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Discussion of the technical material published in this issue is open until 1 October 1989 for publication in the Journal.

ABOUT IFIC

The **International Ferrocement Information Center (IFIC)** was founded in October 1976 at the **Asian Institute of Technology** under the joint sponsorship of the Institute's Division of Structural Engineering and Construction and the Library and Regional Documentation Center. **IFIC** was established as a result of the recommendations made in 1972 by the U.S. National Academy of Sciences' Advisory Committee on Technological Innovation (ACTI). IFIC receives financial support from the **Canadian International Development Agency (CIDA), Government of France,** and the **International Development Research Center (IDRC)** of Canada.

Basically, **IFIC** serves as a clearing house for information on ferrocement and related materials. In cooperation with national societies, universities, libraries, information centers, government agencies, research organizations, engineering and consulting firms all over the world, **IFIC** attempts to collect information on all forms of ferrocement applications either published or unpublished. This information is identified and sorted before it is repackaged and disseminated as widely as possible through **IFIC's** publications, reference and reprographic services and technology transfer activities. All information collected by **IFIC** are entered into a computerized data base using **ISIS** system. These information are available on request. In addition, **IFIC** offers referral services.

A quarterly publication, the *Journal of Ferrocement*, is the main disseminating tool of **IFIC. IFIC** has also published the monograph *Ferrocement*, Do It Yourself Booklets, Slide Presentation Series, State-of-the-Art Reviews, Ferrocement Abstracts, bibliographies and reports. *FOCUS*, the information brochure of **IFIC**, is published in 19 languages as part of **IFIC's** attempt to reach out to the rural areas of the developing countries. **IFIC** is compiling a directory of consultants and ferrocement experts. The first volume, *International Directory of Ferrocement Organizations and Experts 1982–1984*, is now available.

To transfer ferrocement technology to the rural areas of developing countries, **IFIC** organizes training programs, seminars, study-tours, conferences and symposia. For these activities, **IFIC** acts as an initiator; identifying needs, soliciting funding, identifying experts, and bringing people together. So far, **IFIC** has successfully undertaken training programs for Indonesia and Malaysia; a regional symposium and training course in India; a seminar to introduce ferrocement in Malaysia; another seminar to introduce ferrocement to Africans; study-tour in Thailand and Indonesia for African officials; the Second International Symposium on Ferrocement and a Short Course on Design and Construction of Ferrocement Structures. Currently, **IFIC** is involved in establishing the Ferrocement Information Network in Asia and Africa. **IFIC** has organized the *Ferrocement Corrosion: An International Correspondence Symposium.*

EDITORIAL

The first use of ferrocement was Lambot's boats for his horticultural garden pond in France in 1848. Ferrocement has made tremendous strides since then, and a number of factors, such as the ACI "Guide for the Design, Construction, and Repair of Ferrocement", indicate this progress is accelerating. Yet dispite this favorable growth, the marine application of ferrocment has lagged behind its progress on land. Although ferrocement is widely used for marine applications in several countries, majority of marine structures have been built primarily of steel. Perhaps the factors accountable for this predominance have been the quality and quantity of research and development in design, fabrication and construction for steel structures. The comparative deficiency of knowledge for ferrocement represents an obstacle to the more effective and extensive use of ferrocement for marine applications. The objectives of this special issue are to focus attention in the development on marine applications of ferrocement and to encourage ferrocement researchers and engineers to upgrade the level of ferrocement marine technology.

One major aspect of the marine applications of ferrocement is construction procedure. The effective use of the material requires a greater understanding of the design and construction techniques. Economy depends on the practicability and cost of construction and these in turn depend on the methods selected and developed.

The papers in this special issue include experience from China, Cuba, Indonesia, Thailand and Vietnam. The papers from China consider construction procedure and summarize the applications for the last thirty years. Recent developments in Cuba, Indonesia, Thailand and Vietnam are also reported. This issue may serve as a guide to past practices and a stimulus to the development of new and better methods.

The Editor

Factors Influencing the Durability of Ferrocement

D. Alexander*

Corrosion of the ferrocement mesh has affected several ferrocement structures. A knowledge of the factors influencing the durability of ferrocement is indeed vital. In this paper, the durability factors for reinforced concrete are first presented. Based on the discussion of reinforced concrete durability, the factors influencing the durability of ferrocement are set forth. The behaviours of reinforced concrete and ferrocement with regards to the phenomenon of durability differ only in the degree of protection provided by their assembly. The superior resistance of ferrocement to invading acid ions and gaseous CO_2 is probably due to the use of galvanized steel, fine grained well-graded sands, low water cement ratios, chemical neutralization by the alkalinity of rich mortars, and to compaction which is readily obtained as a consequence of the reduced mass of the ferrocement. In contrast, reinforced concrete uses coarse aggregate which makes void filling more difficult, lower cement ratios which may reduce the alkali content and greater mass which within the limits of economic constraint makes the probability of full compaction less likely.

INTRODUCTION

As a consequence of the importance of reinforced concrete as a structural material, there is a large number of analytical and theoretical work supporting protective measures which are singularly directed toward the reduction in permeability of the concrete with the chosen thickness of cover reflecting the degree of permeability of the concrete.

Because of the great disparity in thickness of cover in reinforced concrete and in ferrocement, there are some arguments that ferrocement differs from reinforced concrete in its behaviour. However, the constituents of both composites are identical and it is likely that they differ only in the degree of protection provided by their assembly. The superior resistance of ferrocement to invading acid ions and gaseous CO_2 is probably due to the use of galvanized steel, fine grained well-graded sands, low water cement ratios, chemical neutralization by the alkalinity of rich mortars, and to compaction which is readily obtained as a consequence of the reduced mass of the ferrocement. In contrast, reinforced concrete uses coarse aggregate which makes void filling more difficult, lower cement ratios which may reduce the alkali content and greater mass which within the limits of economic constraint makes the probability of full compaction less likely.

This paper outlines the practice of using thick covers in reinforced concrete because of its much wider and longer-term use that gives a greater insight into the phenomenon of durability. Based on the durability of reinforced concrete, the resistance of ferrocement against corrosion is discussed.

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DURABILITY FACTORS FOR REINFORCED CONCRETE

The model used in considering the structure of reinforced concrete contains pores and capillary channels which provide routes for the diffusion of moisture and gases, and for acid ions carried by the moisture. When the acid ions reach the steel, the condition for corrosion exists but the severity of attack will depend on the concentration of ions and the presence of oxygen. The ingress of moisture generally comply with Ficks Law of diffusion, but the diffusion of ions and gases are probably more tenuously related. However Weyers and Cody [1] contend that the diffusion of chloride ions also complies with Ficks law.

The different rates of diffusion of CO_2 and chloride ions in the presence of water and the arrest of CO_2 by the neutralisation process indicate that physical and chemical conditions impede diffusion. In the case of CO_2 the higher capillary force of water results in preferential pore filling by water and impedence of CO_2 diffusion. It is noteworthy to mention that the greater mobility of the chloride ion is observed in a sharp rise in concentration of chloride ahead of the carbonation front followed by attenuation [2].

While the high concentration of hydroxyl ion is shown to neutralize CO_2 [3], the reaction with the chloride ion is obscure. Browne [2] stated that hydrated cement provides a reservoir of alkali to "mop up" penetrating chloride but Mehta and Gerwick [4] asserted that there is no change in pH in the presence of the chloride ion which is generally assumed to depassivate the insoluble oxide film on the steel by mechanisms not yet established. They stated that the diffusion of moisture persists while capillary channels exist, but that diffusion of chloride ions is impeded when the channel space falls below a critical width [4]. Browne stated that silanes line, the capillary channels and pores inhibit the ingress of the chloride ions which confirms that diameter is important in the diffusion process [2]. It is considered that tricalcium aluminate reacts with chloride ions to form an insoluble precipitate which must further block diffusion [5].

The above effects could be monitored by measuring the difference between the moisture front and that of the chloride but present permeability determinations are not designed to evaluate them. The influence of permeability is clearly recognised by certain codes of practice, viz. BS 8110, but only in terms of grades of concrete which assumes that the permeability decreases progressively with increasing strength of the concrete. Thus durability is primarily defined in terms of permeability.

The basis of these assumptions has been clearly established for the major factors influencing durability and emanates from the proposition that concrete reaches maximum strength when it is void free [6]. Thus plots of strength versus degree of compaction and the use of void fillers such as polymer, silica fume, globularized fats, etc. show similar beneficial relationships. Curing under water greatly improves the impermeability of surface layers [7] but accelerated curing increases porosity [4].

The factors affecting durability are as follows:

1. Influence of hydroxyl ion concentrations using different cement types.
2. Influence of hydroxyl ion concentration due to different cement contents.
3. Incidence of capillary voids at different water to cement ratios.
4. Effect of compaction intensity on permeability.
5. Influence of curing cycles on permeability.
6. Effect of silica fume on void filling.

