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DEVELOPMENTS IN FERROCEMENT CONSTRUCTION IN BOTSWANA

by

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INTRODUCTION

In large parts of Botswana, surface water as well as ground water is scarce. In the villages there is a heavy reliance for daily water supply upon boreholes with water stored in tanks. Over 15,000 boreholes have been sunk to meet this demand. Botswana is a semi-arid country with mean annual rainfall varying from less than 250mm in the extreme Southwest of the country to more than 650mm in the extreme North (fig. 1). Although the rainfall is erratic and concentrated primarily in a rainy season from October to April, the collection of rainwater runoff is considered an effective means of supplementing water needs. This is particularly so in areas where the ground water is too deep, unreliable and saline to provide an acceptable supply for domestic purposes.

In the early 1980's a major limitation to wider implementation of rain water catchment was the availability of suitable water storage tanks. At the time the most readily available tanks were made of galvanised corrugated iron. These suffered many disadvantages, including a short life span due to corrosion.

The potential for Ferrocement Tank construction was therefore investigated. A design manual was prepared and training programmes initiated giving impetus to the construction of these tanks throughout the country. This paper reviews the development of the tank building programme since the early 80's with an assessment of the design and construction problems. The future prospects of ferrocement technology in Botswana is also discussed.

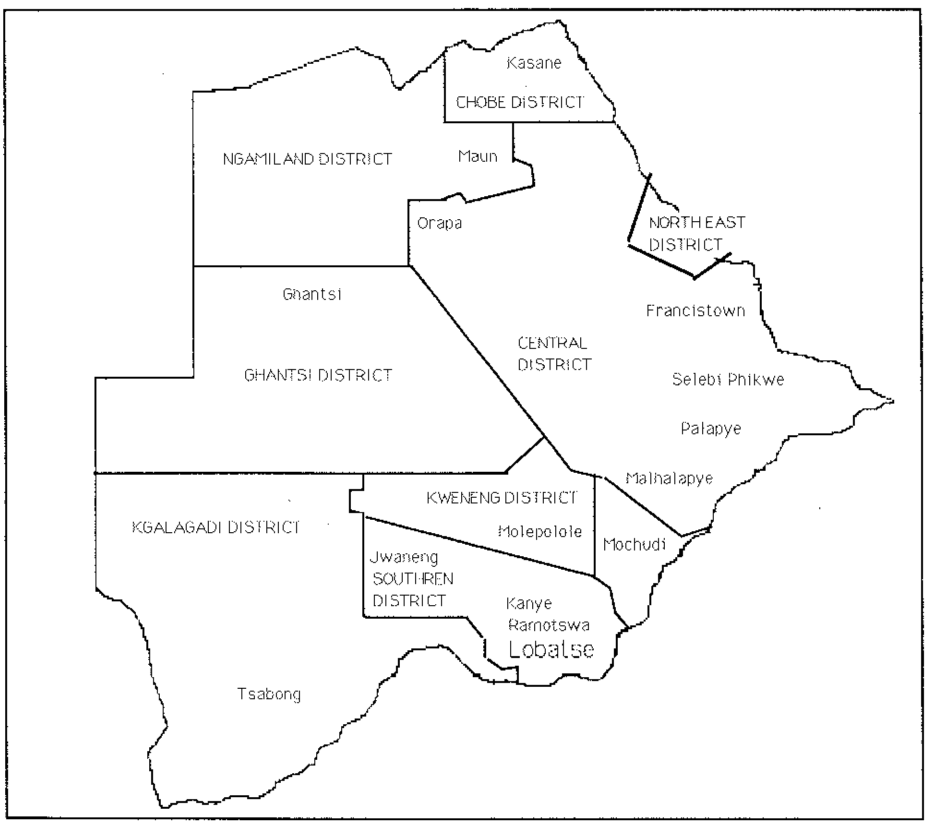

Fig 1 **Map of Botswana**

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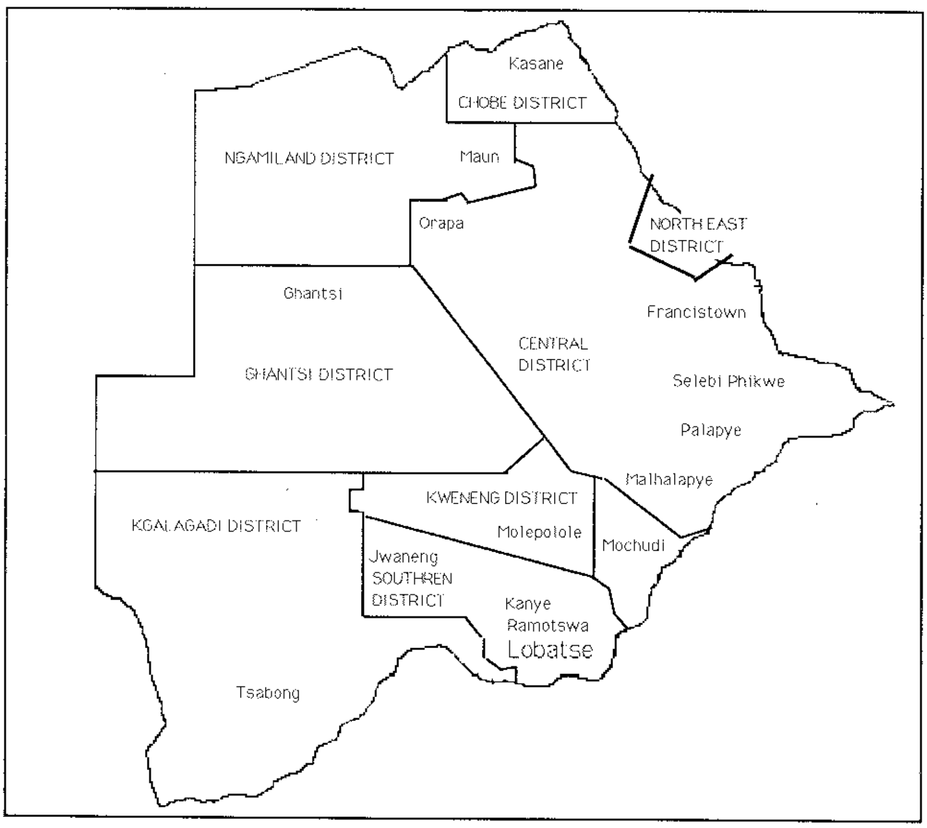

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HISTORY OF FERROCEMENT TANKS 1981 - 1991

