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CONTENTS

Discussion of the technical materials published in this issue is open until **January 1, 1980** for publication in the Journal.

IFIC

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EDITORIAL

In recent months several organizations have through a number of meetings strongly emphasized the importance of technology transfer for developing countries. In particular, the International Council of Scientific Unions' Committee on Science and Technology in Developing Countries (COSTED) has drafted very clear and pressing recommendations to the United Nations' forthcoming UNCSTD meeting (Vienna, August 1979) for finding ways and means for transferring technology to the various types of users in developing countries: not only to scientists and governments but also to local entrepreneurs and most importantly to the considerable numbers of illeterate rural poors. The large number of "Appropriate Technology Information Centers" newly created worldwide is a further indication that there is a strong need and demand in that area.

The establishment of IFIC in 1977 was exactly in keeping with such requirements. From its start IFIC's activities were mainly focused on transferring ferrocement technology to the various types of users in developing countries. IFIC rather quickly satisfied the needs of scientists and engineers but was slower in finding adequate ways of serving "amateurs" and uneducated rural prople. This is not surprising. Classical methods of information dissemination are totally inefficient to reach the rural population and therefore new ways and methods have to be innovated, suitable for an illeterate target audience. To reach them, information must be processed and communicated through any intermediate individual who can be called "extension officer" or "change agent". He is a person who can perform two functions: he must assimilate and master the technology and he must be able to demonstrate it to the villagers in simple terms, using their own language, respecting their psychlology and traditions.

Therefore, IFIC decided it had to produce the tools required by such "change agents" for helping them in their difficult mission. For that purpose IFIC has:

- published brochures on ferrocement in various local languages,
- prepared sets of slides on ferrocement applications,
- started the publication of a series of "Do it yourself" type of booklets on various ferrocement applications, in a simple style and amply illustrated form.
- participated in a 4-month training session on ferrocement construction held at AIT for a group of nine Indonesians.

This last activity is particularly useful. Trainees, once back in their own country will train other people starting a snow-balling effect which is certainly the most efficient and practical way of bringing ferrocement technology right down at the village level. It is hoped that funding will be found in the future to repeat such training sessions for other developing countries.

It can be said today that IFIC is offering a broad spectrum of services besides the Journal of Ferrocement. Though, this Journal is still mostly of interest to scientists and engineers, the Editors have repeatedly expressed their wish to see it publish more practical information coming from amateurs or field workers who are urgently requested to send in any information they think worthwhile communicating to their colleagues.

Any comments or advices from our readers on how IFIC could further improve its activities in trying to reach a broad spectrum of users and especially the rural population will be most welcome.

The Editors

Analysis, Design and Construction of Ferrocement Water Tanks

P. Paramasivam*, G.K. Nathan+ and S.L. Lee†

A study is conducted to investigate the performance and practical application of ferrocement in the construction of prototype cylindrical and rectangular water tanks for use in highrise buildings. The cylindrical tank and the rectangular tank are designed as a thin shell structure and thin plate structure respectively resting on reinforced concrete slab. Design charts are presented to aid in the design of ferrocement water tanks of various practical dimensions. A cylindrical tank of 2.44 m (8 ft) diameter and 2.6 m (8.5 ft) height and a rectangular tank of 3.66 m x 1.83 m (6 ft x 12 ft) in plan and 1.37 m (4.5 ft) in height are designed for which construction procedures and test results are presented and discussed.

LIST OF SYMBOLS

A_c	:	Gross cross-sectional area of concrete mortar
A_s	:	Area of steel reinforcement
a	:	Radius of the cylindrical tank
b	:	Width of the ferrocement composite
D_c	:	Flexural rigidity of the cylindrical wall
D_p	:	Flexural rigidity of the base plate
D	:	Flexural rigidity of the wall for the rectangular tank
d	:	Thickness of the ferrocement composite
E_c	:	Flexural rigidity of ferrocement composite
H_1	:	Span of the rectanguar tank
H_2	:	Height of the water in the rectangular tank
L	:	Height of the water in the cylindrical tank
M	:	Maximum bending moment in rectangular wall
M_c	:	First crack bending moment of ferrocement composite
M_r	:	Radial bending moment per unit length
M_x	:	Bending moment per unit length about the Y-axis
M_y	:	Bending moment per unit length about the X-axis.
N_x	:	Axial force per unit length in the X-direction
N_y	:	Axial force per unit length in the Y-direction
Q_x	:	Transverse shear force per unit length in the cylindrical tank
S_c	:	Slope of the cylindrical wall at the joint
S_p	:	Slope of the base plate at the joint
t_c	:	Thickness of cylindrical shell wall
t_p	:	Thickness of the base plate
w	:	Lateral deflection of the rectangular tank wall
w_r	:	Radial deflection of the shell wall
w_p	:	Displacement of the base plate

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ρ : Specific weight of water
μ : Poisson's ratio
σ_c' : First crack tensile stress of ferrocement
σ_m' : Proof stress of mortar at 0.01 % strain
σ_s' : Proof stress of steel at 0.01 % strain

INTRODUCTION

In highrise buildings, steel tanks are commonly used to store water for domestic use and this may be due to the availability of steel tanks in the prefabricated form. However, the use of such steel tanks has many disadvantages like high cost, rusting and consequent deterioration of the quality of stored water, frequent maintenance and limited life-span due to corrosion. A study is conducted to investigate the performance and practical application of ferrocement as an alternative to steel in the construction of prototype water tanks. Since its introduction as engineering material by Nervi [1] in 1942 it has been widely used as construction material for boat hulls. Extensive experimental studies have been reported on the behaviour of ferrocement in tension and flexure [2-7]. A great deal of interest has evolved in Southeast Asia regarding the potential application of ferrocement in the field of agriculture, industry and housing [8-10]. In this paper, the analysis, design, and construction of cylindrical and rectangular water tanks for highrise flats using ferrocement are discussed.

CYLINDRICAL TANK

The cylindrical tank is suitable for highrise flats where the roof area available is limited. The base plate of the ferrocement tank is resting directly on reinforced concrete slab. The analysis is carried out in two parts by linear elastic theory. The first part deals with the cylindrical shell wall and the second part with the base plate. The total solution for the entire tank is obtained by imposing appropriate boundary conditions at the junction of the base plate and the wall.

Analysis of Cyindrical Shell Wall

For the cylindrical tank filled with water up to height L, an shown in Fig. 1, the governing differential equation is [11]

$$\frac{d^4w_r}{dx^4} + 4B^4w_r = \frac{-\rho\,(L-x)}{D} \qquad \ldots\ldots\ldots \quad (1)$$

where $B^4 = E_c t_c / 4Da^2$ and w_r is the radial deflection, ρ the specific weight of water, L the height of water, D the flexural rigidity of the wall, a the radius of the tank, t_c the thickness of the wall, E_c the flexural rigidity and x the height of the section considered.

Integrating Eq. 1 and applying the boundary conditions, $w_r = 0$ and $dw_r/dx = S_c$ at $x = 0$, yield the radial deflection w_r in the form

$$w_r = \left(\frac{\rho a^2 L}{E_c t_c}\right) e^{-Bx} \cos Bx + \frac{S_c}{B} + \frac{\rho\, a^2}{E_c t_c}\left(L - \frac{I}{B}\right) e^{-Bx} \sin Bx - \frac{\rho\, a^2\,(L-x)}{E_c t_c} \qquad \ldots\ldots\ldots \quad (2)$$

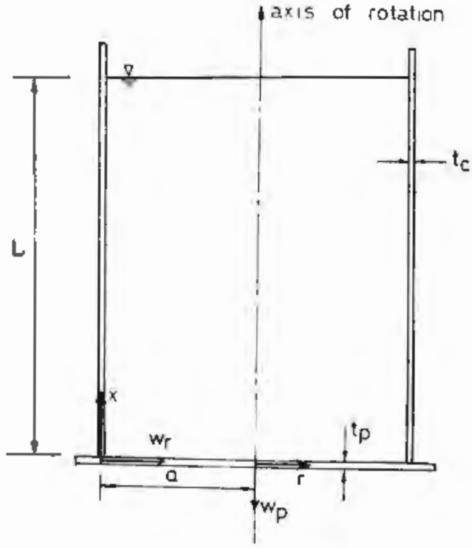

Fig. 1. Cylindrical tank filled with water.

The stress resultants are expressed in terms of w_r by

$$N_x = 0 \qquad (3\text{ a})$$

$$N_y = E_c t_c \, w_r/a \qquad (3\text{ b})$$

$$M_x = -D \frac{d^2 w_r}{dx^2} \qquad (3\text{ c})$$

$$M_y = M_x \qquad (3\text{ d})$$

$$Q_x = -D \frac{d^3 w_r}{dx^3} \qquad (3\text{ e})$$

in which N_x, N_y, M_x, M_y and Q_x are defined in the list of symbols.

Analysis of Base Plate Interaction

Considering the deformation of the loaded tank at the joint, the interaction of the base plate with the cylindrical wall can be approximated as that for the bending of a plate by a radial edge moment uniformly distributed along the edge of the plate, the transverse load on the plate being resisted by the reinforced concrete slab. The direction of the edge moment is such that the interaction between the base plate and the slab may be neglected for design purposes. The governing differential equation can be expressed as [12]

$$\frac{d}{dr}\left[\frac{1}{r}\frac{d}{dr}\left(r\frac{dw_p}{dr}\right)\right] = 0 \qquad (4)$$

where w_p is the plate deflection and r the radial coordinate.

Integrating Eq. 4 and applying the boundary conditions $w_p = 0$, $dw_p/dr = S_p$ at $r = a$ and $dw_p/dr = 0$ at $r = 0$, lead to the plate deflection w_p in the form

$$w_p = \frac{S_p}{2a}\,(r^2 - a^2) \qquad (5)$$

The radial bending moment is expressed in terms of w_p by

$$M_r = -D_p \left[\frac{d^2w_p}{dx^2} + \frac{\mu}{r}\frac{dw_p}{dr}\right] \qquad (6)$$

where D_p is the flexural rigidity of the base plate.

Analysis of Cylindrical Tank

The interaction between the cylindirical shell and the base plate is governed by the compatibility and equilibrium conditions at the junction,

$$|S_c|_{x=0} = |S_p|_{r=a} \qquad (7)$$

$$|M_x|_{x=0} = -|M_r|_{r=a} \qquad (8)$$

A computer program is developed to carry out the above analysis and to determine the stress resultants of cylindrical tanks of various diameters and heights.

Design of Cylindrical Tank

The analysis shows that the maximum hoop stress governs the design of the cylindrical wall rather than the bending moment at the base of the tank. The thickness of the wall and the base plate are normally determined by the amount of reinforcement, spacing of wire mesh and concrete cover. In view of practical considerations, the thickness of 25 mm (1 in) to 38 mm (1.5 in) for the wall and 50 mm (2 in) to 64 mm (2.5 in) for the base plate are considered for the design. Assuming 57 mm (2.25 in) thick base plate, the hoop stress is plotted in Figs. 2a, 2b, 2c, 2d and 2e for wall thickness ranging from 25 mm (1 in) to 64 mm (2.5 in) and for diameters of 2.44 m (8 ft), 3.05 m (10 ft), 3.66 m (12 ft), 4.27 m (14 ft) and 4.88 m (16 ft) and various depths of the water. For ferrocement water tanks, leakage will occur if the maximum hoop stress exceeds the first crack tensile stress of the ferrocement composite. Therefore the hoop stress can be proportioned with a safety factor against the development of cracks. The first crack tensile stress of ferrocement material (σ_c') can be calculated by [4]

$$\sigma_c' = \sigma_s' \left(\frac{A_s}{A_c}\right)^{1.1} + \sigma_m' \qquad (9)$$

where σ_s' is the proof stress of wire mesh at 0.01 % strain, A_s the area of wire mesh reinforcement, A_c the gross cross-sectional area of concrete and σ_m' the proof stress of the mortar at 0.01 % strain.

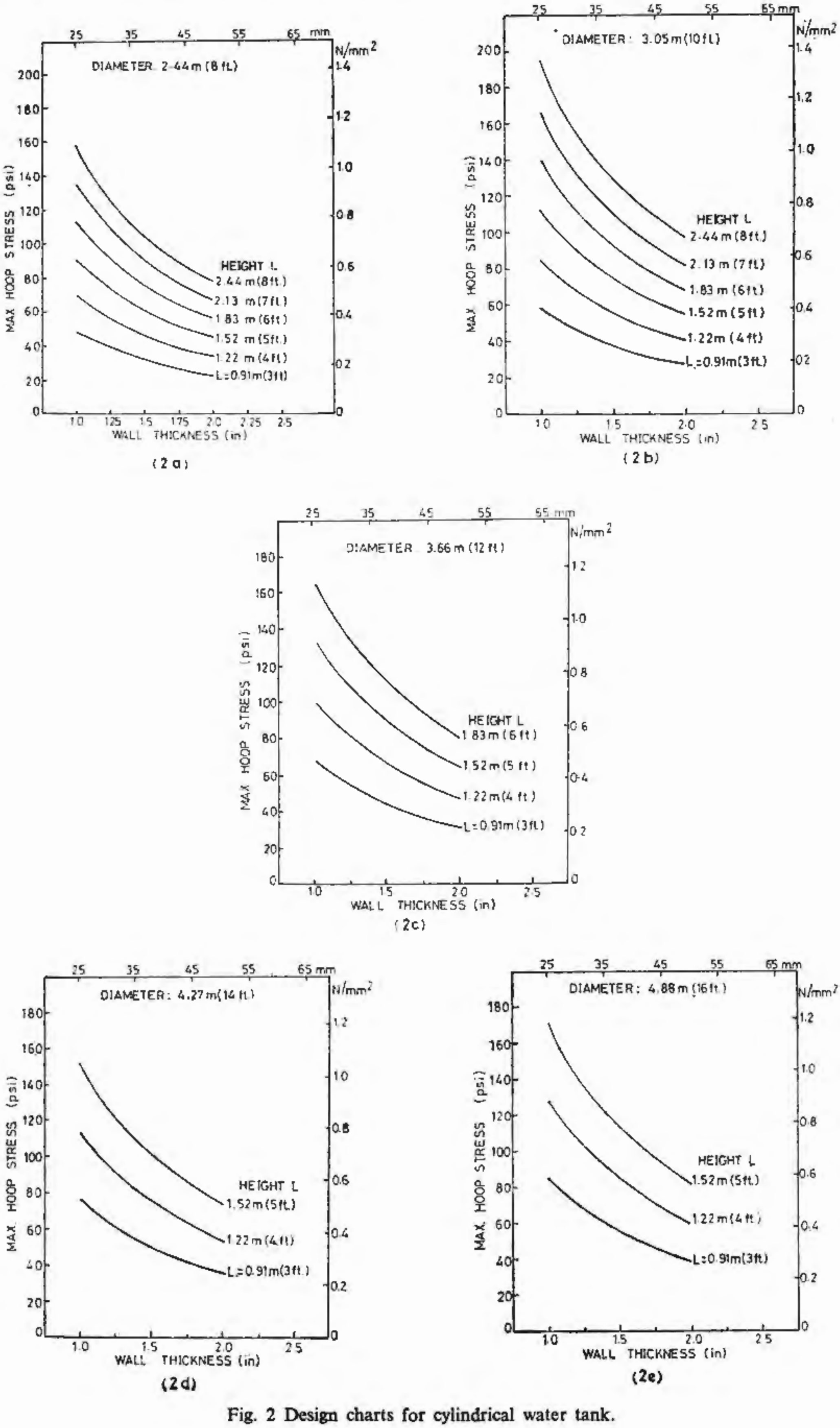

Fig. 2 Design charts for cylindrical water tank.

