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INVITED LECTURE

CONSTRUCTION TECHNIQUES FOR FERROCEMENT WATER STORAGE TANKS.

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ABSTRACT

Ferrocement water storage tanks have been found to be safe, economicaland easy to construct and maintain even in very difficult remote areas. Various site and problem specific construction techniques have been developed by various R&D groups for making ferrocemnt tanks of small and medium capacities. The paper presents few of these techniques. Three casting methods developed at SERC, Ghaziabad in India have become very popular among field engineers/contractors and are being used on large scale in actual field projects and the structures constructed are performing very well.

INTRODUCTION

The importance of storing drinking water in safe and hygienic structures is now being realised in a much better way in many countries. In India, the programme of providing safe drinking water to all rural citizens by the year 1991, has been taken up by the Department of Rural Development, Government of India under a National Technology Mission on Drinking Water. Besides finding and development of other water sources, it has been felt necessary to collect effectively and store the rain water at an appropriate season and utilise it judiciously so that the requirement of water, for drinking purpose, is met with in a sustained manner for a reasonable period. Quite large area of the country, such as North-

Eastern hills, coastal belt and islands, plain areas of central and North India, normally get sufficient rain fall. The Mission has accorded a very high priority for taking up rain water harvesting schemes and ferrocement water storage tanks. In the process of collection and storage of rain water, the role of a safe and hygienic water storage reservoir/tank is very important. It holds the collected water in a hygienic environment for preventing its getting contaminated during storage. It also forms a major component expenditure-wise for any rain water harvesting system.

Several types of reservoirs/tanks are in use for storing of water in various parts of the world. Tanks of various shapes are being adopted. Some of the popular shapes are, rectangular, cylindrical and spherical. Tanks are constructed using (1) brick/ stone/R.C.C. block masonary (2) reinforced cement concrete (3) steel/G.I. sheets (4) ferrocement (5) bamboo reinforced concrete (6) fibre reinforced plastic (7) composite construction using brick and R.C.C./ferrocement, and (8) high density pothythelene.

Detailed studies carried out at various research organizations, experiences in field and long term behaviour studies on ferrocement tanks have established that F.C. tanks have an edge over the other alternatives. Ferrocement is a construction material which is ideally suited for construction of water storage tanks due to its higher resistance against cracking, impact, shock and moisture migration. It can be moulded in any shape and does not require formwork. Structures made with ferrocement are thinner than R.C.C., lighter in weight hence need lighter supporting structure. Ferrocement construction does not require any heavy plant or machinery or highly skilled labour as needed for fabrication of steel or R.C.C. structures. These do not get damaged with normal impact, shock loads or fire as in the case of masonary and plastic tanks. These are economical in comparison with RCC, masonary, steel and plastic (H.D.P.) tanks. With its advantages and easy availability of its constituent materials in most of the places, ferrocement is an ideal construction material for water storage tanks in rural and urban areas for large type of water supply and minor irrigation schemes. Tanks can be installed in underground, part underground and part aboveground and overhead conditions.

In India, the Structural Engineering Research Centre, Ghaziabad has been a pioneer institution in the field of Research & Development on ferrocement. The Centre is one of the main institutions working on rain water harvesting system for the National Technology Mission in India. The Centre has done considerable work on development of ferrocement structures and many techniques, for production of ferrocement applications such as water tanks, storage bins, septic tanks, roofing units, wall panels irrigation channels, manhole covers, leak proofing treatment for masonary and RCC structures, biogas digesters, check dams have been developed.

1. **Traditional Construction Technique (Skeletal Cage System) :** This technique is used in most parts of the world and involve steps of (a) fabrication of a skeletal cage representing the true size and shape of the tank with M.S. bars, (b) fixing of a minimum of two layers of wire meshes over skeletal cage (c) plastering and finishing with trowel and wooden float (d) curing, & (e) painting. Though, this is a simple mouldless construction technique, needing no infrastructure, but has the disadvantage of difficulty in control of uniformity of thickness. Getting thickness below 20mm is difficult even in case of smaller tanks. Fig. 1 to 4 show various stages of a 10,000 litre F.C. tank construction at Jodhpur.

