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A Ferrocement Hyperbolic Paraboloid Shell.

N.C. Das Gupta*, P. Paramasivam+ and S.L. Lee†

This study investigates the feasibility of constructing a ferrocement hyperbolic paraboloid shell in the shape of an inverted umbrella. The shell geometry and design consideration based on the membrane state of stress are described. The shell model was tested under uniformly distributed vertical loads and the structural behaviour is reported in terms of vertical deflections and stresses at critical sections. Salient features of the construction technique and test results are discussed.

INTRODUCTION

Additions of a few layers of wiremesh to plain mortar offer a convenient and practical means of achieving improvements in many of the mechanical properties of the material such as flexural strength, tensile strength, fracture toughness, etc. This material, popularly known as ferrocement, has been successfully tried out at the University of Singapore in a number of applications, among which are water tanks, boats and sunshades [1-4].

In this study, the feasibility of constructing a ferrocement hyperbolic paraboloid shell was investigated. An experimental model was made of four hyperbolic paraboloid units which form an inverted umbrella. This paper treats the behaviour of the model under uniform vertical loads. Test results are discussed in relation to theoretical values obtained from the membrane analysis.

The shell chosen for the purpose has the practical advantage of straight line generatrices. As a result, this type of shell has the particular feature of simple formwork and easy placement of reinforcement. While constructing the experimental model, a special consideration was given to possible mass production of precast units and subsequent field installation.

DESIGN CONSIDERATION

Analysis

An inverted umbrella is formed by four units of hyperbolic paraboloids, which are joined together by horizontal members at the exterior boundary and by inclined members at the interior boundary. These inclined members are depressed at the central column. Fig. 1 shows the quadrant ABOH in which the lines BO and OH are horizontal, coincident with the axes ox and oy and A the depressed corners. The surface of each quadrant is defined by two intersecting systems of straight lines parallel to the plane xoz and yoz. But vertical plane sections parallel to the diagonals form two sets of parabola of which one set is concave upward and the other concave downward.

The analysis of an inverted umbrella is confined to the basic quadrant ABOH, the surface of which is defined in terms of the coordinates x, y, z, by

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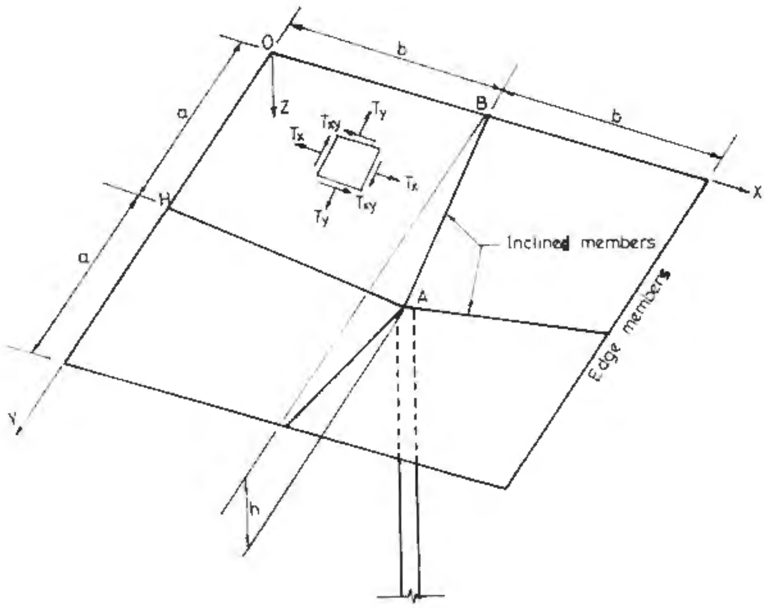

Fig. 1 Inverted umbrella.

$$z = \left(\frac{h}{ab}\right) xy \qquad \ldots\ldots\ldots\ldots (1)$$

Where h is the rise and a and b the plan projection of the sides of each quadrant.

According to the membrane theory [5], the shell under the action of uniformly distributed vertical load q_z per unit area of horizontal projection is subjected to pure shear and the intensity of shear stress resultant T_{xy} is given by

$$T_{xy} = - q_z \frac{ab}{2h} \qquad \ldots\ldots\ldots\ldots (2)$$

Observe that the principal diagonal tensile and compressive normal stress resultants assume the same value given by Equation 2. Following the common sign convention that positive shear stress resultant causes tensile normal stress resultant along the positive diagonal, the negative sign in Equation 2 indicates that the principal normal stress resultant along the positive diagonal is compressive.

The relevant properties of ferrocement required for the design of the shell are taken from previous investigations carried out at the University of Singapore [6]. Based on the law of mixture, the first crack tensile stress σ_c and the modulus of elasticity E_c of the composite are expressed respectively by

$$\sigma_c = \sigma_s \left(\frac{A_s}{A_c}\right)^{1.1} + \sigma_m \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

and

$$E_c = E_s\left(\frac{A_s}{A_c}\right) + E_m\left(\frac{A_m}{A_c}\right) \qquad \ldots\ldots\ldots\ldots\ldots (4)$$

where σ_s and σ_m denote the stresses in steel and mortar respectively at 0.01% strain, A_s and A_c the cross sectional areas of steel and concrete respectively, $A_c = A_s + A_m$, and E_s and E_m the modulus of elasticity of steel and mortar respectively.

Design

The shell considered for the experimental model is an inverted umbrella unit, 2.44 m square in plan. The vertical rise of the shell from the center to the exterior edge is chosen to be 0.37 m. For the overall plan dimensions, this value of rise is considered to be reasonable in respect of the appearance of the structure.

Stresses in the hyperbolic paraboloid shell are low and require only a minimum thickness of concrete. Generally, shell thickness depends upon the concrete cover required for the reinforcement. From practical consideration, two layers of 9.5 × 9.5 mm woven wire mesh of 1.04 mm diameter spaced by 3 mm mild steel bars at 150 mm centres both ways were provided. The cement, sand and water ratio of 1:1.5:0.5 was used for the mortar. Fine sand passing through BS 14 and Portland cement Type I were used. This design leads to a shell thickness of 16 mm with approximately 3 mm concrete cover for the reinforcement.

Table 1. Properties of Constituent Materials.

Plain Mortar	
Cement : Sand : Water	1 : 1.5 : 0.5
Crushing Strength	32.4 N/mm^2
Tensile Strength (Direct Tension)	1.04 N/mm^2
Modulus of Elasticity	2.2 x 10^4 N/mm^2
Wire Mesh	
Grid Size	9.5 mm × 9.5 mm
Diameter	1.04 mm
Ultimate Tensile Strength	358 N/mm^2
Tensile Stress @ .01% Strain	276 N/mm^2
Modulus of Elasticity	2.0 x 10^5 N/mm^2

The relevant properties of constituent materials are given in Table 1. Using these values of the properties and Equations 3 and 4, the first crack tensile stress and the modulus of elasticity of the composite were evaluated to be 2.75 N/mm^2 and 1.8 × 10^4 N/mm^2 respectively. The carrying capacity of the shell in terms of equivalent uniform vertical load with respect to the first crack strength was determined. The design based on the ultimate strength of the composite would provide a higher factor of safety. The total force acting in an edge member equals the sum of the shear forces acting along its length. In the inclined edge members, the compression is zero at the edge and increases to a maximum value at the centre. The reinforcement in the edge members were designed for the carrying capacity of the shell in terms of equivalent uniform vertical load. Plan and sectional elevation of the model, the reinforcement details, the connections between the shell and the column and details of the foundation are given in Fig. 2. The column, column cap and base plate were also designed for the eccentric loading condition where only one half of the roof is loaded.

CONSTRUCTION

The model was constructed in two parts, of which the shell roof was made of ferrocement and the column of structural grade steel. The two parts were connected together by means of four steel bolts (Fig. 2).

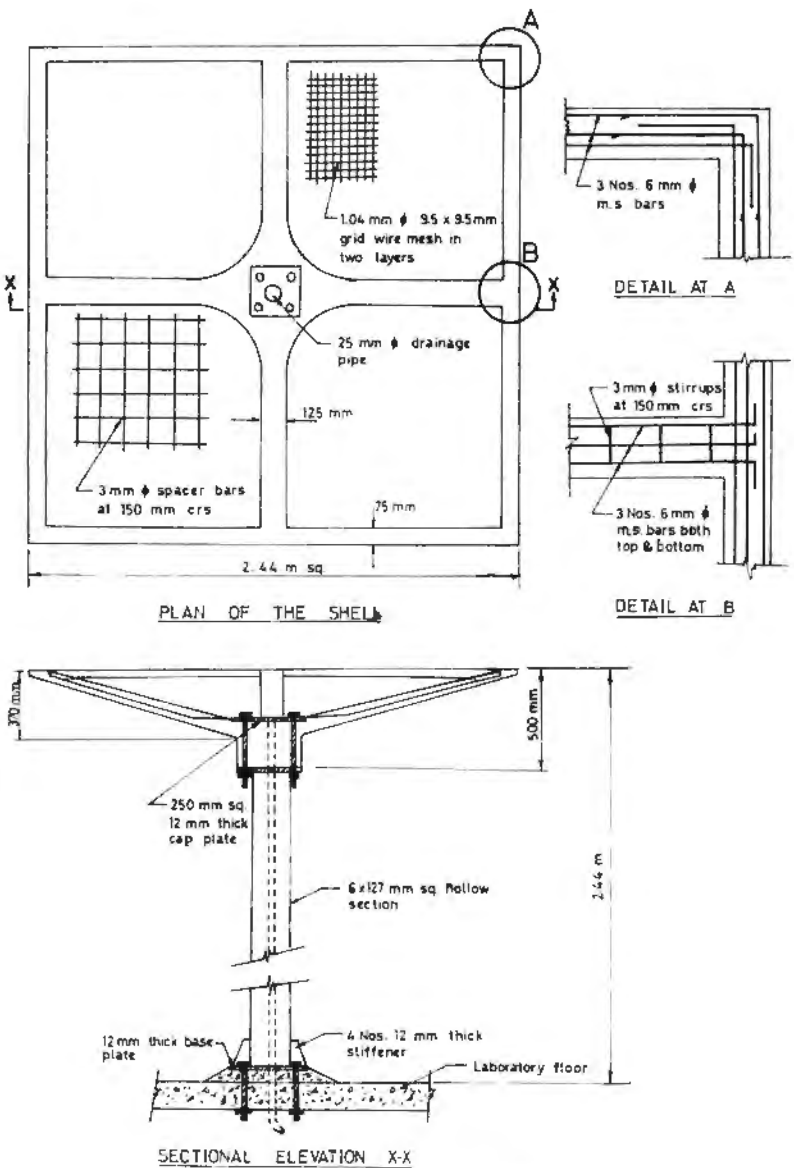

Fig. 2 Reinforcement details.

For the ferrocement shell, a timber mould was constructed by placing 19 mm thick wood joists along the straight line generatrices and then covering the surface by 3 mm thick plywood boards. The surface of the mould was covered with a thin sheet of polythene in order to facilitate removal of formwork. Figs. 3 and 4 show the construction of joists and plywood sheeting cover respectively. On the completed mould, two layers of woven wire mesh were laid with the skeletal steel sandwiched in between. Care was particularly taken in ensuring the continuity of the wire mesh and the skeletal steel at the edge member-shell junction and the column-shell junction. Adequate anchorage of the reinforcement was provided by back folding the individual wire mesh along the exterior boundary. A close-up view of the reinforcement at the edge member-shell junction is shown in Fig. 5.

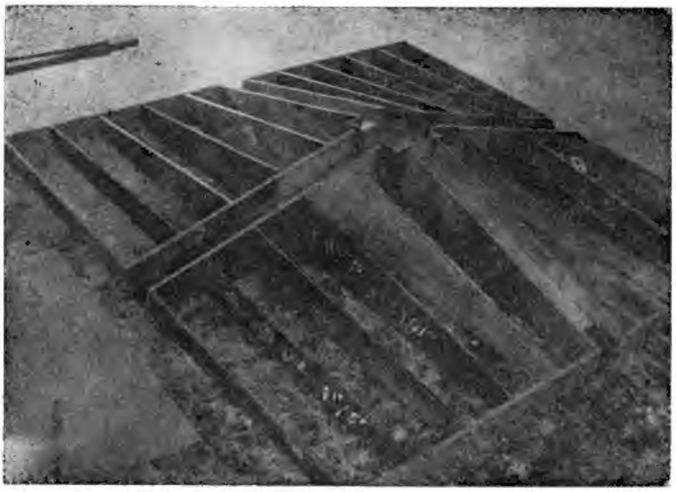

Fig. 3 Wooden joists along straight line generatrices.

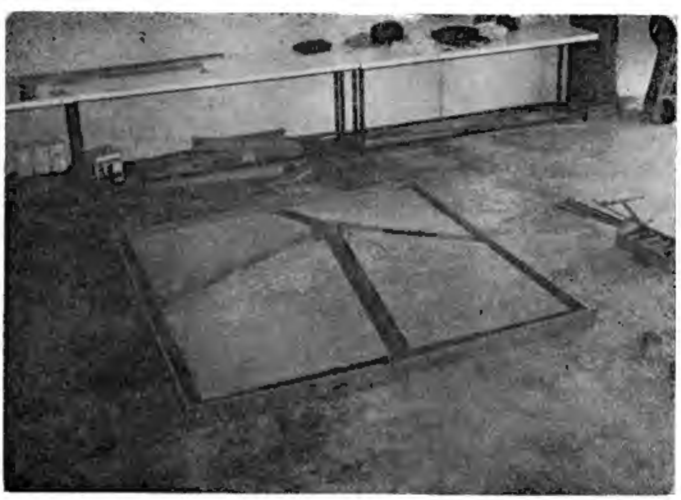

Fig. 4 Completed formwork.

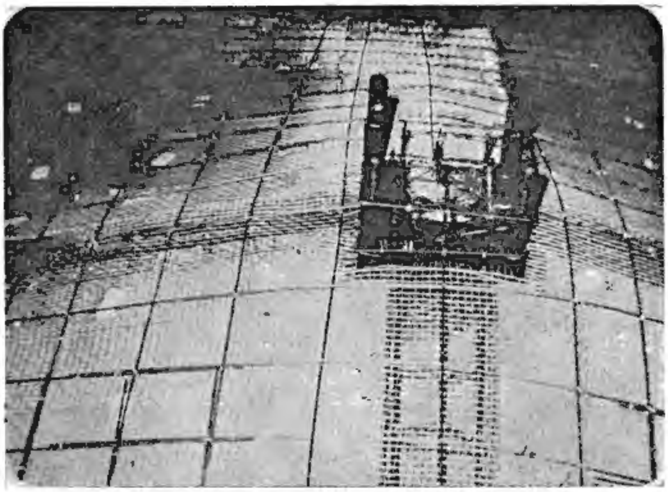

Fig. 5 Reinforcement details.

Plastering of the shell and edge member was carried out in a single operation by hand-pressing. The mortar was vibrated by a portable hand-held vibrator. The bolts for the column-shell connection and the G.I. drain pipe were in position before the plastering operation began. Curing was done by covering with wet hessian and plastic sheets.

The column, made of hollow square steel section, was prefabricated to the requisite length. The base plate and the cap plate were welded to the column with adequate stiffening ribs. The fabricated steel column was erected and fastened to the laboratory floor by means of bolting with appropriate grouting. The shell was erected on to the column and bolted to the column cap. For proper alignment of the shell, the space between the column cap and the shell bottom was grouted with rich mortar. Figs. 6 and 7 show the erection of the shell roof at different stages.

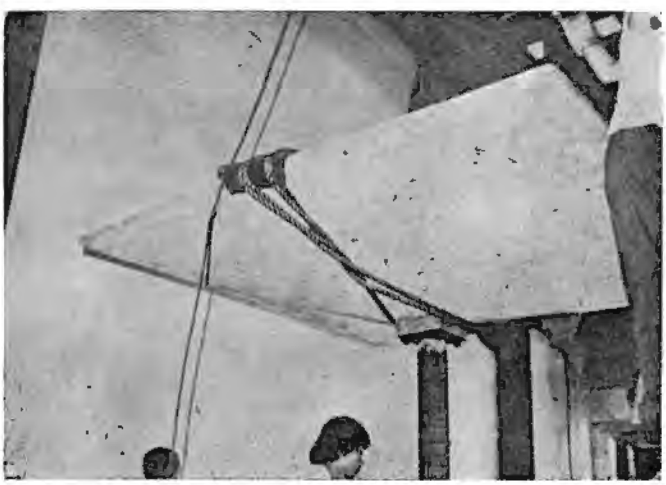

Fig. 6 Lifting of precast shell.