Construction Technique

Several important factors were considered before a decision was made on the dimensions and amount of reinforecment required for a prototype water tank. In view of the roof plan of the highrise building on which the tank will be installed, a tank 2.6 m (8 ft) in diameter 2.6 m (8 ft) in height was selected. The wall and base thickness adopted were 32 mm (1.25 in) and 58 mm (2.25 in) respctively. From the analysis, it was found that the maximum hoop stress governs the design of the cylinder which was proportioned with a safety factor against the development of cracks. In this design the estimated cracking stress and the maximum hoop stress are 2.3 N/mm^2 (335 psi) and 0.8 N/mm^2 (126 psi) respectively.

The cement, sand and water ratio of 1.0 : 1.5 : 0.4 was used for thr mortar. An admixture of Rapidard was added to increase the workability in proportion of 2273 cc per bag of 50 kg of cement. The sand should pass through sieve B.S. No. 14 and greater than No. 100. The cement used was Type I normal portland cement. The relevant properties of the constituent materials are given Table 1. The reinforcement for the wall consists of three layers of woven wire mesh, 8.5 mm x 8.5 mm (0.33 in x 0.33 in) mesh size with 0.92 mm (0.034 in) diameter, and two layers of skeletal steel, 152 mm x 152 mm (6 in x 6 in) BRC weld mesh of 5 mm (0.2 in) diameter, sandwiched together in alternated layers. The skeletal steel was used to form the shape of the cylinder and base plate, rigid enough to carry the weight of the reinforcement and wet mortar. Three layers of wire mesh and two layers of BRC weld mesh and 10 mm ($\frac{3}{8}$ in) diameter mild steel bar centrally placed at 25 mm (12 in) spacing were used for the base slab. Particular care was taken at the junction between the cylindrical wall and the base plate by weaving the vertical wire mesh through the reinforcement of the base plate

Table 1 Properties of Constituent Materials

Plain Mortar		
Cement : Sand : Water	1 : 1.5 : 0.4	
Crushing Strength	37.9 N/mm^2	5500 psi
Tensile Strength (Direct Tension)	1.04 N/mm^2	151 psi
Modulus of Elasticity	2.2×10^4 N/mm^2	3.19×10^6 psi
Wire Mesh		
Grid size	8.5 mm x 8.5 mm	0.33 in x 0.33 in
Diameter	0.92 mm	0.034 in
Ultimate Tensile Strength	358 N/mm^2	52,000 psi
Tensile Stress at 0.01 % Strain	276 N/mm^2	40,000 psi
Modulus of Elasticity	2.0×10^5 N/mm^2	29.0×10^6 psi
Ferrocement Composite		
First Crack Tensile Stress	4.54 N/mm^2	660 psi
Ultimate Tensile Stress	8.03 N/mm^2	1165 psi
First Crack Bending Stress	9.31 N/mm^2	1350 psi
Ultimate Bending Stress	21.75 N/mm^2	3154 psi
Modulus of Elasticity	2.5×10^4 N/mm^2	3.63×10^6 psi

for continuity. Plastering of the tank was carried out in a single day starting from the base plate and a portable vibrator was used to consolidate the mortar in the base plate. An important feature in the construction is that extreme care should be exercised in the curing process especially immediately after plastering. Figs. 3 to 7 show the placing of reinforcement and plastering of the tank at different stages.

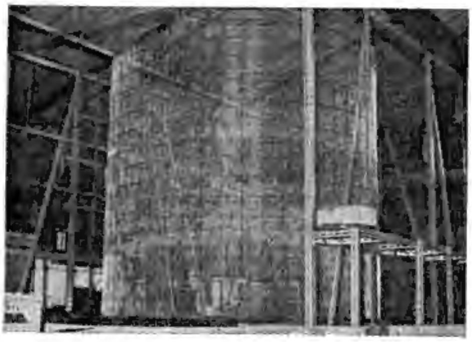

Fig. 3. Reinforcement details of cylindrical tank.

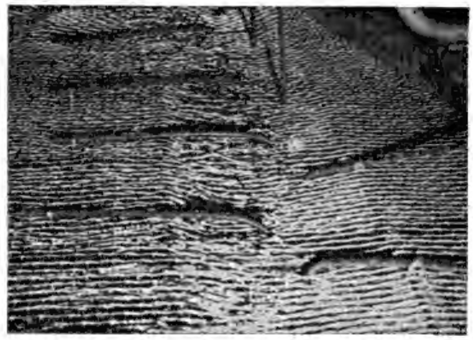

Fig. 4. Bottom view of reinforcement details of base plate at junction of cylindrical wall and base plate.

Fig. 5. Outside view of cylindrical wall and base plate after laying of wire mesh prior to plastering.

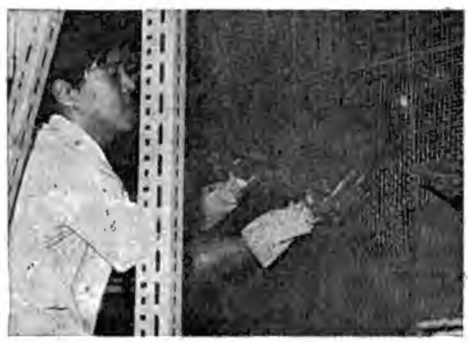

Fig. 6. Plastering of tank wall.

Fig. 7. Finished water tank.

After curing for 28 days, electrical strain gauges were attached on the wall to measure the hoop strain and the tank was filled with water up to 2.44 m (8 ft) high and the strain measurements were made. The hoop stresses determined from the strain reading closely follow the theoretical calculations as shown in Fig. 8. The water was kept for about 12 months and no leakage was observed. It is of interest to mention that no water proofing compound was used in this experiment.

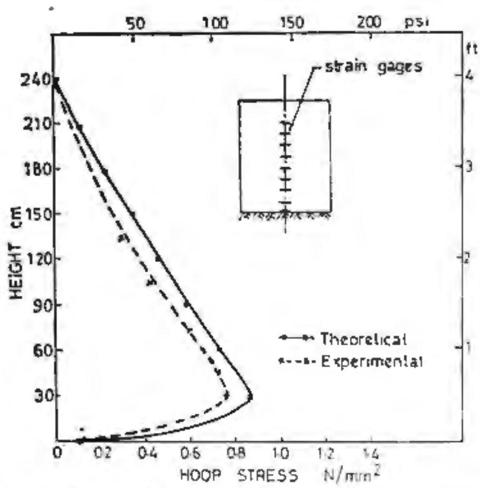

Fig. 8. Comparison of experimental and theoretical hoop streess.

RECTANGULAR TANK

In the case of highrise flats where more roof areas are available, it is desirable to use water tanks of larger lateral dimensions with lower depth of water to provide larger insulated area from the sun. The tank is supported on existing reinforced concrete floor system at the roof level of the building. In this case it is sufficient to analyse the side wall based on the elastic theory of thin plates.

Analysis and Design of Rectangular Tank Wall

For the rectangular tank wall with the tank filled with water as shown in Fig. 9, the governing differential equation takes the form [12]

$$\frac{d^4w}{dx^4} + 2\frac{d^4w}{dx^2dy^2} + \frac{d^4w}{dy^4} = q/D \qquad \ldots\ldots (10)$$

where w is the lateral deflection, q the intensity of lateral load, and D the flexural rigidity of the wall. Eq. 10 can be readily solved for different boundary conditions using finite difference technique [13]. The boundary conditions for the proposed tank wall are that the top edge is free fixed on the two vertical edges and continuous at the base as shown in Fig. 9. For simplicity of analysis, the base is assumed to be fixed against rotation. For these boundary conditions stress resultant coefficients for various heights and spans of the tank are given in reference [13].

From the analysis, it is observed that maximum bending moment at the mid-point of the lower edge governs the design of the wall. The tensile stresses are negligible compared to the bending stress and the wall thickness is governed by the latter. Using the above analysis, the

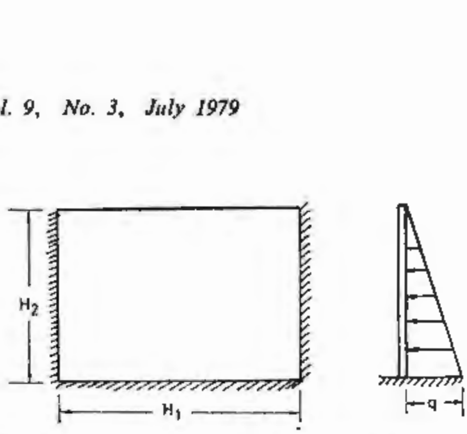

Fig. 9. Boundary conditions of prototype rectangular tank wall.

bending stresses corresponding to wall thickness ranging from 25 mm (1 in) to 56 mm (2.5 in) for 1.25 m (4 ft), 1.6 m (5 ft) and 1.8 m (6 ft) height of water are presented in Figs. 10a, 10b and 10c. To design against leakage, the maximum bending stress must be limited with respect to the first crack bending stress of the ferrocement composite with a factor of safety. The first crack moment M_c for ferrocement composite can be obtained using the expression [5] in Eq. 11.

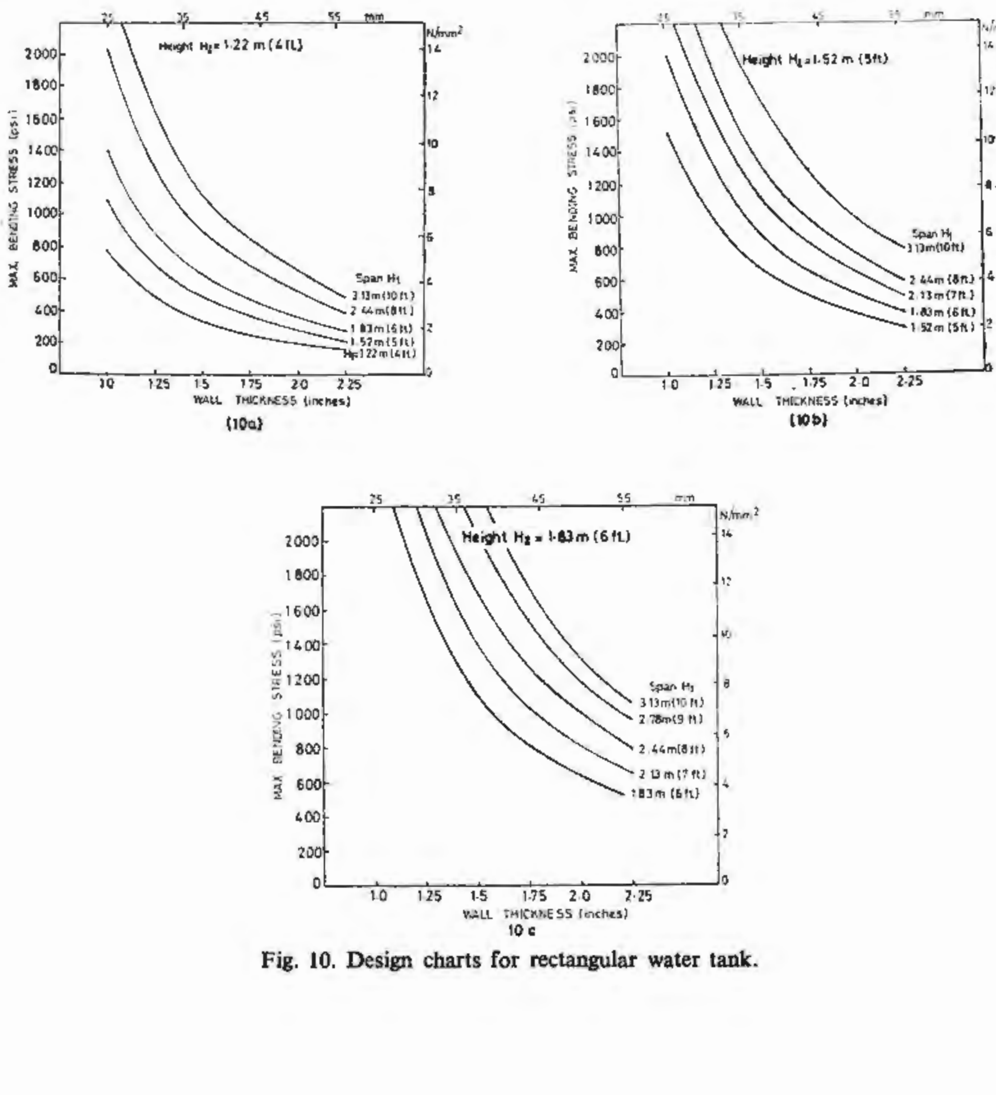

Fig. 10. Design charts for rectangular water tank.

$$M_c = \frac{(d-c)\,(15d+c)b}{144}\left[\sqrt{\frac{\sigma_c'}{E_c \times 10^{-4}}} + \sqrt{E_c \times 10^{-4}}\;\right]^2 \qquad \ldots\ldots (11)$$

where the parameter c is defined by

$$\left(\frac{c}{d-c}\right)^2 = \frac{2}{3} \qquad \ldots\ldots (12)$$

In these equations, d and b denote the thickness and width of the plate element respectively, and σ_c' and E_c are the first crack tensile stress and modulus of elasticity of the ferrocement material respectively.

Construction Technique

In view of the roof plan of the highrise flats, on which the rectangular water tanks are to be installed, a prototype tank of 3.66 m x 1.83 m (6 ft x 12 ft) in plan and 1.37 m (4.5 ft) height supported by three inverted U-shape frames as shown in Fig. 11, was selected to simulate the actual structure. A thickness of 32 mm (1.25 in) was adopted for both the wall and the base plate. As mentioned previously, for the range of dimensions under consideration, the maximum bending stress at the mid-point of the lower edge governs the design. The estimated bending stress obtained was 6.17 N/mm^2 (895 psi) and the theoretical value of modulus of rupture of the ferrocement wall determined by using Eqs.11 and 12 was 8.53 N/mm^2 (1230 psi). The constituent materials were similar to that used in the construction of the cylindrical tanks discussed earlier.

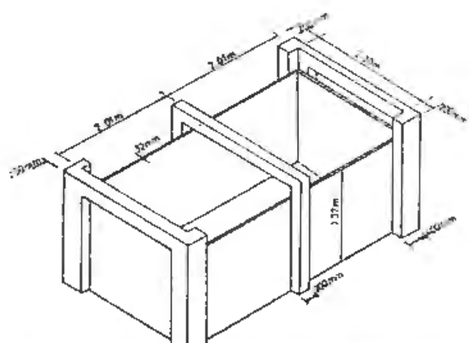

Fig. 11. Lay-out of prototype rectangular water tank.