In 1969 a major study on rainwater collection in Botswana was undertaken by the Intermediate Technology Development Group (ITDG), based in England (1). This outlined a project to install excavated ground catchment tanks for water storage at 12 primary schools in Eastern Botswana for irrigating school gardens and vegetable plots. However, it was not until the 1980's that any significant ferrocement tank construction programme begun. This was initiated by the Ministry of Agriculture through the Arable Lands Development Programme (ALDEP). ALDEP was primarily initiated to provide water for draught animals in the Lands areas (remote areas of scattered population away from village centres) to allow early ploughing at the start of the rainy season. To date almost 600 Tanks have been built for this purpose (see table 1).

Table 1 Number of Water Tanks Distributed under ALDEP - by Region 1982 - 1990

REGION	TANK NOS.
Southern Region	36
Gaborone Region	199
Central Region	324
North East Region	11
Ngamiland/Chobe	12
TOTAL	582

In 1984 Gould (2) on behalf of Botswana Technology Centre (BTC) examined the feasibility of the widespread introduction of both roof and ground catchment systems in Botswana for supplementary water supply in rural areas. The study considered computer models for determining the most appropriate water storage capacities, bacteriological quality of stored rainwater and different tank designs available. The construction of large ferrocement tanks at primary schools and clinics lacking reliable good quality water supplies was proposed. Following these recommendations BTC set out to promote the technology. Demonstration tanks were built at the BTC Headquarters, training courses were organised, and a technical paper (3) giving construction details for a standard $20m^3$ tank was produced using a design based on that of Watt (4). Formwork needed for the construction of the tanks was fabricated and loaned to contractors/individuals building tanks.