7. The effect of the tricalcium aluminate content.
8. Polymer additions to concrete.
9. Effect of surface coatings including penetrant-type solutions (e.g. silanes).
10. Cathodization.
11. Temperature effects.
12. Protective coatings on reinforcement.

The many factors which affect the corrosion susceptibility of the steel underlines the complexity of the problem of specification. A relatively simple solution would be to specify mandatory permeability tests to be carried out after completion of the structure. The tests would be specific not only for moisture but also for harmful agents carried by the moisture. Some care would be needed to ensure that such tests represented real conditions. For instance in a series of diffusion tests carried out [7], it is observed that employing a 7% CO_2 pressurized gaseous atmosphere and a 60% relative humidity, CO_2 penetrated 15 mm into the ferrocement specimens over the nine week period of the accelerated testing. It could be argued that the comparatively dry conditions used in the tests permitted deep carbonation which, in the absence of moisture, would not lead to corrosion. If, however, moist conditions existed, then it is likely that CO_2 would be precipitated as carbonate effectively stopping diffusion of CO_2 to the depths recorded.

REPORT ON LONG TERM EXPOSURE OF FERROCEMENT SPECIMENS

Before proceeding to the discussion on the durability of ferrocement, report on the examination of experimental test plates after a 10.4 year exposure to weather in a moderately severe coastal zone environment is given.

The experimental plates, cast to explore the properties of high tensile wire reinforcement in a 5% fibre mortar, were used in a flexural test [8]. Plain and galvanized wire reinforcements, 2 mm and 2.5 mm respectively, were laid up in layers at 25 mm spacing between wires. The concrete compressive failure stress of the plates was between 48 MPa and 54 MPa. They were deflected to a constant point loading and after unloading showed crack spacings of 18 mm–22 mm and crack widths of approximately 0.05 mm which are generally sub-visual except when wetted. A few wider cracks with a width of 0.07 mm to 0.13 mm occurred in the vicinity of the load points. Although the material differs from mesh reinforced ferrocement its physical behaviour is similar and it is considered that it would reasonably model the corrosion behaviour of the mesh form.

Examination Procedure and Results

The plates selected for examination were locally pulverized to expose the reinforcing steel and fibres in the region of cracks. Observations were carried out in three such regions.

Region 1 – where crack width > 0.07 mm occurred.
Region 2 – where crack width > 0.05 mm occurred.
Region 3 – where no cracks were observed.

The results of the examination are given in Table 1.

Table 1 Results of Crack Examination.

Plate 1	2 mm plain HT wire; 3 mm cover
Zone 1	Corrosion observed at intersections with crack width > 0.07 mm; pitting had commenced.
Zone 2	Incipient corrosion observed at the sites of fine but visible cracks. No visible corrosion observed in sub-visible crack zone. However, on re-examination four weeks later, fine line marking had occurred on the lines of fine cracks adjacent to the coarse crack zone. These markings showed little corrosion in contrast to the rest of the wire where rusting had occurred due to exposure to the atmosphere.
Zone 3	No visible corrosion. No differentiation on re-examination.
Plate 2	2.5 mm HT galvanized wire; 3 mm to 4 mm cover
Zone 1	One single pit type corrosion observed on one wire in a crack width > 0.12 mm zone. No other corrosion observed in this coarse crack zone but on re-examination four weeks later, slight line corrosion was observed under X15 monocular magnification where the crack intersected the wires. It can be assumed that the galvanized coating at these points had been largely consumed during the 10 year exposure. No markings were observed in less-width coarse cracks.
Zone 2	No attack observed either visually or on re-examination with X15 monocular magnifier.
Zone 3	No attack observed. It was noted that the sample plates and all other plates had their fine cracks filled with a white substance. At 5 years exposure this effect was not noted and plates then had to be wetted to distinguish the cracks. Short sections of unfilled crack were locatable with X15 magnification.
Wire-fibre	The ungalvanized wire fibres were totally uncorroded in all pulverized samples up to near surface (1 mm) locations. It was not possible to examine fibres from the crack zone but it seems certain that some corrosion would have occurred in crack sites. As the plate no. 1 carrying plain HT wire showed the same characteristic absence of corrosion, it seems cathodic protection was not a factor.

The conclusions drawn from the observations are: (1) Corrosion attack appears to be limited to crack zones. (2) Galvanized wire is significantly superior to plain wire in crack sites. The author reported further durability observations on warped plate tanks [9] some of which have now been 10 years in service. These tanks have a 22.5 m^3 capacity and are formed (after curing) from 10 mm thick high tensile wire reinforced fibrous ferrocement plates. When formed into tanks the plates show a pattern of just-visible cracks completely around their outer surface at about 18 mm spacings. Destructive testing has not been possible but the tanks show no distress.

DURABILITY OF FERROCEMENT

Based on the discussion on durability of reinforced concrete, the protection of the steel is said to result substantially from the degree of impermeability of the concrete which in turn has been related to the compressive strength of the material.

The main line of defence against corrosion in concrete is the provision of substantial covers to the steel, although in many codes these decrease with decreasing permeability measured in terms of compressive strength. These covers remain substantial.

With ferrocement, covers are minimal, usually between 2 mm to 4 mm. While the permeability of ferrocement may be relatively low when well graded sand, high cement content and low water ratios are used in conjunction with good compaction, evidence does not show that these requirements are effective in reducing the long term diffusion of moisture, CO_2 or chloride ions to depths below than that of the usual 2 mm to 4 mm of cover.

A study on depth of carbonation [7] shows that CO_2 penetration reached depths of 5 mm to 15 mm for a fifteen year equivalent exposure with the lower figure applying to specimens with coated surfaces.

Despite this, there is widespread evidence of long term durability of ferrocement. The results of a ten year examination of cracked test plates discussed earlier showed no deterioration in sub-visual crack zones or uncracked zones of specimens containing galvanized wire.

This does not imply that all ferrocement structures are durable. The result of an examination by Trikha et al. [10] on several ferrocement structures showed substantial corrosion of the ferrocement mesh. However, even in these cases the reduction in strength was of the order of 1 1/2% per annum from which it was concluded that the effective life on the structure would extend well beyond a fifteen year term.

One of the difficulties of adopting permeability criteria is that testing is normally carried out on uncracked sections which may serve the monitoring of reinforced concrete; but ferrocement is designed cracked and exhibits a multiplicity of cracks when subject to working stress and should be tested in this state unless cracks are shown to have little influence on corrosion performance.

For reinforced concrete, Beeby [11] suggested that cracks are not a dominant factor in corrosion, but Mehta and Gerwick [4] showed that crack development contributes to corrosion susceptibility. Brozent et al. [12] showed that a marked increase in diffusivity occurs with cracking while the examination of test specimens after the ten-year exposure reported earlier in this paper showed corrosion of ungalvanized wires to be confined to the crack zones, and of galvanized wire to the coarse crack zone.

It has been shown [13] that in prestressed slabs, corrosion is virtually non-existent in crack width less than 0.05 mm and non-existent in uncracked zones with 50 mm cover when subjected to cyclic exposure to salt solutions.

In the context of relative immunity to corrosion, there are two important differences between reinforced concrete and ferrocement:

1. The reinforcement in ferrocement is historically galvanized, although the ACI Committee 549 does not make this mandatory and suggests it is not necessary in cement rich mortars.
2. With ferrocement the mortar is cement rich and will therefore have greater reserves of alkalinity.

Evidence of the effect of pH is confusing but Hope and Ip [14] suggested that the pH is not affected by the chloride ion concentration. However despite this experimental evidence, it is unlikely depassivation of the steel would occur without a drop in pH [14].

The part the hydroxyl ion concentration plays in the reaction between chloride and tricalcium aluminate to form an impermeable precipitate has not been fully established. The product of this reaction should provide some blocking of pores.

This latter effect is obviously ineffectual in reinforced concrete but the finer capillary and pore structure of ferrocement may permit this function. The apparent deep penetration of CO_2 in ferrocement [7] would not appear to support this thesis but the observation of that study may be invalid in the general case as the infusion of CO_2 was carried out in dry conditions.

It is stated [15,16] that the strongly cathodic protection afforded by galvanized surfaces causticizes the wire environment precipitating chlorides as chloro-aluminate salts.

In seeking an explanation to the comparative immunity of ferrocement to corrosion, the evidence shows that although chloride and CO_2 will penetrate to depths below the level of the reinforcement, they may not activate corrosion unless oxygen coexists. There is also evidence that corrosion in narrow cracks does not proceed because of an absence of oxygen [12] although this absence does not seem likely at the shallow sites of cracks intersecting the steel reinforcement.