Three inverted U-shape frames to simulate the support provided by the actual structure were constructed in the laboratory to support the tank. Dowel bars 7 mm (0.25 in) in diameter by 254 mm (10 in) legnth spaced 305 mm (12 in) on centers, are provided on the inside vertical face of the frame to hold the skeletal steel securely in position during plastering operation. Plastering of the tank was carried out in a single day starting from the base and a portable vibrator was used to vibrate the mortar in the base plate. Moistened gunny sacks were used for the first three days and the completed tank was cured for 28 days by sprinkling water over the base and the wall surface intermittenly. Figs. 12 to 16 show the placement of reinforcement and plastering of the tank at different stages.

Fig. 12. Reinforced concrete U-shaped frames.

Fig. 13. Tank reinforcements details.

Fig. 14. Plastering of tank walls.

Fig. 15. Completed water tank.

Fig. 16. Test set up.

The tank was tested by filling with water and it was observed that there was a seepage path at one corner of the tank where the plastering operation was obstructed and not carried out properly. The tank was then drained and dried and waterproofing coating was applied at that corner. The tank was re-filled with water and monitored for more than 6 months and no leakage was observed during this period. Deflection was measured at the mid-point of the free edge of the side wall using mechanical dial gauges. The experimental and theoretical deflections are compared in Fig. 17, the deflections being determined while the tank was being filled at stages of 15 cm (6 in) height. It can be noted that reasonably close agreement exists between the theoretical and experimental results. The maximum deflection observed is only 11 mm (0.43 in). Strain measurements were carried out to determine the maximum bending stress which is compared with the corresponding theoretical values. Fig. 18 shows that the assumption of complete fixity at the base is not fully justified. The edge rotation reduces the edge moment while the positive moment is increased in comparison with the theoretical prediction. However, the edge moment still governs the design and the proposed method of analysis provides a simple and conservative approach for the design of the tank.

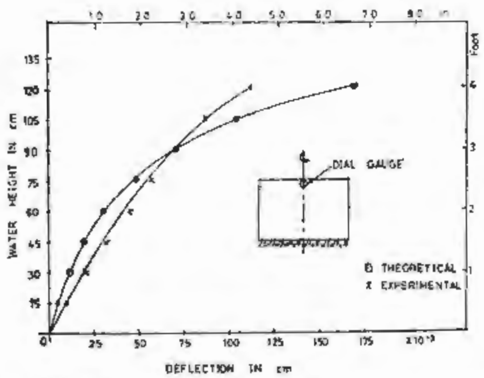

Fig. 17. Comparison of experimental and theroretical deflection.

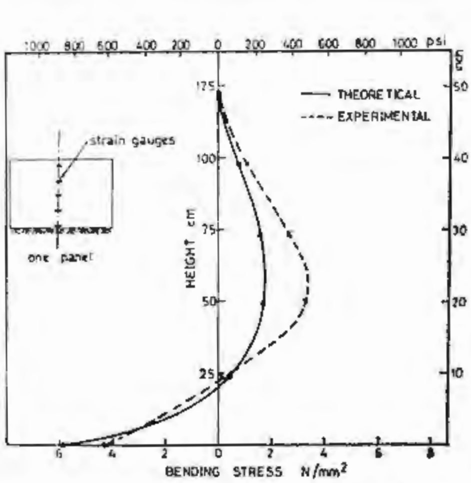

Fig. 18. Comparison of experimental and theoretical bending stress.

CONCLUSION

Cost comparisons were made based on current local cost in Singapore and it was found that ferrocement tanks are cheaper than steel tanks of the same capacities by about 30 percent. The foregoing feasibility studies show that the use of ferrocement in water tank construction deserves further attention from the point of view of economy and low maintenance cost. The advantages of ferrocement as a construction material, in addition to the improved cracking strength over ordinary reinforced concrete, are greater ductility, its feasibility to be produced in thin sections, and its construction does not require high skill labour. The successful performance of the prototype cylindrical and rectangular water tanks confirms its viability in the application in highrise public housing and other apartment flats.

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Ferrocement Bouys for Mussel Culture

Rodolfo T. Tolosa*

This paper describes a method of constructing 12 mm thick ferrocement buoys used as a flotation system in the culture of green mussels (Mytilus Smaragdinus).

INTRODUCTION

The Seafdec Aquaculture Department initiated its mussel research project in September 1975. This was brought about by the indentification of mussel as a rich source of protein and minerals and therefore a good potential for alleviating the protein deficiency in the nutrition of Filipinos. The project was launched with assistance from the Government of New Zealand. The assistance was in the form of material support and consultantship.

One aspect of the project is the design and development of an effective flotation system to be used in the culture of the green mussel, *Mytilus Smaragdinus.* In the Philippines, there are several methods of farming mussels. The two most commonly employed methods are the Stake Method and the Hanging Method.

The Stake Method is employed in subtidal sheltered areas of about 3 meters deep. Bamboo poles are driven and staked firmly on the bottom in rows usually spaced one metre apart. Mussel seeds attach themselves to these bamboo structures and grow to marketable size, after 6 to 8 months. The mussels are then harvested by divers who pull the poles carrying the mussels out of the mud and strip them.

The Hanging Method essentially consists of bamboo plots. Bamboo poles are arranged in rows and kept in place by horizontal bamboo beams. Rope collectors are hung on these beams at equal intervals of about 0.5 metre. The ends of these ropes are held taut by stones or concrete blocks to prevent them from floating to the surface. Mussel seeds attach themselves to the ropes where they are collected when they grow to the desired size.

There are two disadvantages in the methods described above. One is that they rely too much on the use of bamboos. Bamboo as a substrate material is prone to attacks by marine borers and easily rots. Another disadvantage is that the methods are applicable only to areas of limited depths, usually controlled by the length of bamboo poles, the ease of driving them into the ground, and the seabed foundation. This paper presents an alternative method of culturing mussels using ferrocement buoys.

DESIGN AND CONSTRUCTION

In designing a suitable system for the culture of mussels, the following factors were considered and served as bases for its development:

1. The system can be used in areas where the seabed is not suitable for the traditional methods of mussel farming.
2. The system should provide for control of predators to insure less loss of stock;
3. The system should employ materials that have anti-fouling properties; and

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4. The system should employ materials that are durable and resistant to marine borers and rot.

The system developed in this paper is similar to that which is also being developed in Japan and Australia, that is, the use of concrete drums and ferrocement pontoons as flotation units for the culture of mussels.

The nominal dimensions of the first prototype bouy are 0.60 × 1.50 m. It is cylindrical in shape and capped with hemispheroidal ends. It is provided with ears at both ends for mooring purposes and for connecting with other buoys (see Fig. 1).

Fig. 1. First prototype ferrocement buoy.

The buoy is framed with 6 mm steel bars welded at points where the bars intersect each other. The thin shell is reinforced with two layers of welded wire mesh, 6 × 6 mm, ga 20 for the inner layer and 12 × 12 mm, ga 20 for the outer layer. A finer mesh is provided at the inner layer to prevent penetration and accumulation of mortar inside the buoy during plastering. Fig. 2 shows the reinforcements of the first prototype buoy.

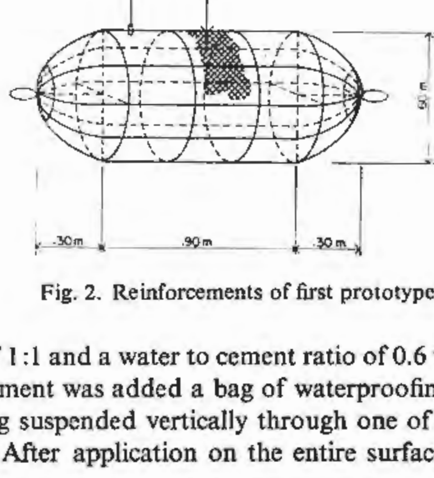

Fig. 2. Reinforcements of first prototype.

A cement to sand ratio of 1:1 and a water to cement ratio of 0.6 were used in mixing the mortar. To each sack of cement was added a bag of waterproofing compound. Plastering was done with the buoy being suspended vertically through one of its ears. This permitted easy application of mortar. After application on the entire surface, cement paste was applied further to attain a smooth and impervious surface. The average thickness of the bouy was about 12 mm. Curing was observed for one day by wetting the surface every 1 to 2 hours. The surface was then coated with epoxy paint. A time interval of one day was further observed before the buoy was moored at sea and allowed to float for one week to determine its performance. Observations indicated that its performance was satisfactory with regards to buoyancy, impermeability and durability.

In the course of improving the design of the buoy, further consultations with researchers of the Department involved in the culture of mussels were made. On the bases of these consultations and observations made during construction, the following revisions were made:

1. The net buoyant capacity of the buoy was increased to 350 kg;
2. The length of the buoy was shortened to 1.0 m;
3. The diameter of the buoy was increased to allow for the changes in nos. 1 and 2;
4. Finer wire meshes were used for the inner and outer layers of reinforcements. It was observed that mortar was deposited inside the buoy during plastering; and
5. The hemispheroidal ends of the buoy were deleted. It was observed that forming the steel bars and wire mesh to obtain the curved surface at the ends was a very tedious process.

Fig. 3 shows the steel framework and reinforcements of the revised buoy. The dimensions are 0.75 × 1.0 m with 3 × 3 mm welded wire mesh, ga 20 used for the inner layer and 6 × 6 mm welded wire mesh for the outer layer.

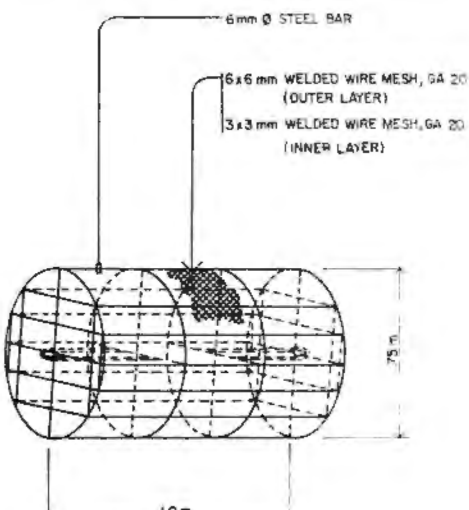

Fig. 3. Reinforcements of the second prototype.

The same mortar mix was used as that of the first prototype. Plastering was no longer monolithic. It consisted of two operations. The first operation consisted of plastering the cylindrical walls and one circular side. The remaining circular base was plastered the following day. The cost of labor and materials for one buoy is approximately US $ 45.00. Fig. 4 shows the revised buoys being tested at sea.

Fig. 4. The revised ferrocement buoys.

The experimental system is composed of three ferrocement buoys arranged and connected as shown in Fig. 5 below. The buoys are spaced at about 5 to 6 meters and tied with polypropylene ropes through the ears. On these ropes are hung collectors for settling and growing mussel spats. The ends of the collectors are fastened to concrete blocks to hold them taut.

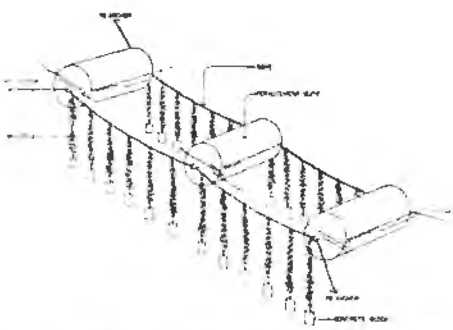

Fig. 5. Hanging method of culturing mussels.

OTHER APPLICATIONS

The buoys may also be used in the construction of a raft house. The raft house serves as guardhouse and storage for feed and other equipment used in the culture of mussels. Fig. 6 below shows a typical arrangement of a raft house made of bamboo.

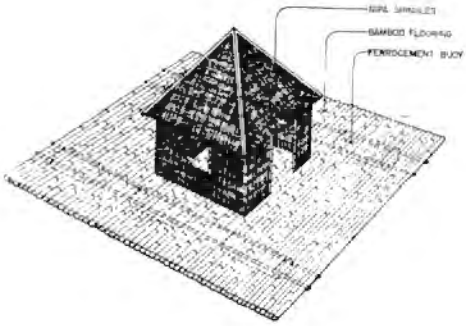

Fig. 6. Raft house.

Another application is in providing a flotation system for nets and cages, moored in sheltered areas. Cylindrical nets, 10 to 20 m in diameter and 3 to 5 m deep, are suspended from a circular ring of ferrocement buoys. The bottom edge of the net is lined with concrete blocks to hold it in place and to keep its shape. 9 of these circular cages could be linked together to form a square configuration and provided with catwalks for easy access to the individual cages. Fig. 7 shows a typical floating cage.

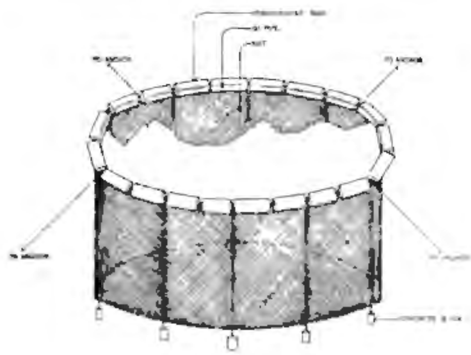

Fig. 7. Floating cage.

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State-of-the-Art Review on Ferrocement Grain Storage Bins

P.C. Sharma*, R.P. Pama+, J. Valls‡ and V.S. Gopalaratnam**

This article presents four very useful types of grain storage structures developed in different parts of the world that have been extensively field tested satisfactorily. Besides giving details of the various stages in the construction of these bins, costs of these alternative bins have also been presented. Additionally, arguments for the choice of bins from these types have been put forward to enable interested parties to effectively select the type of structure ideally suited to their individual requirements.

INTRODUCTION

Grains along with starchy roots provide most of the calorific requirements of the world population. Grains are amongst the easiest to preserve, unlike perishables like meat, fish or vegetables because storage under controlled temperatures is not required. Food-grain production in the developing countries has in the last decade increased manifold. Consequently, losses in storage have also increased proportionately. If ways to reduce thses losses are implemented, the problem of shortage in supplies could be solved to a limited extent. Considering a storage loss of 10-20% (which is generally the case) is equivalent to having no crops once every 10 or 5 years.

Present methods used by most farmers in developing countries are unscientific and unsafe as grains are stored in bags, open rooms, wooden or earth storage structures which are highly suseptable to attack by rodents, vermins, moisture and the like. This results in quality deterioration besides significant losses. Safer storage structures made from materials like concrete or metals are quite expensive and a farmer is in no position to afford these bins.

Ferrocement has been widely used as a construction material for grain storage bins for over a decade in Thailand, India, Nigeria and Ethopia. It is a thin walled material made of cement mortar which is reinforced by layers of wire mesh. The material has many superior engineering properties [1] that makes it ideally suited for storage of grains. Proven suitable for boat-building it has only during the past decade gained acceptance as a versatile building material for potential applications in agriculture, industry and housing.