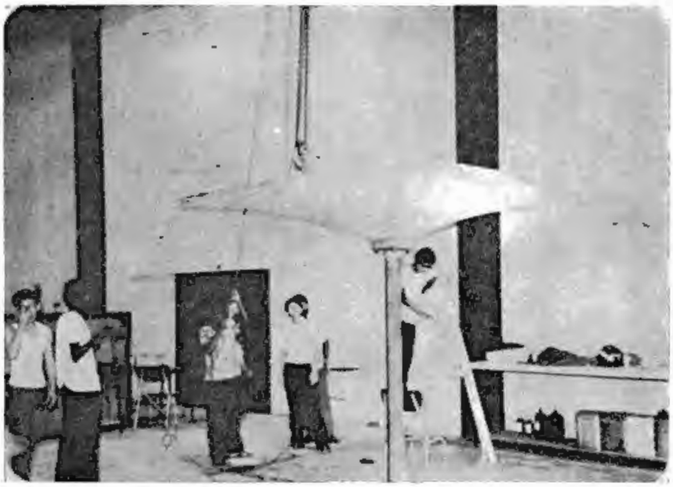

Fig. 7 Erected shell roof.

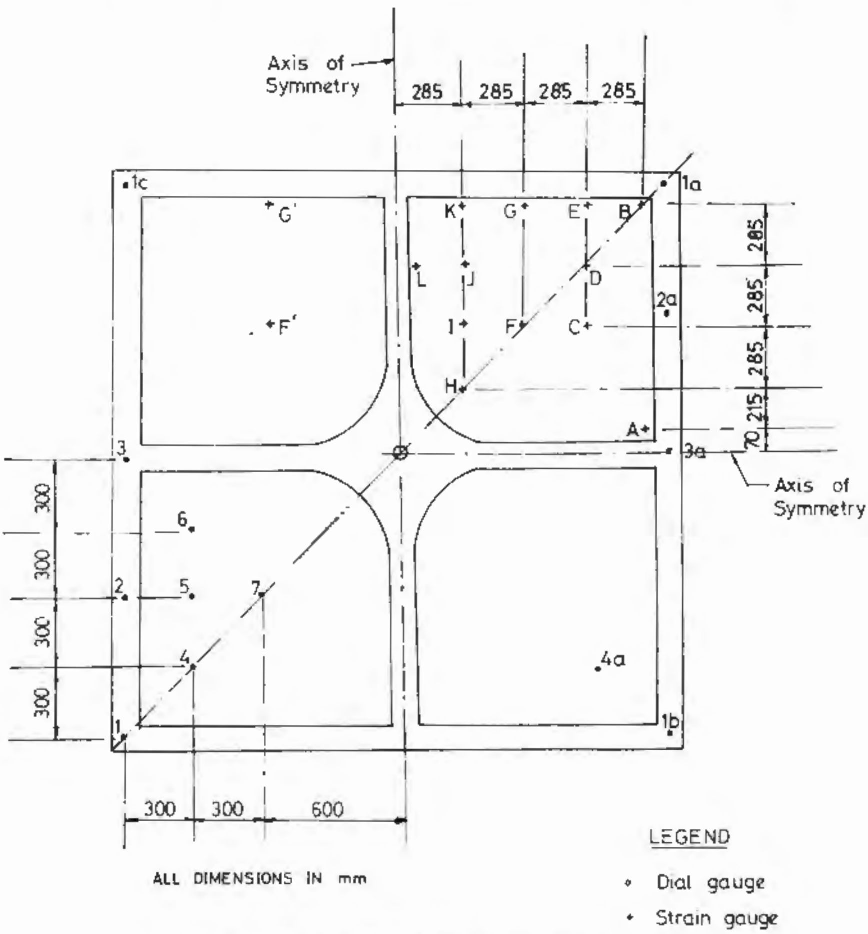

Fig. 8 Positions of dial gauges and strain gauges.

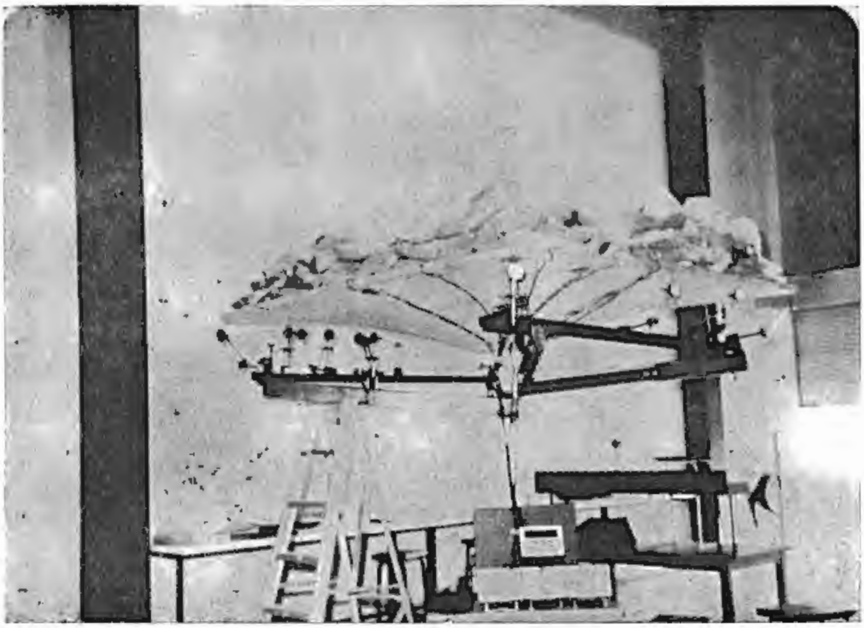

Fig. 9 Test set-up.

TEST PROGRAM

The model was tested under uniformly distributed loads. Vertical deflections were measured at 13 positions on the shell by means of dial gauges. Electrical resistance foil gauges of both linear and rosette types were used to measure strains at various strategic points on the shell and edge members. The positions of the dial and strain gauges and the loading arrangements are shown in Figs. 8 and 9 respectively. The shell was loaded in five stages up to 4.8 kN/m^2 (100 psf) and the readings were taken at both the loading and unloading stages.

TEST RESULTS

The deflection readings at three stages of loading are shown in Table 2. From the load and deflection readings it is observed that the model behaved in a linear manner up to the maximum load recorded. The maximum deflection at 4.8 kN/m^2 loading was 1.6 mm. At this loading, no distress was observed in any part of the shell.

Since the deflections had been reasonably linear with increasing loads, it was assumed that the strains would be linear. A load-strain curve was constructed for each gauge and the mean curve drawn through each set of points was used to obtain the values of the strain. The values of membrane stresses were then calculated at the fourteen gauge positions, using the mean value of the modulus of elasticity obtained from Equation 4 and these are given in Table 3. It is observed, as expected, that away from the edges the membrane forces are reasonably constant. The theoretical value of the membrane shear force using Equation 2 under the action of uniform vertical loading of a 4.8 kN/m^2 is 9.7 kN/m which agrees well with those obtained experimentally.

Table 2. Deflection readings (in mm) at various stages of loading.

Gauge No.	Load (kN/m^2)			
	1.0	2.0	4.8	
Average of 1, 1a, 1b, 1c	0.32	0.96	1.59	
Average of 2, 2a	0.19	0.45	0.79	
Average of 3, 3a	0.08	0.32	0.69	
Average of 4, 4a	0.18	0.45	0.75	
5	0.08	0.45	0.75	
6	0.05	0.18	0.28	
7	0.03	0.10	0.20	

Table 3. Experimental values of membrane forces at uniform vertical loading of 4.8 kN/m^2.

Gauge No.	Values in kN/m		
	T_x	T_{xy}	
A	-3.0	- 5.9	
B*	-	-	
C	-1.5	-11.7	
D	-2.0	-12.1	
E	-2.6	- 7.9	
F, F′ (ave.)	-1.7	-10.5	
G, G′ (ave.)	-1.5	-11.2	
H	-1.6	-11.9	
I	-2.0	-12.5	
J	-1.4	-10.9	
K	-0.7	-11.5	
L	-0.3	-11.0	

CONCLUSION

The ferrocement model made of 16 mm thick shell with two layers of woven wire mesh proves to be too strong for the plan dimension. At a uniform vertical loading of 4.8 kN/m^2, the maximum deflection was 1.6 mm and the maximum shear stress 12.5 kN/m^2. The membrane theory seems to be in good agreement with the stresses in the interior of the shell. It is therefore feasible to construct a shell of larger plan dimension, using the same shell thickness and reinforcement.

The construction technique adopted is particularly suited to the mass production of the units in the factory and subsequent installation at site. This would minimise the cost of construction considerably. Several applications of this type of ferrocement structure can be envisaged, a shelter for bus-commuters being one of them. The cost of construction of the shell and supporting structure was estimated at US$390 in 1977. This appears reasonable compared to the bus shelter made of other materials and used in Singapore.

ACKNOWLEDGEMENT

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Analysis, Design and Construction of Ferrocement Silo

P. Paramasivam* and G.K. Nathan⁺

An investigation is conducted to study the performance and the practical application of ferrocement in the construction of prototype silos for storage of bulk materials. A method is proposed to design silos as a thin shell structure using membrane theory and design charts for different storage materials are presented. A prototype silo, comprising of two cylindrical modules and a conical hopper of total height 2.6 m and cylindrical diameter of 1.5 m, was designed, constructed and tested. The construction procedures and test results are presented and discussed.

LIST OF SYMBOLS

A_s = cross sectional area of wire mesh
A_c = cross sectional area of the composite
D = diameter of the cylindrical module
d = diameter of the discharge opening
F_t = ultimate hoop tension of the cylindrical wall
F_m = ultimate vertical compressive force of the cylindrical wall
F_{th} = ultimate horizontal tangential force of the hopper wall
F_{mh} = ultimate meridional force of the hopper wall
f_c' = cylinder compressive strength
h = depth from free surface of the stored material
K = ratio of horizontal pressure to vertical pressure $=(1-\sin\phi)/(1+\sin\phi)$
p_v = vertical static pressure per unit width
p_h = lateral static pressure per unit width
R = hydraulic radius = area/perimeter
V = total vertical frictional force per unit width
W_h = total weight in horizontal direction
W_m = total weight in vertical direction
W = total weight
μ = coefficient of friction between stored material and silo wall
α = angle of inclination of hopper wall
ϕ = angle of repose of the material
τ_o = cohesion of stored material
ν_c = specific weight of the composite
τ = angle between two adjacent columns
σ_c = first crack tensile strength of ferrocement
σ_s = proof stress of wire mesh at 0.01% strain
σ_m = proof stress of mortar at 0.01% strain
η = capacity reduction factor
ν_m = specific weight of the stored material

INTRODUCTION

In tropical countries, high temperature and humidity promote the growth of mould and rot on food grains, and destroy moisture sensitive materials such as bagged cement, fertilizer etc. Considerable research has been done in a few countries, to study the feasibility and viability of ferrocement silos and bins to compact the above storage problems [1,2]. Extensive studies have been conducted at the University of Singapore, on the behaviour of ferrocement in tension and flexure, the feasibility of using ferrocement in the construction of boats, sunshades, cylindrical and rectangular water tanks, roofing slabs and bus shelters [3-8]. As a continuation

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of this research, a study is conducted to investigate the performance and practical application of ferrocement as a material in the construction of prototype silos. In this paper, the analysis, design and construction of cylindrical silo using ferrocement composite is discussed.

ANALYSIS OF CYLINDRICAL SILO

The prototype silo, comprising two cylindrical modules and a conical hopper is designed as a thin shell structure resting on a reinforced concrete ring beam, supported by four columns as shown in Fig. 1. Analysis of the stresses in the silo is carried out by linear elastic membrane theory of thin shells. The salient features of the pressure developed in silos, the flow pattern, minimum opening design, discharge control device and the stress analysis are discussed briefly.

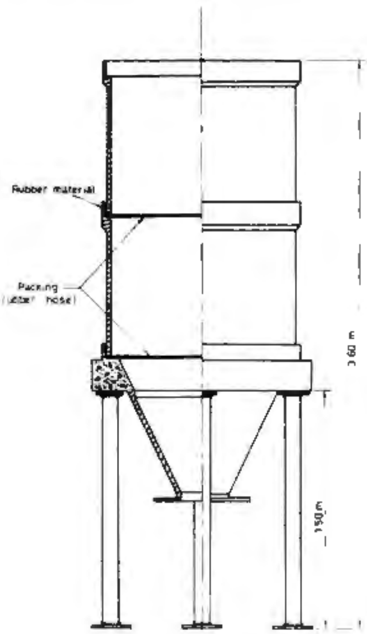

Fig. 1 Half Sectional Elevation View of Silo.

Pressures in Silos

Methods of calculating the pressures on the silo wall have been derived by Janssen [9] and Airy [9]. The former method is more widely used in United States and Europe, and hence, it is used in this investigation. The vertical static unit pressure p_v and lateral static unit pressure p_h at a depth h below the free surface of stored material [9, 10] are as follows:

$$p_v = \frac{v_m R}{\mu K} (1 - e^{-\mu K h/R}) \qquad \text{.............. (1)}$$

$$p_h = K p_v \qquad \text{.............. (2)}$$

in which v_m is the specific weight of the stored material, R the hydraulic radius, μ the coefficient of friction between stored material and silo wall and K the ratio of horizontal pressure to vertical pressure. The total vertical frictional force per unit width V acting on the silo wall of depth h is

$$V = (v_m h - 0.8p_v)\ R \qquad \text{.............. (3)}$$

The pressures for design are obtained by multiplying by an appropriate factor over pressure correction factor or impact factor whichever gives the greater total pressure.

Flow Pattern, Minimum Opening Size and Discharge Control Device

The rate of flow and the minimum opening size required to ensure continuous flow are important factors to be considered in the design of hopper, in order to avoid the segregation, degradation and chemical reaction of the stored bulk materials. Investigation by Kvapil [11] shows that two distinct zones are at the vicinity of discharge opening. As shown in Fig. 2, Zone A is the section within which primary (vertical) and secondary (rotational) motions take place if a first in-first out flow pattern is desired beyond Zone B then the slope of the hopper must be contoured to that of an ellipsoid. Generally, hoppers are designed with an inclination α to achieve the above requirement [11] as:

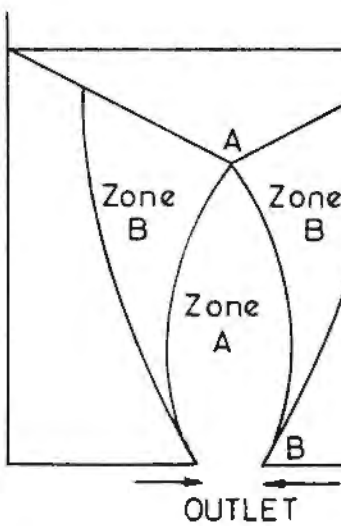

Fig. 2 Flow Zones at the Vicinity of Outlets of Hopper.

$$\alpha \geq 45^{\circ}\ \phi/2 \qquad \text{.............. (4)}$$

Where ϕ is the largest angle of repose of the bulk material.

In order to eliminate the discontinuity of material flow caused by the arching effect, the provision of a large enough non-arching opening is essential. The minimum non-arching opening is expressed in the form of hydraulic radius R [12] as:

$$R = \tau_o\,(1 + \sin\phi)/v_m \qquad \text{.............. (5)}$$

in which τ_o is the cohesion of stored material and ϕ is the angle of repose of the material.

The material weight that acts on the discharge control device can be estimated by finding the profile of arch formed at the opening. For a circular discharge opening the volume under the arch [13] is given as:

$$\text{Volume} = \frac{\pi d^3}{12} \qquad \text{.............. (6)}$$

and the total load arching on the control device is:

$$\text{Total load} = 1.7 v_m \frac{\pi d^3}{32} \qquad \text{.............. (7)}$$

in which d is the diameter of the discharge opening.

Stress Analysis of the Cylindrical Silo Wall

Since the silo is symmetrical and there is no eccentric loading and discharging of material, the cylindrical silo wall is subjected to direct tension due to radial pressure exerted by the stored material. The ultimate hoop tension F_t per unit height of the wall and the ultimate vertical compressive force F_m including the load factors of 1.7 for live load and 1.4 for dead load can be obtained using the membrane theory of shells [10,14] as:

$$F_t = 1.7\, p_h\, (D/2) \qquad \text{.............. (8)}$$

$$F_m = 1.4\, v_c\, h + 1.4\, \frac{V}{t} \qquad \text{.............. (9)}$$

in which p_h is the static lateral unit pressure, D the diameter of the silo, V the static vertical unit pressure, v_c the specific weight of the composite, h the height of the wall, and t the thickness of the wall.