It may be conjectured that at the boundary of the mortar surrounding the steel reinforcement, the diffusion characteristics are influenced by chemical reactions arising from the onset of galvanic activity.

The rationale of this layer lies in the much greater volume of influence created by the fine subdivision of the reinforcement in comparison to that of reinforced concrete. Thus ferrocement may consequently contain a greater quantity of reactive material of a type that promotes pore blocking. This function could also be invoked extraneously by the addition of globularized fats, silica fume, polymers, etc., but these substances are ineffectual in arresting corrosion in crack zones. Where galvanized steel is used the cathodic nature of the coating may create a caustic plenum to the shallow reinforcement which would be evident at crack sites as well as internal sites. A study [14] concludes that once chlorides have depassivated the oxide film, the pH at the steel surface drops to between 5 and 9, leaving the system open to ongoing corrosion. This may not occur if a high concentration of hydroxyl ion is built up in the crack zones by the cathodic action of galvanizing. Of interest is the observation that the fine cracks in the specimens reported earlier are now extensively filled with a white deposit which is probably the symptom of the often reported autogenous healing of cracks in ferrocement structures.

CONCLUSION

1. One mechanism accounts for the protection of the steel reinforcement in ferrocement. Evidence however suggests that chemical and electro-chemical protection rather than physical attenuation of diffusion by depth of cover as in reinforced concrete, is the dominant mechanism.

2. The use of fine grained mortar designed to reduce the dimensions of the pore and capillary channel spaces should be maintained together with other devices assisting this process such as low water-cement ratios, thorough compaction in order to render the interstitial spaces more susceptible to pore blocking processes and a moist curing regime.

3. A chemical environment conducive to neutralization of acid radicals entering the system should be employed. This is best accomplished by high cement content but the actual ratio will depend on the fineness of the sand used. ACI Committee 549, recommends a sand-cement ratio of 1.5 to 2.5. The composition of the cement may need to be specified in terms of available calcium and tricalcium aluminate content in which event, cements suitable for use in reinforced concrete may not be appropriate to ferrocement. The literature generally indicates the beneficial effect of

the chloride alkali reaction but the author is unaware that the concentrations needed would in any event be related to the magnitude of the porosity and the channel occurring in the concrete.

4. Despite the evidence of protection of near surface fibres it may be that neither the fibre (where used) or reinforcement wires are immune to attack in a crack zone when the steel is not galvanized. It can be concluded that insufficient hydroxyl ion is mobilized in these zones to afford protection by passivation.

5. ACI Committee 549 recommends that cracking be limited to 0.05 mm width for outside exposures and to 0.10 mm for internal exposures. The evidence for the effectiveness of the former limit appears established but the permissiveness of the internal exposure limit has not been established in this review and has had doubts cast upon it [7].

6. It is not thought that devices such as polymer impregnation, or coatings, or surface impregnations by silanes would be effective in protecting the reinforcement if corrosion attacks at crack sites. The author's observations on coatings, especially elastomers such as chlorinated rubber, show fracture failure over time across both the visible and sub-visible cracks in the ferrocement.

7. In many cases sealing of cracks can occur autogenously. Sealing can also be achieved by the use of impregnating solutions such as Protectasilane [17] after they have developed.

8. The introduction of pore filling substances, such as globularized waxes, silica fume, etc. in the event that corrosion via cracks predominates but is prevented by subsequent crack sealing devices, contributes to an extended life. Neither device may be necessary.

9. The fine subdivision of the steel reinforcement in ferrocement may create a much larger effective volume of boundary layer than that surrounding the large diameter rods used in reinforced concrete and could contribute to the greater chemical protection apparent with ferrocement.

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Ferrocement Fishing Boat

Oemar Handoyo*

The demand for fishing boats to strengthen the growth of offshore fisheries is increasing, as a result, there is a need to identify alternatives to wooden boats. The DTC-ITB has developed six types of ferrocement boat to answer this need. The ferrocement fishing boats developed by DTC-ITB did not only serve as an excellent alternative to wooden boats but the technology is also found to be appropriate for the Indonesian Development Plan.

INTRODUCTION

Development Technology Center (DTC), Institut Teknologi Bandung (ITB) has undertaken development research on ferrocement fishing boat since 1974. Six types of boat have been developed up to a total capacity of 22 000 kg (22 tons). The field applications of various type of boats, construction materials and method of construction was developed in the preceding years. The objectives are to answer the need for fishing boats that will strengthen the growth of offshore fisheries in Indonesia and to identify an alternative to wooden boats. DTC-ITB developed prototype that can equal the seaworthiness and the safety of wooden boats and can promote the government program on preservation of natural environment.

The recent industrial development in Indonesia made all constituent materials for ferrocement locally available, as they are produced in Indonesia. The simple construction method of the ferrocement fishing boat make the development scheme feasible. Local manpower can easily be trained for the construction. The technology is appropriate for the Indonesian Development Plan. Based on those reasons, DTC-ITB developed the ferrocement fishing boat as an alternative to wooden boat.

FERROCEMENT FISHING BOAT

Technical Details

The following is the technical description of the boat adapted by DTC-ITB (Fig. 1):

Overall length	:	12.38 m
Width	:	2.70 m
Freeboard	:	0.67 m
Height	:	1.16 m
Net height	:	4.38 m

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Hull thickness	:	25.4 mm
Longitudinal steel reinforcement	:	6 mm diameter
Cross-sectional steel reinforcement	:	3.2 mm diameter, 100 mm spacing
Hexagonal wire mesh	:	0.6 mm diameter, 12.7 mm opening, 8 layers
Frame reinforcement	:	9 mm and 6 mm diameters
Deck reinforcement	:	6 mm diameter, 50 mm spacing
Sand	:	conform to ASTM C33-74a
Cement-sand ratio	:	1:1.75 by weight
Water-cement ratio	:	0.35–0.40
Mortar crushed strength	:	540 kg/cm² (52.97 MPa)
Engine	:	Diesel 23 HP (Yamaha ME 120H)
Normal speed	:	6.5 knots
Maximum speed	:	8.5 knots
Cargo load	:	3000 kg (3 tons)
Classification	:	Indonesia Classification Bureau (BKI)

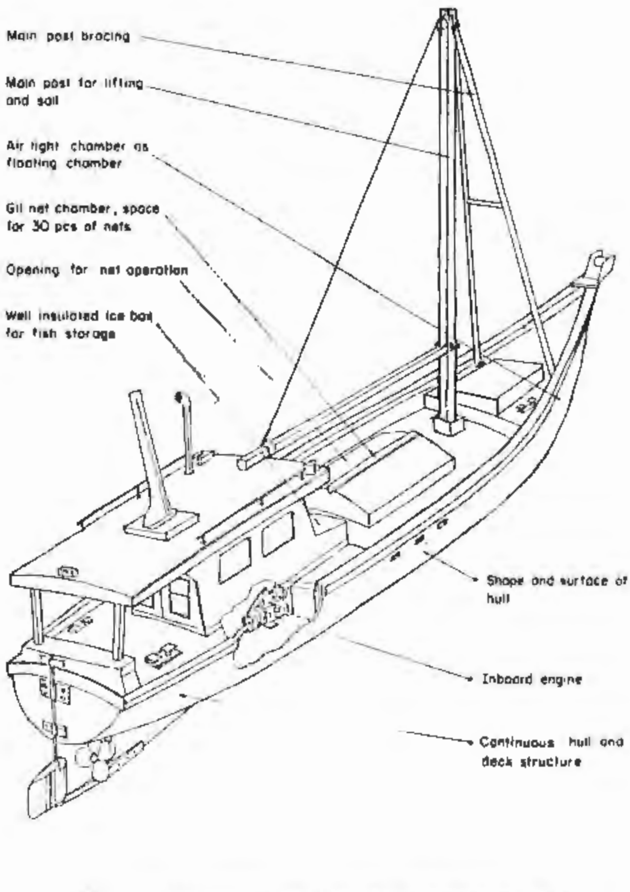

Fig. 1. Ferrocement fishing boat design adapted by ITM.

Fig. 2. The completed armature.

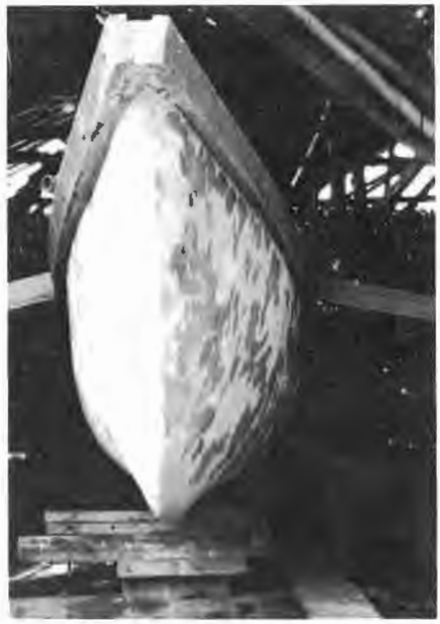

Fig. 3. The completed hull.

