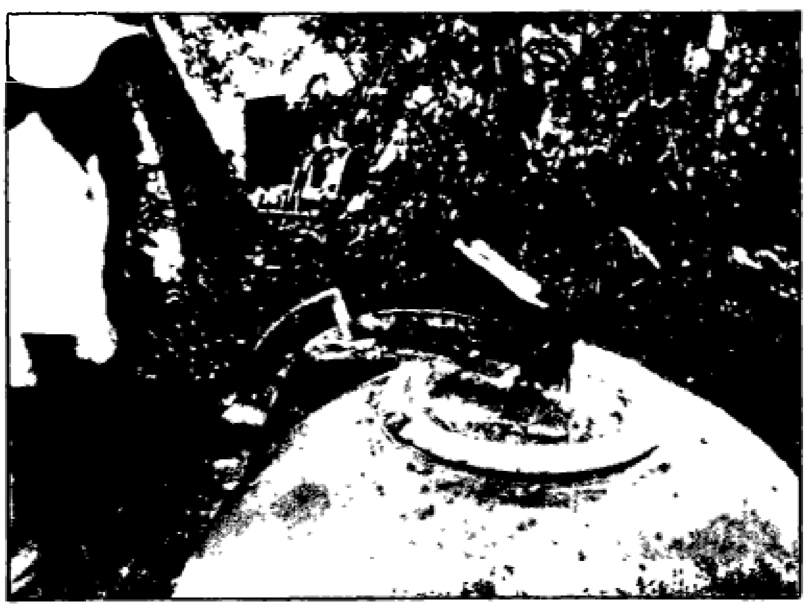
After at least one day of curing a special 'puller' is used to lift the casting a few inches from the mold.

Six or eight persons may then lift the casting clear.

Since later castings released very easily a circumferential strap (tightened around the casting near the base) might eliminate the need for these hooks and provide temporary strength for handling.

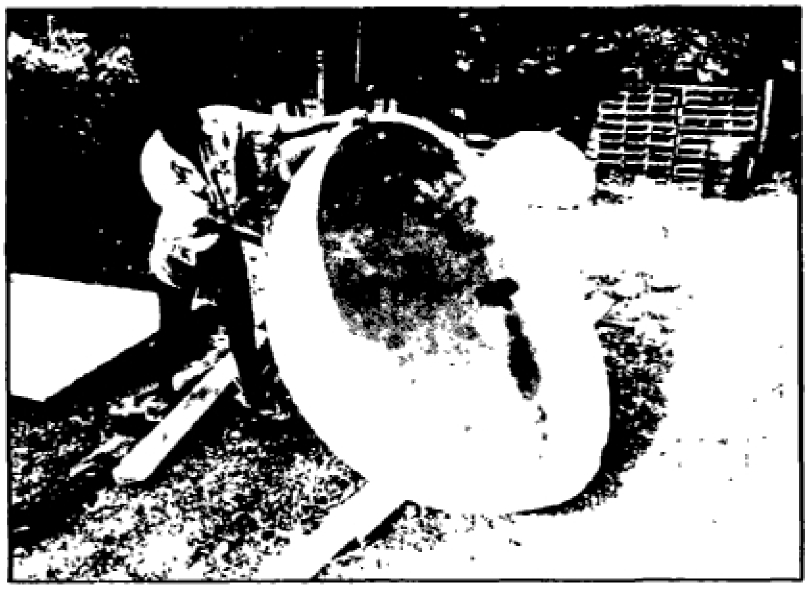
The bottom half of the tank is cast over a plastic hose to make a groove as shown. A mating projection in the top half of the tank comes from the mold when the hose is not used.

The mold remains clean after the casting is removed. The slots provided for the lifting hooks are filled with mud or sand and leveled with a cement and water paste. (This step might be eliminated since the hooks may not be necessary.)



The upper half of the tank is cast in the same way. A lip can be shaped with a sheet metal template clamped to the pivoting template as shown.

The lip provides extra strength and an accurate fit for the manhole cover / screened inlet cast in the position shown.