Stress Analysis of Conical Hopper Wall

Conical hopper shell wall is subjected to circumferential and meridional tensile membrane forces due to the stored material [10,14]. The ultimate horizontal tangential force F_{th} per unit length of the wall including the load factor is

$$F_{th} = \frac{1.7\, q\, D}{2 \sin \alpha} \qquad \text{.............. (10)}$$

where $q = p_h \sin^2 \alpha + p_v \cos^2 \alpha$ .... (11)

in which α is the angle of inclination of the hopper wall.

The ultimate meridional force per unit length [10] including load factor is given by:

$$F_{mh} = 1.7 \left(\frac{p_v D}{4 \sin \alpha} + \frac{W_m}{\pi D \sin \alpha} \right) + \frac{1.4\, W_h}{\pi D \sin \alpha} \qquad \text{.............. (12)}$$

in which W_m and W_h are the total weight in meridional and horizontal directions respectively.

Analysis of Ring Beam

A ring beam is required to resist the horizontal component of the meridional force of the conical hopper [14] and to transmit the total silo weight onto the supports. Stresses induced in the ring beam are analysed as a curved beam with the eccentricity of loads taken into consideration. For a circular beam with loads and supports acting along the circumference, the bending moments at support, mid-spans and the twisting moments are given by [15]

$$\text{Moment} = KW\frac{D^2}{4}\tau \qquad \text{.............. (13)}$$

in which K is a parameter tabulated by Vazirani and Ratwani [15] for different support conditions. W the total weight and τ the angle between two adjacent supporting columns measured from the center axis of silo in radians.

DESIGN OF SILO

The analysis shows that the ultimate hoop tension governs the design of the cylindrical wall and the circumferential and meridional tensile membrane stresses govern the design of conical hopper wall. The maximum tensile stresses must be limited with respect to the first crack tensile stress of the ferrocement composite. The first crack tensile stress of ferrocement material (σ_c) can be calculated by [3, 4]

$$\sigma_c = \sigma_s \left(\frac{A_s}{A_c}\right)^{1.1} + \sigma_m \qquad \text{.............. (14)}$$

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

Design Charts

The thickness of the cylindrical and conical hopper wall is normally determined by the amount of reinforcement, spacing of wire mesh and concrete cover. In view of practical considerations, the thicknesses of 20 mm, 30 mm and 40 mm are considered for the design of ferrocement shell. A set of design chart is developed to facilitate the design of cylindrical silos with conical hopper using the above analysis. The silos are to be constructed in modules which can then be assembled together. Generally the calculation of the stress of structural components of silo is based on the set of properties of the stored material which give the most critical load condition. The properties of some of the commonly stored materials given by the ACI Code [11] are presented in Table 1.

Table 1. Properties of Various Stored Materials. [10]

Bulk materials	Weight (kg/m^3)	Angle of Repose	Coefficient of friction against concrete	Identification
Sand	1600-2000	25°-40°	0.40-0.70	A
Portland cement	1344-1600	24°-30°	0.36-0.45	B
Grains	736- 990	23°-37°	0.29-0.47	C
Sugar (granular)	1000	35°	0.43	D
Flour	600	40°	0.30	E
Lime powder	700	35°	0.50	F
Lime	600	40°	0.80	G

The relationship between the storage capacity of the silos and its dimensions such as height, diameter and height to diameter ratio is given in Fig. 3. The storage capacity of the hopper is small in comparison with cylindrical silo section and is omitted in the computation.

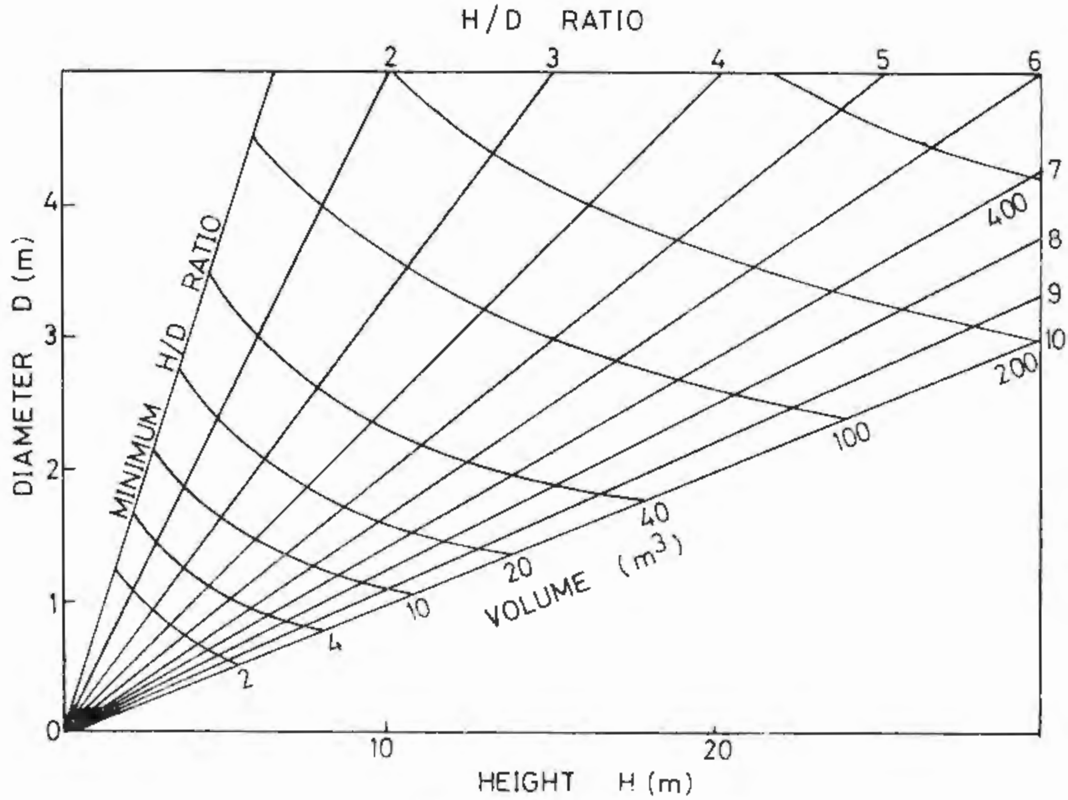

Fig. 3 Design Chart for Storage Capacity.

The cylindrical silo wall is designed and based on ultimate hoop force. Introducing a capacity reduction factor η the Equation 8 can be rewritten as:

$$F_t = 1.7\, p_h\, D/2\eta \qquad (15)$$

Substituting Equations 1 and 2 in Equation 15 with the capacity reduction factor η as 0.7, and neglecting the exponential terms in Equation 1, the ultimate hoop tension can be obtained as:

$$F_t = \frac{0.61\, v_m\, D^2}{\mu} \qquad (16)$$

The ultimate hoop tension for various diameters is drawn in Fig. 4 for different bulk materials.

The permissible ultimate compressive stress f_m at the bottom of the silo wall in which buckling does not control shall not exceed [10]

$$f_m = 0.55\, \eta\, f_c' \qquad (17)$$

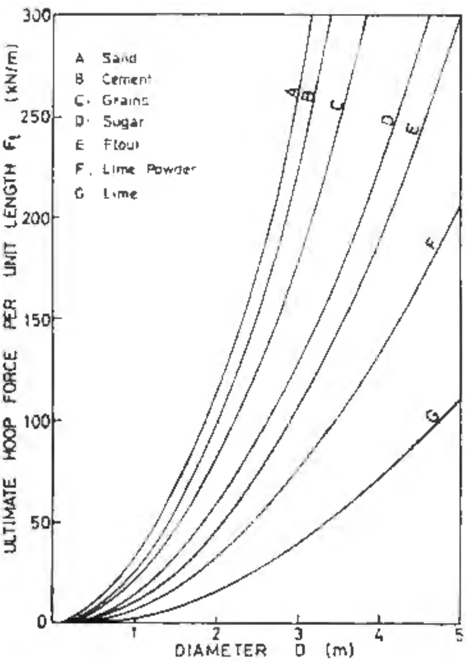

Fig. 4 Ultimate Hoop Tension for Various Diameters.

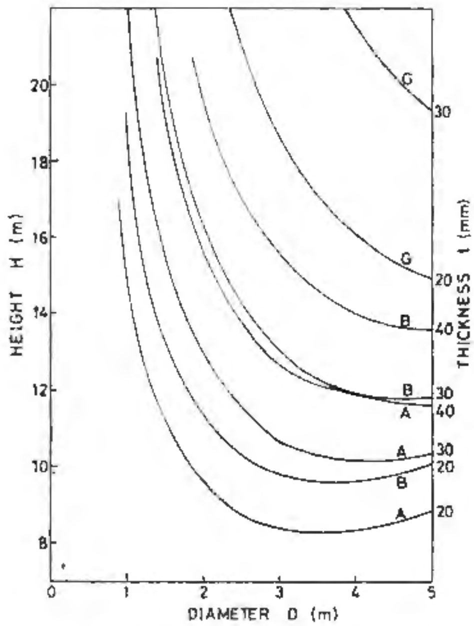

Fig. 5 Permissible Silo Height for Different Wall Thickness.

in which f_c' is cylinder compressive strength. In view of the allowable compressive stress given by Equation 17, using the Equations 9 and 3 and putting the allowable height H equal to h, we can obtain

$$H = \left[0.4 f_c' + \frac{0.17\ v_m\ D^2}{\mu K\ t}\right] \Big/ \left[1.4\ v_c + \frac{0.85\ v_m D}{t}\right] \quad \ldots\ldots\ldots\ldots\ldots \quad (18)$$

in which all the variables are defined as in the list of symbols. Fig. 5 presents the design chart to obtain the permissible silo height for the given wall thickness and the materials to be stored.

The required inclination of hopper in order to establish a first in-first out flow pattern normally falls within the range of 60° to 65° for the most of the stored materials. An inclination of 65° is used to develop the design chart. The design values of horizontal tangential force F_{th} and ultimate meridional force F_{mh} are obtained by dividing Equations 10 and 12 by capacity reduction η, where $\eta = 0.7$ is assumed. The maximum values of 40 mm thickness is used for dead load computations. The design values of F_{mh} and F_{th} are presented in Figs. 6 and 7 respectively for different values of diameters. From these design charts, the design forces can be obtained and the thickness and reinforcement of ferrocement can be proportioned according to Equation 14.

CONSTRUCTION TECHNIQUE

In view of cost and other limitations, a prototype cylindrical silo of following dimensions, internal diameter of 1.2 m and overall height of 3.6 m were selected. The silo comprised of two cylindrical modules, each measuring 1.0 m in height and a conical hopper with an inclination

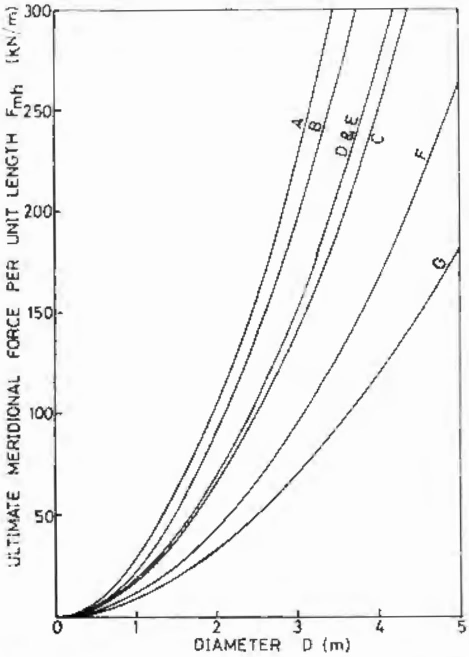

Fig. 6 Ultimate Meridional Force for Various Diameters.

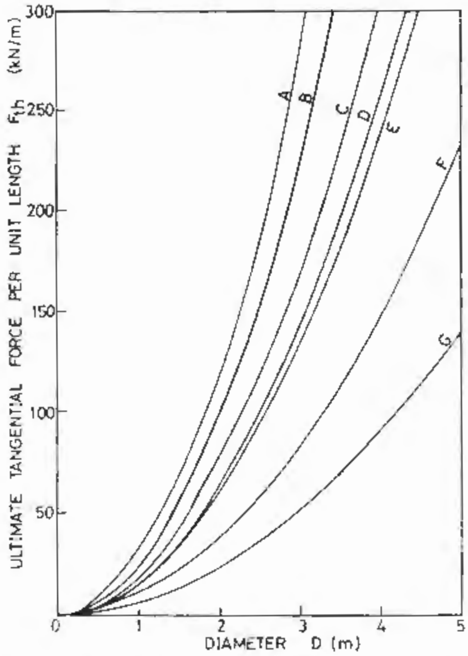

Fig. 7 Ultimate Tangential Force for Various Diameters.

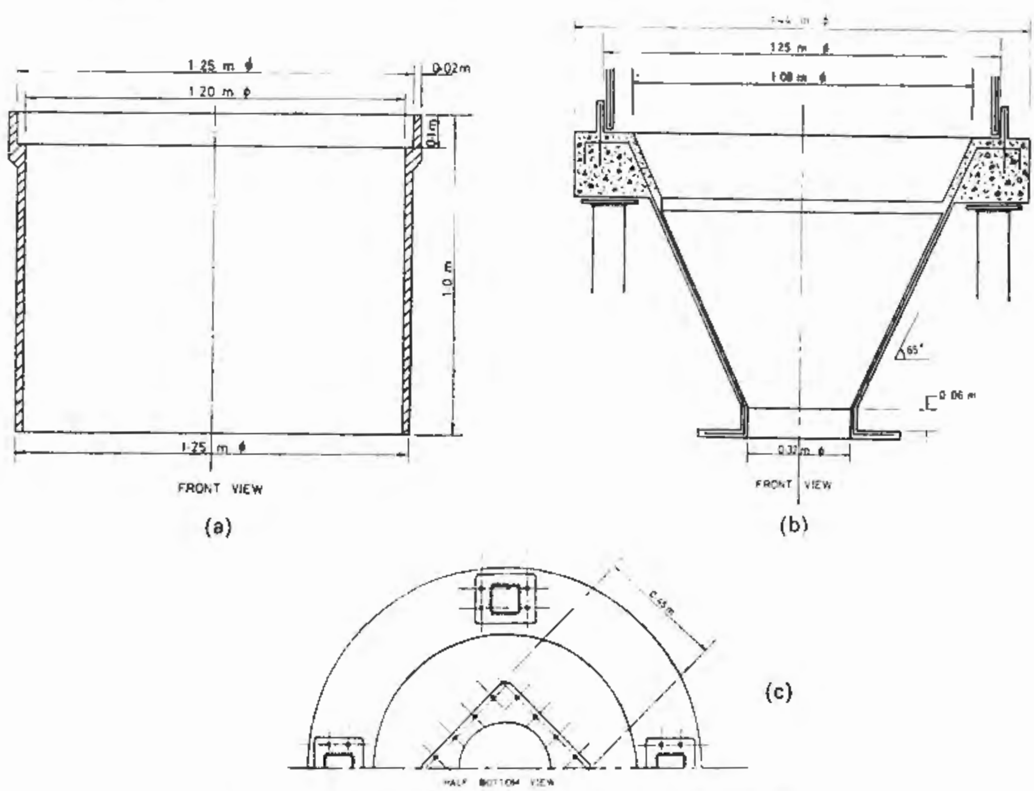

Fig. 8 Dimensions of Cylindrical and Conical Modules.

of 65° and a height of 0.9 m as shown in Fig. 8a, 8b and 8c. The design was carried out using a load factor of 1.7 and a capacity reduction factor of 0.7 thereby giving an overall factor of safety of 2.5. In this design the estimated ultimate hoop and meridional stresses for cylindrical wall are 0.84 N/mm^2 and 0.9 N/mm^2 at the bottom of the cylindrical wall respectively and for conical hopper the hoop and meridional stress are 1.18 N/mm^2 and 2.46 N/mm^2 respectively for the stored material sand.

The cement, sand and water ratio of 1.0 : 1.5 : 0.4 was used for the mortar. The sand should pass through B.S. No. 7 and greater than 100. The cement used was type I normal Portland cement. The relevant properties of the constituent materials are given in Table 2. The thickness adopted for cylindrical wall and hopper was 20 mm. The reinforcement for the cylindrical wall consists of two layers of woven wire mesh, 8.5 mm × 8.5 mm mesh size with 0.92 mm diameter, and one layer of skeletal steel, 152 mm × 152 mm BRC weld mesh of 5 mm diameter, sandwiched together. The skeletal steel was used to form the shape of the cylinder and also the initial rigidity to carry the weight of the reinforcement and the wet mortar during construction.

Table 2. Properties of Constituent Materials.