Construction Proceedures

All drawings and specifications were prepared at DTC-ITB. The boat was constructed without using mold (Fig. 2). The first step is to fabricate the frames according to the full size drawing. When all frames have been fabricated they are then set up in their correct positions. Welding of the frame needs considerable care to ensure that the finished frame does not get distorted. Then four layers of mesh is tied into both side of the frame.

Plastering of the hull and the deck is done in two stages (Fig. 3). This simple method avoid the need for heavy equipment and will allow the use of local manpower. Fig. 4 shows the relation between hull length and manhours needed.

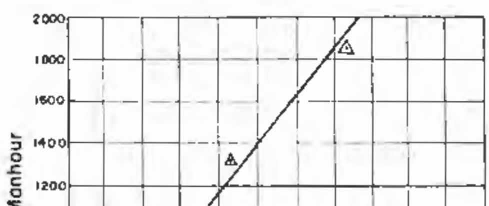

Fig. 4. Manhour relationship to the hull length.

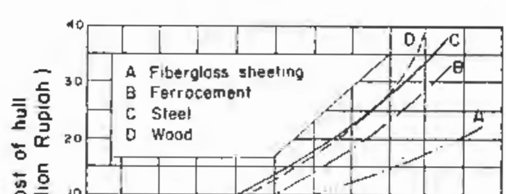

Fig. 5. Cost of hull as function of length.

Table 1 Economic Analysis.

	Ferrocement boat	Wooden boat Small	Wooden boat Big
Number of nets (pieces)	30	20	30
Engines	diesel	bensin	diesel
Design life (years)	10	3-6	6
Investment cost (Rupiah*) (boat, engine, net)	18 900 000	5 000 000	15 800 000
Catch per year (ton)	47.0	19.5	47.0
Gross revenue per year (Rupiah*)	15 600 00	7 100 000	15 600 000
Operational cost per year (Rupiah*)	10 350 000	5 500 000	10 500 000
Net present value (Rupiah*) discount rate 10.4%	6 900 000	650 000	3 250 000
Internal rate of return (%)	19.0	15.5	17.0
Repayment period (years)	3.5	5.0	3.5

* US$ 1.00 = Rupiah 1670

Table 1 shows the economic analysis between a ferrocement boat and wooden boats. The analysis is based on a fishing boat using gill net and on prices in February 1983. Fig. 5 shows the cost of hull of different materials as a function of length.

CONCLUSION

The ferrocement fishing boats developed by DTC-ITB has been successfully used for fishing with gill net, fishing trap and trawl (Figs. 6–7). The 22 tons (22 000 kg) ferrocement fishing boat, launched in June 1982, is in operation up to the present time in the South Java Sea and West Sumatra Sea (Figs. 8–10). No problems have been reported.

Fig. 6. Some ferrocement fishing boats made by DTC-ITB.

Fig. 7. The seventh boat constructed by DTC-ITB.

Fig. 8. Launching preparations at Pelabuhan Ratu, West Java.

Fig. 9. The Samiaji during the fishermen's day.

Fig. 10. The fourth boat made by DTC-ITB.

ACKNOWLEDGEMENT

The ferrocement fishing boat project channelled through the Department of Education and Culture, is registered in the National Planning Board as Project JTA-9(a)-4 and JTA-9(a)-81.

ITB gratefully acknowledges the technical aid from UNDP and from the Cooperation Project of DTC-ITB, TOOL and TH Eindhoven. ITB is also grateful for the support of the Government of the Republic of Indonesia, the Royal Government of the Netherlands and the District of Sukabumi.

Ferrocement Floating Docks: A Solution for the Marina in Cayo Largo del Sur

R. Pajon Brache*

An economical solution for the construction of light berths for pleasure crafts is described. This solution as applied to Cayo Largo del Sur, more than 100 km far from the main Island of Cuba, increases in importance since it greatly reduces the transportation volume of construction materials in relation to the traditional berths. Some construction details, the general dimensions of the facilities, and the harmonization of the structures with the environment are shown.

INTRODUCTION

The Cuban tourist development includes the increase and diversification of facilities for the reception and attraction of tourists.

With this objective, a hotel infrastructure is being constructed in Cayo Largo del Sur, a Cuban key whose geographic position, water transparency, and beautiful beaches offer excellent conditions to develop a marina allowing the berthing of many pleasure craft sailing near it (Figs. 1–2).

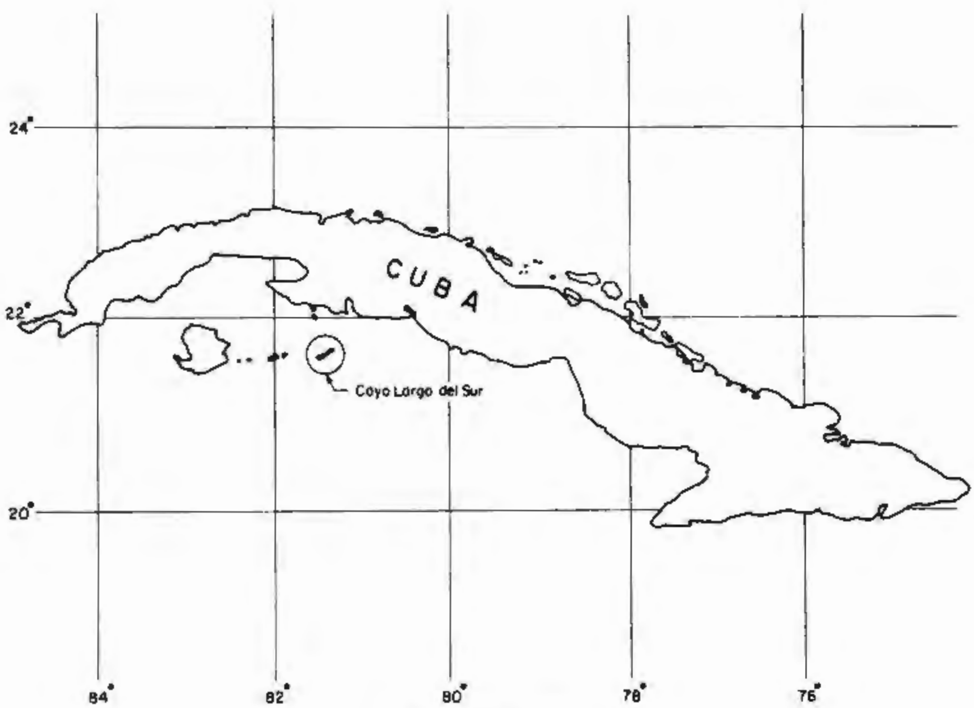

Fig. 1. Map of Cuba.

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MARINAS

The world trend in these facilities was conceived with a large number of berths, where many services are to be supplied: water, electricity, fuel, food, maintenance, minor repairs, nautical activities, etc. Currently the most advanced construction technology uses floating plastic pontoons, or floating reinforced concrete boxes. And for long time now, designers of these facilities have already abandoned the idea of traditional berths with piles.

PROPOSED SOLUTION

The commonly used traditional berth structures, forming part of the Cuban construction practices, do not guarantee the beauty and attraction required in a tourist area. Furthermore, Cayo Largo del Sur is very far from the main Island of Cuba, and consequently all the construction materials are to be carried by ship. Hence it is necessary to reduce volumes and weight in transportation, so as to reduce the cost of the works being executed.

Each traditional 10 m berth precast reinforced concrete or steel piles and cast in situ reinforced concrete beams consumes more than 8.0 m^3 of concrete and 8 piles with 10 m–12 m length; in addition, the equipment and workforce necessary to carry out the activities of pile driving, cutting and levelling, assembly of formwork, positioning of steel and placing of concrete, are all done with floating equipment. This technology when used in Cayo Largo del Sur turns to be too difficult and expensive; the execution of only one berth would cost more than 1000 Cuban pesos.

Floating structures with ferrocement pontoons use only 1/4 of the materials and need only 2 piles for each 10 m of berth. These piles are simpler than those traditional ones, and consequently of lower cost and consumption of materials.