There is no doubt that all these efforts gave an impetus to the construction of ferrocement tanks in the country. The skills were transferred not only to individuals and local contractors but also to the Brigades. The latter are centres where artisans for construction are trained and production of building materials like sand cement bricks are undertaken for sale. For instance the Tswelelopele Brigades in Ramotswa built over 30 tanks between 1985 and 1988. In one such project in a school for the deaf built in 1985, 8 ferrocement water tanks ($2 \times 20m^3$ and $6 \times 10m^3$) were built giving a total storage volume of $100m^3$, collecting runoff from approximately $300m^2$ roof area. The tanks were inspected in May 1991 and found to be in good condition though the lack of maintenance has meant that gutters and down pipes desperately need attention.

The enthusiasm for ferrocement tanks for rain water catchment was to continue all through the 80's. However, as centralised water supply became more readily available in the villages the momentum certainly slowed down. Also due to the problems of leakage and tank failure BTC itself had stopped promoting construction since 1987.

FERROCEMENT TANK CONSTRUCTION

ALDEP Underground Tanks

The ALDEP ferrocement tanks are basically a hole in the ground lined with brick and mortar or ferrocement and fitted with an iron sheet or ferrocement roof with a covered latch. The ferrocement design was basically a double layer of 1mm diameter chicken wire mesh (25mm openings) and mortar for the base while the walls consist of single layer mesh stapled to the sides and cemented. The water is collected from a threshing area usually plastered with mud and dung but sometimes concreted. The building instructions for the tank construction were very basic with practically no advice on curing, importance of the soils for the mortar or limitation of the design for a specific volume. Ainsley (5) reported that 25% of the tanks built in the first two years experienced problems of cracking. In the light of this he recommended that the tank floor be increased to 150mm from 100mm and that 2 layers of 50 mm mesh be used for the wall. It is not clear whether these recommendations were ever implemented.

The other problem with the tanks was that although the standard design recommended $10m^3$, in reality sizes varied from 8 to $29m^3$ with an average of 17 (5). It appears that the standard design was used for these tanks unless individual builders made changes from their own experiences. There are no up to date figures as to what percentage of these tanks are performing adequately.

Despite the problems the underground tanks have provided a ready water source to the ALDEP farmers. While initially the tanks were envisaged primarily for draught animals, they were also increasingly used for human consumption. The latter has been a problem as tests on the water have shown it to be far from suitable for human consumption (5).

It has also been noted that the underground tank programme has never been popular due to the design and construction difficulties. In response to these problems ALDEP designed a modified water catchment facility in 1990 which included a raised galvanised iron roof ($40m^2$) with rainwater collection into a $7m^3$ polyethylene tank. This can provide a source of clean drinking water if certain design features are implemented such as building away from trees and water is collected only after the first rains. It is likely that this new design will be adopted by ALDEP in the future, though questions about the durability of polyethylene tanks under the intense sunshine of Botswana and the fact that the tanks are imported remain unanswered. ALDEP however, is very open to the possibility of substituting the polyethlene tanks for a ferrocement version if costs are comparable and reliability assured.

BTC Above Ground Tanks

For the BTC ferrocement tank design a factory made corrugated iron formwork was used. In general most of the tanks built in Botswana are of this capacity, $10m^3$, $20m^3$ or $30m^3$. The experience with ferrocement tanks throught the country has been mixed, while a significant number of these tanks have performed adequately there are also cases of failure. In a recent investigation (7) 40 ferrocement tanks were inspected, in the Eastern corridor of the country (North East District to the Gaborone/Ramotswa area) of which 14 were found to be leaking, the remaining 26 being structurally sound and watertight. This suggests that 35% of the Tanks sampled had failed. In general, failure was at the joint between wall and slab, the most vulnerable part of the tank, due to stress concentrations. As there are over 150 ferrocement tanks in the country, the present survey is incomplete. Past correspondence in the BTC files (8) also appears to confirm that as many as 50% of the tanks have suffered some degree of leakage. The possible reasons for these failures will now be discussed.