2. Improved Techniques for Casting of Cylindrical F.C. Wall Units for Water Tanks

2(a) Semi-Mechanised Process for Producing Cylindrical Ferrocement Units - (Indian Patent No.145250) :

In this semi-mechanised casting process developed at SERC, Ghaziabad, a continuous winding of wire mesh from a wire mesh roll on to a cylindrical mould and simultaneous application of high strength cement sand mortar on the wire mesh as and when it is wound on the mould is achieved. This enables to have high degree of compaction of mortar and a very good control over the thickness of the cast unit. Process is labour intensive and does not require power or expensive machinery. Diagramatic representation(elevation) of the casting process equipment is presented in Fig. 5. The process of casting consists of the following steps (refer fig.5) :

1. Wire mesh roll for the reinforcement of the wall unit is mounted on the Spindle 'A' and the wire mesh roll, for collar portion reinforcement of unit, is mounted on Spindle 'B'. Spindles carrying the reinforcing meshes are fixed over a 'A frame' fixed vertical over stand 1.
2. Mould (made of quickly openable three to six segments) bolted together for casting the cylindrical wall unit is mounted on stand 2. Joint battens are provided in between two mould segments.
3. End of the mesh rolls wrapped over spindles are passed through guide rollers A&B as shown in Fig. 5 and initially tied to the cylindrical mould by passing a twin twisted steel wire through holes provided in one of the joint battens.
4. Cylindrical mould is rotated in the forward direction as shown by arrow in Fig.5, so that the mesh gets wound on the mould and moves along with the mould. When a sufficient portion of the wire mesh is wound on the mould, the rotation of the mould is arrested by inserting a 40 mm dia M.S. pipe through the mould and over connecting angle CA. 12 x 3 mm M.S. flat pieces are inserted between the mould surface and the mesh and high strength cement sand mortar (1:2) added with poresealing and plasticizing compounds, is applied on the portion of the wire mesh wound on the mould. After the application of mortar, the mould is rotated further so that the next portion of wire mesh gets wound on the mould and mortar is applied on the wire mesh in continuation of the portion on which mortar was already applied. Thus, the

process goes on continuously and the application of cement mortar is done layer by layer on the mesh till the required number of wire mesh layers are wound on the mould and the required thickness of the mortar in wall unit is obtained.

5. The last layer of wire mesh is given an extra overlap length and the wire mesh is tied to the mesh below (already plastered) at close interval. The mesh is then cut and the surface is finished with cement mortar maintaining proper cover to the outer most reinforcement layer.
6. The unit is demoulded after 24 hours but the mould could be shifted from the stand soon after the casting is over.
7. The wall unit is given a finishing coat with 1:1·5 cement, sand mortar on the inside surface and is cured for at least 7 days with water before using it for assembling of tanks.

The process described is being used for producing wall units for water storage tanks upto 5,000 litre capacity which has a thickness of only 18 mm. The same wall units are also used for assembling of septic tanks, grain or oilseed storage bins, biogas digesters, garbage bins etc. The base of the tank is precast in RCC. The dome shaped roof and lid are cast using ferrocement. Figure 6 shows various precast components for a F.C. tank of 1250 lit. capacity, produced using SERC process. Low cost masonary moulds (constructed by plastering soil deposited in shape) have been developed for casting of roof and lid. Tanks casted with this technique are light in weight but strong in strength. This process has been released through N.R.D.C. to more than 55 entrepreneurs for commercial production of cylindrical ferrocement structures.

2 (b) SERC Segmental Units : Casting and Jointing Method (Indian Patent No.175250)

During mass production trials and transportation tests conducted by SERC on ferrocement tanks, bins and septic tanks, it was observed that cylindrical units having larger diameter above 1.5m need special care and effort during transportation and handling. For solving this problem, a system of using vertical F.C. segmentalunits for assembling of cylindrical walls for tanks etc. was developed at SERC. Using this technology, units needed for construction of cylindrical structures can be easily cast, transported, erected and joined. The shape of these precast units are cast in the form of a segment of a cylinder. The circumferential surface of cylinder is divided into 4,6,8 or even more number of parts. These segments of sthe cylinder are cast as individual precast units with meshes and cross reinforcement wires/bars projecting on both sides of the unit. This projected reinforcement is used for jointing of a segment with the adjacent segments on both sides. The projection of reinforcement is kept in such a way that laps transfer the full hoof stress coming in the unit on full load. The units are transferred and placed in jointing position. Mesh joints are fixed and mortar is applied. These individual units have been termed as segmental shell units. A system of making and using low cost masonary moulds has been developed and used for casting of these precast segmental units.