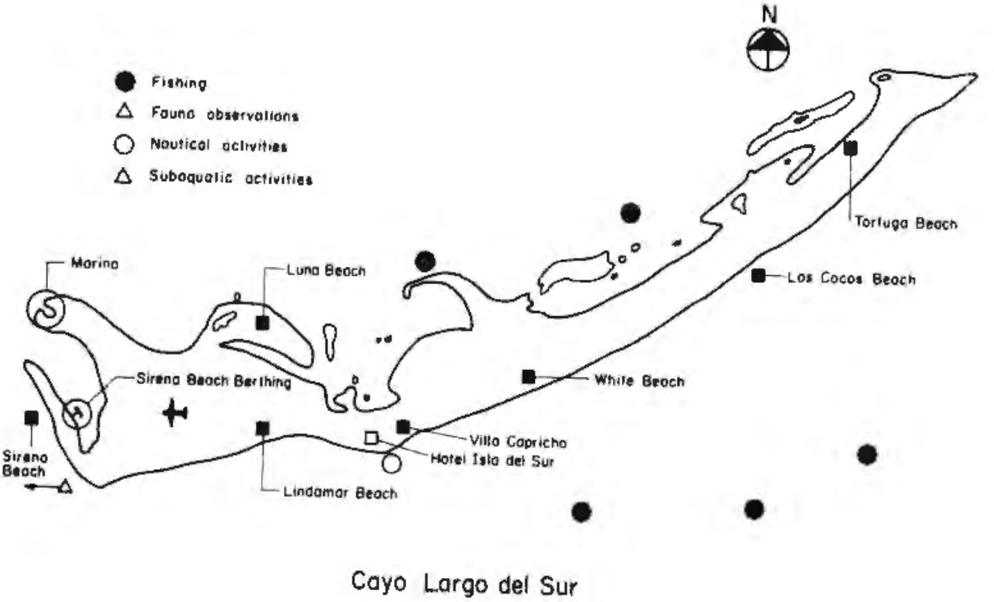


Fig. 2. Map of Cayo Largo del Sur.

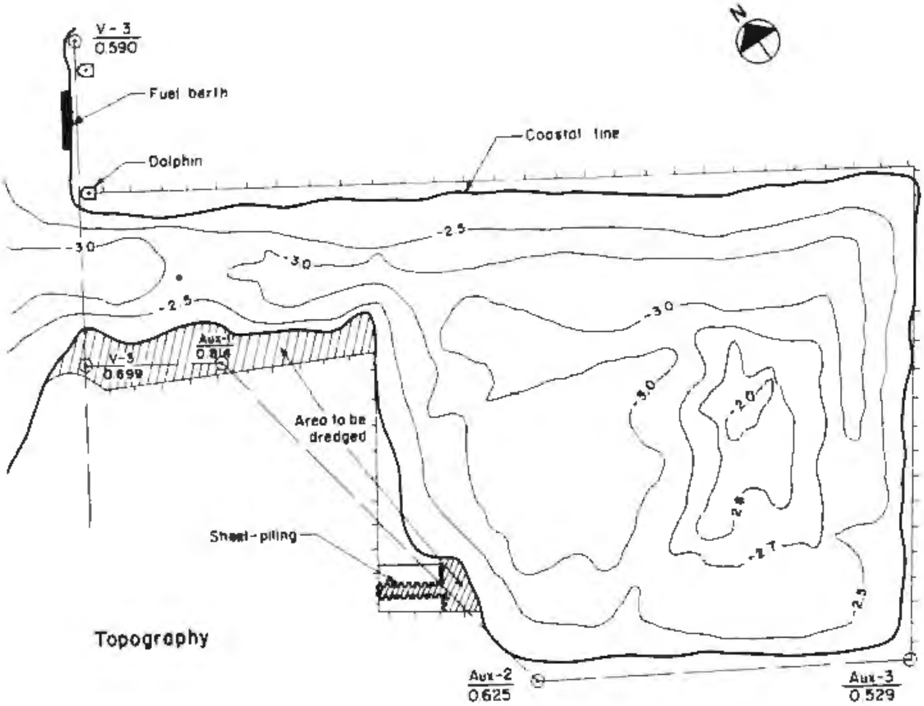


Fig. 3. Topographic map of the marina.

The general solution embraces the perimetral area of the marina, such that the natural coastal environment is not disturbed (Fig. 3). For that purpose a sidewalk covering the retaining structure is foreseen; its front is to be filled in order to shape the slope resulting from the dredging in that area.

The berth access is through a footbridge supported on the sidewalk and on the first pontoon. The details of the ferrocement slab for the pedestrian pavement are shown in Figs. 4–7.

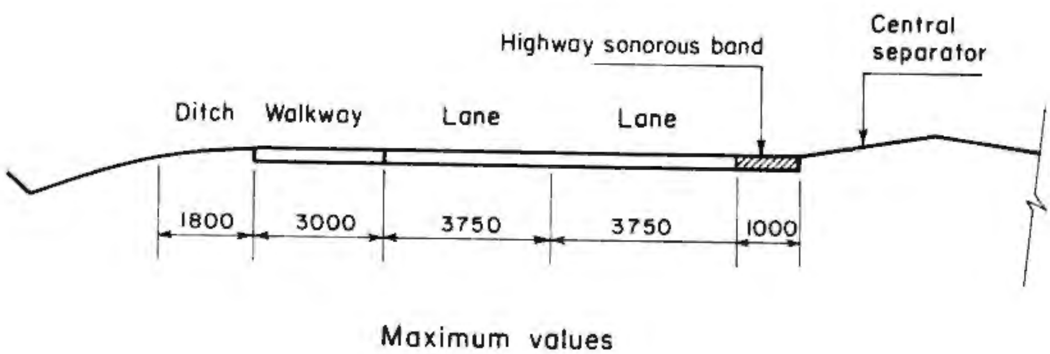


Fig. 4. Tranverse cross-section of the roadway.

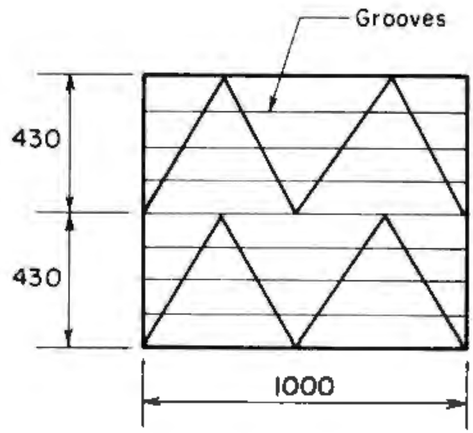
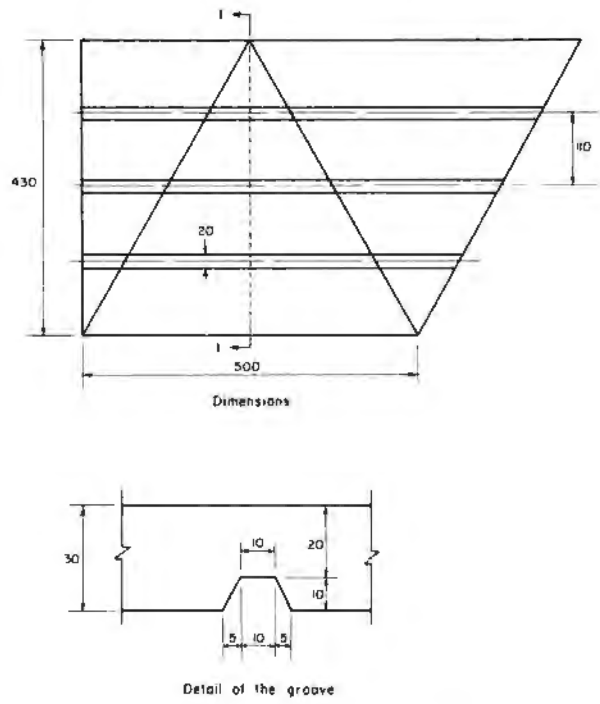


Fig. 5. Plan of the sonorous band.



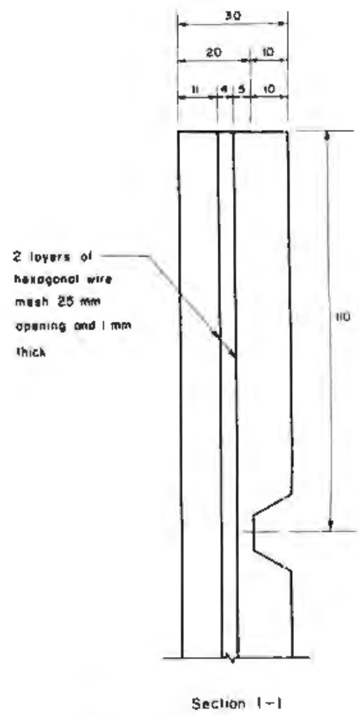


Fig. 6. Dimensions and detail of the sonorous band.

Fig. 7. Details through section 1-1.

The undoubted ease of execution and low cost of ferrocement berth, along with the possibilities to obtain a better finish, assures that a marina in Cayo Largo del Sur could be built and will attract the attention of all visitors (Figs. 8–9).