Four types of grain storage bins that have been extensively field tested have been presented in detail in the next four sections to follow.

CONICAL FERROCENEMT BIN

The first experimental bins were designed and constructed at the Asian Institute of Technology (AIT), Bangkok and later, developmental work was carried out by a team of experts from the AIT, Ministry of Agriculture (Government of Thailand) and the Applied

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Scientific Research Corporation of Thailand (ASRCT). Such bins can be constructed for storage capacities in the range 1-10 tons and are shaped as the frustum of a circular cone (larger diameter at the base and the smaller diameter at the top). Bins with flat bases or saucer shaped bases can be constructed as shown in Fig. 1.

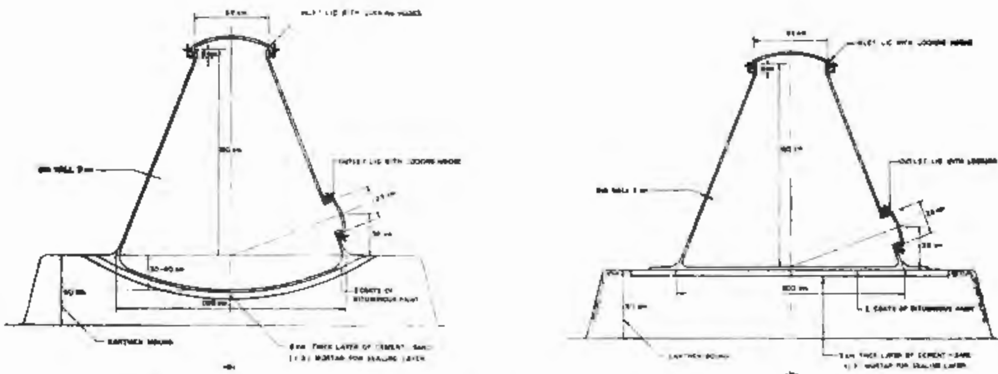


Fig. 1. Section showing demensional details for a 2.0 tonne conical bin,
(a) Saucer shaped base, (b) Flat base.

Construction of these bins with a few added improvements is to be carried out in the following stages mentioned below [2-3]:

1. Based on the capacity required the geometry of the bin is worked out (diameters, heights, wall thickness, etc. — refer to Appendix I).

2. An earthen mound about 30-60 cm high and diameter about 1 m greater than the bin base diameter is made and earth rammed to get a good consolidation.

3. A saucer shaped base for the bin is to be incorporated in this mound if so desired, while ramming earth.

4. A sealing layer of 5 cm thickness is laid using a cement-sand mortar (1:3). After 3 days of curing and a day of drying, 2 coats of bituminous paint is applied over this surface.

5. Two layers of woven mesh (or hexagonal mesh) of ½ in., 20 or 22 gage is spread over the sealing layer. The orientation of these two layers should be so adjusted so that mesh openings are reduced.

6. Steel pipes of inside diameter 10-12 mm in numbers depending upon the size of the bin are cut to a length equal to the length of the sloping surface of the bin. These pipes are held in position by small depressions made in the base (sealing layer) and corresponding holes in a temporary plywood template at the top (Fig. 2).

7. Diameter of the bin is measured at 30-35 cm (depending upon the size of the bin) along the sloping pipes. Rings of 6 mm - 10 mm diameter steel bars are tied or welded to the pipes at locations specified earlier in this step. Welding would undoubtedly lend additional rigidity to the skeletal steel frame. One intermediate 6 mm - 10 mm diameter bar is provided between the pipes as vertical reinforcement. These are tied or welded to the rings

placed in the last step. This would ensure a fairer profile for the bin wall (Fig. 2). The plywood template at the top is removed.

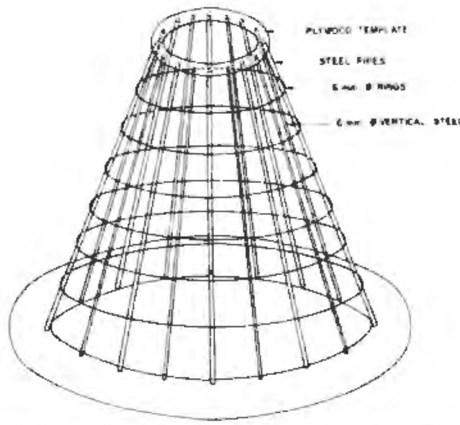


Fig. 2. Placement of skeletal steel rainforcement.

8. Wire mesh protruding from the base is rolled up onto the sloping wall and tied — one on the inside of the skeletal steel frame and the other on the outside. Two layers of wire mesh, one on the inside of the sloping wall and the other on the outside are tied, ensuring adequate overlaps where joints in meshes exist.

9. A circular opening of diameter 25 cm at a height of 30 cm (center of the opening) from the base is to be cut out of the wall. Extra reinforcement is provided for this opening which is to project 8 cm outside from the sloping wall. This will serve as the bin wall outlet collar projection. Hooks are provided on two diametrically opposite sides of this opening which will be used as locking hooks for the outlet lid (Fig. 3).

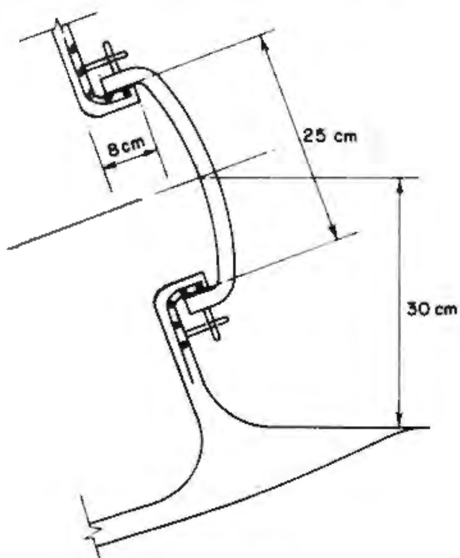


Fig. 3. Section showing details of bin outlet.

10. When the frame of the wall is ready two inlet projection rings are to be held by 8 vertical bars as shown in Fig. 4. This is to serve as the bin wall inlet collar projection. Hooks are provided on two diametrically opposite ends of this opening which will be used as locking hooks for the inlet lid. Both these inlet and outlet wall projections are to be covered with two layers of mesh, one on the inside and the other on the outside.

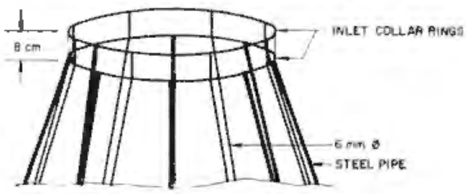
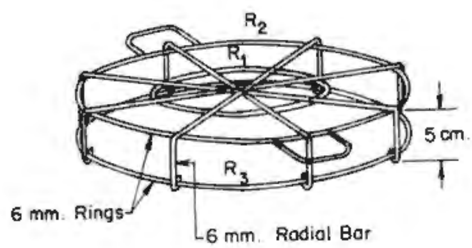


Fig. 4. Reinforcement for bin inlet collar.

11. Reinforcement cage for inlet and outlet lids are to be prepared using 6 mm diameter steel bars as shown in Fig. 5. For these cages, two layers of wire mesh one on each side, as earlier, is to be tied.



Diameter in cm

	R_1	R_2	R_3
Inlet	30	68	68
Outlet	15	28	28

Fig. 5. Reinforcement for inlet/outlet lids.

12. For ease of plastering an arrangement as shown in Fig. 6 is made. A helper is to get into the cage and hold a 24-gauge galvanized iron or a 3 mm thick plywood sheet (12"x 12") from the inside while a mason applies plaster from the outside. The mason impregnates mortar onto the mesh layers with a trowel, as the helper holds the galvanized iron/plywood sheet from inside. This backing sheet is then shifted to an adjoining area keeping a 5-cm overlap on the freshly plastered area. Mortar is first applied by hand and then compacted with a trowel. This process is repeated until the entire surface of the bin is plastered. The mortar layer should be thick enough to provide a 2 mm cover to the skeletal steel cage.

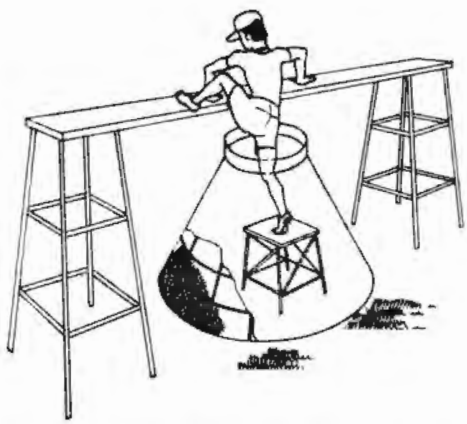


Fig. 6. Arrangement for entering the bin while plastering.

13. The undermentioned precautions should be taken while plastering:

(i) Ensure mortar penetration in mesh layers is proper.

(ii) Mortar should be properly mixed. It should not be too watery nor should it be too harsh (not an easily workable mix). A cement-sand mix of 1:2 with a water-cement ratio of 0.4 is suited for most terrestrial ferrocement structures.

(iii) No patches of unplastered area should exist.

(iv) The helper is to scrape out excessive mortar build-up on the inside surface. Both the external and internal surfaces should be roughened, to ensure proper bonding with the next layer of mortar that is to be used for finishing the surface.

14. The surface of the bin is cured after a 18-24 hour period for three days before finishing coats of mortar is applied and trowelled to get an effective wall thickness of 3 cm.

15. The bin is cured for 7 days before it is filled with water to check for cracks, holes or any other casting defects. During this testing, the outlet opening is temporarily sealed using plaster between the bin outlet wall projection and the outlet lid. Defect locations are marked and repaired.

16. The bin is cured for another 14 days and dried for 7 days before painting is undertaken. Original works suggest using internal painting with chlorinated-rubber but it has been observed that external coating of bituminous paints is more economical and is also readily available in most developing countries.

PREFABRICATED FERROCEMENT BIN

These bins were developed at the Structural Engineering Research Centre (SERC), Roorkee, India. The bin has undergone numerous modifications during its evolution stages and the method presented herein, is a very convenient semi-mechanized process for producing such bins. Such bins are produced in the form of precast elements and assembled on site. This process has been patented with the National Research Development Corporation of India (NRDC), New Delhi which issues licenses to use the technique. The bin is cast in five components the base, the wall unit, the roof unit and the inlet/outlet lids. In the casting process, a continous winding of wiremesh from a wiremesh roll onto a cylindrical mould and simultaneous application of the cement mortar on the wire mesh as and when it is wound on the mould is achieved [4]. This ensures a high degree of compaction of mortar and enables a good control over thickness. The process is labour intensive and does not use expensive machinery. A diagrammatic representation of the casting equipment developed at the Centre is illustrated in Fig. 7.

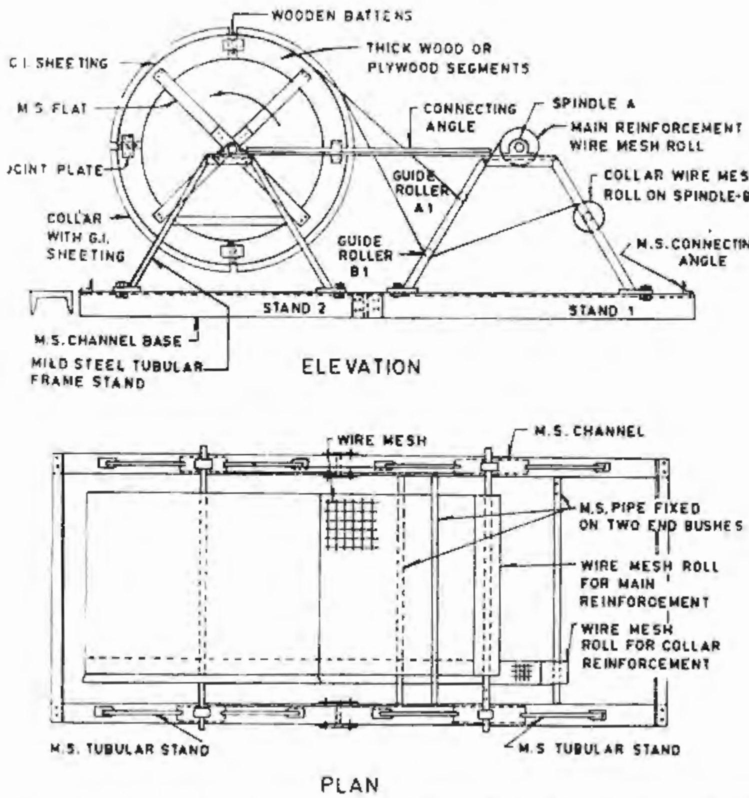


Fig. 7. Semi-mechanized casting process equipment for producing cylindrical wall units.

The design is based on analysis carried out using the thin shell theory applicable to a circular cylinder. The dome roof is analysed using the theory of shells of revolution taking into consideration a live load of 200 kg/m^2 of roof shell surface and live load around the inlet opening due to inlet lid. A wind load of 200 kg/m^2 is also taken into account for the above analyses. All joints at the junction of the various pre-fabricated units of the bin are assumed to be hinged as they are merely filled with cement mortar. Perturbational effects due to fixity conditions at the joints caused by various loadings have been analysed. The critical stresses are well within the permissible stresses for the type of ferrocement used hence the design preseted herein uses a minimum wall thickness and reinforcement which have been adopted from practical considerations of erection and feasibility of casting. The process of casting the wall unit consists of the following steps:

1. The wire mesh roll for the wall unit is mounted on spindle 'A' and the wire mesh roll for the collar portion of the unit is mounted on spindle 'B'.

2. The mould for casting the cylindrical unit is mounted on stand 2. The wire mesh is initially tied to the cylindrical mould.

3. The cylindrical mould is rotated in the forward direction as shown by the arrow in Fig. 7 so that the mesh gets wound on the mould. When sufficient portion of the mesh is wound on the mould, the rotation of the mould is arrested and a 1:2 cement mortar mix (with waterproofing compound if necessary) is applied over this portion. The mould is rotated further and the process repeated until the required number of layers of wire mesh are wound on the mould and the required effective thickness is obtained.

4. The last layer of wire mesh is given an extra lap length and the wire mesh is cut from the roll and tied to the inner layers of wire mesh already in position. The surface is finished with cement mortar maintaining proper cover to reinforcement.

5. After 24 hours, the mould along with the casting is removed from the process equipment and the wall unit is then demoulded. The wall unit is given a finishing coat of cement mortar on the inside surface and is cured for 14 days with water before it is used for assembling the bin.

The R.C.C. base slab and the dome-shaped ferrocement roof unit and ferrocement inlet and outlet lids are cast using suitable moulds. Masonary moulds for these units have proved to be economic because of their long durability.