On special requirement for construction of underground water takns, digesters and septic tanks (where extra excavation will be needed due to joint filling from both sides) a method of providing a joint lip, with projected reinforcement in it, was developed at SERC for F.C. segmental units. The lip is cast on one side of the segment and the full reinforcement projecting on the other side, is left unplastered. 50% of the reinforcement provided in the lip area is also left unplastered (by using a masking method) and it projects within the lip area. For jointing such units, the projected reinforcement is inserted into the lip area, laps of the inserted reinforcement are fixed and tied with the reinforcement projecting in the lip area. The mesh laps at all the joints are adjusted, tied and plastered from inside itself. Such a system saves extra earth work in case of underground structures and cost of extra outside scafolding in case of above ground structures as the joint finishing can be done from inside itself. The ultimate crushing strength of the mortar used for casting and also for jointing of these precast segments should not be less than 200 Kg/ cm^2. Poresealing compounds and plasticizers are added in the mortar for improving the strength. The case, electricity is available at casting site, a surface vibrator mounted over a wooden scandling or steel channel may be used. Use of vibrator will improve the strength and performance of the precast unit. In case, vertical ribs or horizontal bands are to be prodiced in a tank, these could also be cast during the casting of segments. Fig. 7 shows the seven stages of casting and assembling of cylindrical ferrocement units with SERC segmental system as enumerated below :

1. Reinforcement cage fabricated using steel wires/bars and woven mesh placed over mould.
2. Cement:Sand mortar mixed and applied over cage, ensuring full impregnation. Hand application followed by tamping or vibration for ensuring optimum compaction. The reinforcement projections are left unplastered for jointing with the adjoining units.
3. Surface of unit finished using wooden float. After a gap of 24 hours another unit can be cast over previously cast unit after placing a thin PVC sheet in between.
4. Units are lifted off the mould & the lip former mask provided (in case of joint lip is provided for jointing on one side) is pulled out.
5. Unit inverted after demoulding.
6. Segmental units, with lip cast on one end, are placed in position - reinforcement laps tied and mortar applied over joints (jointing type I).
7. Segmental units with reinforcement projecting on both sides, placed in position-laps tied & mortar applied for filling joints (jointing type II).

Figures 8,9,10 & 11 shows various construction stages of a 5,000 ltr. tank at Jodhpur (Rajasthan). Segmental precast ferrocement roofs and precast segmental bases are being used for assembling of ferrocement tanks in remote areas of Rajasthan and in North-Eastern States for rural water supply and rain water harvesting system.

2 (c) **Tempformer System for Casting** :

The system developed at SERC is an improvement in the traditional skeletal cage technique used for casting of F.C. cylindrical tanks. In this system, a formwork is used for providing a temporary support/backing to the outer mortar layer cast for the tank wall. The temporary formwork is removed after 12-24 hours after the casting. The whole process can be divided into following steps :

1. The RCC base unit for the tank is cast in position leaving some projected dowels (6 to 8 mm dia bars & 8 to 16 in number) at the tank wall position.
2. The tempformer fabricated with wood and G.I. sheet, in 3 to 8 segments, is erected in position. Reinforcement is bent and assembled on the tempformer.
3. Sockets for inlet, outlet, scouring and overflow pipes are then fixed in position and firmly tied to the reinforcement cage.
4. Cement : sand mortar is mixed in 1:2 ratio and applied over the cage carefully. The mortar is applied in two layers. The outer mesh layer is left unplastered in the first application and cover layer is provided after about one hour.
5. Depending upon the climate, the tempformer is removed from the partially cast wall after 8 to 24 hours.
6. The inner surface of the tank is then finished after removing loose mortar from first casting.
7. The precast F.C. roof is erected in position.
8. The tank is cured, dried and painted.

Figures 12 & 13 shows a tempformer with reinforcement cage tied over it and the first layer of mortar applied over it.

Fig. 8 - Reinforced Cage for Segments of a 5,000 lit. F.C. Tank placed over soil deposit mould.