Materials: Clean river sand of a certain grading (9) is required for the ferrocement mortar while this is readily available in the South East (Metsemotlhabe River), and the North East District/Selebi Pikwe area (Shashe, Tati, Motloutse Rivers), (see fig.1) it is rare in some parts of the country. The Brigades in Palapye for instance have to truck in river sand from the Tewane River over 50 km away, near Mahalapye. Under such conditions unless strict control is exercised unsuitable sands are likely to be used. Costs can therefore vary considerably throughout the country (Table 2).

Skilled Personnel: While one of the attractions of ferrocement is the possibility of self-help, the need of skilled plasterers and close supervision on detail are critical if tanks are to be of sound construction.

Curing: It is well known that proper curing is of great importance with regard to ferrocement. This is even more critical in the dry hot environment of Botswana. The control of this aspect is particularly difficult in the field which assumes ready availability of water and an appreciation for curing.

Temperature gradients: The intense heat during the summer months in Botswana (November to February) can lead to surface temperatures as high as 60°C. Under such conditions the use of bituminous aluminium paints to reflect heat may be advisable.

The BTC ferrocement manual produced in 1984 (3) has been used extensively to construct ferrocement tanks. Several shortcoming however need to be highlighted.

- The manual gave the impression that unskilled builders could build ferrocement after a short training programme.
- Enough emphasis was not placed on the importance of the material components of the mortar mix to be used.
- While curing was emphasised, no clear direction was given as to how this could be ensured.
- These shortcomings may have contributed to some of the problems in the field.

The other factor was that while able to provide the impetus for the technology the BTC did not have sufficient resources to be able to keep a close control of developments in the technology. It was left to interested individuals, contractors and brigades to implement the technology and in some cases very commendably. One additional factor contributing to the problems of tank leakage may infact have been due to inadequate design.

Design: The 20m^3 BTC tank design (3) was basically of external diameter 3.9m and height 2.2m. The reinforcement used was a single layer of a 25mm hexagonal mesh (chicken mesh) of 1mm diameter wrapped around the mould covering the whole surface. A 4.2mm galvanised fencing wire is then wrapped around the outside of the chicken mesh starting at the bottom. The corrugations of the mould at 80mm centres give the spacing between wires. Two wires are wrapped at each centre up to the 8th corrugation then once per corrugation up to the top three which again have two strands each. The hoop wires are fastened to the chicken mesh with thin tie wire. Plastering is then done in the usual way with a 1:3 mix, with two layers externally followed by 1 layer internally after the mould is removed. The finished depth of section is 50mm.

Using the design guidelines outlined in the American Concrete Institute (ACI) publication 549.1R - 88 (10) the volume of steel specified for the BTC tank was found to be far short of the 3.5% minimum volume fraction and 0.16mm^2/mm^3 specific surface of steel recommended for water retaining structures. This could explain the high incidence of tank leakage discussed above and suggests a need for a new design for the future.

Durability and cost

One of the advantages often sited for the use of ferrocement is the inherent durability of the materials. A design life of over 25 years is normally quoted. It is likely that with proper design and control this can also be achieved in Botswana.
The average cost of tanks in Botswana is summarised in Table 2. It is clear that considering capital costs alone ferrocement tanks are a viable option especially for capacities above 20 m^3. However, if the recurrent maintenance costs, the so-called design life costs are taken into consideration the cost effectiveness of the tanks are without a doubt.

In a recent nationwide survey (11) 39 galvanised iron water storage tanks in 32 villages were evaluated for the extent and nature of tank corrosion. The majority of these tanks were found to be leaking through rust holes within 3 years of construction. This is because water of $pH < 6.5$ and chloride content over 400 mg/l is very aggressive to galvanised iron (11) and common in Botswana. These waters are however, not likely to attack ferrocement. In fact, it is well known that due to the highly alkaline matrix (at least 1:3 mix by volume) around steel a high degree of protection is afforded to steel reinforcement. The experience with ferrocement boats for instance exposed to sea salts has confirmed the excellent durability of ferrocement to a saline environment. It has also been shown that small diameter wires with their high surface area to volume ratio provides added protection against corrosion problems. Corrosion of reinforcement has not been noted in the field investigations so far (12).
In the case of plastic tanks which are increasingly being used UV degradation is likely to be a problem. In the intense sunlight of Botswana, 3250 hrs per year,this is likely to be a significant problem. Although manufacturers claim to use UV stabilised plastic, a maximum of 15 years servicibility can be expected for high density polyethylene (11). It is likely that unstabilised plastics will have a much shorter lifespan.