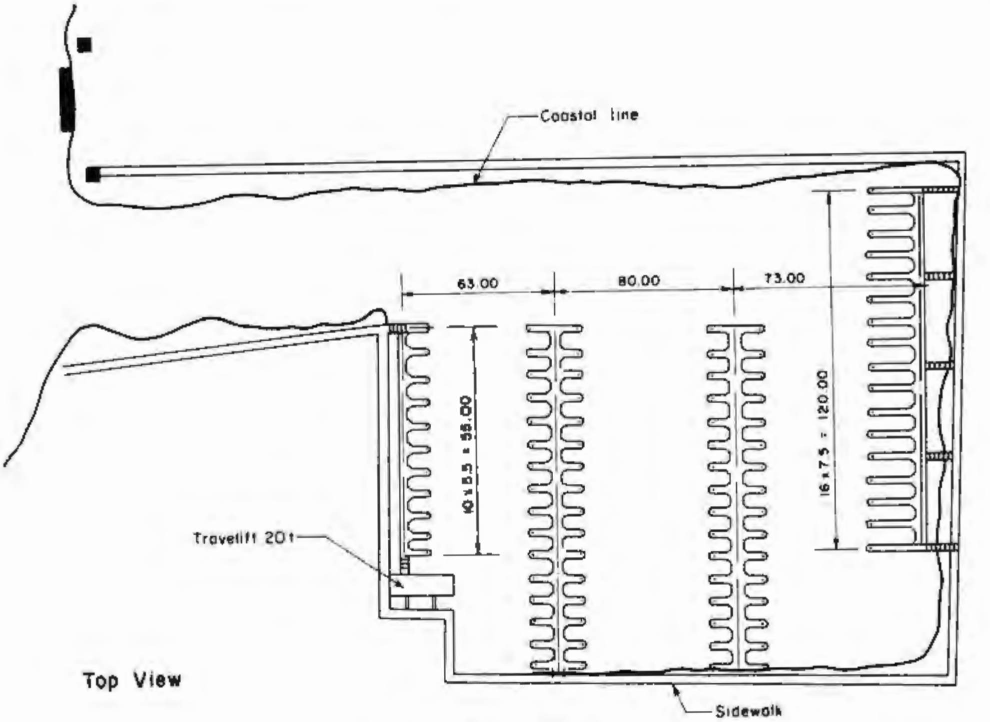


Fig. 8. Plan for the marina.

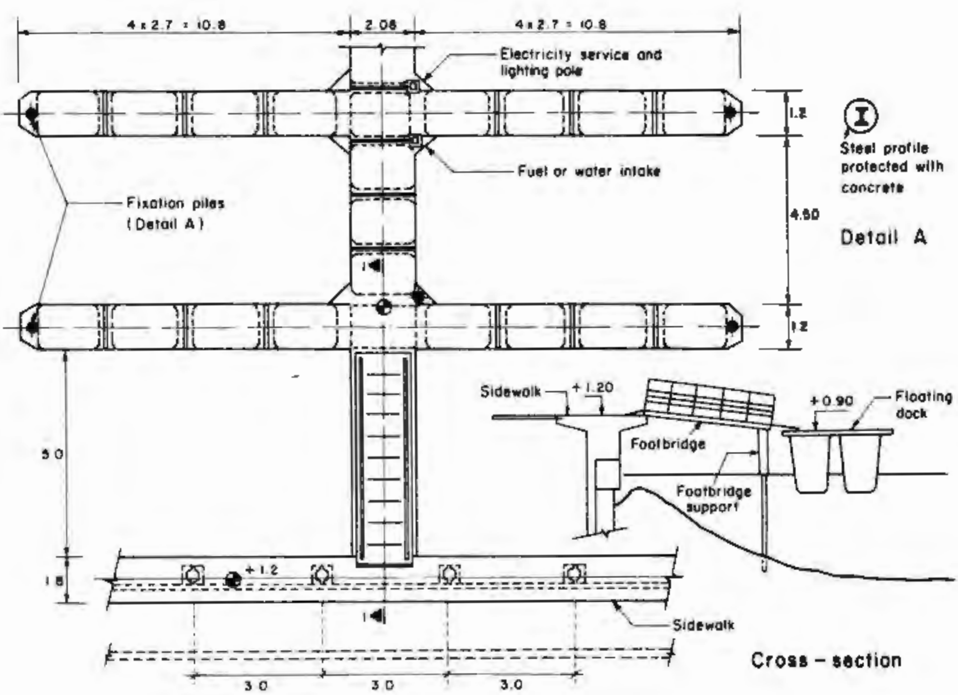


Fig. 9. Details of the marina.

CONCLUSIONS

Ferrocement berths to be used for sport or tourist facilities offer the following advantages:

1. Lesser consumption of materials.
2. Easier execution.
3. Lesser use of floating equipment and skilled labor.
4. Better aesthetic and finish possibilities which allow greater harmonization with the environment in which they are being developed.
5. More versatile and do not require extensive geotechnical studies.
6. Possibility to develop and to enlarge this technology to be used in other nautical facilities.

Ferrocement Sheeting for Steel Hull

Do Kien Quoc*

A new technique using ferrocement for lining steel hull is presented. The construction procedures in treating a steel vessel with corrosion problems is described, as applied to a 20 m long and 5 m wide steel vessel in Vietnam. It was shown that this method is economically feasible and could also be employed to wooden vessels to protect them from the attack of shipworms.

INTRODUCTION

Majority of fishing vessels in Vietnam are made of steel. Working in the environment of sea water, the hull thickness is reduced rapidly due to corrosion. The thickness reduction may be as much as 3 mm in some parts of the hull. Usually 20%–30% of the hull area must be replaced by new steel after one year of operation as it becomes too thin to be safe. This repair is costly since steel is not locally produced in Vietnam.

A new technique using ferrocement for lining a fishing vessel of 20 m length and 5 m width was first tried in May 1988.

FERROCEMENT TREATMENT

The steel hull was lined by ferrocement with a mean thickness of 14 mm on an area of 200 m^2 (Fig. 1). The ferrocement consisted of 2 layers of wire mesh 1 mm in diameter with opening 10 mm x 10 mm at both sides and a layer of skeletal steel bars 6 mm in the middle (Fig. 2).

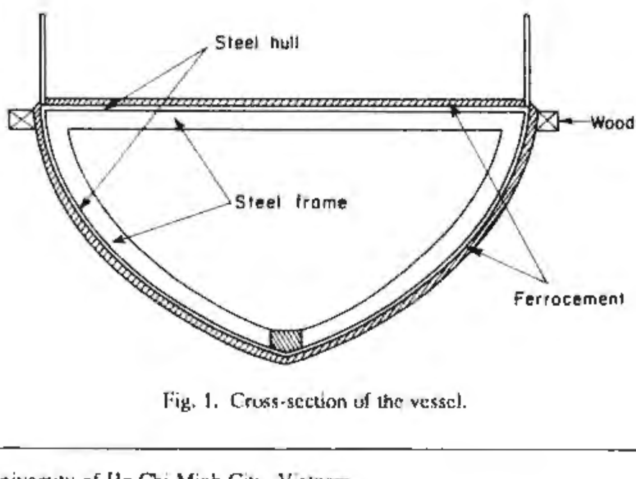


Fig. 1. Cross-section of the vessel.

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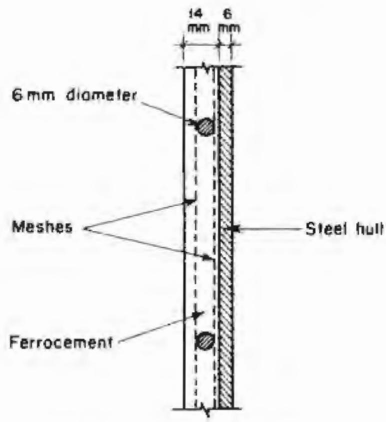

Fig. 2. Details of ferrocement lining over the hull.

The lining procedure was carried out as follows:

1. The parts of the steel hull with thickness less than 3 mm were replaced by new steel with thickness 6 mm. Wire brush was used to clean the steel surface.

2. A wire mesh along the hull was applied and kept in the right position, then steel bars 6 mm were attached along the mesh and welded to the steel hull gradually. The procedure was repeated again for other meshes from upper to lower parts. The welding length of 15 mm was repeated at distance of 100 mm to give sufficient bond between the ferrocement and the steel hull (Figs. 3–4).