Fig. 9 - F.C. Segments placed vertical over the R.C.C. base of the tank - 5,000 lit. capacity, RPHED, Jodhpur

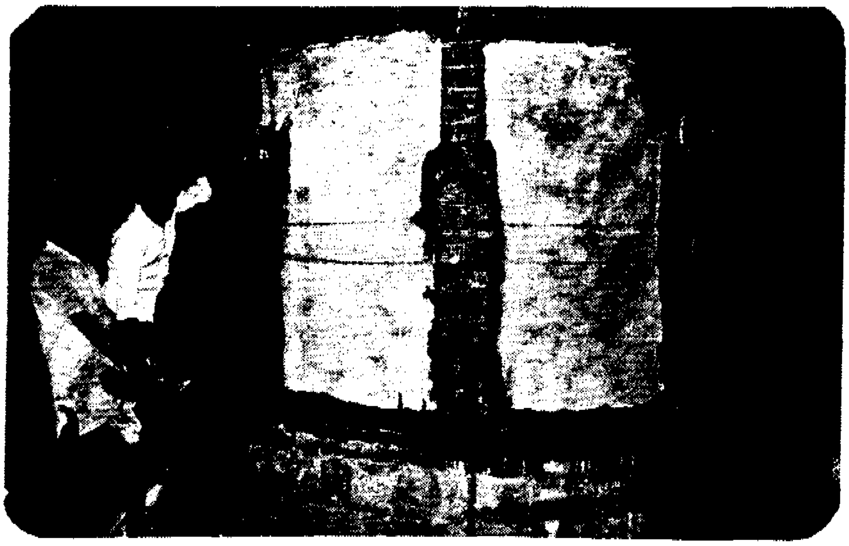

Fig. 10 - Projected reinforcement from Sgements are lapped and tied - Mortar applied over joints.

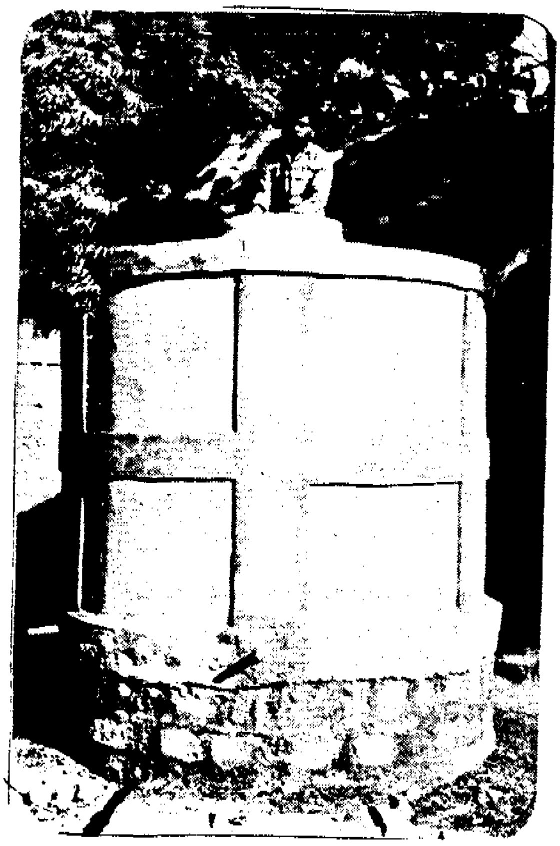

Fig. 11 - Completed 5,000 lit. F.C. Tank
R.P.H.E.D., Jodhpur

Fig.12 - Tempformer with Reinforcement & mortar application 10,000 lit.F.C. Tank, Bhopal (M.P.)

Fig.13 - Ist mortar layer applied over reinforcement - 10,000 lit. tank - Bhopal (M.P.)

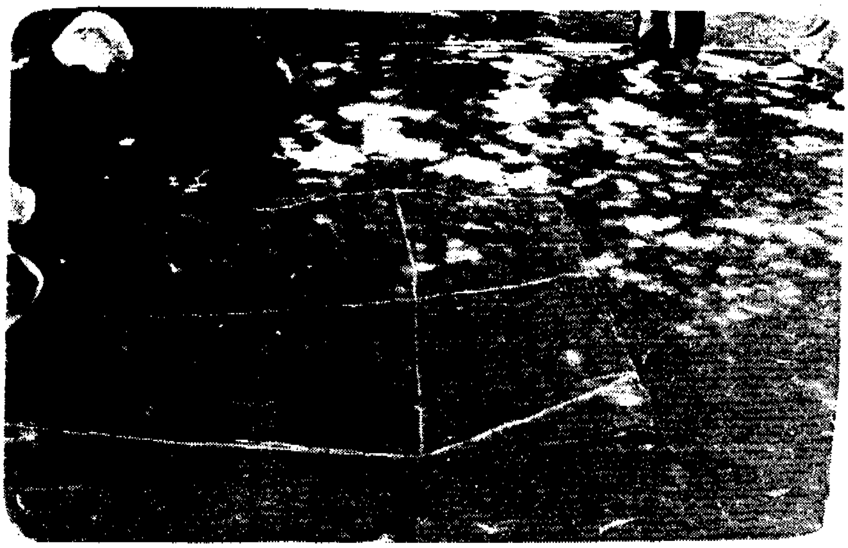

Fig. 14 - Marking & cutting of two hesian cloth pieces for stitching a sack mould for water tank.