Plain Mortar	
Cement : Sand : Mortar	1 : 1.5 : 0.4
Crushing Strength	31.25 N/mm^2
Modulus of Rupture	3.01 N/mm^2
Modulus of Elasticity	1.71×10^4 N/mm^2
Wire Mesh	
Grid Size	8.5 mm x 8.5 mm
Diameter	0.908 mm
Ultimate Tensile Strength	400 N/mm^2
Tensile Stress at 0.01 % Strain	200 N/mm^2
Modulus of Elasticity	1.95×10^5 N/mm^2
Ferrocement Composite	
First Crack Tensile Stress	2.82 N/mm^2
Ultimate Tensile Stress	7.25 N/mm^2
Ultimate Bending Stress	9.06 N/mm^2
Modulus of Elasticity	1.95×10^4 N/mm^2

A circle of diameter 1.24 m was drawn on a piece of plywood on to which the outer metal mould of 100 mm high was nailed to control the bottom portion cylindrical module. The reinforcements were placed as shown in Figs. 9 and 10. The cylindrical shape was maintained by the rigidity of the BRC weld mesh and the bottom mould. The upper section of the module for housing another module was constructed by bending 6 mm diameter bars of length 300 mm into '⌉_' shape and inserting them in between the wire meshes all round the top portion of the reinforcement framework at a spacing of 150 mm as shown in Fig. 11. The steel bars, 6 mm diameter, were also bent into circular shape and were tied to the '⌉_' bars and layers of wire mesh were wound round the skeletal framework and inner mould of 1.25 m diameter and 100

Fig. 9 Skeletal Framework for Cylindrical Module.

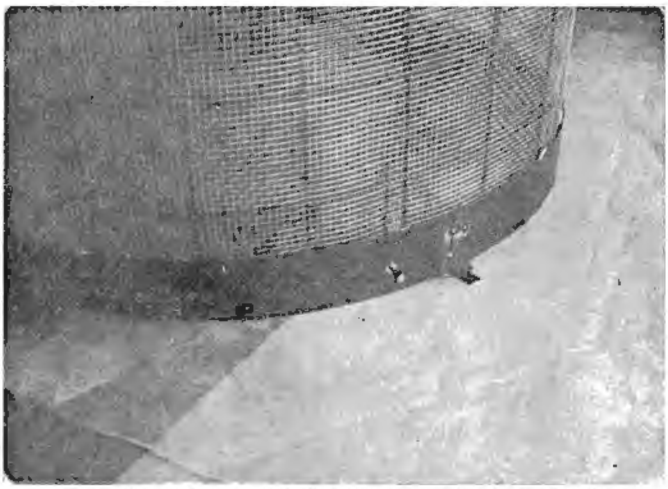

Fig. 10 Cylindrical Skeletal Framework within Mould.

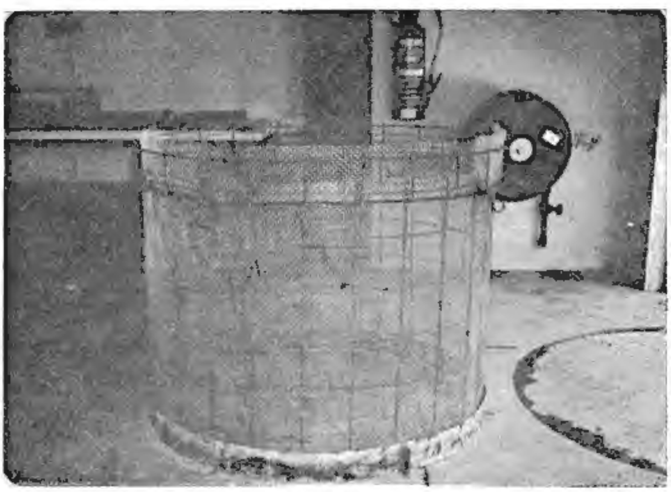

Fig. 11 Reinforcement Details Around 7 Bars.

Fig. 12 Position of Inner and Outer Moulds of the Cylindrical Module.

mm high was placed to control the inner diameter as shown in Fig. 12. The metal moulds were used at the top and the bottom to control the diameter of the modules. Controlled dimensions are required to assemble the modules after fabrication and curing.

A ferrocement ring section of 1.25 m inner diameter provides the joint between the ring beam and the cylindrical module. It is 100 mm high and 20 mm thick reinforced with two layers of wire mesh and a layer of BRC weld mesh. It was then fixed in between the inner and outer moulds of the ring beam (Fig. 13). Reinforcement protruded 0.1 m outside the ring section to be embedded in the ring beam. The ring beam was reinforced with 10 mm diameter

Fig. 13 Ferrocement Ring Section for the Joint between the Ring Beam and Cylindrical Module.

mild steel bars with stirrups of 10 mm diameter. Due to the difficulty of bending the BRC weld mesh into a conical shape, 6 mm diameter steel bars were used as spacers for the conical hopper with a vertical spacing of 150 mm near the ring beam. The steel bars were bent into the required shape and tied to the reinforcement of the ring beam to provide continuity.

Fig. 14 Conical Hopper Skeletal Framework.

Fig. 15 Reinforcement Details of Conical Hopper.

Fig. 16 Plastering of the Cylindrical Module.

The 6 mm diameter bars were also bent into circular shapes of different diameters and tied horizontally to the former at a spacing of 150 mm along the surface to achieve the conical shape of the hopper as shown in Fig. 14. Layers of wire mesh were wound round on each side of the spacer and were tied onto the reinforcement of the ring beam (Fig. 15). Extra layers of wire mesh were provided at the joint between the hopper and the ring beam, and the hopper discharge opening to resist any additional induced bending moment. The mould was used only for the ring beam. The plastering of the cylindrical and conical hopper modules was done manually by pressing the mortar from outside as shown in Fig. 16. The modules were cured for 28 days after plastering with moist gunny sacks.

Fig. 17 Conical Hopper Supported by Columns.

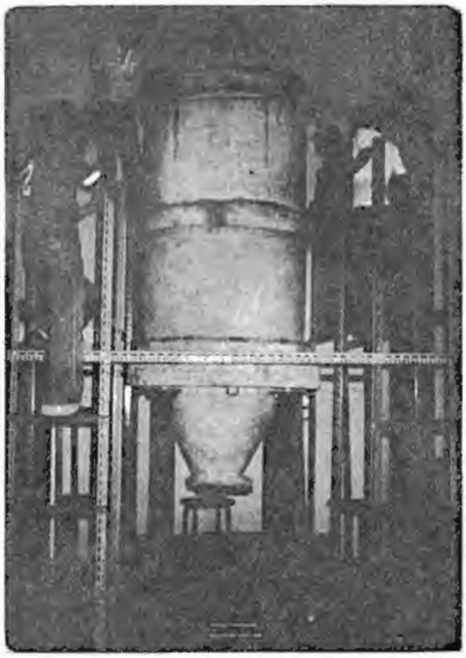

Fig. 18 Assembly of the Modules.

The conical hopper and cylindrical modules were assembled to form the silo. The conical hopper cast in upside down position was overturned and placed on the supporting columns (Fig. 17). Then the cylindrical module was lifted up and made to sit in the ring joint section of the ring beam (Fig. 18). Rubber hose material was provided as a packing material to fill the gaps at the joint. In the same manner, the upper cylindrical module was assembled into the lower cylindrical module (Fig. 19).

TESTING OF SILO

The tests were carried out by filling the silo with sand in six stages. The silo was filled with sand to mid height of the hopper and proceeded at interval of half the height of each section until the silo was topped up. Electrical strain gauges were used to measure the strains induced in silo (Fig. 20) and the position of these strain gauges are shown in Fig. 21a. The strain gauges were fixed on both inside and outside surfaces of the silo, and in the vertical and transverse directions. Fig. 21b and 21c show the theoretical and experimental correlation of the hoop and

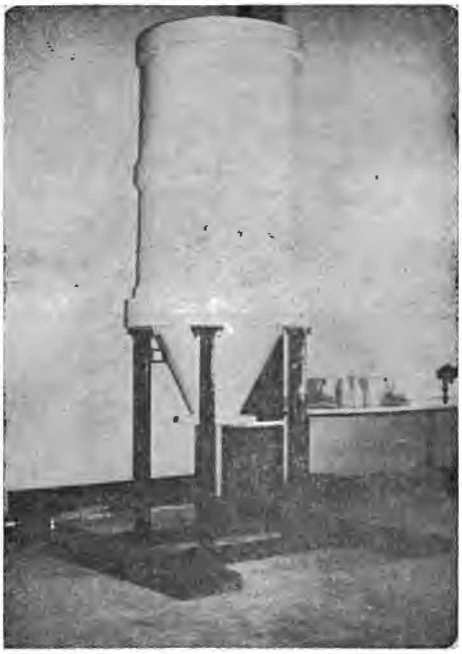

Fig. 19 Completed View of Ferrocement Silo.

Fig. 20 Testing of Silo in Progress.

meridional stresses respectively when the silo was filled up to the brim. The pressure is assumed to be active for the theoretical consideration. Two theoretical curves were drawn with and without the consideration of the overpressure and impact factor. Comparing the theoretical and experimental values for the cylindrical modules, the experimental results obtained for both the hoop and meridional stresses lie within the theoretical curves drawn with excluding and including the overpressure and impact factor. For the conical hopper, the experimental

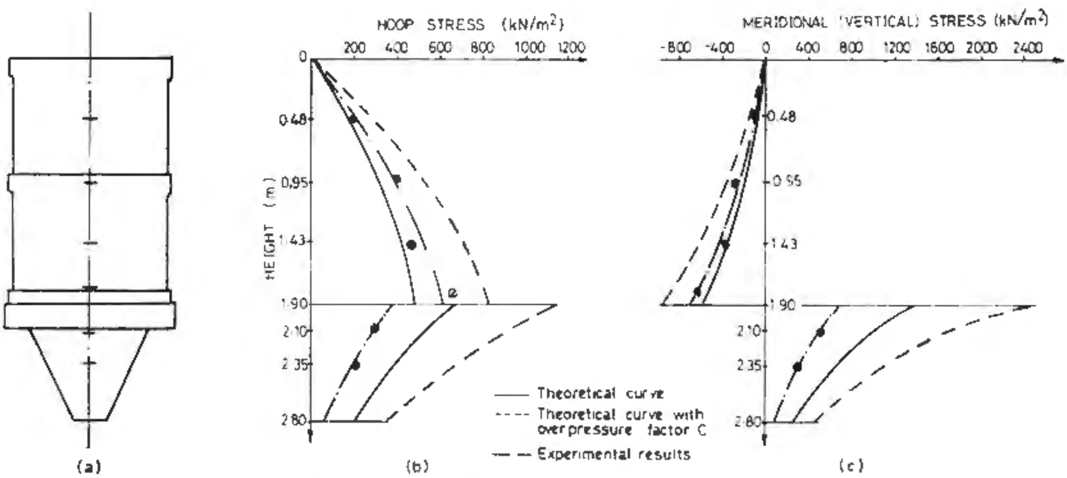

Fig. 21 Comparison of Theoretical and Experimental Results.

results were less than the theoretical values. The casting of ring beam and conical hopper as one section added much rigidity to the hopper. As a result, smaller strains were induced in the conical hopper.

CONCLUSION

Cost comparisons were made based on local cost in Singapore, December 1978, and the estimated cost of the two cylindrical modules and conical hopper is about S$600 and this is very much cheaper than steel bins of similar size used for storing of cement. The satisfactory performance of the prototype silo confirms its viability in the proposed application, specially in the developing countries.

ACKNOWLEDGEMENT

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Ferrocement Pyramidal Dome for a Temple

M. Raisinghani* and V. Venkappa*

The construction of a ferrocement dome over a small temple is described. Ferrocement was found to be an ideal material for the dome in view of its very thin section and consequent low self-weight.

INTRODUCTION

Ferrocement has innumerable applications in construction activities. Although the present main use of ferrocement is in boat building its applications in agriculture, industry and housing have gained impetus. Because of its inherent low self-weight and excellent structural properties, it encompasses almost all forms of construction.

Indian temples invariably have domes (shikhara) of considerable height. The shapes of the dome vary and the usual shapes are shown in Fig. 1. Though reinforced concrete is a versatile material for the construction of domes, considerable self-weight and high cost of formwork inhibit its use.

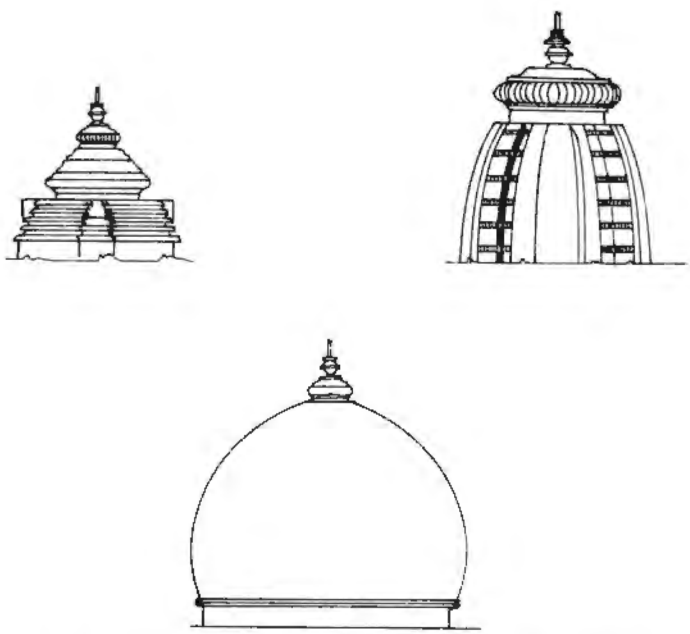

Fig. 1. Normally adopted dome shapes for Indian temples.

Ferrocement was chosen for the construction of a dome over a small temple in Jaipur, India. Its use was dictated by low self-weight, height of the dome (about 5 m), avoidance of formwork, and availability of unskilled labour.

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GENERAL DESCRIPTION

The roof over the main portion of the temple in which the idols are kept has a plan dimension of 9m × 6m as shown in Fig. 2. The roof is an inverted T-beam floor.

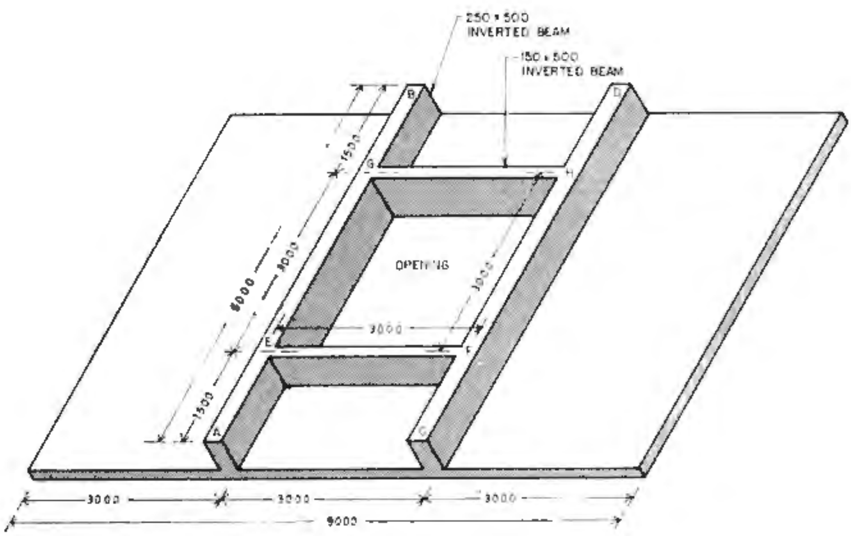


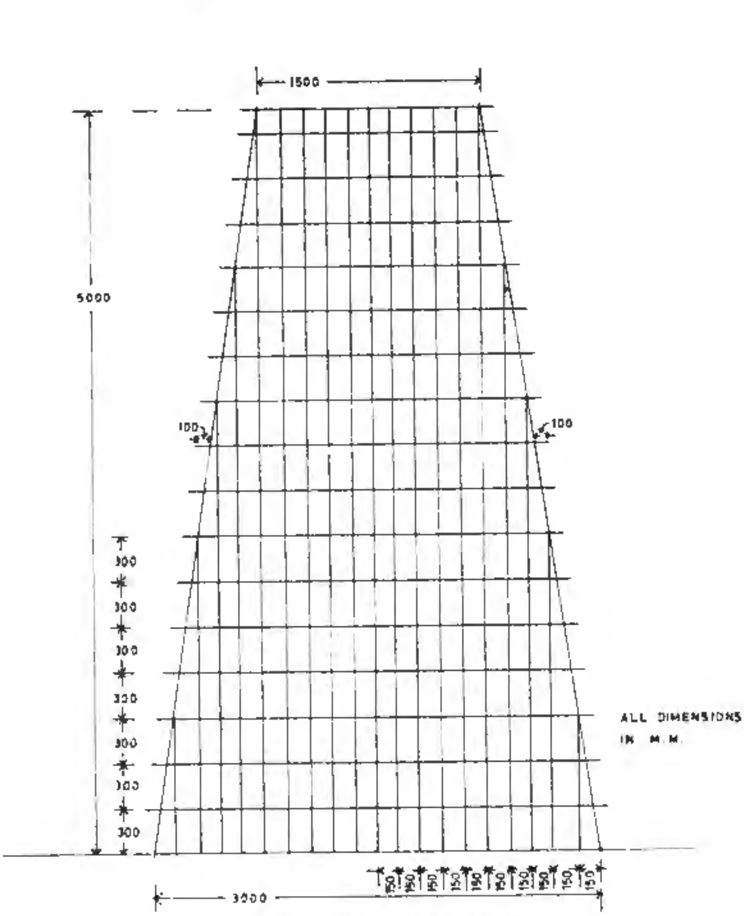
Fig. 2. Inverted T-beam roof over the main portion of the temple.

