25th WEDC Conference Addis Ababa, Ethiopia, 1999

INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION

A ctesiphon arch V.I.P. latrine

Dr Peter Glover and Ned Breslin, South Africa

THIS PAPER DESCRIBES and illustrates the Arch VIP toilet structures that are currently being developed in rural Zululand (Nongoma KwaZulu). The structures, in the form of a catenary, are produced entirely of unreinforced mortar plastered hessian which is formed by temporary wooden supports. The overall cost of the structures is remarkably low, and their strength and durability outstanding.

The catenary arch

A catenary is the shape that is made when a chain hangs between two supports. The chain links are not rigid, so therefore cannot transfer a bending moment. The shape the chain makes is therefore such that the chain is under pure tension. If gravity is reversed, or the shape inverted, it represents a shape that under equal load distribution will be under pure compression.

Soil, bricks, blocks, and mortar building materials have very good strength characteristics under pure compression, but poor characteristics under bending or tension. The Ctesiphon arch was built in Iraq in 400AD and is shaped as a pure catenary. It is claimed to be the largest single vault span in the world. In 1985 the Tigres flooded seriously damaging the city, but left the arch untouched.

The beauty of the catenary arch is that any cracks in the arch experience compression which tends to close them. Effectively gravity reinforces the structure.

The archloo

The archloo is currently built in a variety of models: with doors, without doors, spacial, squashed, and with variety of pit cover options.The structures are built entirely without reinforcing. The hessian is present in the catenary purely as an insitue formwork. Wall thicknesses can be as low as 25mm. Hessian and mortar also provide a low cost (and highly effective) ventpipe and pit cover.

The Archloo superstructure is produced by draping (stapling) course hessian between two catenary forms. This hessian is then painted with a thin slurry, and then a thin layer of plaster is added. Up to 3 layers of plaster are added, allowing drying time (4-7hrs) between layers.

Once the outside layer has gone off, the structure is already self supporting, and the wooden forms can be removed.

Pit lining

The hessian plaster system can also be adopted for the rest of the structure. 3-4 pockets of cement will entirely line a 1.5x3m deep pit using hessian as a base for the plaster. However, the lightweight of the construction means that a small collar is adequate in many soil conditions.

Pit cover and pedestal

Various options are available for the pit cover. One option is a conventional SanPlat (Brandenburg 1985) which has the advantage of low cost, and reduced floor cost as the slab takes up the majority of the internal floor space. The SanPlat does require a pedestal to be constructed for the South African end user. Another option has been developed using two merging catenary arches to cover the pit and provide a pedestal in one. This cover requires less crucial quality control and curing requirements, and provides a relatively foul free pedestal.

The pedestal construction illustrated in the photos above is prefabricated. This means that it can be constructed while the pit is being dug and lined and the superstructure is being