Table 2 Available Tanks in Botswana

Type Of Tank	Capacity (m^3)	Construction Cost (P * per m^3)	Estimated Life Expectency (Years)	Remarks
Brick	10	500		Used Mainly in District Council Projects
Corrugated Iron	9 21	250 275	3-10	PVC lined with cover No Stand or Delivery
Ferrocement	10 20	350 225	20-25	Includes Stand Cover is in situ
Poly-ethylene	7	140	10-15	No Field Data on Durability

*1 US Dollar = 2 Pula (P). All prices for June 1991 The price of sand and cement varies considerably e.g in Gaborone, cement is P7.50 per 50 kg while it is P16.00 in Maun. All Tank Prices are based on Southern and South Eastern Districts

FERROCEMENT IN BOTSWANA - THE FUTURE

Water storage is likely to be a key requirement in Botswana during the coming years. Although reticulated water is available in the urban areas and is incresingly becoming available in the villages the need for storage remains critical especially to cope with breakdown of supply and drought. In the Rural Water Supply Design manual (13), prepared as a guide for District Councils for instance it is clearly recommended that emergency storage of water is needed. The Table 3 shows the recommended capacities for diferent population sizes.

Table 3 **Standard Storage Volumes for Rural Villages**

Number of inhabitants	Storage Volume (m^3)	Specific storage (litres/person per day)
600	25	42 -
600 - 1 200	50	42 - 84
1 200 - 1 800	25 + 50	42 - 63
1 800 - 2 500	50 + 50	40 - 56

If the emergency consumption rate of 10 l/person/day is enforced, the storage capacities are sufficient for 4 to 8 days of restricted consumption. At the moment these needs are being met primarily with Iron tanks. However, as already noted above, a three year lifespan for these tanks is not uncommon in Botswana. Ferrocement tanks can provide a safe, durable and cost- effective alternative. The capacities suggested in Table 2 are also ideal for this construction method.

The Design Manual (13) also recommends that large consumers such as certian types of industries and consumers who are dependent on a reliable water supply , e.g. hospitals, clinics and schools should be encouraged to provide their own emergency storage. The availability of a cost-effective and durable solution to water storage is likely to encourage such users to contemplate emergency storage.

Rainwater from roof run-off continues to be implemented on many projects. During a recent field visit to the North East district a new housing project at Masunga was visited where 150 housing units are being built (7). At least 70 of these had 10m³ brick tanks built with them. As noted earlier, brick tanks tend to be the most expensive option and for such mass applications ferrocement tanks are ideal as moulds can be reused and savings due to bulk purchase of materials are likely to make tanks very cost effective.

To further the interest in ferrocement in future and its wider application the following is being pursued,

* Factory production of tanks is to be considered, to bring down costs and provide consistent quality. The experience in New Zealand, India and Thailand to be considered.
* The use of aggregate crusher dust from the local quarry as an alternative to river sand is to be tried and appears to be promising.
* The possibility of Training and Certification of contractors with proven experience.
* The establishment of a Ferrocement Working Group to bring together the considerable ferrocement experience in Botswana.
* The possibility of other ferrocement applications such as roof elements, timber replacement, lining of wells etc.

CONCLUSIONS

Ferrocement tanks have heen a feature in Botswana for over a decade. Although problems have been highlighted with the implementation of these technologies, ferrocement tanks are likely to feature highly in the future. This is precisely because of the specific conditions of water salinity and the poor durability of other available options and the need for storage. With the renewed involvement of the BTC and the coming together of all interested parties it is hoped to extend the availability and use of ferrocement greatly in the coming years not only for tank construction but also for other building elements.

ACKNOWLEDGEMENTS

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