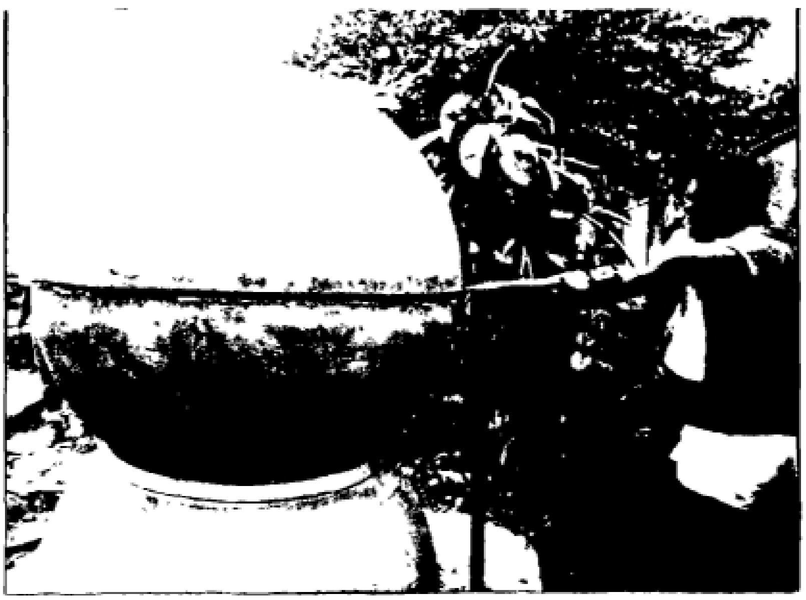


The castings are carried into position or rolled as shown. Or they could be joined first by tipping their mortar covered edges together and the sphere later rolled to the site.

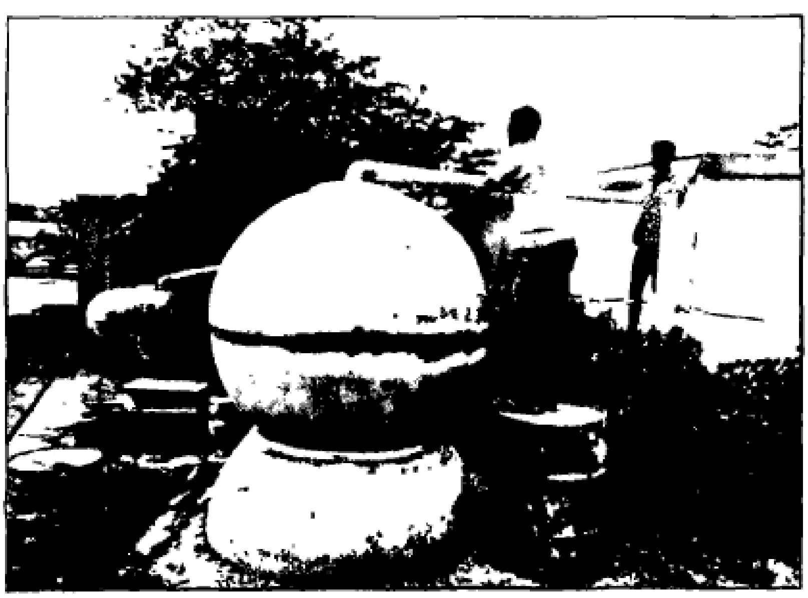
In each of the trials the halves were assembled on a stand constructed using the same technique.

The top half is supported temporarily on boards and carefully positioned over the lower half.

A rich cement and fine sand mortar is leveled into the groove. . .



. . . and the top half is dropped one side at a time to join the castings. A cement slurry coating on the seam from the inside may be needed to complete the seal.



The tap is positioned to draw all of the water from the tank yet a bucket can still fit under it. A short stand pipe inside the tank (see the cross section, pg. 5) prevents sediments from being drawn out, but it can be lifted out for washouts.

Results

A total of three spherical tanks were constructed, one in each location. Each included a stand to show clearly that option. The latter two were sealed and connected for use. They both filled safely a few days after assembly.

The design cross section (see page 5) was not modified during the trials except for an improved taper on the skirt area of the mold to assure easy release of the castings. Experimentation was limited to finding the best techniques for mold construction and mortar placing. Involving a number of skilled and unskilled participants from the concurrent training exercises was also a priority.