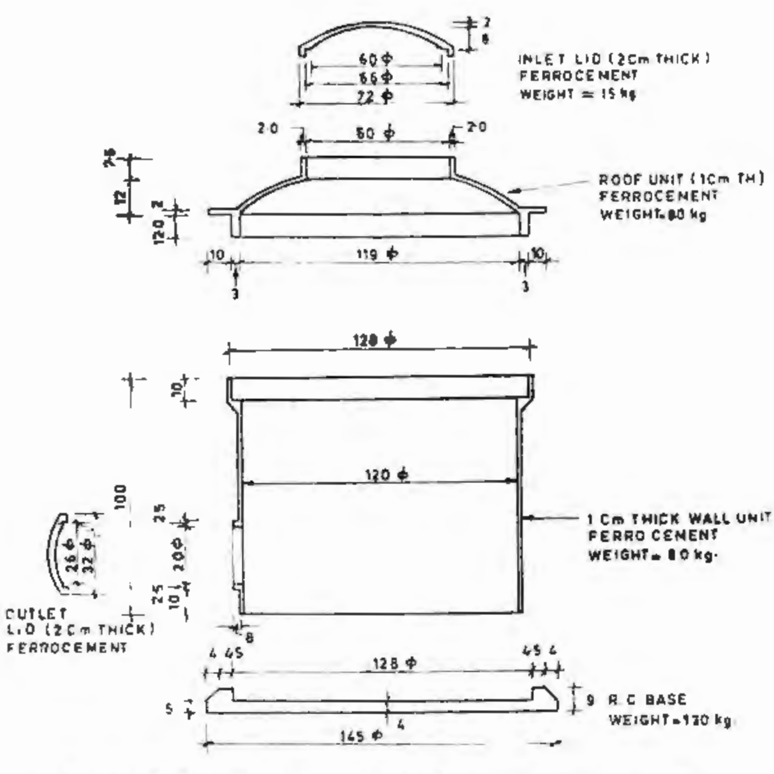


Fig. 8. Prefabricated component for bins upto 3 tonne capacity.

While casting the wall unit, provision is made for an outlet opening by leaving the required circular area of the outlet portion unplastered. After the wall unit is demoulded, the wire mesh portion left unplastered is cut and bent outwards to form a ring around the outlet opening. Additional reinforcement in the form of mild steel wire-rings and wire mesh is tied to the main wall wire mesh. The outlet opening is finished with suitable locking arrangements by applying cement mortar.

After curing the precast components of the bin for 14 days, they are transported to the sites and assembled. The joints are filled with cement mortar mixed with waterproofing chemicals and these joints are cured for a further period of 7 days. Two coats of bituminous aluminium paint are applied on the exterior surface mainly to improve the aesthetic appearance. This coating further improves the waterproofing of the bin. Fig. 8 presents detailed sectional elevations of the various prefabricated components of the bin while Fig. 9 illustrates a half sectional elevation of a fully assembled 3-tonne capacity outdoor bin.

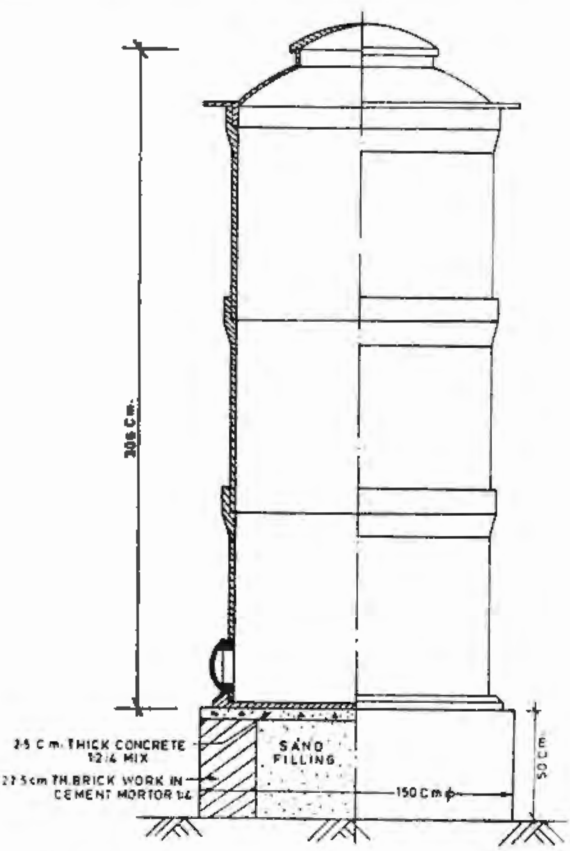


Fig. 9. Half sectional elevation of a 3-tonne capacity outdoor bin.

CYLINDRICAL FERROCEMENT BIN

Unlike the earlier described bin, these bins called 'FERRUMBU' are cylindrical bins cast in-situ. Developed by Mr. K.N. Ostergaard for African conditions, the Ferrumbu is based on inspiration drawn from traditional timer-tatch crib for foodgrain storage in northern Nigeria (Rumbu). The dimensions of the bin can be decided from the empirical furmula given below:

$$H = 0.0413 \times (V/r^2) - 0.333\ r$$

where

H = height of the cylindrical part of the wall in meters,

V = capacity of the bin in number of 90 kg bags, and

r = inner radius of the bin in meters.

Construction of such bins is undertaken in the stages mentioned below [5]:

1. Base layout: A circle with a diameter of 2 m over the required diameter of the bin is marked on the site where a Ferrumbu is to be built. 5-10 cm of topsoil is removed from the marked area.

2. Preparation for base: Stones of various sizes are filled to a height of between 0.75 m to 1.0 m, sloping about 45° inwards (the smaller stones on the top and the bigger ones at the bottom - Fig. 10).

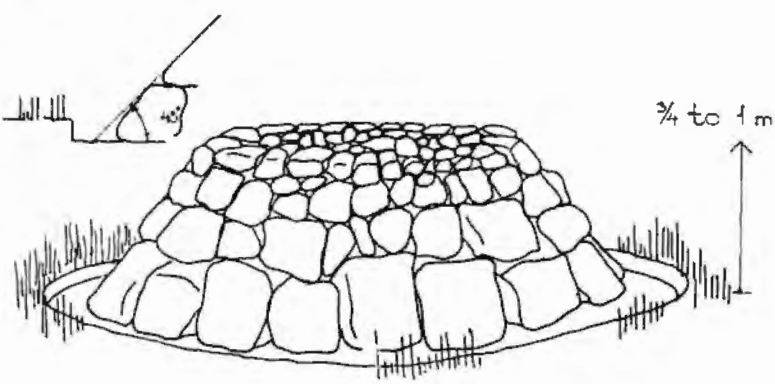


Fig. 10. Details of the stone base.

3. Outlet spout: The length of an outlet spout of ferrocement for a 1-tonne capacity Ferrumbu is about 1.0 m while for a 10-tonne capacity an outlet spout of 2 m length is required. The diameter of the spout increases with bin size, however, a minimum size to allow an arm to pass through should be provided. A cylindrical pipe of hexagonal mesh in the required length and diameter is plastered on the outside with a 1.5 cm thick layer of mortar and cured in damp conditions for about 2 days. It is later plastered on the inside using a smoothening stick or by hand. The spout is then set on the stone base pitching 30° downwards. The mouth of the spout is placed higher than the stone level, while the outlet end is let to sufficiently overhang to permit ease of collection while emptying the bin.

4. Plastering the base: The top of the stone base is plastered with a thin layer of mortar setting the spout in position (Fig. 11). Loose outside stones are plastered with mortar, ensuring that they are not locked air tight. Voids must be present in the stone base to allow damp air which builds up inside the base to migrate out through the sides instead of migrating up through the bottom of the bin.

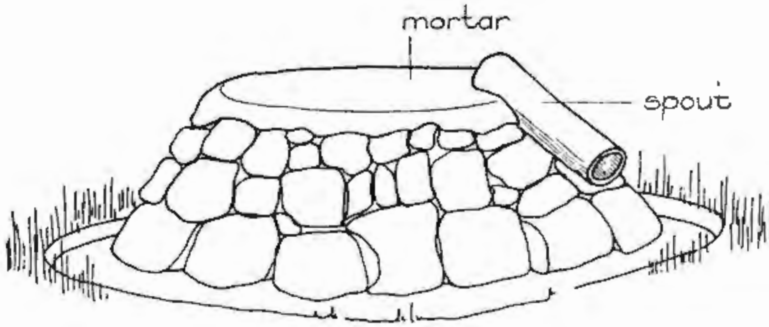


Fig. 11 Plastered stone base with spout in position.

5. Frame: A wooden frame of sticks and thin laths in the required shape and size of the bin is built. Two pieces of hexagonal wire mesh are laid transverse on top of the finished stone base, after cutting them around the outlet spout. The wooden frame is then placed and centered on top of the base. The base wire mesh is then bent upwards around it, forming a basket (Fig. 12).

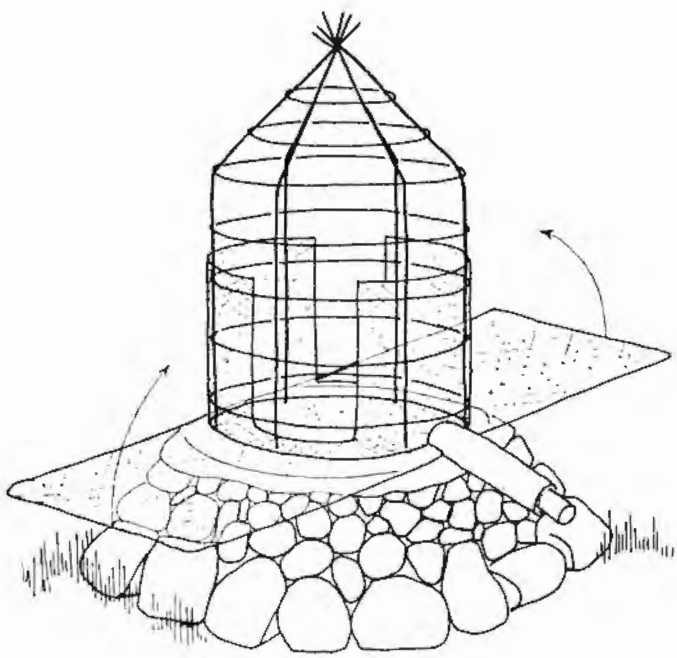


Fig. 12 Mesh placement.

6. Mesh placement: Hexagonal wire is then wrapped (in the required number of layers) all the way around the frame allowing a 10 cm overlap of meshes at joints. The wire mesh from the cylindrical portion is then bent on the top and folded inwards into a conical shape (45° inwards). Additional pieces of wire mesh are used to form the conical part, leaving

a manhole a few centimeters wider than the final hole (50 cm). Fig. 13 gives the detail of the bin which is now ready for plastering.

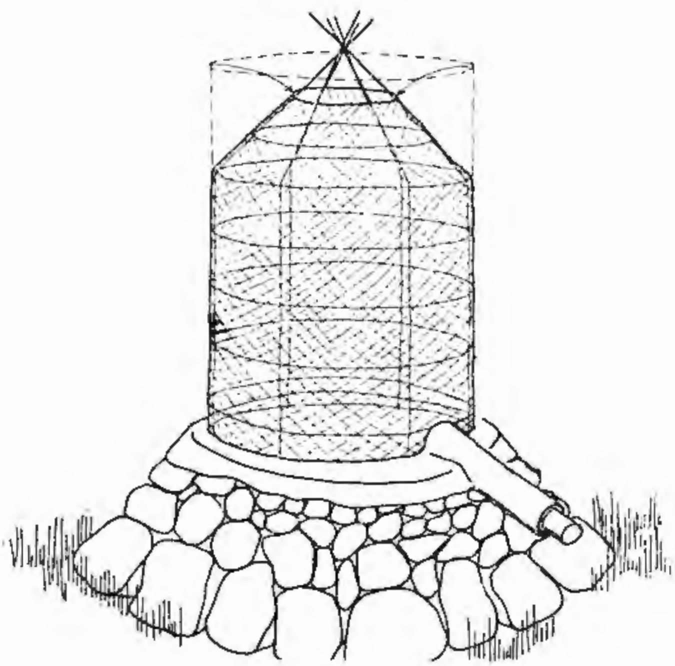


Fig. 13. Reinforcment ready for plastering.

7. Plastering the bin: The bin is then plastered on the outside to half the thickness of the final wall. The thickness of the final wall is shown in Fig. 14 for different capacity bins. The bin is cured in damp conditions for 3 days after which the inner wooden frame is removed. The inside is plastered next after carefully wetting the old plaster. It is again cured for 3 days after sloping the floor evenly towards the outlet spout.

8. Manhold lid: Size of the manhole is kept the same for all sizes of the Ferrumbu (diameter of 70 cm with a pitch of 45°). The lid is fabricated thin, so as to reduce the load on the bin. A more evenly finished lid ensures a better fit. A hat of thin poles, Sorghum stems or the like is formed, firmly held by laths on the outside. Hexagonal wire is wrapped before the outside of the lid is plastered and cured for 3 days. The lid is then placed in a small conical hole in the ground so as to expose its inside for plastering. The wooden frame is removed before the inside is plastered. The lid is again cured for 3 days (Fig. 15).

9. Coating, drying and painting: The bin is coated on the outside by smearing onto it a thin porridge of cement and water (no sand). If found necessary it can be painted after a few weeks. When the bin has been damp cured for about 7 days, it is left open for drying (before filling the new Ferrumbu with grain, a $1\frac{1}{2}$ month drying period should be allowed). An old bicycle tyre is put round the manhole over which the lid rests. This serves as a gasket. A wooden plug wrapped with some bicycle inner-tube is used to plug the outlet spout. In a carefully planned Ferrumbu, the user could arrange to fix up hooks for locking the manhole lid as well as the outlet spout plug.

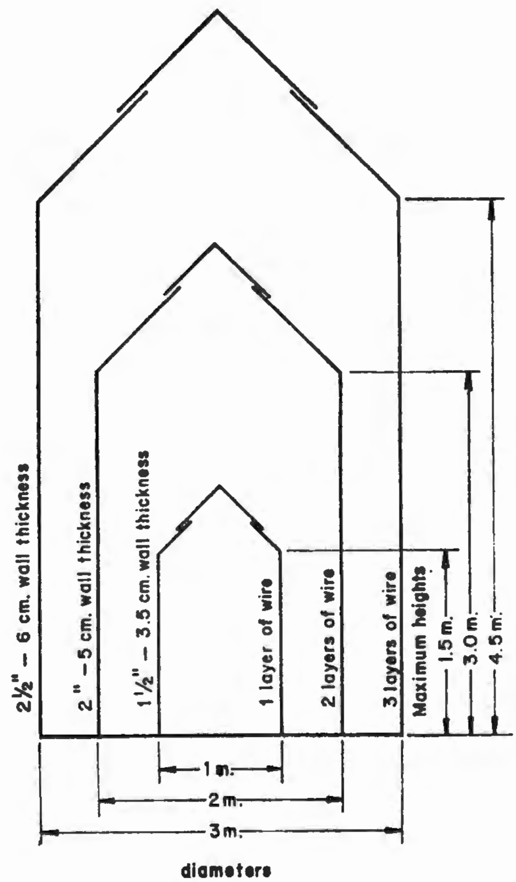


Fig. 14. Dimensional details.