Fig. 15 - Sack Mould is filled with rice husk and reinforcement cage made over it

3. Sackmould Technique for Small Tanks :

Sackmould method was originally developed and used in Thailand for making of mortar (unreinforced) water jars. These jars have been found to be very useful and can be produced on self-help basis by villagers without any equipment. Some modifications have been carried out at SERC in the above technology for making it suitable for use in Indian villages. The technique is suitable for domestic storage of drinking water, grains, oilseeds, pulses, seeds etc..

A hesian sack mould is stitched and filled with rice husk/saw dust/waste fodder or fallen dry leaves for obtaining a shape having internal dimensions of the tank/bin. Wire mesh and cold drawn wire is cut and tied over the sack mould. The sack mould surface is made slightly moist by spraying water and cement sand mortar mix of 1:2 to 1:3 is applied and impregnated into the reinforcement cage. The outer surface is finished smooth. This cast unit is left unplastered for a period of 24 to 36 hours and the rice husk filled in the sacl mould is then removed out of it. The empty sack mould is pulled out and the inside of the unit is cleaned and finished with cement sand mortar. Jars upto 2 M^3 volume can be cast easily with this technique. Figures 14 & 15 shows stages of this technique.

Apart from the three processes described at 2(a), 2(b) & 2(c), SERC, Ghaziabad has also developed a process for centrifuging of F.C. cylindrical units and a vibro pressing method for tank segments. Methods of casting and jointing of segments for RCC base and ferrocement roofing units have also been developed and used. All the casting techniques mentioned above have been used for construction of large number of ferrocement water storage tanks in India for capacities upto 30,000 litres. The advantages of improved methods developed at SERC are reduction in dead weight of the tank by 20 to 50%; reduction in consumption of materials by 30%, better finish, shape and compaction of mortar and suitability for factory/

community level production of tanks, septic tanks and digesters etc. Apart from the above, a pit lining method has been developed for underground tanks in laterite or similar soil stratas. The complete technology, training and process packages are available from SERC for commercial use.

As an important activity for the National Drinking Water Mission, Government of India, SERC is undertaking training courses and demonstrations in construction techniques for Rain Water Harvesting and Ferrocement Tanks in the different parts of the country. Eleven such programmes (upto October, 1989) have already been organised and approximately 600 Engineers and Technicians have been trained in this technology. Many more training programmes have been planned. States covered are - Manipur, Meghalaya, Nagaland, Tripura, Madhya Pradesh, Uttar Pradesh, but participants from Rajasthan, Gujarat, Karnataka, Andhra Pradesh, Assam and Maharashtra have also attended these courses.

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The paper is published with the kind permission of Director, SERC, Ghaziabad.

REFERENCES

1. Sharma, P.C., 'Ferrocement Water Tanks for Safe Storage of Drinking Water'. Seminar on Drinking Water Mission at CSMCRI, Bhavnagar, India, April, 1987.

2. Sharma, P.C., Gopalaratnam, V.S., 'DO IT YOURSELF' book on 'Ferrocement Water Tanks'. Published by IFIC, Asian Institute of Technology, Post Box No.2754, Bangkok, Thailand.

3. Sharma, P.C., 'Developed Casting Technique for Cylindrical Ferrocement Units'. Proceedings of the IIIrd Training Course on Construction Techniques for Rain Water Harvesting Systems and Ferrocement Tanks, sponsored by UNICEF, SERC, Ghaziabad, India, November, 1988.

4. Gopalakrishnan, S., Sharma, P.C., Raman, N.V., 'Small Capacity Ferrocement Water Tanks'. Proceedings of the 8th Session of International Association of Shell Structures (IASS) Committee on Pipes and Tanks, Budapest, Hungary, June, 1978.

5. Sharma, P.C., 'Construction Techniques for Ferrocement Units'. Proceedigns of the Asia and Pacific Training Course on F.C. Application for Rural Development, Roorkee, India, 1984.