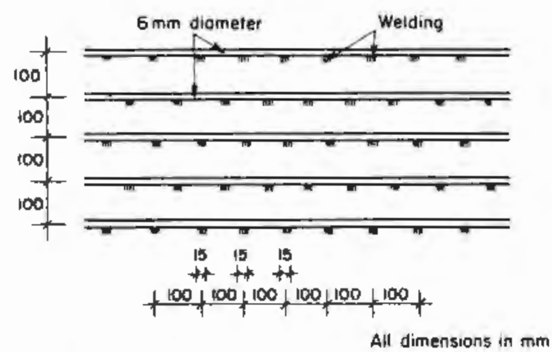

Fig. 3. Attachment of the first wire mesh layer to the hull.

3. The second layer of wire mesh was applied over the skeletal steel bars 6 mm and steel wires 1 mm were placed into the gaps between the bars and the hull to tie the meshes to the bars at distance of 100 mm. Mesh overlap was 80 mm. The ties were flattened to the second mesh layer (Fig. 5).

For the treated vessel, the time to finish the above steps was 20 days.

4. Mortar was used to plaster the meshes. The application of mortar was divided into 2 steps: mortar was applied fully to the level of the second mesh layer and then covered with a thickness of 2 mm–3 mm mortar finish. The total thickness of the ferrocement layer was 14 mm.

Fig. 4. The steel bars welded to the steel hull.

Fig. 5. The wire mesh in place.

For the treated vessel, the mortar was designed to have sand-cement ratio of 1.7 and water-cement ratio of 0.4 by weight.

Plastering was finished in 15 days with four plasterers and two helpers.

5. Water curing was done for a period of 14 days by keeping the treated surface fully wet.

Cost of treatment was equivalent to US$ 3.2/m^2 (about 40% of the cost of the former procedure).

The plastering period was carried out under strong sunshine during summer, hence mortar became hard to work with due to quick evaporation of water. To make mortar more plastic, the plasterers added more water so the water-cement ratio was no longer 0.4 as designed. Excessive water caused gaps between mortar and the steel hull in some parts, and some very small cracks on the surface. These defects may reduce the waterproof ability of the ferrocement layer. However, the vessel has been operating safely on sea since June 1988 with some local corrosions that could easily be treated at sea.

CONCLUSION

The treatment is an alternative to deal with corrosion problem of steel vessels. It is economically feasible if the procedure is to be strictly carried out. This ferrocement treatment could also be applicable to wooden boats and vessels in order to protect them from the attack of shipworms.

Ferrocement Vessels in China

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Jiujiang Experimental Building Yard of Concrete Vessels
Jiujiang Design and Research Institute of Concrete Vessel Engineering

For over three decades, ferrocement vessels have been widely produced and adopted in the People's Republic of China. Its field of application has extended widely as well. Experimental researches have been conducted to develop mechanized methods of construction of the vessel, due to the steady growth of production need. The modern production methods have improved the quality of the vessels. Several vessels, with their varying applications, are presented in this report. These ferrocement vessels have proved to be technically and economically satisfactory.

INTRODUCTION

The development, production and wide adoption of ferrocement vessels in the People's Republic of China started in 1958. During the past two decades, its production scale has been growing steadily, and the number of shipyards has increased remarkably. Accordingly, its field of applications has extended from rivers to the coast. At present, there are four categories of ferrocement vessels available, i.e. agricultural vessels, transport vessels, work boats and fishing crafts. However, these boats are now used for a variety of special vessels.

A series of standard design for ferrocement farm boats, for small ferrocement coaster series and for inland transport vessels have been drafted to meet the requirement of standardization and product series.

Based on experimental research, mechanized methods of construction have been developed. The methods are mechanized moulding, vibro-moulding with inside and outside moulds, vibro-grouting with dry and hard grout, circular joints with anchored reinforcing bars, and hull assembly with prefabricated blocks. The modern production methods have, consequently, improved the quality of the vessels.

AGRICULTURAL VESSELS

In 1961, ferrocement agricultural vessels was initiated in Changjiang Delta provinces. At present, 20 provinces, municipalities and autonomous regions are capable of producing ferrocement agricultural vessels. In fact, in certain regions, ferrocement boats have completely replaced wooden boats.

There are 100 types of ferrocement farm boats in production in China (Figs. 1–9). The most widely adopted types are the 1000 kg–15 000 kg (1 t–15 t) manpowered farm boat, the self-

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Fig. 1. An 8000-kg (8-ton), 12.67 m farmboat equipped with 12 hp engine and adjustable pitch propeller, suitable for agriculture and transport.

Fig. 2. A dual purpose 12 hp farmboat suitable for irrigation and rural transport.

Fig. 3. A 5.75 m, 500 kg (0.5 t) river sludge boat. It has light hull and can be pulled by one man across field ridges. This is produced by vacuum moulding and is used in Guangdong Province.

Fig. 4. A 15 000 kg (15 t) manual sailing boat in Southern China, suitable to transport agricultural products.

Fig. 5. A 5000 kg (5 t) farm boat used in Shanghai.

Fig. 6. A 10 000 kg (10 t), 24 hp engine, used in the waterways network of Zhejiang Province

Fig. 7. A 40 hp agricultural tug boat in Shanghai.

Fig. 8. A 17.12 m, 20 000 kg (20 t) and 25 hp self-propelled farm boat.

Fig. 9. A 15 dwt, LWL 16.6 m, 13.26 km/hr speed and 24 hp engine, self-propelled farm boat popular in Fuzhou City. It was produced by circular block method.

propelled boats up to 40 hp for agricultural transport, the multipurpose agricultural vessels up to 60 hp and the irrigation vessel.

TRANSPORT VESSELS

Ferrocement transport vessels are classified into freighters, including self-propelled barges (Figs. 10–21), passenger ships (Figs. 23–26), tug boats including push boats (Figs. 21–30), ferries (Fig. 31), barges including liquid cargo barges (Figs. 32–37) and traffic boats (Figs. 38–39). The inland river barges are widely used throughout the country. A 300 dwt ferrocement coastal freighter has been operating in coastal waters for 23 years. The hull of this vessel practically does not need repair. The hull is periodically examined and painted.

To develop bigger transport vessels, prototypes were constructed of 3000 dwt coastal freighter, 1320 hp tug boat and the 500-person passenger ship for the Changjiang River. Based from this experience, ferrocement transport vessels not larger than 40 m are technically reliable and economically feasible.

Fig. 10. The cargo ship "Gutian", China's biggest coaster ferrocement vessel (99.1 m LWL, 14.5 m moulded breadth, 8.1 m moulded width, 5 773 000 kg (5773 t) in full load displacement and 13 knots in speed) was in service in Fujian Province, carrying cargo (especially corrosive cargoes) between Chinese coastal harbors for 9 years since 1975. The hull was built with large sized thin web framing and post tensioned prestressed deck. It was produced by sectional method of hull construction, moulding of high frequency vibro-grouting.

Fig. 11. Since 1984, small cargo coasters (32 m length, 2.25 m draught, 2.75 m depth) have been built in Fujian Province. At least 30 of this type have been completed and put into service. The ship is prefabricated in segment and then assembled. To assure the quality of the ship, mortar plastering of the entire hull is carried out under high frequency vibration. It is reported that the initial cost per dead ton weight of these ferrocement ships is 42% less than that of steel ships of the same tonnage.

Fig. 12. "Minhai No. 167" is China's first ferrocement coaster (38.85 m LWL, 7.4 m moulded breadth, 3.7 m moulded depth, 330 dwt and 10 knots speed with a 306 hp main engine). The ship has been in operation for more than 22 years on the Fuzhou-Shanghai route and Xiamin-Hong Kong route. Its hull has not yet been overhauled and its anti-corrosion coating is still intact.

Fig. 13. The cargo ship "Zhehuangji No. 3" with 300 000 kg (300 t) payload capacity, was constructed in accordance to the standard design CB3085-80 promulgated by China Standardization Commission of Ship.

Fig. 14. "Zheciji No. 7" has 150 000 kg (150 t) payload capacity and is popular among operators.

Fig. 15. The 100 dwt coasting cargo ship "Dongying No. 6" operates in the coastal waters of Fujian Province on the Xiamen-Hong Kong route since 1982.

Fig. 16. The 17.1 m, 65 000 kg (65 t) dwt coastal sailing vessel with speed down of 10 knots was commissioned in Fujian and Guangdong Provinces in 1968. On July 1969 it went through a hurricane (No. 12 Beaufort Wind Scale) and heavy tidal waves for more than four hours. Its only damage was one loosen wooden bilge keel with the ferrocement hull left undamaged. The vessel has been operating quite well since then.

Fig. 17. An 85 000 kg (85 t), 24 m LWL, 40 hp self-propelled dump barge in Hunan Province. It is hybrid structure of ferrocement shell with steel framing.

Fig. 18. The 115 000 kg (115 t) barge "Beibo No. 17" operates in the coastal waters of Guangxi Province.

Fig. 19. "Huaishanleng No. 1", a ferrocement refrigerated vessel built in Jiangsu Province, has 32.47 m LWL, 6.6 m moulded breadth, 2.8 m moulded depth and 16 km/hr speed.