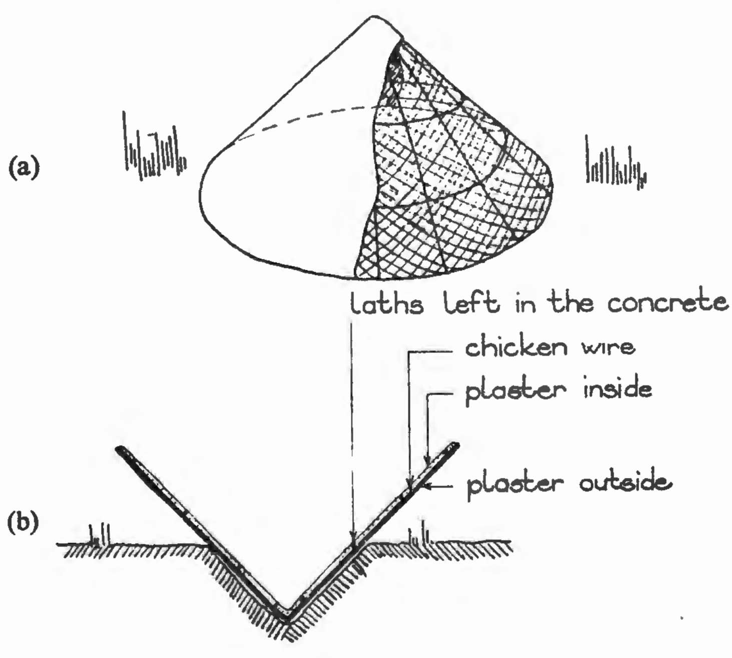


Fig. 15. Lid of the Ferrumbu,
(a) Outside of the lid after partial plastering,
(b) Cross-section of the lid while plastering of the inside.

FERROCEMENT-LINED UNDERGROUND SILOS

Traditionally grain is stored in pits in the Harar Province of Ethiopia in capacities ranging from $\frac{1}{2}$ to 20 tonnes of grain (there are records of pits holding as much as 70 tonnes also). In theory even the largest of these could be ferrocement-lined, but to date the largest lined pit has a 7-tonne capacity [6]. This pit is 3 m deep and 4 m diameter at base of the pit. Most lined pits hold $\frac{1}{2}$ - 2 tonnes. A $\frac{1}{2}$ - tonne pit is approximately 1 m deep and 1 m diameter at base of the pit. A 2-tonne pit is correspondingly 1.75 m deep and 2 m at the base of the pit. Such pits have been built in all the major soil types of the province and ferrocement linings have been observed to be performing satisfactorily in even the wettest soil. Lining of the pit as developed in Ethiopia is carried out in the following stages:

1. Before a pit is lined, a thorough cleaning operation is carried out. All rubbish is removed and the walls are smoothed by scraping off loose soil. Evidence of termites is sought and if found, the walls of the pit are treated with an appropriate termiticide.

2. A layer of hardcore is laid in the floor of the pit to a depth of about 10 cm, and a 5-cm layer of concrete is laid on top. A 3-cm layer of cement mortar (1:3) is applied by using a trowel along the sloping walls. A layer of $\frac{1}{2}$", 20 ga hexagonal wire mesh is tacked onto the surface while it is still moist, and a second layer of mortar is also applied on top.

3. The lining is moist cured for 7 days, after which a waterproofing coat is applied. The surface is prepared by brushing off loose material, and a priming coat of bitumen emulsion is diluted with water (1:1 by volume) and applied with a stiff brush. The emulsion is scrubbed well into the cement layer. After the priming coat is dry, a bonding coat of neat emulsion is applied and allowed to dry. Finally, a cement, emulsion, water mixture (1:10:1 by volume) is prepared and brushed over the whole surface of the lining. As this method of waterproofing using bitumen emulsion is relatively expensive and requires careful application, a single layer of bitumen has been tested. This layer applied between the two cement mortar layers has been found to be perfectly satisfactory.

4. The design of the mouth of the pit has been modified to incorporate a sloping lip which will carry away any water that might penetrate the soil. Drain pipes can easily be included to carry water even further from the pit (Fig. 16). Traditional wood-strip lid is re-

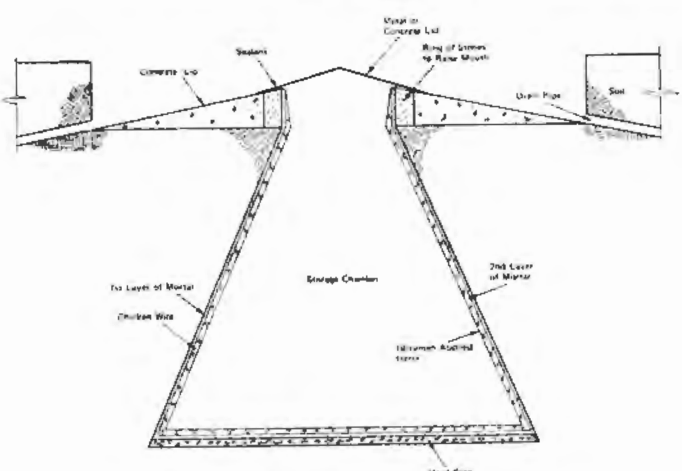


Fig. 16. Cross-section of ferrocement lined underground storage pit.

placed by a metal or concrete lid with a sealant such as bitumen. A truly airtight silo can thus be constructed. Condensation on the inner surface of metal lids sometimes occurs, but can be avoided by use of a piece of old sacking as inner liner to the lid.

5. Additional locking hooks as in the earlier designs could always be provided thus facilitating surety against theft of the grains stored.

COST OF THE BINS

The relative costs of the various bins cannot be compared for the most obvious reason that they have been developed in different parts of the world where material and labour costs are distinctly different. However, this section will attempt to present the costs of the bins described in the earlier four sections of this article in relation to other alternatives available in that part of the world. In all cases ferrocement bins have been found to be economical and the cost saving is in the range of 40-50% as when compared to bins of the same capacity made of alternative material. In other places where alternatives are unscientific (like unlined pits in Ethiopia or timber-thatch cribs in Nigeria), ferrocement offers a truly airtight and hermatically sealed storage structure (though at a higher cost than traditional structures).

The cost of a 5-tonne capacity conical bin developed in Thailand was estimated at US$ 139.50 (1973) while a 3.5-tonne capacity costs US$121.00 (1968) which was about 50% cheaper than metal, concrete or masonary bins of the same capacities (estimated at the same time). The cost of ferrocement bins along with other alternatives as been compared in Table 1

Table 1. Cost Comparison of Various Bins (1975 Indian Rates)

Material & Organization	Capacity and cost in US$			
	½ t	1 t	2 t	3 t
Indoor bins:				
Ferrocement (SERC)	22.0	33.0	45.0	58.0
Metal (U.P. Agro Industries Lucknow)	28.0	44.0	-	-
Save grain & allied products (Delhi)	-	49.0	-	-
Plywood bin (IPIRI)	21.0	31.0	44.0	57.0
Outdoor bins:				
Ferrocement above ground	-	36.0	49.0	62.0
Ferrocement underground	-	37.0	51.0	65.0
Concrete (ACC)	-	58.0	105.0	138.0
Concrete (CBRI)	-	63.0	-	-
Mondified brick (CBRI)	-	-	-	157.0
Brick (IARI Pusa bin)	-	-	59.0	-
Metal (IGSI Hapur)	-	-	182.0	197.0
Plywood (IPIRI)	-	38.0	54.0	70.0

SERC = Structural Engineering Research Centre, Roorkee.
IPIRI = Indian Plywood Industries Research Institute, Bangalore.
IARI = Indian Agricultural Research Institute, New Delhi.
IGSI = Indian Grain Storage Institute, Hapur.
ACC = Associated Cement Companies, Secundrabad.

for the type developed in India. Here too as evident from the table, a ferrocement bin is more economical. While details of cost estimates are not available for the Ferrumbu, it has been reported that lining a 1-tonne capacity bin with ferrocement costs only US$20.50 (1972 estimate based on material costs in Ethiopia).

MERITS OF FERROCEMENT FOR BIN CONSTRUCTION

Ferrocement as a construction material has numerous merits, but only those relevant to its use in bin construction have been highlighted. Bins made of ferrocement have the following advantages:

1. Economically, bins made of ferrocement are cheaper compared to bins of same capacities made of plywood, steel, aluminium or R.C.C., while they are equally effective in providing a hermatically sealed storage structure.

2. They are much lighter compared to a R.C.C. bin of an equal capacity.

3. Ferrocement bins have a relatively better thermal insulation property (thermal conductivity of ferrocement is only a sixth of that of steel) as when compared to metal bins.

4. The condensation and moisture migration problems in stored foodgrains are much less compared to metal bins.

5. They can be easily constructed at the rural level (where these are most required). The construction technique is simple and can be easily accquired by the local labourers.

6. The construction equipments consist only of small hand tools which are normally available in the rural areas. The materials that constitute ferrocement are available in most parts of every developing country.

7. Ferrocement bins are rodent-proof, fireproof, moistureproof and can be made airtight easily by sealing the inlet and outlet openings.

8. These bins require little or no maintenance at all, unlike metal or plywood bins. Any structural damage can be easily repaired by replastering the damaged section after chipping old plaster and straightening the skeletal steel.

SELECTION OF THE TYPE OF BIN

Selection from amongst the various types of bins described earlier is to be based on the conditions suitable to individual requirements as well as environmental and location constraints.

Conical bins and Ferrumbu are ideally suited for outdoor in-situ construction. A modified method of construction for the prefabricated cylindrical bin avoiding the use of the cylindrical mould for the wall unit, could also be used for outdoor bins, if only a few such bins are required When larger numbers of storage bins are required, then it is preferable to adopt the semi-mechanized process for prefabrication of cylindrical bins (in a centralized workshop). Underground ferrocement lined storage silos are suited in situations when space available is limited. These could even be constructed inside a house in an open courtyard or the storeroom. However, under extremely wet soil conditions such bins constructed outdoors, is unlikely to prevent water seepage into the pit in the long run. When constructed in expansive soils (like clay) these bins have to be adequately reinforced to avoid caving in of the walls.

If long term durability is to be considered, conical bins and prefabricated cylindrical bins are by far the best as they contain adequate amount of skeletal steel besides meshes. This skeleton of steel would be adequate to prevent excessive deformations when exposed to extreme and adverse climatic conditions.

CONCLUSIONS

The state-of-the-art for the construction of small and medium capacity ferrocement storage structures is at a fairly advanced level and prospective users could readily decide on a type and/or size of a bin to suit their requirements. Since all these bins have been very satisfactorily field tested in as adverse climatic conditions as Africa and Asia, they have the potential to replace both existing traditional storage structures which are unscientific and unhygenic, as well as costlier urbanised storage structures like metal, wood or R.C.C. bins. Since the technology is more labour intensive as when compared to any other, offering an equally scientific method for storage of foodgrain, it is all the more likely to be readily accepted by developing countries of the world. It is on these merits that the material has aptly secured a niche for itself in the past decade as a technology appropriate to the rural areas of the developing countries.

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APPENDIX I

Dimensions and Other Construction Details of Conical Bins of Various Capacities*

Grain Storage Capacity		Internal diameter (m)		Height‡ (m)	Wall thickness (cm)	Skeletal steel reinforcement					
(Tonnes)	(m^3)	Top+	Base			No. of pipes	Diameter of pipe** (mm)	No. of Vertical bars	Diameter of vertical bar (mm)	Ring Spacing (cm)	Diameter of ring bar (mm)
1.0	1.2	0.6	1.5	1.35	3.0	8	10	8	6	35	6
2.0	2.5	0.6	2.0	1.80	3.0	10	10	10	6	30	6
3.0	3.6	0.8	2.5	1.60	3.5	10	12	10	8	30	8
4.0	4.8	1.0	2.5	1.60	3.5	12	12	12	8	30	8
5.0	6.0	1.0	3.0	1.80	3.5	16	12	16	10	30	10

*Bins of these dimensions can also be cast as flat based ones instead of a saucer shaped base.

+For bins of capacity 3, 4 and 5 tonnes, the diameter for the bin top is to be reduced at the inlet opening to 0.6 m. This ensures that the same standard lid of 0.6 m diameter can be used for bins of all capacity.

‡Height has been kept below 2 m to facilitate ease of loading operations.

**Internal diameter is specified. Pipe wall thickness of about 2 mm is assumed. For the one tonne bin 10 mm diameter bar can be used instead of pipes.

Note; 1. For bins of 1 and 2 tonne capacity, $\frac{1}{2}$ in. 22 gage hexagonal wire mesh is to be used while for bins of 3, 4 and 5 tonne capacity, $\frac{1}{2}$ in. 19-20 gage hexagonal wire mesh is to be used. In all cases 2 layers of wire mesh, one on the inside of the skeletal steel cage and one on the outside. Galvanised mesh is always preferable.

2. Mortar mix specified is cement: sand: 1:2 (by weight)
3. Water - cement ratio equals 0.40 (by weight)
4. Base thickness of 5 cm is to be assumed for bins of all sizes.
5. Center of outlet opening should be located at a height of 30 cm from the base.

Building a 24-Feet Sloop

L. Mahan†

Everyone is looking for an inexpensive way to get on the water and Paul Larkin was no exception. One day Paul was driving by a yard that had a small sail boat on the front lawn. He stopped and asked the owner if the boat was for sale. The man said, "If you can get rid of the boat within the next week it's yours." Paul looked it over and thought he could salvage it. It was wooden centerboard sloop, 24′ with a 7′ 10″ beam. There was quite a bit of rot but Paul thought he could repair it. The next Satuday Paul and a couple of his friends came down and loaded the boat onto a trailer and brought it home. There, after more careful scrutiny, Paul concluded that the wood part of the boat would be too expensive to repair or rebuild. He decided to use the hull as a mold for a ferrocement cover.

Turning the boat over, the hull was covered with a layer of polyethylene and then four layers of one inch galvanized chicken wire* were stapled on. This was followed by two layers of 1/4″ rod. Horizontally, with 2″ spacings and the vertical rods were spaced approximately 6″. Four more layers of the 1″ galvanized chicken wire were added and stapled down. In many places the 1/4″ rod was not fair. The rod used for this project came off a large spool and was straightened by hand thereby producing wavy results. To overcome this waviness of the rods, wherever they raised up from the wood boat mold, stainless steel hook nails were driven in. This is a straight nail with a hook just below the head. Once you drive the nail down it hooks the rod and pulls the rod down and holds it firmly in place.

The original boat was a centerboard model and Paul elected to eliminate the centerboard and build up a keel to take its place. Using the 1/4″ rods, a form was constructed and starter rods were bent into the hull steel work. Paul feels that he made this keel a little too thick (4″) but it allowed him to get four, fifty lb. iron pigs into it from the top, after the boat was turned, for ballast. This keel was covered with the same chicken wire layup and hand tied.