6. Surya Kumar, G.V., Sharma, P.C., Gopalakrishnan, S., 'Improvements in or Relating to Precast Ferrocement Cylindrical Units for Use in Structures like Grain Storage Bins, Water Tanks, Biogas Holders and Pipes', SERC, Roorkee, India, Patent No.145250.

7 .Sharma, P.C., 'Ferrocement Structures for Rain Water Harvesting Schemes' - Moving Technology, Vol.3, No.6, December, 1988.

8. Sharma, P.C., 'Construction Techniques for Ferrocement Tanks for Rain Water Harvesting' - Fourth International Conference on Rain Water Cistern Systems, Manila, August 2-4, 1989.

9. Design Packages and Guidelines, Vol. I & II, published by National Drinking Water Mission, Govt. of India for Seminar on Water Harvesting Systems & their Management, Bangalore, December, 1988.

10. Sharma, P.C., 'A Mechanised Process for Producing Ferrocement Roof and Wall Elements', Journal of Ferrocement, Vol. 13, No.1, January, 1983.

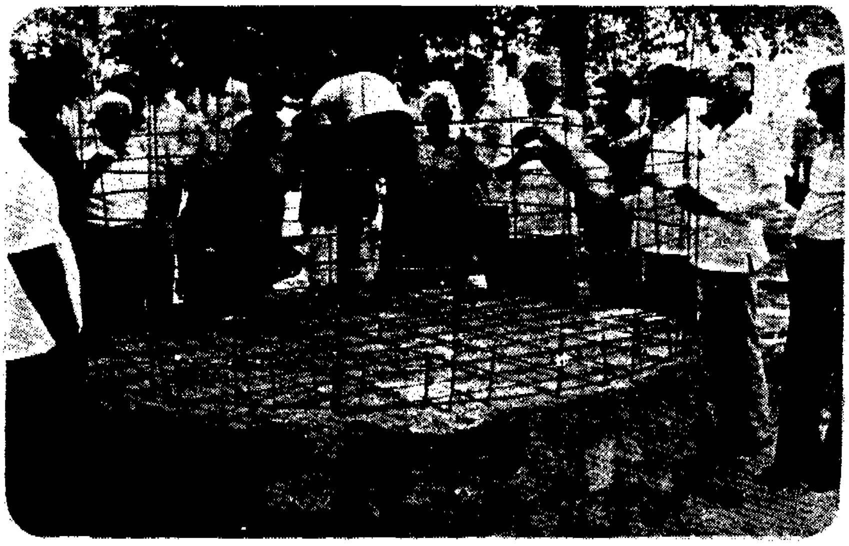

Fig. 1 - Skeletal Cage for F.C. Water

Fig. 2 - Wire mesh being fixed over Skeletal Cage

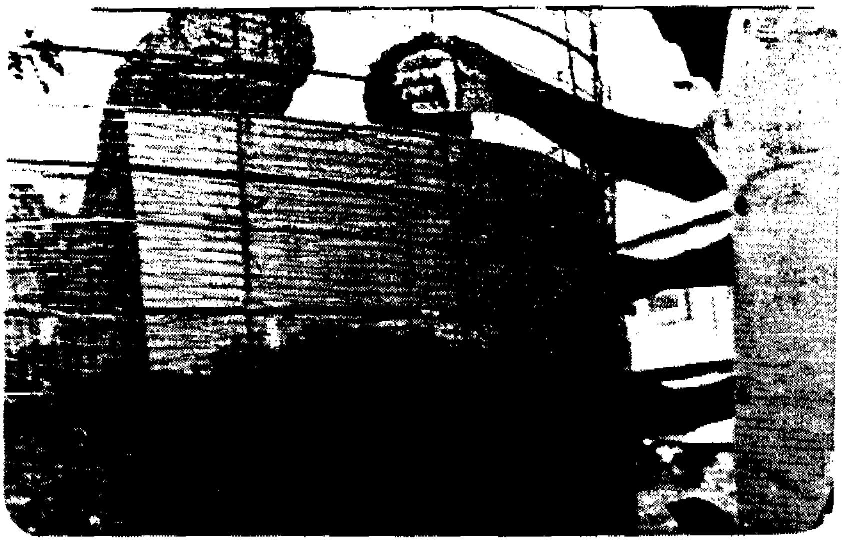

Fig. 3 - Piece of G.I. sheet held on the inside mesh surface - Mortar being applied from outside