The main beams AB and CD spaced at 3m have a span of 6m. Two subsidiary beams, EF and GH rest on the main beams. The opening EFGH with an area of 3 m × 3 m is to be covered by the dome.

The height of the dome is 5m. It's cross section is box 3m × 3m at the base (i.e. over the beams) tapering to 1.5m × 1.5m at the top. Mild steel bars, 6mm in diameter, spaced at 150 mm centre to centre and anchored to the beams over the length EFGH were left projecting out to a height of about 0.60 m. These bars were utilised for securing the skeletal reinforcement of the ferrocement dome.

BUILDING OF DOME

After examining various alternatives, it was decided to prepare the reinforcement cage of the dome in four segments, each representing one side of the square pyramidal dome. Each segment had bottom and top width equal to 3m and 1.5m respectively and a height of 5m. The reinforcement consisted of skeletal grid of 5 mm diameter mild steel bars with a spacing of 150 mm in the horizontal direction and 300 mm in the vertical direction. Three layers of chicken wire mesh (22 gauge) were tied to each side of the steel grid in alternate directions to obtain homogeneity. To achieve continuity between segments, 100 mm overlap of the horizontal mild steel bars and chicken wire mesh were provided. The reinforcement details of one segment are shown in Fig. 3.



SKELETON REINFORCEMENT

Fig. 3. Skeletal reinforcement details for one side of the dome.

After the preparation of the four segments separately, they were lifted and positioned on the beams of the inverted roof over the opening EFGH (Fig. 2). The parts were secured to the beams by means of the anchor rods. The lap lengths of the bars were bent at the corners. It was interesting to note that the reinforcement almost had the perfect geometry of the dome. Only slight adjustments were necessary to obtain the required inclination.

Cement-Sand mortar in the ratio of 1:2 with a water-cement ratio of 0.40 was adopted. Ordinary Portland Cement conforming to IS 269-1967 and locally available river sand having a fineness modulus of 2.6 were used. For obtaining good results two workers from inside held plywood sheets close to the reinforcement and one worker distributed the mortar over the chicken wiremesh from outside with a trowel. Subsequently mortar was also pushed in from inside as well. Initial pouring was done to a height of 1.0m in one continuous operation. Care was taken to ensure that the mortar has penetrated well through the mesh. It was found necessary to provide props to retain the shape as the finished part had a tendency to sag. The next pouring operation was performed on the third day enabling the mortar to gain sufficient strength. If rapid hardening cement were used, the pouring operations could be carried out much earlier. The next pour was taken to a height of 1.2m and the total height of the dome (5 m) was achieved in subsequent pours of height 1.3 m and 1.5 m. It might be mentioned that the two top pours required little propping.

The thickness of the initial pour was about 20mm. Smooth finish was subsequently obtained by plastering with cement-sand mortar in the ratio 1:4. The total thickness of the dome after plastering was about 35mm.

Curing was done by covering the outside surface by wet jute bags which were kept moist by periodically sprinkling with water.

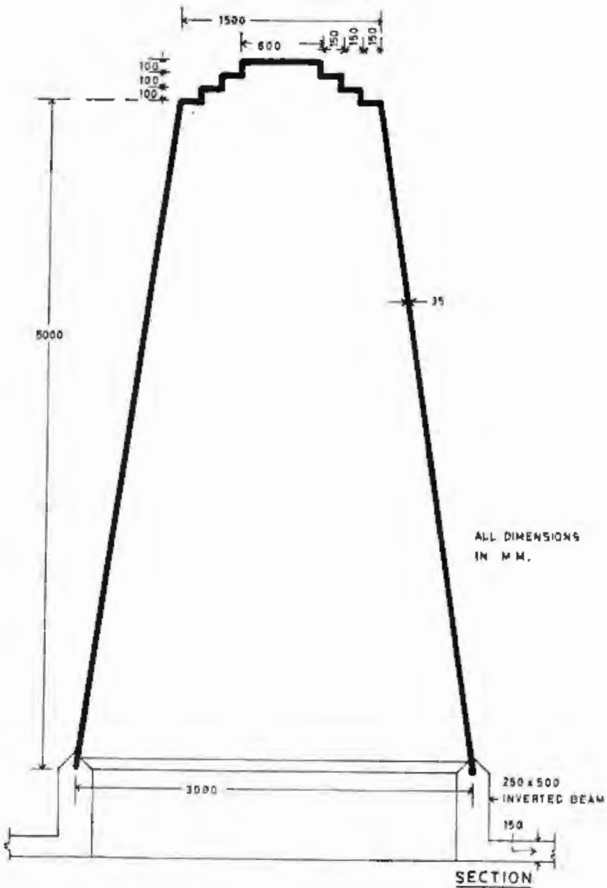


Fig. 4. Section of dome showing top cover detail.

TOP COVER

The top of the dome was covered by ferrocement slab as shown in Fig. 4. Mild steel bars were bent to the required shape in both directions and placed at 150 mm centre to centre. Three layers of chicken wiremesh were tied to each side and the pouring operation was completed as described earlier. Fig. 5 shows a view of the completed dome.

Fig. 5. An Overall view of the completed dome.

CONCLUSION

The dome was constructed in September, 1979. No defect has yet been reported although it has undergone severe weather conditions. The present condition which can be described as excellent, indicates that the design and construction of this particular ferrocement dome is acceptable. It may be mentioned that if the construction techniques described are adopted, there is no limit for the size of the dome that can be achieved. Moreover, for a dome of the size described the cost of a reinforced concrete dome would have been much higher.

Ferrigloo Houses in Papua New Guinea*

Jeremy Herklots**

A new form of low cost housing has recently been developed in the Eastern Highlands of Papua New Guinea, where the climate is relatively cool. Known as the 'Ferrigloo', a name coined from ferrocement and igloo, they have been designed and built by an enterprising English engineer, Bryan Hawker. His early versions did indeed bear a striking resemblance to igloos, but the design has evolved and improved over the last two years and recent models are more mushroomlike in appearance. (Figs. 1-2)

Fig. 1

Fig. 2

There are about 8 New Guinean working partners in Bryan Hawker's firm, each taking on a team of five locally recruited labourers for a specific building contract. The houses are built by first constructing an intricate framework of bush sticks and timber, thus making full use of local materials and local skills (Figs. 3-5). When complete, the frame is covered with plastic sheeting and on top of this three layers of hexagonal mesh are carefully tied in place. (Fig. 6). Mortar with a cement-sand ratio of 1:2 is then applied. Locrete is used as an admixture in the mortar and for waterproofing both the house and the water tank. It is also

Fig. 3

Fig. 4

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* Submitted also for publication to the Appropriate Technology Journal

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used to stick sand on to the outside of the finished house for decorative purposes and to stick hesian to the inner surfaces to prevent condensation. Structural strength is achieved after about three weeks curing, during which time the mortar is kept under dampened conditions.

Fig. 5

Fig. 6

The current highlands version now incorporates a stove, integral watertank, lavatory and external septic tank. Gutters are moulded into the roof during construction and these are connected to the watertank, via pipes built into the house. (Figs. 7-9)

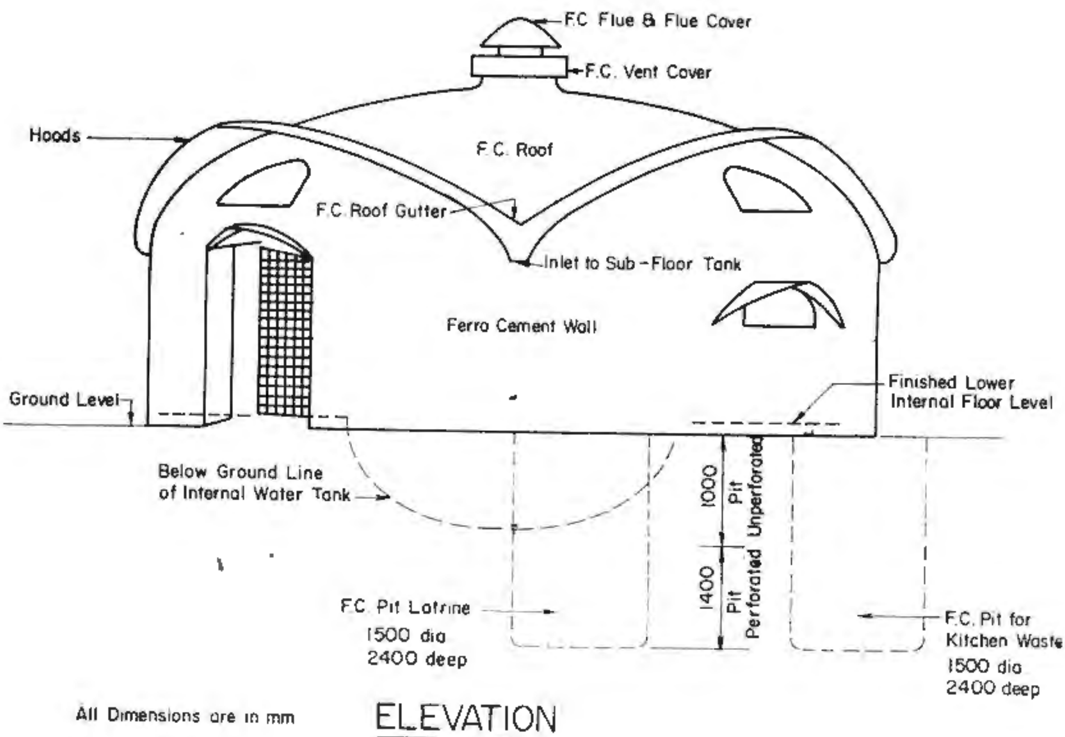

Fig. 7

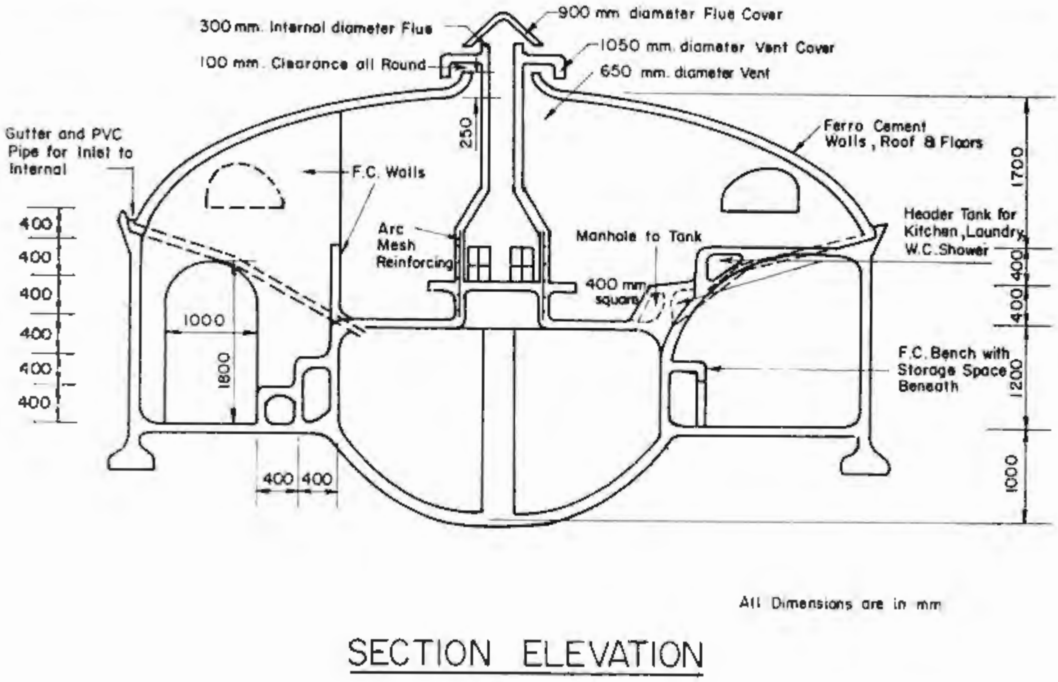
300 mm. Internal diameter Flue
900 mm diameter Flue Cover
100 mm. Clearance all Round
1050 mm. diameter Vent Cover
650 mm. diameter Vent
Gutter and PVC Pipe for Inlet to Internal
F.C. Walls
250
Ferro Cement Walls, Roof & Floors
1700
Arc Mesh Reinforcing
Manhole to Tank
400 mm square
Header Tank for Kitchen, Laundry, W.C. Shower
400
400
400
400
400
400
1000
1800
F.C. Bench with Storage Space Beneath
1200
400 400
1000
All Dimensions are in mm
SECTION ELEVATION

Fig. 8

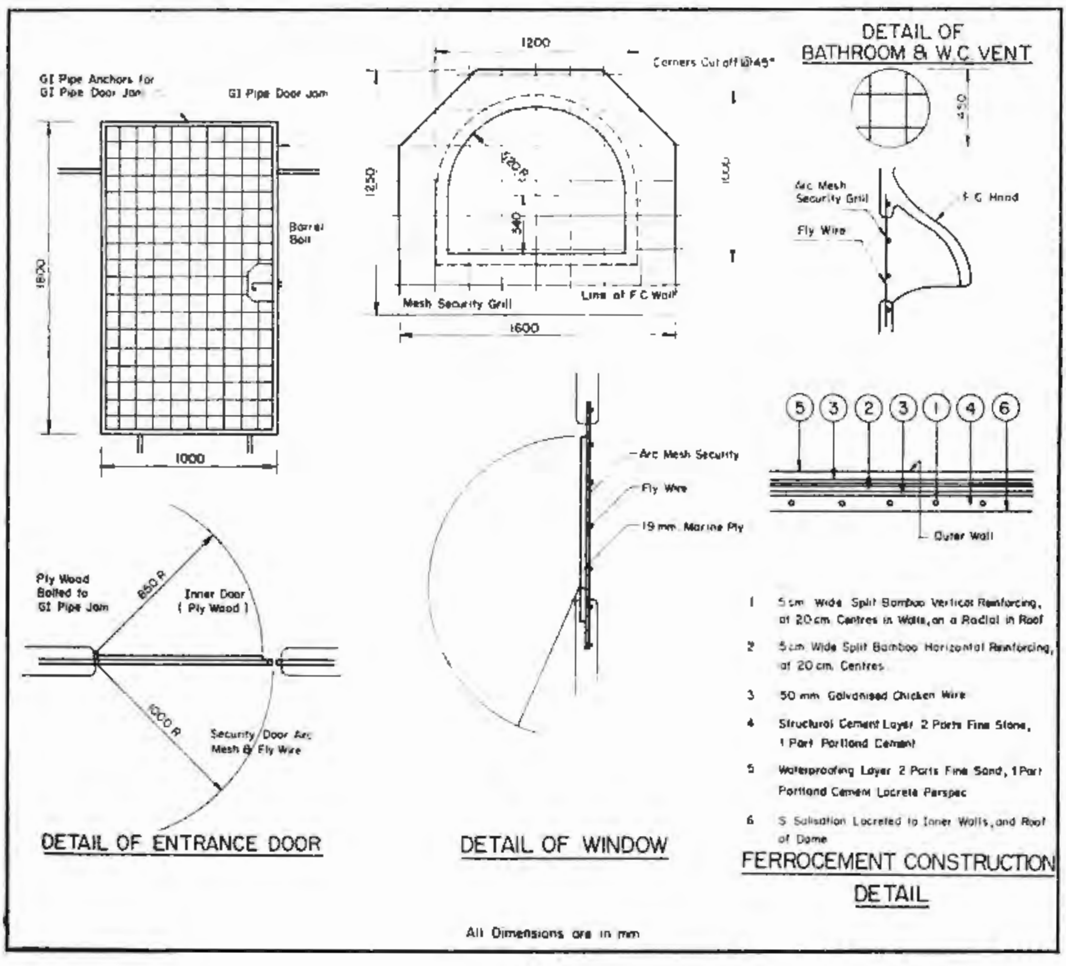
GI Pipe Anchors for GI Pipe Door Jam
GI Pipe Door Jam
Barrel Bolt
1800
1000
1200
Corners Cut off @45°
1250
1000
340
Mesh Security Grill
Line of F.C Wall
1600
DETAIL OF BATHROOM & W.C VENT
450
Arc Mesh Security Grill
F.C Hood
Fly Wire
Ply Wood Bolted to GI Pipe Jam
850 R
Inner Door (Ply Wood)
1000 R
Security Door Arc Mesh & Fly Wire
DETAIL OF ENTRANCE DOOR
Arc Mesh Security
Fly Wire
19 mm. Marine Ply
DETAIL OF WINDOW
5 3 2 3 1 4 6
Outer Wall
1 5 cm Wide Split Bamboo Vertical Reinforcing, at 20 cm Centres in Walls, on a Radial in Roof
2 5 cm Wide Split Bamboo Horizontal Reinforcing, at 20 cm. Centres
3 50 mm Galvanised Chicken Wire
4 Structural Cement Layer 2 Parts Fine Stone, 1 Part Portland Cement
5 Waterproofing Layer 2 Parts Fine Sand, 1 Part Portland Cement Locrete Perspec
6 S Salisation Locreted to Inner Walls, and Roof of Dome
FERROCEMENT CONSTRUCTION DETAIL
All Dimensions are in mm

Fig. 9

Typical costs in November were as follows:

7 cu. metres of sharp no-fines sand (up to 5 mm)	20	Kina
60 × 1 cwt bags of Portland Cement	300	Kina
10 gallons of locrete	150	Kina
Hexagonal mesh/screen wire	1000	Kina
Poles etc	100	Kina
Labour	500	Kina
Supervision and Overheads	500	Kina
	2570	Kina (US $ 3700)

At a selling price of 3,000 Kina (US $ 4300), this house is considerably cheaper than a standard 'low cost' bungalow which with basic fittings would come to about 12,000 Kina (US $ 17,200). Apart from the cost advantages, ferrigloos are expected to last for many years with minimum maintainance.