Figure 1. The double arch loo

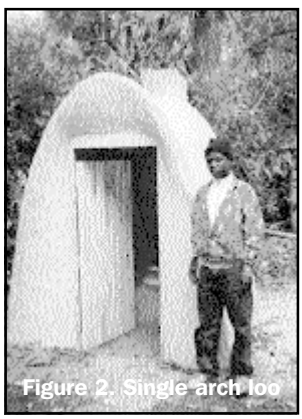

Figure 2. Single arch loo

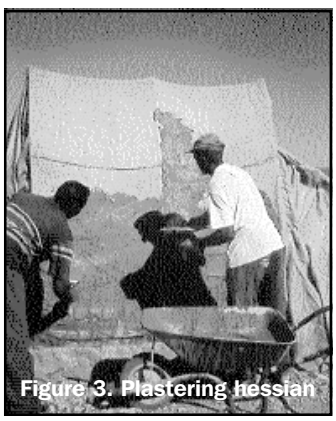

Figure 3. Plastering hessian


Figure 4. Removing

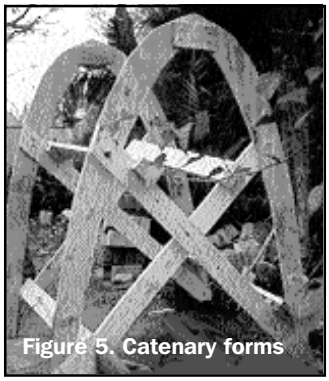
Figure 5. Catenary forms

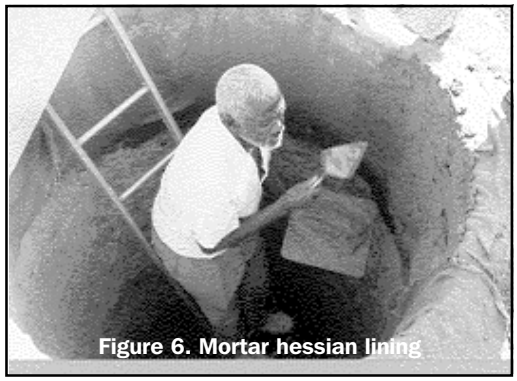
Figure 6. Mortar hessian lining

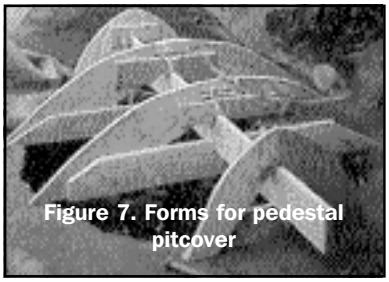
Figure 7. Forms for pedestal pitcover


Figure 8. Precast pedestal pit cover


Figure 9. Pit cover form removal

built. This parallel construction has the potential to significantly increase speed of construction.

Vent pipe

The use of a 110mm or larger ventpipe is common, but in view of the construction method used on the rest of the structure, a ventpipe can be cheaply constructed with hessian supported by four 25mm section planks which is then plastered like the rest of the structure. The planks can then be removed. A 200 -250mm square section vent can be constructed relatively cheaply and the level of ventilation significantly enhanced. The ventpipes are covered with a stainless steel flymesh.

Subsidence

The catenary arch is susceptible to subsidence and poor foundations. To ensure safety of users, a test was done on a Archloo which was built without foundations. Severe subsidence was imposed on the structure. Fears were immediately alleviated when the strength/weight ratio of the structure was sufficient to allow the whole superstructure to pivot on the pit lining, confounding attempts to induce subsidence. Some destructive intervention eventually made it possible to induce 500mm subsidence without any catastrophic failure.

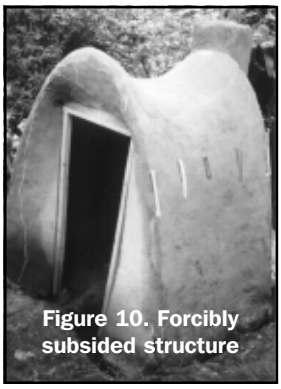
Figure 10. Forcibly subsided structure

Hand washing facilities

The hessian plaster structure lends itself to the simple incorporation of a hand washing sink and water tank. Work is currently underway to find the best design for these utilities.

Construction management - sanitation programmes

The requirement for some skilled supervision, and some wooden forms make the structure awkward for one-off construction projects. However, if a number of structures can be produced, the cost of the forms can be negated as it is shared between the structures. Under experimental conditions it was found that one semiskilled labourer working alone could construct an entire superstructure including slab/pedestal ventpipe, arch, walls door and floor in 4 days. Cost of construction could be kept down if one skilled trainer/finisher were to be responsible for the simultaneous construction of a number of toilet structures. The trainer could set the householders to the construction process, and then start at the next house, only returning to check the work. It is anticipated that up to 5 toilets could be constructed per week by an individual trainer/finisher in this way. This is yet to be verified.