Fig. 4 - Mortar application finishing F.C. Tank, 10,000 Litres - R.P.H.E.D., Jodhpur

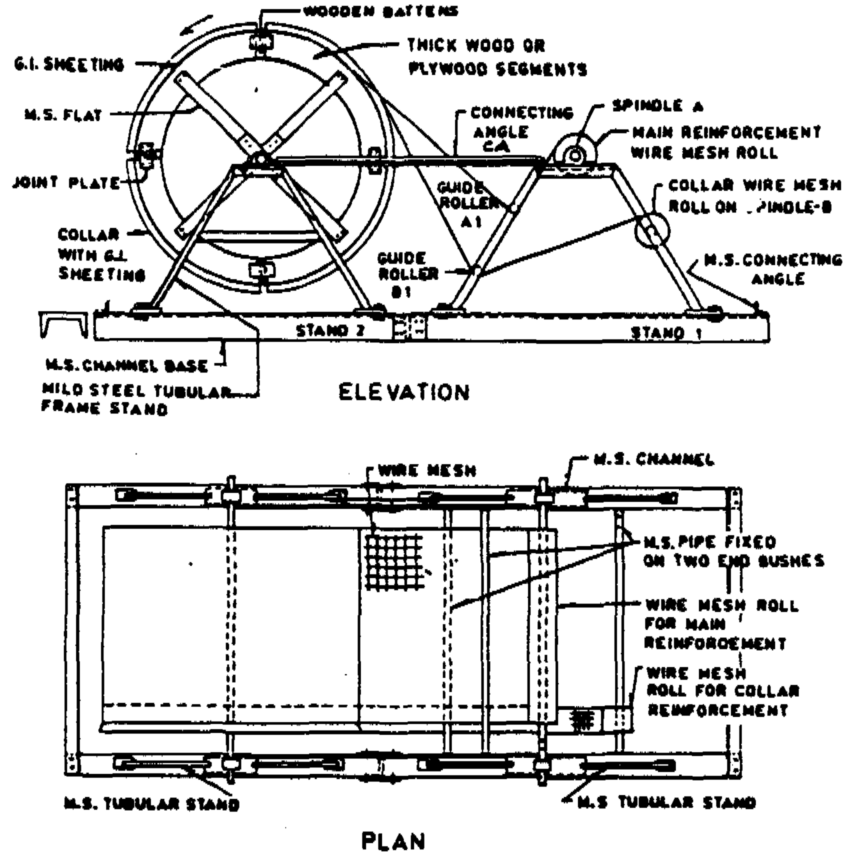

Fig. 5 - Semi-Mechanised Process for producing F.C. Cylindrical units-Patented Process