Following the success of the Highland version, Bryan Hawker is now developing a type suitable for the hot coastal belt. This will need considerably more ventilation than the earlier models. Figs. 4 and 5 show one of the prototypes under construction at Lae. For the future he would like to develop a cheaper version to sell at 2,000 Kina. Cost reductions might be achieved by using fibre reinforced cement for some parts of the structure to reduce the amount of mesh and screen wire needed. Another idea is that non load bearing prefabricated components could be made in a temporary building materials workshop on the site of the housing project. This would allow a certain degree of mechanisation to be introduced.

Research and Development on Ferrocement Structures at the University of Singapore

P.C. Sharma*

The Civil Engineering Department of the University of Singapore, under the aegis of Dr. P. Paramasivam, Dr. G.K. Nathan and Prof. S.L. Lee, has done very useful developmental and research work in the field of ferrocement and fibre reinforced mortar. Theoretical and experimental investigations have been carried out. Several prototype structures using these two materials have been designed, produced and tested and are found to be structurally feasible and economical.

The University students studying at the Civil Engineering Department are required to undertake a project of one year duration as a requirement for the Bachelors of Engineering degree. A number of students choose projects on ferrocement and fibre reinforced concrete and in the past few years very valuable experimental work has been carried out by these students.

Some of the topics investigated include:

1. Effect of various types of metal fibres on tensile and flexural properties.
2. Effect of weaving pattern of meshes and type of meshes on strength of ferrocement.
3. Effect of mix proportion on flexural strength of ferrocement components.
4. Use of natural fibres like sisal, jute, coir, etc. as reinforcement in fibre reinforced mortar.

Boats

One ferrocement boat hull (Figs. 1-2) was designed, produced and tested at the University sometime ago. After its initial successful performance the boat was registered and sailed to Australia. The boat compares well in weight with the timber boats.

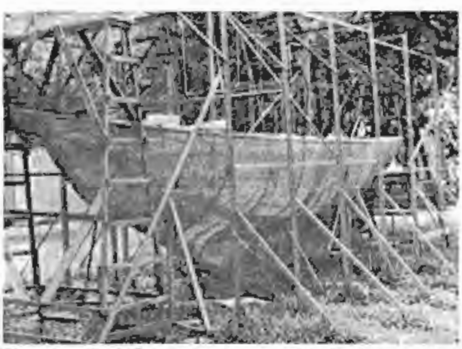

Fig. 1. Reinforcement cage ready for mortar application.

Fig. 2. Completed ferrocement boat.

The boat hull, 12.5 mm thick, does not have any skeletal reinforcement and uses merely wiremesh as reinforcement. The latter consist of 0.863 mm diameter wires woven into 8.382 mm (3 hole in 1 inch) mesh. The hull section provides better strength than the limits prescribed in Lloyds specifications for ferrocement boats.

*Scientist, Structural Engineering Research Centre, Roorkee (India) and India Correspondent of the **Journal of Ferrocement.**

To support and keep the meshes in the actual shape, 20 mm diameter steel conduit pipe framework was used. Pipes bent to the shape of the support frame, were tied together and then welded.

Mortar of 1:1.5 Portland cement-sand mix proportion with 0.45 water-cement ratio was used for plastering the hull. Mortar in the keel area was vibrated. A filler waterproofing coat has been applied on the outer surface.

The boat produced about five years ago is in continuous service at sea since then.

Secondary Roof Slabs and Sun Shades

Secondary roof slabs serve as thermal insulation for top most houses in multistorey buildings in Singapore. These slabs are placed 9″ above the structural roof. Ferrocement slabs, 90 cm x 90 cm x 2.5 cm, have been tried instead of reinforced concrete slabs. This has resulted in considerable dead weight and cost reduction. It has also solved the problem of cracking of reinforced concrete slabs. The ferrocement slabs are reinforced with one layer of 3.2 mm wire welded at 15 cm x 15 cm and two layers of 16 gauge 12 mm square woven wiremesh.

Precast ferrocement sun shades designed and developed by Dr. Nathan and Dr. Paramasivam have gained wide popularity and are being used in large scale in the buildings in the country.

Development of Water Storage Tanks

Two types of ferrocement water storage tanks have been found suitable as overhead water tanks over multistorey buildings. Cylindrical tank, 2.44 m diameter, 2.6 m height and 11.50 m^3 capacity (Figs. 3-4) and 3.66 m x 1.83 m x 1.37 m rectangular tank of 9.17 m^3 capacity were tested under normal loading conditions. (Fig. 5)

The cylindrical wall of the tank has been analysed as cylindrical shell and the base of the tank as a flat plate. Both analyses use linear elastic theory. Wall thickness is 32 mm and the base, 58 mm. The estimated cracking stress and maximum hoop stress in the tank wall are 2.3 N/mm^2 and 0.8 N/mm^2 respectively.

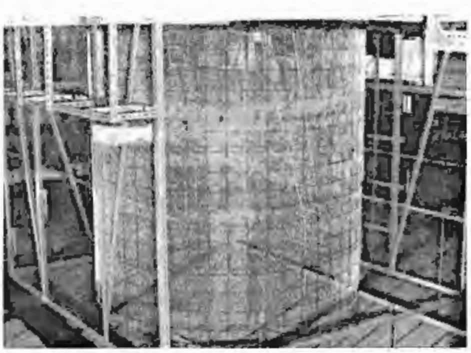

Fig. 3. Reinforcement cage for ferrocement water tank.

Fig. 4. Finished ferrocement water storage tank.

Three layers of 8.5 mm x 8.5 mm woven mesh made of 0.92 mm galvanized wire having ultimate tensile strength of 358 N/mm^2, modulus of elasticity of 2.0×10^5 N/mm^2 and tensile stress of 276 N/mm^2 at 0.01% strain; and two layers of 152 mm x 152 mm welded wiremesh made of 5 mm diameter mild steel wires have been provided as reinforcement for tank wall. Base slab has been reinforced with 10 mm diameter mild steel bars tied at 300 mm on centres in both direction in addition to 2 layers of welded mesh and 3 layers of woven wiremesh. Cement-sand mortar of 1:1.5 mix and 0.4 water-cement ratio, attain 28 day crushing strength of 37.9 N/mm^2, modulus of elasticity of 2.2×10^4 N/mm^2, and tensile strength in direct tension of 1.04 N/mm^2.

Field tests show that ferrocement composite section yields a modulus of elasticity of 2.5×10^4 N/mm^2, tensile stress at first crack stage of 4.54 N/mm^2 and ultimate tensile stress of 8.03 N/mm^2.

Base plate mortar was vibrated and the wall plastering was carried out by hand in one complete operation.

In the case of highrise flats where ample roof space is available rectangular tanks with larger lateral dimensions and shallower depth are used. The rectangular tank wall (thickness 32 mm) has been designed as thin plates using elastic theory. Three inverted U shape reinforced concrete frames support the walls at both ends and at mid point. These frames are connected to the walls using 7 mm diameter dowel bars. The mortar mix used was 1:1.5 with a water-cement ratio of 0.40. The reinforcement provided was similar to the cylindrical tank (Fig. 5).

Fig. 5. Rectangular ferrocement water tank supported with three ⊔ type reinforced concrete frames.

The tanks were tested for a period of 6 months and were found to be leakproof and structurally strong. The cost comparison with available steel tanks in Singapore showed that ferrocement tanks are cheaper by 30%. Based on the successful performance and economical cost these tanks have been recommended for use on high rise public housing and apartment flats in Singapore.

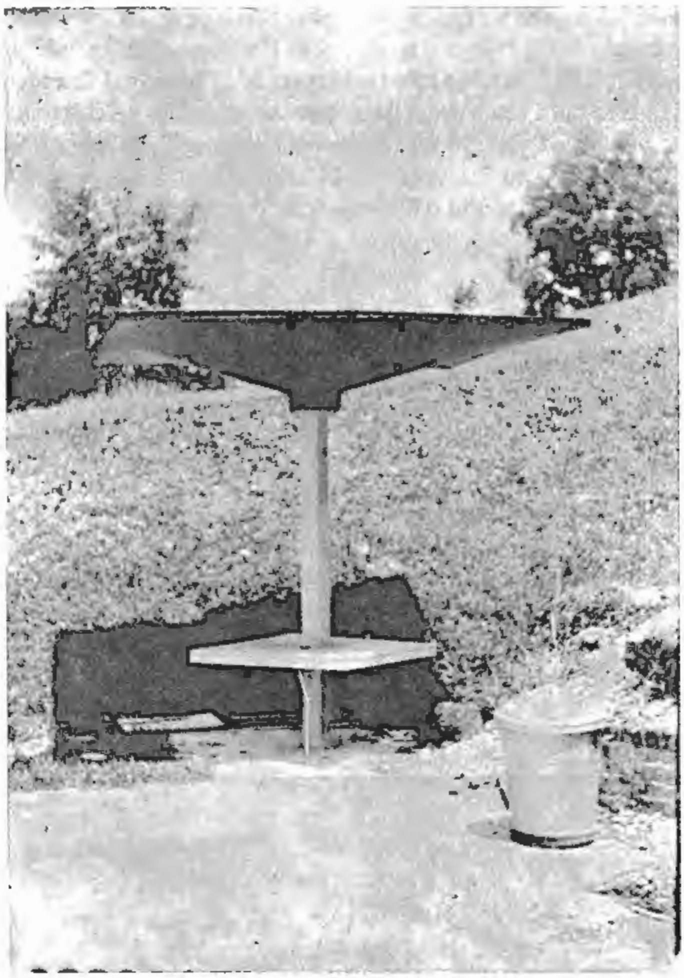

Fig. 6. Ferrocement shell roof for bus stop shelter.

Bus Stop Shelters

At present the inverted umbrella shape bus stop shelters at Singapore are made of fibre reinforced plastic. However, precast ferrocement hyperbolic paraboloid shell (Fig. 6) connected to precast reinforced concrete column and footing have been found at the University to be structurally equivalent, more economical and aesthetically pleasing.

Investigations on butterfly shape ferrocement shell with built in reinforced concrete supporting beams are also being carried out. This precast or cast in situ structures can be connected to a line of columns in the centre. This provides a better structural and architectural shape for the bus stop shelters, cycle shed and small shopping stalls. (Figs. 7a and 7b)

a

b

Fig. 7. Reinforcement pattern for butterfly shape ferrocement shell.

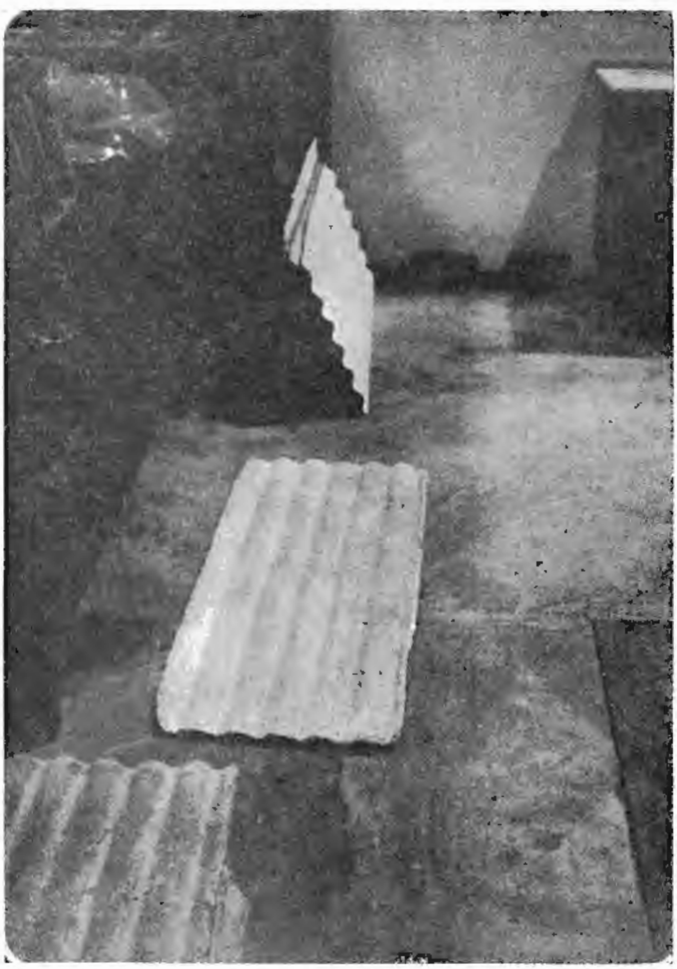

Fig. 8. Corrugated roof unit reinforced with coconut fibres.

Corrugated Roofing Units

Corrugated roofing sheets, 60 cm x 120 cm, having the pattern and shape of normal asbestos cement corrugated sheets have been produced using coconut fibres as reinforcement (Fig. 8). These sheets are found to have better shock and impact resistances and to be cheaper than the asbestos cement sheets. These sheets could be easily produced by the rural population in developing countries.

The correspondent also visited the Department of Building Sciences at the University of Singapore where a team of structural, mechanical, electrical engineers and physicists is doing very useful work in the field of Building Sciences under the leadership of Prof. Dr. K.R. Rao. This team has developed a system of natural ventilation shaft for providing air circulation into the crowded multistorey residential buildings by enclosing the open shaft areas. This system has been found to be very effective. This correspondent suggested the use of ferrocement panel components for enclosing the shafts to achieve further economy and faster rate of construction.

ACKNOWLEDGEMENTS

The correspondent wishes to thank Dr. G.K. Nathan and Dr. P. Paramasivam for sparing their valuable time, inspite of the University holidays; to Dr. K.R. Rao, Head of the Building Science Department and Sri Surender Singh, Lecturer, for making arrangements for his visit and discussion with the faculty members of various departments of the University.

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This list includes a partial bibliography on ferrocement and related topics. The AIT Library and Regional Documentation Center has these articles and books. Reprints and reproductions where copyright laws permit, are available at a nominal cost (see page iv). Please quote the serial number of the list at the time of request. Earlier parts of the bibliography have been published in the past issues of the Journal and are also available in the first volume of "Ferrocement and its Applications—a Bibliography" which contains 736 references compiled from the list. Copies of this IFIC publication can be ordered at a cost of US$2.00 per copy (surface postage included). For air mail postage add an additional amount of US$2.00.

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NEWS AND NOTES

IFIC NEWS

Do-It-Yourself Booklets Released

IFIC recently released the following three booklets in the Do-it-yourself series on specific utility structure (see also the Book Review section):

Ferrocement Water Tank	—Booklet No. 2
Ferrocement Biogas Holder	—Booklet No. 3
Ferrocement Canoe	—Booklet No. 4

Each booklet is presented in two parts:

Part I contains the descriptive text in a non-technical language. It is a comprehensive presentation of the material specifications, material estimations, construction and post-construction operation of each utility structures. It includes additional readings and appendices on sample calculations.