Appropriate technology

The problem of sanitation improvement is huge. Countries spending billions on diarrhoea treatment while 80 per cent

Table 1. Cost break down for sanplat archloo with 3m lining

Item	*Unit*	*Quantity*	Unit *Cost R*	Total *R*	UK *Pounds*
Hessian	m2	15.56	3.17	49.33	4.93
Sand	m3	0.94	30.00	28.20	2.82
Cement	bags	8.22	23.00	189.15	18.92
Mesh	m2	0.13	193.80	25.19	2.52
Seat	piece	1	20.00	20.00	2.00
Door frame	piece	1	25.00	25.00	2.50
Door	piece	1	80.00	80.00	8.00
Door paint	pot	0.5	10.00	10.00	1.00
Hinges	set	1	6.00	6.00	0.60
			Total	432.88	43.29

of the population has no sanitation facility and are poorly educated in health and hygiene issues. Hardware alternatives provide part of the solution, and the Archloo is a low cost option for some. The appropriateness of the technology will depend largely on the perception of users and the support facilities available to manage and supervise construction, and of course the availability and affordability of the materials.

Costs

The cost of the structure varies massively with the area, cost of sand, cost of cement etc. The cheapest unit so far has a total material cost of R450 (45pounds May 99), with approximately R100 (10pounds) for a full 3m lining, and R100 for the door and frame (10pounds May 99). This cost is very specific to the Nongoma area. The material quantities are shown below.

The license

In view of the need to improve sanitation technology, this solution is available for general use under an open license agreement. The purpose is to ensure the technology can be widely used without royalty, and that developments can be shared openly.

This license applies to implementation or modification of the Archtoilet as developed by Glover Development Engineers. Modification and implementation of the ArchToilet designs can be made under this license.

You may modify improve and implement designs of the Archtoilet without a royalty charge providing:

- that you cause all developments of and derivations from the designs to be licensed as a whole at no charge to all third parties under the terms of this license.
- NO WARRANTY/INDEMNITY
  Because the designs are licensed free of charge, there is no warranty or indemnity for the designs, to the extent permitted by law, except where otherwise stated in writing, the designs are provided "AS IS" without warranty of any kind. Should the designs prove defective in anyway, you assume the cost of repair, servicing and correction.
- Glover Development Engineers (PO Box 447 Nongoma 3950 South Africa 0358 310457 gde@gde.co.za) are informed of modifications and improvements and are free to implement, modify and distribute such without royalty under the conditions of this license agreement.
- A copy of this license agreement should be attached to any distributions of these designs or modifications produced under this license.

You are not required to accept this license, since you have not signed it. However, nothing else grants you permission to modify or implement the Archtoilet designs. These actions are prohibited by law if you do not accept this license. Therefore by modifying or implementing the said designs you indicate your acceptance of the license to do so.

Further research

Currently work is being undertaken to further reduce the cost of the structure with the use of cement stabilised soils, onsite door manufacture, and more rapid construction. The work hopes to identify the optimum methods of construction. It is anticipated that a construction manual will be produced. Information on developments will be made available through the South African Water Research Council, and Glover Development Engineers' website. Dimensions and drawings will be made available via the GDE website and a instruction manual is under development.

Conclusions

The Archloo provides a further alternative low cost solution for sanitation provision. It should not be considered an appropriate solution for all situations but its low cost makes it significantly more attainable than many of the cement block and ferrocement structures currently available. The technology is more suited to a programme of sanitation provision than to a one-off construction initiative. Efforts to bring the cost down further may broaden its appeal.

References

BRANDBERG, B., 1995, Why should a latrine look like a house? Waterlines, Vol.3, No.3, p24-26.

Acknowledgements

The Authors would like to thank: the Mvula Trust for their financial support and their strong stance on prioritising sanitation; the South African Water Research Commission for assistance with research expenses; and Crispen Angood of the University of Southampton for his contribution to the research and provision of some of the above photos.

PETER GLOVER, Glover Development Engineers, PO Box 447, Nongoma, 3950 South Africa, email: peter@gde.co.za webpage:www.gde.co.za

NED BRESLIN, Mvula Trust Braamfontein, South Africa, e-mail:ned@mvula.co.za webpage:www.mvula.co.za