On plastering day, a two to one mix was used. Two parts of aggregate, one part of cement and enough water to make a wet mix. By a wet mix, Paul said that he thought the mix should be wetter than that used on a normal open mold ferrocement construction. He cannot remember exactly how much water was used. Also some posilin was added to each mix. Describing the aggregate, it is a burnt rock or stone that has been fired in a furnace then it is crushed. It comes in various sizes from 1/4″ to 2″. In order to get enough to do the boat Paul had a whole dump truck load delivered and he had to sift about half of the load to get the required small sizes needed. He used a size 100 screen in order to get the finest grade. I asked Paul what he thought this aggregate weighed. He thought it was about one third of the weight of an equal volume of sand. According to the company he purchased it from they claim it is one third the weight of normal masonry sand. (You assume this is dry sand).

The reason he added the extra water was to facilitate penetration right to the polyethelene. No electric vibrators were used but Paul said he had his own manual vibrator. His son, Steven, was stationed under the hull as the plastering commenced. Paul would put his hand under the boat and tell Steven that he was going to be working in a particular area and to

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* Chicken wire is the common name for hexagonal mesh.

take the hammer and pound the hull in that area. Each time an area was pounded the mortar would sink into the mesh and penetration was adequate. Finally Paul skinned it over and smoothed it up as best as he thought he could do. The hull was cured for thirty days with the wet cure using soaker hoses and blankets.

A crane was hired at the end of curing to turn it over. Now the tedious job of ripping out the original boat could start. Paul said this job wasn't as bad as he thought it was going to be. They took the boat apart and removed all of the planking up to approximately 6" from the deck line. As they also wanted to have a concrete deck, they left the remaining hull planking and all deck woodwork in place. The mesh and rods that ran wild at the sheer were now bent over and a corresponding hull layup was stapled to the deck. Cut outs were made for the hatches and the deck likewise plastered and cured for 30 days.

After this curing period, the deck mold was removed and all stapled ends and stainless nails were ground off. Penetration problems did arise in the usual areas of dead wood and stem piece. These areas were later filled with a product called Top and Fill. Paul described it as a mortar mix that is used for patching cellar floors and walls and it seems to contain a very fine sand and ordinary cement. The mix was made very loose to ensure proper penetration in these hard to get at areas. All the rest of the hull the penetration was perfect. The keel area was now filled with four iron pigs and topped off with a very loose mortar mix and subsequently was pounded with a hammer and rodded to ensure good penetration.

The balance of the construction was done in wood and with much use of salvage material. For instance, a trip to the local department of public works produced a large quantity of 3/4" marine plywood. This plywood came from descarded road marking signs, the type used to designate exit or rest areas on a major highway. All internal bulkheads were built using these discarded signs.

When fastening the woodwork to the hull itself, Paul noticed how easy it was to drill the hull material. He thought it drilled as easily as wood. I wondered if that was the indication of weakness. Paul assured me it wasn't as the boat now has three years of sailing under its belt. Hard sailing at that he added. Often they have used this boat for racing other boats. With the exception of light air sailing, Paul said that because they can carry sail longer and more of it they usually win. The balance of the wood work follows normal construction procedures so I will not get into this aspect of the construction.

In summing up, Paul has had excellant results with his boat, he has gained a large amount of room with the absence of frames and he and his family have cruised all summer long for three summers, sailing to and from the islands in Boston Harbor. Many times the boat has gone aground and many times, while toed up at the dock, tides have caused chafe, rubbing action or pounding with no damage to the hull except scraped paint. Paul has found that the boat has done damage to various docks on some occasions.

As far as using the lightweight aggregate, Paul said he would use it again even on a larger boat. Of course the small size of his 24' sloop allowed the elimanation of webs or stiffiners but he added that on a larger boat he would incorporate these stiffining features. Paul did feel that even though the material was drilled easily, it had adequate strength and would serve another builder well. To me, it looks like ordinary cinder that is used in cinder block construction. As you know, these are noticably lighter when comparing them to a conventional concrete block.

The finish of the hull consisted of a coat of polyester resin. Any divits or imperfections in the fairness of the surface were filled using a polyester based auto body filler material.

Each year after the sailing season was over, noticeable rust streaks and spots would be showing. Paul would grind these rust areas back to the hull surface and fill them over with the polyester based auto body filler material. After the third season Paul says that the rust areas have almost been eliminated.

Profiles of the Editorial Staff-Part I

In order to provide sound credentials which any reputed international journal needs, to be fully accepted as an authoritative publication, the International Ferrocement Information Center called for honorary services of men of repute associated with ferrocement. Today more than two years after IFIC took over editorial and publication rights for the Journal of Ferrocement from the NZFCMA, we have 13 members on the Editorial Board besides 3 Correspondents and an Editorial Assistant from around the globe.

With growing interest in ferrocement the world over, we decided it would be the right time to introduce our readers to the men behind the scene, who have donated much of their valuable services to promoting the standards of the now well-established Journal of Ferrocement.

Published in parts, this article will briefly highlight qualifications and experience of the Editorial Staff. The Editorial Staff comprises men involved in both research as well as the industry and who are specialized in numerous distinct applications of the material.

Jacques VALLS

After engineering studies which made him Chemical Engineer of the "Ecole Superieure de Physique et de Chimie Industrielles de la Velle de Paris (ESPCI)" he did his Ph.D. at the College de France (Paris) in the field of Organic Chemistry Synthesis.

Immediately, after his Ph.D. in 1954 J. Valls joined the research Centre of the leading French Pharmaceutical firm where, first as Research Chemist, then as Director of the Central Documentation Center, he acquired during 20 years considerable experience in the field of pharmaceutical chemistry, chemical reactions mechanisms and scientific documentation.

From 1974 to 1976 he joined UNESCO as a Consultant and implemented 4 information projects in Cuba, Thailand (twice) and Tunisia thus becoming acquainted with developing countries' needs and conditions.

In February 1976 he was appointed Director of the Library and Regional Documentation Center at the Asian Institute of Technology in Bangkok, Thailand under a secondment of the Government of France (presently serving in the same capacity). In that position he was instrumental in creating AIT's Regional Documentation Center to coordinate AIT's increasing information activities and meet more efficiently some of the considerable information requirements of the Third World. The Regional Documentation Center was progressively developed and presently comprises 4 specialized Information Centers devoted to Geotechnical Engineering (AGE), Ferrocement (IFIC), Renewable Energy Resources (RERIC) and Environmental Sanitation (ENSIC); in addition several regional pilot projects and feasibility studies aiming at improving access to information in the region have been undertaken by him.

Dr. Valls has co-authored numerous papers and books both on Organic Chemistry and on Scientific Information and attended on invitation, several conferences and workshops both in Europe and Asia. He is a member of the Societé Chimique de France, International Federation of Documentation

(FID), Society for International Development (SID), South-East Asian Society for Soil Engineering (SEASSE) and International Solar Energy Society (ISES).

Ricardo P. PAMA

A Filipno citizen, Professor R.P. Pama did his Master of Engineering degree (Structual Engineering) at the Asian Institute of Technology and obtained his Ph.D. at the University of St. Andrews in Scotland where he was appointed on the teaching staff from 1965 to 1970. He then joined the faculty of the AIT's Structural Engineering and Construction Division where he played a leading role first as Associate Professor then as Associate Chairman and full Professor. In June 1978 he was appointed Vice President for Development of the Asian Institute of Technology.

His intensive activities and expertise have led him to participate in a considerable number of activities such as: Regional Director of the International Association for Housing Science (1977-present), member of the Editorial Board o the Journal of the International Association for Housing Science (1977-present), active member of the three international committees of the American Concrete Institute, the International Association for Bridge and Structural Engineering and the American Society of Civil Engineers, Coordinator of the Network of Cooperating Institutions on Low-Cost and Low-Income Housing (1976-present).

Professor Pama was instrumental in setting up at AIT the International Ferrocement Information Center (IFIC) of which he is Associate Director and Editor of the Journal of Ferrocement.

He has organized 3 international conferences, 2 workshops and 1 seminar. He has authored 3 books, 44 technical papers and reports and edited 3 volumes of Conference Proceedings.

Douglas ALEXANDER

Mr. Alexander has been associated with ferrocement since its inceptive days when he cooperated as a designer with Morley Sutherland in expanding the usage of ferrocement into the commercial boat field. Vessels such as the Pak Tak (Hong Kong), South Wind & Bay Fisher are representative of the many vessels built in the 1960's, to his design. During this period two way prestressing of barges was also developed and several barges using this concept were built including a 600-tonne gross explosive barge.

In response to the inherent weaknesses of mesh reinforced ferrocement his practice turned toward developing improvements to the material and in a series of innovative tests demonstrated the greatly enhanced strength properties of high tensile wire reinforced fibrous ferrocement which is now exclusively used by his practice.

He is engaged in international consulting in the marine field and his current work includes various types of motorized barges, tugs and fishing vessels besides tanks, buildings and the sheathing of a 2,000-tonne steel barge.

He is shortly to publish a book under the title of 'Widening Applications of Ferrocement' which outlines the theory and practice of the high tensile wire reinforced fibrous ferrocement form of ferrocement. He is also a corresponding member of the ACI Committee 549 on Ferrocement.

Anthony R. CUSENS

Presently, Professor and Head of the Civil Engineering Department, University of Leeds (since January 1979), he previously held a similar position at the University of Dundee in Scotland since 1965. Earlier he has been Professor of Structural Engineering at the Asian Institute of Technology in Bangkok (1960-1965).

In addition to his important academic activities Professor Cusens is Consultant with Posford Pavry and Partners since 1977. He is the author of numerous papers on concrete technology and concrete structures and co-author of two books on bridge engineering.

Martin E. IORNS

After his studies done at the University of Washington (Seattle) and at the University of Southern California in the field of Industrial Engineering, Mr. Irons began his professional life by conducting research on traffic safety for the State of California. During World War II while serving with distinction in the U.S. Navy he became acquainted with concrete ships used as supply vessels.

Upon his return to California in 1946 he participated in the first commercial production of fiberglass boats but later became disillusioned with fiberglass as a boat building material. In 1960 his attention was called to Nervis' work with ferrocement and he realized the material had a great potentials. He then developed suitable methods to apply to ferrocement, the laminating techniques in a cavity mould already known for fiberglass. First in association with L.L. Watson he went into commercial production of marina floats and barges and built in 1963 the first commercial ferrocement boat in North America (still in service). Later Iorns formed the Fibersteel International Company to conduct further research and make the technology available to builders outside California.

Iorns has written several articles on ferrocement for various publications and was a member of the National Academy of Sciences ad Hoc Panel which prepared the widely distributed book "Ferrocement: Applications in Developing Countries". He is a member of the American Concrete Institute, an affiliate member of the Society of Small Craft Designers, and is Ferrocement Subcommittee Chairman of the Society of Naval Architects and Marine Engineers panel on "Ferrocement and Concrete Marine Structures".

Seng-Lip LEE

A graduate of the Mapua Institute of Technology (Philippines), he did his M.S.E. at the University of Michigan and later his Ph.D. at the University of California, Berkeley in 1953.

Professor Lee has an outstanding academic record in the field of Civil Engineering having taught successively at Northwestern University (U.S.A.) (1955-1968), at the Asian Institute of Technology, Thailand (1968-1975) and presently at the University of Singapore (1975 onwards). In addition, he served in a consulting capacity to a number of engineering firms in the Philippines, U.S.A. and Singapore which benefited from his considerable professional experience.

He is a distinguished member of many learned societies in capacity as a:

> fellow of the American Society of Civil Engineers (Chairman of its Committee on Elasticity 1975-1967), fellow of the Institution of Civil Engineers, London, fellow of the Institution of Civil Engineers, Singapore, member of the American Society for Engineering Education, member of the International Association for Bridge and Structural Engineering, member of the International Association for Shell Structures, member of the Southeast Asian Society of Soil Engineering, etc.

Professor Lee is an author and co-author of more than one hundred and forty research papers.

Surendra P. SHAH

Dr. Surendra P. Shah is Professor of Civil Engineering, and Director of Graduate Study, Department of Materials Engineering, University of Illinois at Chicago Circle. Professor Shah is internationally known for his research on ferrocement, fiber reinforced concrete, fracture mechanics and concrete technology. He is the Chairman of the new RILEM Committee 48-TFC, Testing of Ferrocement. He is also a member of the American Concrete Institute's Committee on Ferrocement.

Professor Shah received his M.S. Degree from Lehigh University and Ph.D Degree from Cornell University. He was a Visiting Professor in 1969-70 at Massachusetts Institute of Technology and in 1976-77 at Delft University of Technology.

He is a Fellow of the American Concrete Institute and the Founding President of the Chicago Chapter of ACI. He is a member of the ACI technical committees on Fiber Reinforced Concrete, Fatigue of Concrete and Polymer Concrete. He was a Chairman of the Properties of Materials Committee of the Engineering Mechanics Division of the American Society of Civil Engineers. Dr. Shah is a member of the Transportation Research Board's Committee on Mechanical Properties of Concrete, and the Prestressed Concrete Institute's Committee on Glass Fiber Reinforced Concrete.

Professor Shah has published extensively in various professional journals on topics dealing with mechanical properties of concrete, high strength concrete, inelastic behavior, lightweight concrete, low-cost housing and new materials in concrete consitution. He was the editor of the proceedings of the conference on New Materials in Concrete Construction, University of Illinois at Chicago Circle, Dec. 1971. He has been a consultant to industries in the U.S. and elsewhere.

Bernard Ryszard WALKUS

Professor B.R. Wakus made his studies at the Technical University of Warsaw (Poland) where he was awarded a M.Sc. in 1952 and a D.Sc. in 1965.

He has a distinguished academic record in the field of Civil Engineering at the Technical University of Lodz (Poland) where he is presently Professor, Civil Engineering Department. He is a member of several University Committees and Head of the Institute of Civil Engineering College Research Committee.

His industrial experience is considerable having supervised structural engineering works on several instances. In 1959-1961 he was Consultant Engineer and Expert in reinforced and prestressed construction for the Technical Design Office in Lodz and since 1966 he serves as Expert in building structures for the Polish Civil Engineers and Technicians Association.

Professor Walkus is a member of numerous professional committees such as:

> Division of Concrete Construction Committee of Civil Engineering Polish Academy of Sciences, Division of Properties of Materials, Committee of Civil Engineering Polish Academy of Sciences, Commission of Sciencies, Association of Polish Civil Engineers and Technicians, IASS Working Group on Ferrocement, etc.

He has been actively involved in the organization of various Conferences and Symposiums starting with the Colloquium on Ferrocement held in Lodz as early as 1965.

He has published some 76 papers, many of which are devoted to ferrocement, a topic in which Professor Walkus has become a worldwide acknowledged expert.

NEWS AND NOTES

IFIC NEWS

First in the Series of Do-it-yourself Booklet Released.

The IFIC released the first booklet in the Do-it-yourself series collection on specific rural utility structures. This amply illustrated booklet on ferrocement grain storage bin (see also the Book Reviews section) contains two very useful designs of such storage structures. It describes details of construction in a non-technical language supplemented by illustrations alongside the text. For the amateur builders, it is expected to be an invaluable guide as it also includes appendices which provide all the dimensional and reinforcing details for various sizes of the conical bin (developed in Thailand) as well as the cylindrical bin (developed in India).