Part II contains construction drawings and construction guidelines which ensures better workmanship and product.

The first volume of the Do-it-yourself booklet, Ferrocement Grain Storage Bin was published in May 1979. Production of Booklet No. 3 and No. 4 were financed by the Intermediate Technology Development Group (ITDG), London. Additional volumes on Roofing Elements and Waterproofing and Repair of Structures are under consideration. IFIC aims by the publication of these series to accelerate the transfer of ferrocement technology in the rural areas of the developing countries.

Staff Farewell and Hellos

Mr. V.S. Gopalaratnam, Senior Information Scientist of IFIC, left the Center in July to pursue a Doctoral degree in Materials Engineering at the University of Illinois at Chicago Circle. His two years in the Center was marked by the expansion of IFIC's customer services and improvement of the Journal of Ferrocement. Mr. Gopalaratnam from Madras, India, did his Bachelor of Science in Civil Engineering at Birla Institute of Technology and Science, India. In 1978 he obtained his Master of Engineering, major in Structures at AIT under a United Kingdom Government Scholarship Grant. He is author and co-author of twelve papers, nine of which are on ferrocement.

Mrs. Lilia Robles-Austriaco, joined the IFIC in June 1980 as a Senior Information Scientist. She obtained a Bachelor of Science in Civil Engineering (Cum Laude) from the Mapua Institute of Technology, Philippines and a Master of Engineering, major in Structures from the Asian Institute of Technology. Prior to joining IFIC, Mrs. Austriaco served as Civil Engineer, Bureau of Public Works, Philippines; Associate Professor and Reviewer, School of Civil Engineering, Mapua Institute of Technology, Philippines; Information Scientist, Asian Information Center for Geotechnical Engineering, Asian Institute of Technology, Thailand and Lecturer in the undergraduate and graduate program of the School of Housing, Building and Planning, University Sains Malaysia, Malaysia.

Mr. Caesar Singh from Rangoon, Burma joined the IFIC as a Research Assistant in June, 1980. He obtained his Bachelor of Technology (Civil) from the Indian Institute of Technology, Madras, India.

Joining the Journal of Ferrocement Editorial Board as correspondent from New Zealand is Dr. Gary L. Bowen, former member of the Editorial Board of the Journal. Dr. Bowen, 1978 corresponding member of ACI Committee 549 on Ferrocement has been active in the research and development of ferrocement technology since he was a Senior Lecturer at the School of Engineering, University of Auckland. Currently, he is the Assistant Project Manager of a Hydro Project in New Zealand.

INDIA

Cement Technology Training Programme

The Cement Research Institute of India organized twelve training courses under its Technological Talent Development Programme for 1980-81. The courses offered until 31st October 1980 were:

1) Concrete mix design and quality control,
2) Raw materials characteristics and their roles in cement making,
3) Instrumentation and its maintenance in cement plants.
4) Workshop on Instrumental methods for evaluation of cement raw materials and cement,
5) Concrete foundations in aggursive environments.

The schedule of the remaining courses is given below. Detailed bulletins on an individual course will be made available on request, four weeks in advance of the commencement of the course.

The fees per participant is Rupees 100/- per day for Indian participants and US$ 20/- per day for foreign participants. The course fee includes tea/lunch and training course materials during training days. A fifty percent concession in the course fee will be given to participants sponsored by member organizations of CRI and such organizations whose sponsored projects are on hand of CRI either at the time of registration of the participants for the course or during the period of the course.

A set of lecture notes of a particular course is sent free of cost to each of the sponsoring organizatons apart from what is supplied to its officials attending the course.

Course Reference	Title	Intended for	Duration and Venue
TT-7.6	Fuel economy in cement manufacture.	Manufacturing engineers, Raw materials and cement technologists, Production chemists, Production engineers and Process engineers.	5 days (10-14 November 1980) CRI - B*
TT-7.7	Improving kiln utilization	Manufacturing engineers, Production chemists, Process engineers, Quality control chemists and burners.	4 days (8-11 December 1980) Rourkela

Course Reference	Title	Intended for	Duration and Venue
TT-7.8	Physico-Chemical and mineralogical control in cement manufacturing processes.	Manufacturing engineers, Raw material and cement technologists, Production chemists, Process engineers and quality control chemists and engineers.	10 days (12-23 January 1981) CRI-B*
TT-7.9	Workshop on mine planning and quarrying practices in cement plants.	Mining engineers, Quarry managers, Raw material specialists, Production engineers and supervisors, Geologists and drilling engineers.	5 days (2-6 February 1981) Quarrying and prospective sites in Andra Pradesh.
TT-7.10	Design and construction of concrete structures in cement plants.	Engineers engaged in the planning, design and construction of civil works in cement plants and similar industrial structures in process industries.	5 days (23-27 February' 81) Bombay
TT-7.11	Fuels and firing systems in cement plants.	Manufacturing engineers, Production chemists, Process engineers, Quality control chemists and burners.	5 days (9-13 March' 81) Hyderabad
TT-7.12	Testing and evaluation of in-situ concrete and concrete structures	Engineers, site supervisors and concrete technologists concerned with concrete constructions.	5 days (23-27 March' 81) CRI-B*

*Cement Research Institute of India, Ballabgarh (Haryana).

Seats are limited and hence enrollment will be on "First come first served" basis. For further details contact:

The Director-General,
Cement Research Institute of India,
M-10, South Extension II,
New Delhi-110 049,
INDIA.

(Reported by Mr. C.P. Singh, Deputy Manager (Training), CRI)

INDONESIA

Developments in Application of Ferrocement

From the Faculty of Engineering, Syiah Kuala University in the Aceh Province, Mr. M.S. Bandaro and Mr. B. Husin reports on the further developments of the construction of ferrocement water tanks, walls, domes and boats. Both were participants of the 1978 Ferrocement Technology Programme held at the Asian Institute of Technology.

Fig. 1 illutrates the initial stage of construction of a 2,000 litre cylindrical water

Fig. 1

tank in South Aceh. A finished water tank of 3,000 litre capacity with 2 layers of wiremesh and a 20 mm thick wall is shown in Fig. 2. Fig. 3 ilustrates another water tank with a

Fig. 2

Fig. 3

number of water taps. This is exclusively used for washing hands before prayers in the mosque. It is of 2,000 litre capacity with 2 layers of wiremesh and a wall thickness of 20 mm. Fig. 4 shows two cylindrical water tanks;

Fig. 4

the one on the left is a completed skeletal steel cage while on the right is an armature ready for plastering. The diameter of the tank is 0.6 m, the height, 0.8 m and the wall thickness is 15mm.

Fig. 5 depicts the construction of a dwelling unit in South Aceh with ferrocement walls. The framework uses bamboo and wood with 2 layers of wiremesh as reinforcement. The thickness of the walls is 20 mm.

Fig. 5

In Banda, the capital of Aceh Province, domes for mosque are constructed using ferrocement. Fig. 6 shows the stage when the

Fig. 6

skeletal framework is installed. A 10 m diameter, 8.5 m height finished dome is shown in Fig. 7. Three layers of wiremesh has been provided and the dome thickness is 25 mm. For this mosque, ferrocement was also used

Fig. 7

for the gutter-length 18 m, depth 0.5 to 1.2 m, breadth 2 m and with two layers of wiremesh (Fig. 8).

Fig. 8

Another dome of diameter 2.5 m and height of 1.5 m has been constructed (Fig. 9) for a mosque in South Aceh with 2 layers of wiremesh and a thickness of 20 mm.

Fig. 9

Ferrocement sampans are being constructed in South Aceh. Fig. 10 shows the application of three layers of wiremesh reinforcement for a sampan. Figs. 11 and 12 show the finished

Fig. 10

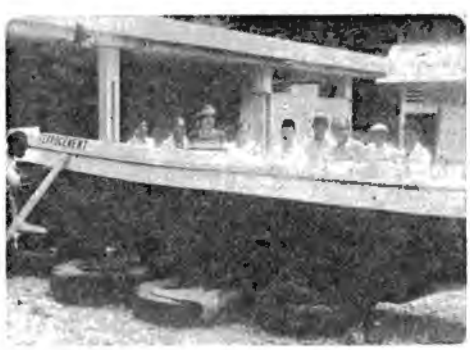


Fig. 11

Fig. 12

sampan, length 8 m, breadth 1.5 m, depth 1.2 m and thickness 20 mm. A smaller version of a sampan, length 3 m, breadth 0.80 m, depth 0.60 m and thickness 15 mm, is shown in Fig. 13 where 2 layers of wiremesh is provided as reinforcement.

Fig. 13

JAPAN

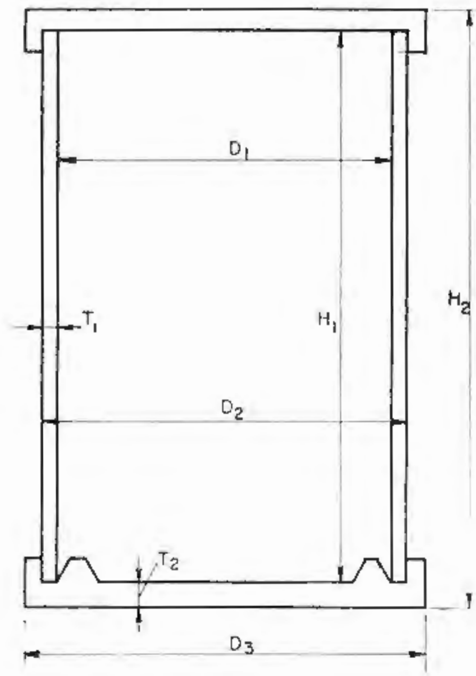
Ferrocement Water Tanks

In the densely populated metropolitan areas of Japan, houses are highly vulnerable to fire. Consequently, the municipal governments are introducing ways to fight the menace. One solution is to install ferrocement water tanks below the ground level for fire-fighting purposes.

The Japan Ferrocement Ltd., Tokyo, is manufacturing ferrocement water tanks of different sizes and more than 200 tanks have already been installed. Schematic diagram of a typical tank and standard dimensions are shown in Fig. 1. Detail of the base connection to the cylindrical wall are shown in Fig. 2.

Fig. 3 illustrates ferrocement water tanks ready for transportation and installation. Figs. 4-11 show the entire transporting process while Fig. 12 shows the installed tank.

An outstanding feature of the ferrocement tank is its ease of transportation and installation in narrow lanes and crowded areas. In this case, the storage tanks are transported in separate parts and are assembled at the site.



	Ferrocement tank (units in metre)			
	N-3	N-5	N-7	N-10
D_1	1.33	1.65	1.98	2.30
D_2	1.39	1.74	2.06	2.38
D_3	1.50	1.84	2.17	2.49
H_1	2.43	2.43	2.43	2.43
H_2	2.55	2.55	2.55	2.55
T_1	0.03	0.04	0.04	0.04
T_2	0.06	0.06	0.06	0.06
Capacity (m^3)	3.30	5.10	7.40	10.00

Fig. 1

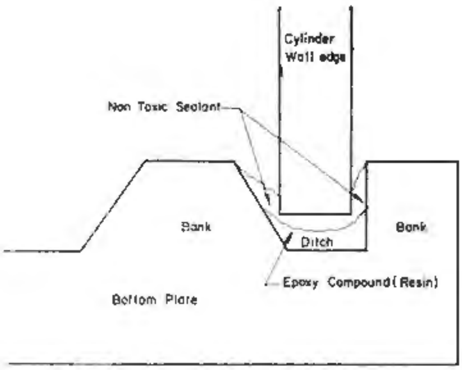


Fig. 2

Fig. 3

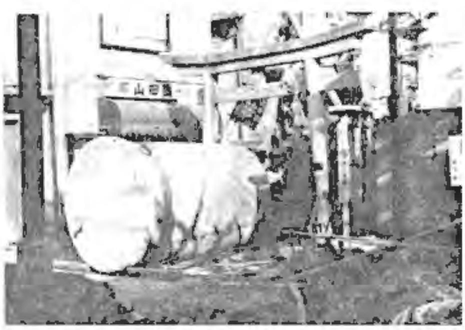


Fig. 4

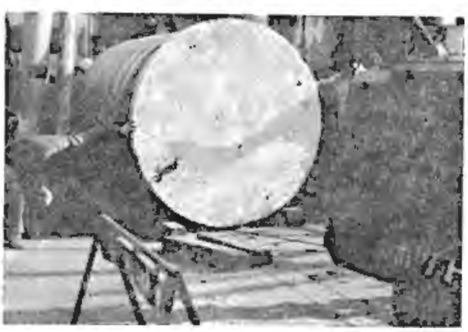


Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fil. 11

Water storage tanks suitable as overhead water tanks are now being tested and inspected. Overhead water tanks will save pumping energy and serves as source of water during water shortage.

(Report compiled based on informations and photographs provided by Mr. Kiyoshi Tamura, President, Japan Ferrocement Ltd.)

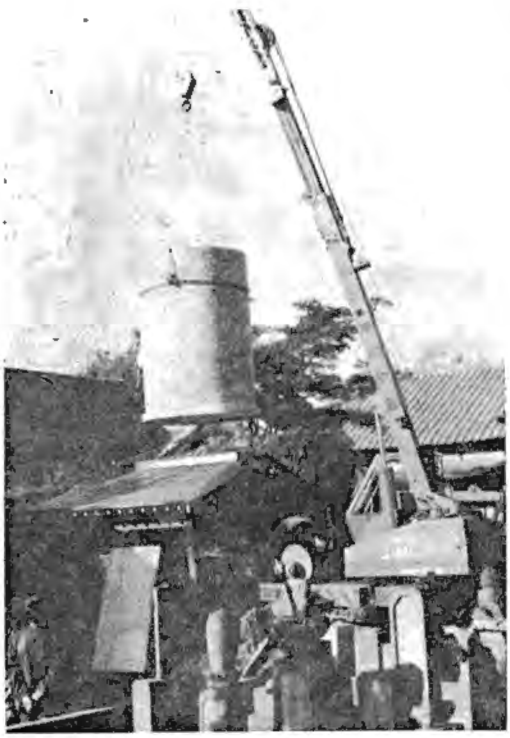


Fig. 10

Fig. 12

MAYOTTE, AFRICA

New Housing Ideas

Mayotte is a small French Island between Africa's Mozambique and Madagascar. Only 10 miles across, it has a population of 45,000.

The French government sponsored eight full time members of the Social Habitat team to counter some of the development problems in the Island. The main concern is housing. Mayotte is in a cyclone zone, and high winds and heavy rains can mean disaster. Traditional building methods need to be improved. The team is trying new ideas with local artisan.

Information sent by VITA has led to testing of ferrocement as a building material. The Mayotte team is trying prefabricated panels of cement, sand and crushed lava mounted within a framework of iron rods and chicken wire.

Ten experimental models have been started outside Mamoutzou, the capital. The walls are made of ferrocement or sun-dried brick. New types of wood and roofing designs are also being used. Local reaction so far has been positive.

(Report compiled from VITA News, April 1980).

THAILAND

Short Course on Computer Analysis of Structures

The Division of Structural Engineering & Construction and the Continuing Education Center of the Asian Institute of Technology, under the sponsorship of Carl Duisberg Gesellschaft of the Federal Republic of Germany, are organizing this course for Asian structural engineers at the AIT campus on August 17-29, 1981.

The course aims to provide participants with latest technologies in and a deeper understanding of Structural analysis and design of multistory buildings and large span bridges. Emphasis will be on dynamic analysis, the use of available computer programs, with special attention drawn to those suitable for small digital computer, and the interpretation of analysis results. Participants should gain proficiency in using the special tools available to those involved in the practice of Structural Engineering.

This intensive course is designed for 45 Asian structural engineers. Target nationals are from Afghanistan, Bangladesh, Burma, India, Indonesia, Iran, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, and Turkey. Participants should have a first degree in civil engineering and at least one year structural designing experience.

The course will involve formal lectures, class discussions and directed problem-solving workshop sessions. Generally, theories and techniques will be illustrated with numerical examples. During workshop sessions, trainees will work in groups, with regular AIT M.Eng. students as group leader under the direction of a faculty. Workshop sessions will reinforce lectures through the participants working on practical structural problems. All computer programs will be run on an IBM 3031, model 6, of AIT's Regional Computer Center.

Each participant will receive a fellowship which covers costs of air ticket, meals and lodging at the AIT dormitory. Grant for this purpose had been provided to AIT by the Carl Duisberg Gesellschaft of the Federal Republic of Germany.