A PATENTED PROCESS

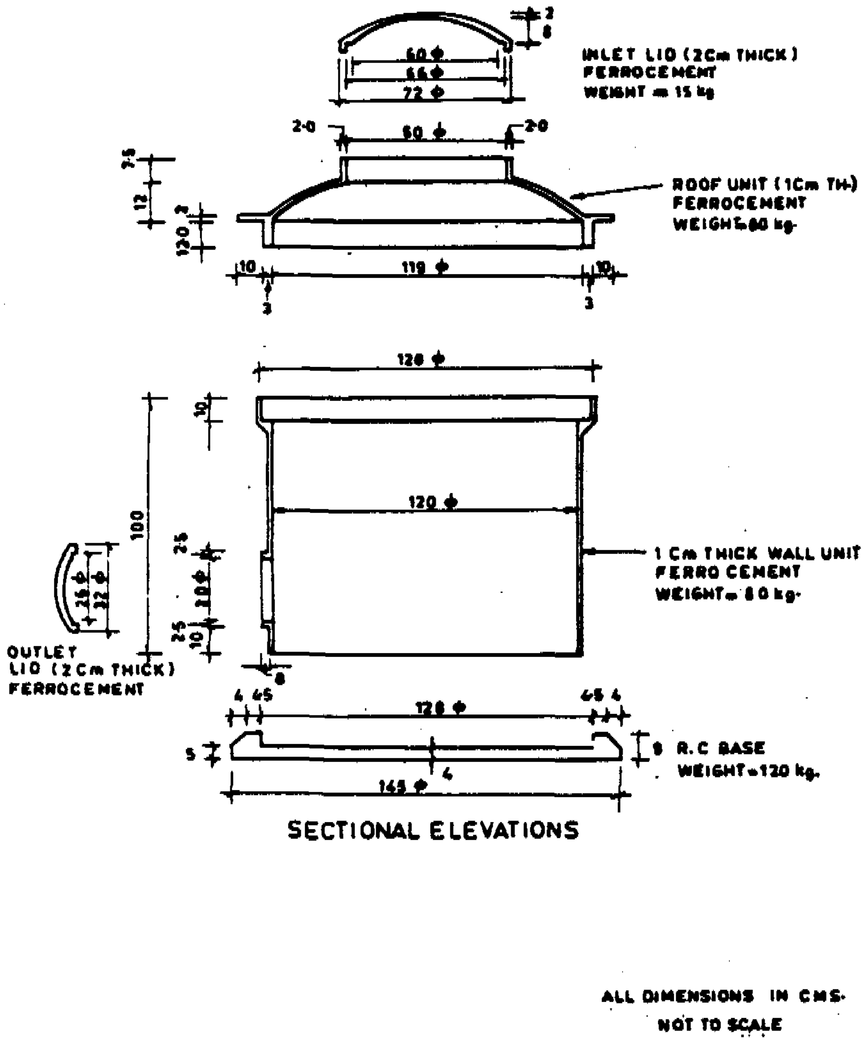

Fig. 6 - Ferrocement Precast Elements for Tanks and Bins

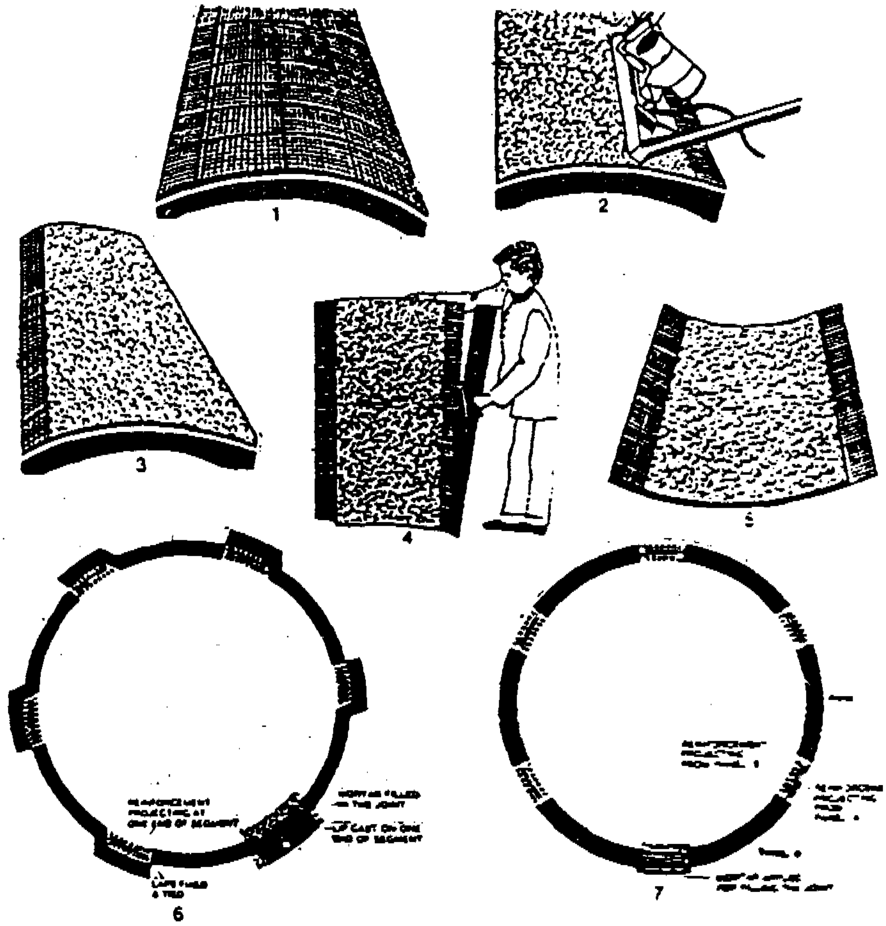

Fig. 7 - S.E.R.C. Segmental Technique for Cylindrical Tanks, Bins, Septic Tanks & Digesters - various stages

Fig. 16 - Mortar applied over the sack mould

Fig. 17 - Final finishing carried out.