Steel fiber reinforcing was used in all but the very first casting to assure success in the limited time of the trials (which were on public display). The sphere halves, sometimes carried and rolled only a day after casting, might have been unnecessarily thick. Also the percentage of steel fiber was less than optimum.[*]

Plastic fibers, coconut fibers, or other available fibers could probably substitute for the steel fibers used. Totally unreinforced castings might also be practical with an improved handling procedure, page 12.

A table of material quantities and sample costs is provided on page 19. However calculated, the material efficiency of the sphere is an improvement. Even with a stand included, it may require as little as half of the material of comparable ferrocement alternatives. It follows that labor is also low.

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[*] the fiber:cement ratio of 1:10 by weight that was used is about half of the optimum for strength. Thus castings much lighter or greater in capacity could be expected when steel fiber is available. This material is gaining more attention; references 4,5.

Less obvious advantages to the spherical shape were discovered in course; the easily cast and tight fitting manhole cover, the outlet with access to all of the water, and the ease of washouts. Also worth noting is that the procedures involve no measurements (except for mixing the mortar). That is, only visual checks are required.

The trials with the spherical tank attracted special interest, in addition to curiosity, among the wide range of casual observers at each location.

Conclusions

The positive results from the hurried first tries with a very unusual construction method are especially encouraging. With this the Water Decade, there is an obvious need for a program to take the spherical water tank idea into the field and determine its actual potential.

The design would seem ideally suited to rural locations because of the mold made of earth, the low overall cost, and the potential that exists for the recipient's input through labor. Even without refinements the tank could be the focus of community self-help, where at least one person skilled in the technique is provided.

More ideal, but very possible, is tank construction as the basis for a small-scale rural enterprise. The low cost to start and lightweight equipment is an advantage.

The earth-molded spherical water tank may also demonstrate that a low cost 'appropriate' technology can be precise, and very attractive in serving its function.

TABLE 'A'

List of Equipment and Materials
Required

MATERIALS FOR MOLD

- wooden post
- soil
- cement
- special socket

MATERIALS FOR TANK

- sand
- cement
- fiber for reinforcing
- pipe and fittings
- inlet screen
- newspaper

SPECIAL EQUIPMENT

- pivoting template
- casting puller
- reinforced plastic hose (5m)

NORMAL TOOLS

- tools for mixing mortar
- brace and adjustable bit
- locking pliers (2pr)
- small pry bar
- sheet metal scraps
- plastic sheeting
- screwdriver
- wire brush

Note: The total cost for the special equipment (one set) and the adjustable bit, plastic sheeting and locking pliers was about US $200. (machine shop labor at US $6.00 per hour, prices in Fiji 1982)

TABLE 'B'

Sample Quantities and Costs*

for one spherical tank
approx.cap: 2m^3 (500 USgal)

Material	Quantity	Unit cost	Cost
Sand	420 kg (924 lbs)	0.01/kg	4.20
Cement	210 kg (462 lbs)	0.11/kg	23.10
Steel fiber**	16 kg (35 lbs)	0.91/kg	14.56
Misc.	Pipe, fittings, tap, inlet screen		10.

approximate total: US $52.

* costs in 1982 US dollars in Fiji from non-government sources including delivery

** 'Fibresteel' 14.5 mm straight with deformed ends

References

[1] "In Third World Villages a Simple Handpump Saves Lives" Allen Morrison, CIVIL ENGINEERING/ASCE October, 1983

[2] "Small is Beautiful-But Development Strategies Must Go To Match" Dr. Robert Waddell, PACIFIC ISLANDS MONTHLY June, 1982

[3] FERROCEMENT; A VERSATILE CONSTRUCTION MATERIAL-ITS INCREASING USE IN ASIA, International Ferrocement Information Center, Asian Institute of Technology Bangkok, 1980

[4] "Fiber Reinforced Concrete" Kneeland A. Godfrey Jr., CIVIL ENGINEERING/ASCE November, 1982

[5] "New Reinforcing Fibers Slim Concrete Slabs" ENGINEERING NEWS RECORD April 16, 1981