Other booklets that are also to be published in the near future in this series are on Water Storage Tank, Biogas Holder, Canoe, Roofing Element, Water-proofing and Repair of Structures. The booklet on Water Storage Tank will be available to interested persons by October 1979.

The Intermediate Technology Development Group (ITDG), London has offered to finance the publication of two of these booklets and IFIC is grateful to ITDG for its timely and useful funding. IFIC keenly looks forward to other organizations working on "Appropriate Technology" to finance such small and worthy ventures. Such ventures would undoubtedly ensure eventual transfer of ferrocement technology to the rural areas of the developing countries.

ITALY

The Journal "Il Cemento" Celebrates the 75th Aniversary of its Foundation

The Italian Journal "Il Cemento", scientific revue of the "Associazione Italiana Tecnico Economica del Cemento" (AITEC) celebrated its 75th anniversary by publishing a special issue of 302 pages with 32 articles written by renowned specialists coming from all parts of the world. The high scientific standard of the articles make this special issue most informative and underlines how the remarkable progress in the field of cement is strictly connected to the great activity of the cement industry in the field of basic and applied research. In that respect it is worthwhile reminding that the Italian Cement Industry is outstandingly active and occupies the first place among European cement producers with a production of 38 million tons of cement yearly. (That special issue is available from: "Il Cemento", Via S. Teresa 23, 00198 Roma, Italy.)

NEW ZEALAND

Focus on Terrestrial Applications

Having successfully used ferrocement for boatbuilding and water tank construction, New Zealand, a pioneering country in ferrocement applications has of late turned its attention to other terrestrial applications. Used for amusement and other functional purposes the new applications include a playground slide, rainwater collectors, sunshades besides cost saving dwelling units. Photographs that follow illustrate the above mentioned applications.

Fig. 1

Fig. 1 shows a playground slide built by New Zealand Ferrocement Services for the Henderson Borough Council. These have been in use for about two years.

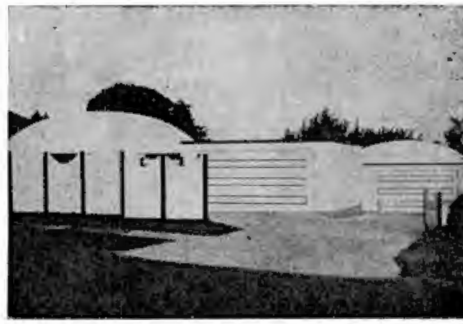


Fig. 3

Fig. 3 illustrates ferrocement dwelling units built by Gainor Jackson. The builders claim a 30% cost savings over conventional construction.

Fig. 2

Fig. 2 depicts ferrocement canopies which collect rainwater from shear walls of a skyscraper (West Plaza) in downtown Auckland. Built by Ferrocement Marine, these have been in service for over five years.

Fig. 4

Fig. 4 shows a set of sunshades and air vents on the Swanson Towers in downtown Auckland. These structural components were constructed by Ferrocement New Zealand Ltd.

INTERNATIONAL MEETINGS

World Congress on Shell and Spatial Structures. Madrid, Spain, September 24-28, 1979

Held on the ocassion of the 20th aniversary of the International Association for Shell and Spatial Structures (IASS), the congress is expected to comprise two types of sessions. Main sessions on the following topics: Theoretical studies related to development of shell and spatial structures, non-traditional and outstanding projects and designs carried out in the last decade, new materials for construction of shell and spatial structures besides general reports on the work of some of the IASS working groups, presented by their chairmen. Other sessions dedicated to some of the specific working groups. For further information contact:

Mr. L.M. Ortega,
Laboratrio Central de En sayo de Materiales de Construccion,
Alfonso XII, No. 3,
Madrid-7, Spain.

International Conference on Concrete Ships and Floating Structures, Rotterdam. Holland, November 12-14, 1979

A major conference on "Concrete Ships and Floating Structures" will be held at the Hilton Hotel in Rotterdam, Holland. It is expected that the conference will cover all aspects of the topic and for the first time in Europe an entire session will be devoted to ferrocement structures.

IFIC will be presenting a paper entitled "A Review of Marine Applications of Ferrocement in Asia" while another contribution from Ferrocement Marine Services of England will review recent developments in Africa and the Indian Ocean. Besides these two informative articles, it is expected that a few other contributions will make the session on ferrocement interesting. The conference is planned as a major event, and its proceedings will subsequently be published in full for the benefit of those who might not be able to attend.

The conference is being organised by Thomas Reed Publications Ltd., of 36 Cock Lane, London ECLA 9BY, who are already well-known in marine engineering circles for their highly successful series of conferences on tugs and on offshore crafts. For further information contact.

Mr. F.H. Turner,
Conference Organiser,
International Conference on Concrete Ships and Floating Structures,
3, Leyburn Close, Woodley,
Reading RG5 4PX, Berkshire, U.K.

Symposium on Wood, Ferrocement and Plastics in Shells and Spatial Structures, University of Oulu, Oulu, Finland, June 9-14, 1980

The IASS Symposium 1980, organized by the International Association for Shell and Spatial Structures in collaboration with, the Finnish Academy of Technical Sciences will be devoted to two trends both central in the present development of thin-walled and spatial structures. The first half of the Symposium will concentrate upon the use of wood material in shells and spatial systems, the latter half dealing with more modern meterials such as ferrocement and plastics.

The symposium is organized in three sessions, each one offering ample scope for discussion. The first session treats wooden shells and spatial structures, and the appropriate theory. Although the Symposium will place most weight on the ingredients of a good structural solution, design fabrication and constructional technique, opinions about future development are also welcome. The second session is devoted to concrete-like composites such as fine-aggregate concrete with various binders or cement paste. These almost entirely thinwalled shell structures make use of microreinforcement, asbestos, glass, metal, plastics, etc. In this session the properties of the composites form an interesting part. The third session is reserved for structures of plastics, without more accurate specifications.

Participants are invited to present papers within the scope of the Symposium as outlined above. Authors are asked to provide a summary not exceeding 300 words, accompanied by such drawings and/or photographs as might be appropriate. The abstracts should sent be in two copies before October 15, 1979, to:

The Finnish Academy of Technical Sciences
The IASS-Symposium Committee
Lönnrotinkatu 37
00180 Helsinki 18
Finland

On the basis of abstracts submitted, the authors are requested to prepare, in three copies, final manuscripts not exceeding the 6000-word model in length and send them addressed as above before January 15, 1980. Instructions on the preparation of papers will be sent to authors so as to facilitate reproduction and preprinting before the Symposium.

All abstracts and papers should be submitetd in English. For further information, contact:

Prof. Dr. Paavo A. Tupamäki
Chairman, IASS Symposium 1980
Department of Civil Engineering,
Kasarmintie 8
University of Oulu
90100 Oulu 10
Finland

The International Congress on the Chemistry of Cement, Paris, France, June 30 - July 5, 1980.

The following themes have been selected for the above Congress: Influence of raw materials, fuels and manufacturing processes on clinker structure and properties; hydration of pure Portland cements; structure of slags and hydration of slag cements; structure of pozzolanas and fly-ash-hydration of pozzolanic and fly-ash cements; special cements' cement pastes-rheology; interface reaction between cement and aggregate in concrete mortar. For further information contact:

CERILH,
23, rue de Cronstadt,
75015 Paris, France.

Session on Experimental Wind Engineering on Structures
Florida, U.S.A., October 27-31, 1980

The Committee on Experimental Analysis and Instrumentation will sponsor a session at the ASCE Annual Convention, October 27-31, 1980 in Hollywood, Florida. The theme is "Experimental Wind Engineering on Structures". However, other outstanding papers related to special projects will also be considered.

Abstracts (approximate 500 words) should be sent to Prof. Leon R.L. Wang or Prof. James Colville (addresses mentioned alongside). Deadline for receiving abstracts is October 1, 1979.

Prof. Leon R.L. Wang
Department of Civil Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181
U.S.A.

Prof. James Colville
Department of Civil Engineering
University of Maryland
College Park, Md. 20742
U.S.A.

BOOK REVIEWS

FERROCEMENT GRAIN STORAGE BIN
DO IT YOURSELF SERIES-BOOKLET NUMBER 1

By P.C. Sharma and V.S. Gopalaratnam
Published by International Ferrocement Information Center, Asian Institute of Technology
P.O. Box 2754, Bangkok, Thailand.

This puplication is the first of a series of "Do it yourself" booklets on specific ferrocement applications, aiming at providing users with all the information they need to build ferrocement structures by themselves.

The first booklet describes in detail how to build ferrocement grain storage bins either of conical or of cylindrical shapes. It is divided in six chapters: Ferrocement Bins; Material Specification; Material Estimations; Bin Construction; Post Construction Inspection and Appendices.

Many illustrations are given alongside the descriptive text to facilitate comprehension. The booklet ought to prove useful to any one wanting to build himself a grain storage bin and in particular to "extension officers" active in rural areas of developing countries.

28 pp.
English
180 mm x 265 mm
Flexicover edition
May 1979
US$2.00 (surface mail)
US$4.00 (air mail)

PROCESS TECHNOLOGY OF CEMENT MANUFACTURING

Published by Bauverlag GmbH
D-6200 Wiesbaden, P.O. Box 146, Federal Republic of Germany

The proceedings of the congress "Process Technology of Cement Manufacture" (Dusseldorf Sept. 1977) has now been published in the form of a convenient book entitled" Process Technology of Cement Manufacturing". The numerous papers presented under seven major subject sections by leading experts from many countries and the discussions that followed are presented in bilingual texts German and English. Summaries of all these articles are also included in French. The book is an important source of information related to cement manufacture which provides a comprehensive survey of the State of the Art and is expected to retain its authoritative value for years to come.

The papers published in this book are subdivided under the following main subject headings:

1) Raw materials quarrying and preparation: Raw material deposits, prospecting and exploitation planning, quarrying methods, loading, transport, precrushing, homogenization.

2) Size reduction: Crushers, grinding installations for raw meal and slurry, cement mills, circuit grinding.

3) Pyroprocessing: Kiln systems, precalcining, coolers, refractory linings, coatings, firing systems, waste heat recovery, cyclic processes.

4) Process control: Measuring and control systems, central control rooms, automation concepts for cement plant installations.

5) Auxiliary installations: Materials handling and storage, dispatch facilities for cement and clinker, utilities, cement plant layout.

6) Environmental protection and energy utilization: Emissions and imissions of air pollutants, noise and vibrations, raw materials conservation, reclamation, rational use of energy.

7) Influence of process technology on cement properties: Influence of the manufacturing processes of clinker and blast furnace slag and of the grinding and storage of cement on setting and hardening.

712 pp. *300 mm × 215 mm* *Hard Cover Edition 1979*
German/English (Summaries in French also) *Cost: Not mentioned*

SMALL CAPACITY FERROCEMENT WATER TANKS

By E. Abdul Karim and G. Paul Joseph
Published by Structural Engineering Research Centre
CSIR Campus, Adyar, Madras 600 020, India

This booklet contains in brief, construction details of cylindrical and rectangular (square) ferrocement water tanks of upto a 10,000 litre capacity. Detailed design dimensions have been presented for a wide range of capacities in a very convenient tabular form. This is expected to be indispensable to amateur builders who have little or no engineering skills. The authors have several useful tips to offer regarding the selection of the types, sizes and shapes of the tanks based on their experience in the construction of ferrocement water tanks. The booklet is also amply illustrated.

20 pp. *275 mm × 210 mm* *Flexicover Edition*
English *December 1978*
Free distribution

THE FIRST FERRO BOAT BOOK

By Pete Greenfield
Published by Hollis & Carter (The Bodley Head Ltd.)
9 Bow Street London WC2E 7AL United Kingdom.

This publication though not the first on ferrocement boat-building is specifically suited for readers who have little or no experience in building ferrocement boats. Drawing on his own practical experiences and those of many other amateur ferrocement boat-builders the author attempts to take the reader lightly through all the decisions that are to be made, from the choice of design to the methods of welding the frames, meshing, plastering and utilimately fitting out. The reader is also exposed to valuable labour/cost saving hints as well as several timely warnings of snags that are likely, in this useful publication that contains numerous illustrations.

192 pp.	*200 mm × 130 mm*	*Flexicover/Hardcover Editions*
English		*July 1978*
		£ 3.50 (Flexicover edition in U.K.)

Abstract

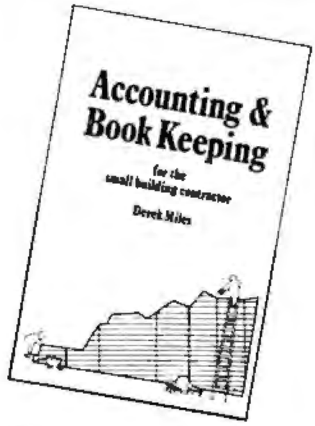
JFP17 ANALYSIS, DESIGN AND CONSTRUCTION OF FERROCEMENT WATER TANKS

KEY WORDS: Analysis, Construction, Design, Testing, Water Tank.

ABSTRACT: A study is conducted to investigate the performance and practical application of ferrocement in the construction of prototype cylindrical and rectangular water tanks for use in highrise buildings. The cylindrical tank and the rectangular tank are designed as a thin shell structure and thin plate structure respectively resting on reinforced concrete slab. Design charts are presented to aid in the design of ferrocement water tanks of various practical dimensions. A cylindrical tank of 2.44 m (8 ft) diameter and 2.6 m (8.5 ft) height and a rectangular tank of 3.66 m x 1.83 m (6 ft x 12 ft) in plan and 1.37 m (4.5 ft) in height are designed for which construction procedures and test results are presented and discussed.

REFERRENCE: PARAMASIVAM P., NATHAN, G.K. and LEE, S.L., "Analysis Design and Construction of Ferrocement Water Tanks", Journal of Ferrocement, Vol. 9, No. 3, Paper JFP17, July 1979, pp. 115-128.

Books for the Small Building Contractor



Accounting and Book-keeping for the Small Building Contractor
Financial Planning for the Small Building Contractor
by Derek Miles. Published by Intermediate Technology Publications Ltd., 9 King Street, London WC2E 8HN, U.K. Telephone: 01-836 9434.

These are the first two books in a series of three resulting from the author's long experience in helping small contractors in developing countries to get themselves established and to run their businesses effectively. The material has been used as a basis for training courses and should be invaluable for the managers and owners of small contracting businesses interested in improving their managerial capacity. The approach is decidedly practical, and most of the ideas and techniques are just as relevant to good management in the public sector as in private businesses. Saving time – and saving money – are the twin themes.

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Volume 2, *Financial Planning for the Small Building Contractor* covers: planning the year's work; job programmes, cash flow; investment decisions; billing procedures and work study techniques; practical exercises.
188 pages, illustrated. ISBN 0 903031 55 8. Paperback. £3.95 net.
Publication date March 5 1979.

Volume 3, *The Small Building Contractor and the Client*, is planned for publication at the end of the year.

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