All applications should be received not later than February 7, 1981 and be sent to

The Director
Continuing Education Center
Asian Institute of Technology
P.O. Box 2754,
Bangkok, Thailand
Telephone No. 5168311-5 Ext. 337
Cable Address: AIT Bangkok

Applicants will be informed about the status of their applications not earlier than March 15, 1981.

INTERNATIONAL MEETINGS

Symposium on Durability of Concrete, Orlando, Florida, December 1980.

Sponsor: ASTM Committee C-9 on Concrete and Concrete Aggregates.

Contact: Kathy Greene
ASTM, Publications Division
1916 Race Street
Philadelphia, PA 19103
U.S.A.

Conference on Large Earthquakes, Napier, New Zealand, January 31 - February 3, 1981.

Contact: Dr. T. Hatherton, Convenor
Conference on Large Earthquakes
Geophysics Division
DSIR
P.O. Box 1320
Wellington, New Zealand

International Conference on Fatigue, University of Warwick, March 24-27, 1981.

Organizer: Society of Environmental Engineers, Fatigue Group.

Contact: J.B. Sturgeon
Materials Department
Building R50, Royal Aircraft Establishment
Farnborough
Hants, GU14 6TD, U.K.

Fifth International Conference on Fracture, Cannes, France, March 29 - April 3, 1981.

Contact: J. Poirier
CEA-DMECN-ICF5
BP. No. 2
91190, GIF-SUR-YVETTE
France

Third International Congress on Polymers in Concrete, Nihon University, Fukushima-ken, Japan, May 13-15, 1981.

Contact: Polymer Concrete Congress 1981 Secretariat
c/o Dr. Yoshikho Ohama
Dept. of Architecture College of Engineering
Nihon University
Koriyama, Fukushima-ken 963
Japan

International Symposium on the Mechanical Behaviour of Structured Media, Carleton University, Ottawa, Canada, May 18-21, 1981.

Contact: Prof. A.P.S. Selvadurai
Department of Civil Engineering
Carleton University
Ottawa, Ontario K1S 5B6
Canada

Colloquium, Advanced Mechanics of Reinforced Concrete, Delft, The Netherlands, June 2-4, 1981.

The International Association for Bridge and Structural Engineering in collaboration with ASCE, CEB and RILEM will sponsor this Colloquium to be held in Delft University of Technology, Delft, The Netherlands.

The contents of the colloquium fall into three categories:

1. Modelling of material behaviour.
2. Structural modelling for numerical analysis.
3. Applications and experimental verification.

Each session will include an introductory lecture and a limited number of accepted papers followed by a general discussion. Papers are presented in English. Discussions may take place in other languages but no simultaneous translation will be provided.

Final report will be published in December 1981. It will contain the accepted papers and the written contributions to the discussions. Each participant will receive the final report free of charge.

Further information can be obtained from:

Secretariat of the IABSE
ETH-Hönggerberg
CH-8093 Zurich, Switzerland
Tel. 01/377 2647
Telex 54 354 EHOPZCH

Second International Conference on Superplasticizers in Concrete, Ottawa, Canada, June 10-12, 1981.

Contact: Mohan Malhotra, CANMET
405 Rochester Street
Ottawa, Ontario
Canada KIA OG1

ICP/RILEM/IBK
International Symposium on Plastics in Material and Structural Engineering, Prague, Czechoslovakia, June 23-25, 1981.

Contact: ICP/RILEM/IBK
International Symposium 1981
Prague Secretariat
c/o Dum Techniky Cs. VTS.
Gorekeho nam 23, Prague 1
11282 Czechoslovakia

Second Australian Conference on Engineering Materials, University of New South Wales, Australia, July 6-8, 1981.

Contact: Dr. D.J. Cook
School of Civil Engineering
University of New South Wales
P.O. Box 1
Kensington, NSW 2033
Australia

International Conference on New Concepts for Concrete (incuding rolled concrete dams), London, England, September 1981.

Organizer: CIRIA

Contact: Mrs. Jennifer Eyles
CIRIA
6 Storeys' Gate
London SWIP 3AU

International Symposium on Concrete Roads, London, England, October 19-23, 1981.

Organizer: The Concrete Society, PIARC and CEMBUREAU.

Contact: Gerald Young
The Concrete Society
Terminal House, Grosvenor Gardens
London SW1W OAJ

International Seminar and Exhibition on Modernisation of Concrete Construction Techniques in Madras, India, January 21-24, 1982.

The Structural Engineering Research Centre, Madras, in collaboration with Eight National and International Organisations is organising an international seminar and exhibition on "Modernisation of Concrete Construction Techniques in India" to be held at Madras from 21st - 24th January 1982. Indian and international experts will deliver lectures on hardware and techniques employed in concrete construction. Discussions on relevance and need for these in India will follow. Some of these methods, systems and techniques will also be on display at the exhibition. The themes selected will include: Concrete mixing and placing; Concrete chemicals and hardware; Form systems and scaffolding; Repairs and renovation techniques; Production techniques for precast concrete; Testing and control services for concrete; Reinforcements and fabrication. This is expected to usher in uses of advanced techniques and therefore, collaboration between Indian and international firms dealing with hardware and techniques of concrete construction for operation in India and in third countries.

Further details can be had from:

Mr. Zacharia George
Assistant Director
Structural Engineering Research Centre
Madras-600 020, India

CALL FOR PAPERS

The Nervi International Symposium on Ferrocement, Bergamo, Italy, July 22-24, 1981.

The International Union of Testing and Research Laboratories for Materials and Structures (RILEM), the American Concrete Institute (ACI), and the International Association for Shell and Structures (IASS) are planning an International Symposium on Ferrocement in Bergamo, Italy on July 22-24, 1981. The goal of the symposium is to synthesize information on:

*Materials Properties
*Structural Design
*Technology of Production
*Cost Evaluation
*Applications
*Recommendations for Code of Practice

Prospective authors wishing to present a paper are invited to submit an abstract of about 200 words by November 30, 1980. The manuscript of accepted papers must be mailed by March 31, 1981. The preprints will be distributed before the symposium. The final proceedings of the symposium will be published by RILEM. Please submit the abstracts to either of the co-chairmen of the symposium:

Professor Ing. Guido Oberti
Istituto Sperimentale Modelli E Strutture (SPA)
Viale Giulio Cesare, 29
24100 Bergamo
Italy

or

Professor S. P. Shah
University of Illinois at Chicago Circle
Department of Materials Engineering
P.O. Box 4348
Chicago, IL 60680 USA

Session on High Strain Rate Effects and Crack Propagation in Brittle Materials, St. Louis, USA October 26-30, 1981

The committee on Properties of Materials of Engineering Mechanics is planning a session on High Strain Rate Effects and Crack Propagation in Brittle Materials at the American Society of Civil Engineers' National Convention in St. Louis on October 26-30, 1981. The topics will include:

*impact and dynamic loading of rocks and concrete

*instrumented impact testing

*wave propagation

*strain-rate effects

*fracture

Persons interested in presenting a paper at this session are invited to submit an abstract by December 31, 1980 to:

Professor S.P. Shah
University of Illinois at Chicago Circle
Department of Materials Engineering
P.O. Box 4348
Chicago, IL 60680 USA

AIT CALENDAR

International Conference on Industrial Systems Engineering and Management in Developing Countries, Asian Institute of Technology, Bangkok, Thailand, November 3-6, 1980.

The Asian Institute of Technology and Carl Duisberg Gesellschaft e.V., Germany in collaboration with the American Institute of Industrial Engineers, Japanese Institute of Industrial Engineers and Japanese Industrial Management Association will sponsor this International Conference.

This Conference gives an opportunity for those involved with the education, training and practice in the field of industrial systems engineering and management (in industry, educational and research institutions, government and international agencies) to meet and exchange experiences, views and opinions regarding the field and its state-of-the-art. Speakers and delegates to the Conference will be coming from many parts of the world. Around sixty contributed papers will be presented and nine state-of-the-art lectures will be given by prominent persons in the field.

All papers in the technical session will be published in the proceedings. The state-of-the-art lectures will be published in a separate volume and will also be available during the conference.

All correspondence should be addressed to:

Dr. M.T. Tabucanon
ISEMDC Conference Secretary
Asian Institute of Technology
P.O. Box 2754
Bangkok, Thailand.

International Conference on Agricultural Engineering and Agro-Industries in Asia, Asian Institute of Technology, Bangkok, Thailand, November 10-13, 1981.

This first International Conference in the Asian Region on the subject is sponsored by the Asian Institute of Technology and the Carl Duisberg Gesellschaft e.V., Germany. The main objectives of this Conference are:

1. to identify areas requiring research and development work to help agricultural industries to increase food supplies;
2. to stimulate basic and applied research in the fields of agricultural engineering and agro-industries; and
3. to promote the exchange of ideas and experiences pertaining to present and future developments in agricultural engineering and agro-industries.

Papers accepted for the Conference will be printed and published in the proceedings which will be distributed before the Conference.

All correspondence should be addressed to:

Dr. V.K. Jindal
Secretary
International Conference on Agricultural Engineering and Agro-Industries in Asia
Division of Agricultural & Food Engineering
Asian Institute of Technology
P.O. Box 2754
Bangkok, Thailand.

BOOK REVIEWS

FERROCEMENT WATER TANK, DO IT YOURSELF SERIES-BOOKLET NUMBER 2

by P.C. Sharma and V.S. Gopalaratnam

Published by International Ferrocement Information Center, Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand.

The 38 page booklet is the second in the Do-it-yourself series, published by IFIC.

The booklet begins with a brief but informative description of ferrocement water tanks and material specifications. It goes on to describe the material estimation and tank construction. A useful section on post-construction operations is included which mentions repairs and installation. Many other aspects are looked at including costings and semi-mechanized process for casting.

The design and detail of construction are illustrated in a way which anyone with basic technical knowedge could understand. It is in fact, a booklet which will be used to great advantage by those involved in the transfer of technology to rural areas.

38 pp.	*180 mm × 265 mm*	*Flexicover edition*
English		*May 1980*
		US$2.00 (Surface mail)
		US$4.00 (Air mail)

FERROCEMENT BIOGAS HOLDER, DO IT YOURSELF SERIES-BOOKLET NUMBER 3

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 booklet, the third in the Do-it-yourself series, published by IFIC aims to promote the use of ferrocement for building simple and inexpensive biogas holder in many villages of developing countries.

Divided into two parts, Part I, clearly describes in a concise and readable form, the development of biogas holder, material specifications, cost estimations, construction and post-construction operations. It includes additional readings and appendices.

Part II provides extensive illustrated information and details of construction to help user to construct biogas holder quickly, easily and economically.

42 pp.	*180 mm × 265 mm*	*Flexicover edition*
English		*June 1980*
		US$ 2.00 (Surface mail)
		US$ 4.00 (Air mail)

FERROCEMENT CANOE, DO-IT-YOURSELF SERIES, BOOKLET NUMBER 4

By P.C. Sharma and V.S. Gopalaratnam

Published by International Ferrocement Information Center, Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand.

The latest in the Do-it-yourself series, this booklet discusses, briefly the design and construction of a 6 m ferrocement canoe. Post-construction operation, additional readings, sample calculations on load carrying capacity, static stability check of the hull and cost comparison of the ferrocement canoe with a timber hull of the same size are presented. The clarity and practicality of the explanations assure the usefulness of the booklet as an easily understandable guide.

This booklet will have a special attraction to amateur builders and development officers in rural areas of developing countries.

37 pp.	*180 mm × 265 mm*	*Flexicover edition*
English		*July, 1980*
		US$2.00 (Surface mail)
		US$4.00 (Air mail)

Abstract

JFP26 A FERROCEMENT HYPERBOLIC PARABOLOID SHELL

KEYWORDS: Analysis, Construction, Deflection, Design, Hyperbolic Paraboloid, Shell, Testing.

ABSTRACT: This study investigates the feasibility of constructing a ferrocement hyperbolic paraboloid shell in the shape of an inverted umbrella. The shell geometry and design consideration based on the membrane state of stress are described. The shell model was tested under uniformly distributed vertical loads and the structural behaviour is reported in terms of vertical deflections and stresses at critical sections. Salient features of the construction technique and test results are discussed.

REFERENCE: DAS GUPTA, N.C., PARAMASIVAM, P. and LEE, S.L., "A Ferrocement Hyperbolic Paraboloid Shell", Journal of Ferrocement, Vol. 10, No. 4, Paper JFP 26, October 1980, pp. 273-282.

CONTENTS LIST

Volume 10 contains four issues and this partial list of contents includes all technical articles including papers on research and development, papers on applications and techniques, notes from amateur builders and feature articles published in the Journal of Ferrocement during 1980.

Number 1, January 1980

Number 2, April 1980

Number 3, July 1980

Number 4, October 1980

PAPERS ON APPLICATIONS AND TECHNIQUES

FEATURES

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Volume 10, January/April/July/October 1980

Contributions to the Journal of Ferrocement are indexed jointly in three categories:

1. **Title: Cost Reduction and Quality Control in Ferrocement and Marine Concrete**
   · M.E. Iorns 11
2. **Author: Iorns, M.E.**
   · Cost Reduction and Quality Control in Ferrocement and Marine Concrete 11
3. **Subject: Application**
   · Marine Uses 11

Volume 10 Contains four issues, namely: **No. 1-January 1980** (pages 1-68), **No. 2-April 1980** (pages 69-176), **No. 3-July 1980** (pages 177-269), **No. 4-October 1980** (pages 270-342). Apart from technical Contributions, a separate index for items published in the News and Notes section is also included.

A

B

INDEX—NEWS AND NOTES

Volume 10, January/April/July/October 1980

JOURNAL OF FERROCEMENT

Aims and Scope

The Journal of Ferrocement is published quarterly by the International Ferrocement Information Center (IFIC) at the Asian Institute of Technology. The purpose of the Journal is to disseminate the latest research findings on ferrocement and other related materials and to encourage their practical applications especially in developing countries. The Journal is divided into four main sections:

(a) Papers on Research and Development
(b) Papers on Applications and Techniques
(c) Notes from Amateur Builders
(d) Features—Bibliographic List, News and Notes, International Meetings, Book Reviews, and Abstracts

Notes for the Guidance of Authors

Original papers or technical notes on ferrocement and other related materials and their applications are solicited. Manuscripts should be submitted to:

The Editor
Journal of Ferrocement
IFIC/AIT
P.O. Box 2754
Bangkok, Thailand

Papers submitted will be reviewed and accepted on the understanding that they have not been published elsewhere prior to their publication in the Journal of Ferrocement. There is no limit to the length of contributions but it is suggested that a maximum length of 12,000 word-equivalent be used as a guide (approximately 15 pages).

1. The complete manuscript should be written in English and the desired order of contents is Title, Abstract, List of Symbols, Main Text, Acknowledgements, References and Appendices. The Standard International System of Units (SI) should be used.

2. The manuscript should be typed on one side of the paper only (preferably 8" × 11" bond paper) with double spacing between lines and a $1\frac{1}{2}$ in. margin on the left.

3. Two copies of the manuscript and illustrations (one set original) should be sent to the Editor.

4. The title should be brief (maximum of 150 characters including blank in-between words or other non-alphabetical characters) and followed by the author's name, affiliation and address.

5. The abstract should be brief, self-contained and explicit. The suggested length is about 150 words.

6. Internationally accepted standard symbols should be used. In the list of symbols Roman letters should precede Greek letters and upper case symbols should precede lower case.

7. Each reference should be numbered sequentially and these numbers should appear in square brackets [ ] in the text.

Typical examples are:

1. BROUTMAN, L.J. and KROCK,R.H., "Modern Composite Material", Addison-Wesley Publishing Co., London, 1967, pp. 16—19.
2. DARANANDANA, N. SUKAPADDHANADHI, N. and DISATHIEN, P., "Ferrocement for Construction of Fishing Vessels", Report No. 1, Applied Scientific Research Corporation of Thailand Bangkok, 1969.
3. NAAMAN, A.E. and SHAH, S.P., "Tensile Tests of Ferrocement", ACI Journal, Vol. 68, No. 9, September 1972, pp. 693—698.
4. RAISINGHANI, M., "Mechanical Properties of Ferrocement Slabs", M.Eng. Thesis, Asian Institute of Technology, Bangkok, 1972.

8. Graphs, charts, drawings, sketches and diagrams should be drawn in black ink on tracing or white drawing paper. Illustrations should preferably be drawn on 8"x11" sheets. Photographs should be black and white prints on glossy paper and preferably $3\frac{1}{2}$ in. x 7 in. size.

9. Illustrations should be numbered consecutively and given proper legends and should be attached to the end of the manuscript.

Published by the
International Ferrocement Information Center
Asian Institute of Technology
P.O. Box 2754
Bangkok, Thailand
No. 22/80, October 1980

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