Fig. 20. A 60 000 kg (60 t), 21.5 m LWL, 40 hp self-propelled river barge in Guangzhou.

Fig. 21. "Chuangxin No. 101", an 80 000 kg (80 t) self-propelled barge built in 1974 along the ferrocement ship series of Guangdong inland river, is capable of navigating alone or pushing a 120 000 kg (120 t) barge. The ship series consists of 120 000 kg (120 t), 50 000 kg (50 t), 30 000 kg (30 t) and 20 000 kg (20 t) barges.

Fig. 22. "Wuhuo No. 34" is a 25 000 kg (25 t), 19.6 m LWL, 20 hp self-propelled barge in Anhui Province.

Fig. 23. A self-propelled and self loading inland river barge 31 m long built in Kuantung Province.

Fig. 24. Passenger ship "Rongke No. 201" with 26.05 LWL, 250-person carrying capacity was built in 1966 and has been operating satisfactorily in Minjiang river, Fujian Province.

Fig. 25. A 200-person passenger ship "Xiake No. 4" has its external surface coated with epoxy-bitumen, an anti-corrosion paint. It operates betwen Xiamen and Shima, and also in Tongan, Fujian Province.

Fig. 26. A 350-person carrying capacity boat built in Guangzhou in 1975. It is a hybrid structure of ferrocement shell with steel framing.

Fig. 27. An 80 person capacity passenger ship, the "Shenhang No. 815", operates in Zhejiang Province.

Fig. 28. An inland river tug, "Changjiang No. 1014" with 50 m length and 1320 hp, operates in Changjiang River.

Fig. 29. "Ronggangtuo No. 203," a 15.4 m, 120 hp harbor tug. Built in 1958, it is the first ferrocement harbor tug used in China and has been in operation in Fuzhou Port since then. Compared with wooden hull, the savings in repair cost for the ferrocement hull amounts to a sum enough to build another two similar tugs.

Fig. 30. A ferocement tug operating in the Huaihe River in Anhui Province.

Fig. 31. A 19.75 m inland river tug in Jiangsu Province.

Fig. 32. A 48.8 m car ferry, capable of carrying 12 trucks on deck, widely adapted in Changjiang River.

Fig. 33. A 35 m and 300 000 kg (300 t) payload capacity dual purpose integrated barge–capable of carrying both dry and liquid cargoes.

Fig. 34. A 120 000 kg (120 t) payload capacity pusher barge fleet in Xiangjiang River, Hunan Province.

Fig. 35. A 300 000 kg (300 t) carrying capacity integrated pusher fleet in Hubei Province.

Fig. 36. A 30.5 m and 120 000 kg (120 t) payload capacity deck barge in Changjiang River.

Fig. 37. A 180 000 kg (180 t) cargo barge, operates in the shallow river with cobble bed in Yueshan Region, Sichuan Province.

Fig. 38. A 110 000 kg (110 t) cargo barge featuring large hatch opening, operates in the inland rivers of Zhejiang Province and Changjiang River.

Fig. 39. A patrol boat in the inland river between Songjiang and Wusongkou.

WORK BOATS

The ferrocement work boats in China include suction cutter dredger (Figs. 40–41) and floating cranes (Fig. 42). The applications of ferrocement work boats are still increasing.

Fig. 40. A 16 m and 15 000 kg (15 t) inland river sailing vessel in the Minjiang River, Fujian Province.

Fig. 41. A suction cutter dredger in the Minjiang River near Fuzhou City.

Fig. 42. A 168 m, 80 m^3/hr output and 10 km/hr suction cutter dredger operating in Xiaoqing River, Jinan City.

FISHING CRAFTS

There are many types of ferrocement fishing crafts used both in fresh water and sea water (Figs. 43–45). During recent years, research work has been undertaken to optimize the ship structural design and improve construction technology. In practice, new types of hybrid structure are now being used.

Fig. 43. A 16.7 m, 29 KW (40 hp) and 3000 kg (3 t) lifting capacity floating crane.

Fig. 44. A 28.26 m LWL trawler operating in Fujian Province.

Fig. 45. A ferrocement seine netter in Taihu Lake, built according to its wooden prototype, capable of operating in strong wind (Beaufort Wind Scale No. 6).

SPECIAL VESSELS

On account of the merits of ferrocement vessels, a variety of special vessels (Figs. 46–50) are now in use which prove to be economically sound. These increase the diversified applications of ferrocement.

Fig. 46. A water supply vessel, in Xiamen-Gulangyu route for fresh water supply, with 160 000 kg (160 t) carrying capacity.

Fig. 47. A 100 passenger yacht in Taihu Lake.

Fig. 48. A 25 m floating dormitory, accommodates 25 persons.

Fig. 49. A 12 m and 15 000 kg (15 t) sand dumper. It carries and dumps sand and clay during river dredging operations.

Fig. 50. A coating experimental vessel in Xiamen.

Fig. 51. A 50 m long, 25 m wide floating swimming pool in Wuming County, Guangxi Province.

CONCLUSIONS

Ferrocement vessels have been in use in the People's Republic of China for more than 30 years and its production scale has been growing steadily. The number of shipyards has increased remarkably and its applications have been extended to many different crafts. These ferrocement vessels have proved to be technically sound and economically feasible.

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Ferrocement for Water Treatment Plant Ship

Huang Youzhen*

The technique of producing fresh water in cement ships has been developed in China since 1970. These ships are referred to as water treatment plant ships and they are used to supply fresh water to medium and small sized cities as well as large and medium sized industrial enterprises. The experience on the design and use of reinforced concrete and ferrocement for this type of ship is discussed.

It was concluded based from performance that ferrocement is suitable for small water treatment plant ships while reinforced concrete is good for bigger ships.

INTRODUCTION

In China, vessels of reinforced concrete or ferrocement have been built for the last 30 years. Approximately, 4000 thousand tonnage of all types of these vessels have been built. Many technical teams have been trained to design and construct different types of cement ships.

In some medium and small sized cities and also in large and medium sized industrial enterprises, fresh water supply is a problem. The technique of producing fresh water in cement ships has been developed since 1970.

These ships are referred to as water treatment plant ships. The first 5000 t/d ferrocement water treatment plant ship was built in 1977. In the past 10 years, 30 ships have been built with the ability to produce clear drinking water from 2000 t/d to 50 000 t/d. These ships have the total capacity to produce about 400 thousand t/d.

The advantages of water treatment plant ship over the same size terrestrial treatment plant are: non-use of arable land, compact cleaning technique and lower cost. About 80% of all water treatment plant ships have been built with reinforced concrete and ferrocement. Steel hull is only used for ships operating on area of limited draft and rapids. Some ships are hybrid structure of ferrocement with reinforced concrete.

THE WATER TREATMENT PLANT SHIP

The water treatment plant ship is usually rectangular in shape with fixed berth during operation period. Two floors of superstructure are installed above the main deck, the principal floor of the vessel. An example of a water treatment plant ship is the 50 thousand t/d (Fig. 1) the biggest in China, built in reinforced concrete by Ma An Shan Third Waterworks. The dimension of this ship is as follows:

Overall length	82.00 m
Moulded width	21.00 m

* Senior Engineer, Changjiang Ship Design Institute, China.

Moulded depth	3.70	m
Draft	2.70	m
Displacement	4445	t
Frame–space	1.10	m
Deck height		
from main deck to upper deck	3.30	m
from upper deck to topside deck	2.80	m
Complement	40	persons

Fig. 1. The 50 thousand t/d water treatment plant ship.

The office rooms, laboratory, the meeting rooms, the galley, the mess room and accommodations are in the upper deck while the treatment plant is on the main deck. The treatment plant includes central control room, add-chlorine room, add-alum room, air compressor room, vacuum pump room, cleaning tanks and pump room.

The pump room, containing the water pump, mud pump, wash-water pump, etc., should be located either in the middle of the main deck or at the ends according to the production technique and hull strength. It is, however, advisable to place the pump room in the middle to reduce the maximum peak value of the bending moment under full load.

The two cleaning tanks, intake tank, lift room, three stage ferro-net, mixing pond, precipitating pond and filtering pond are located on either side of the pump room (Fig. 2).

Some details of the interior of the 50 thousand t/d water treatment plant ship are shown in Figs. 3–5. The main hull and members of the 50 thousand t/d ship is of reinforced concrete, some secondary members of cleaning tank in ferrocement and superstructure in steel. The specification for the constituent materials are:

Design strength for concrete

Axis anti-pressure strength limit	Ra = 17.2	MPa
Bending anti-pressure strength limit	Rw = 21.6	MPa
Ultimate tensile strength limit	Rc = 1.7	MPa

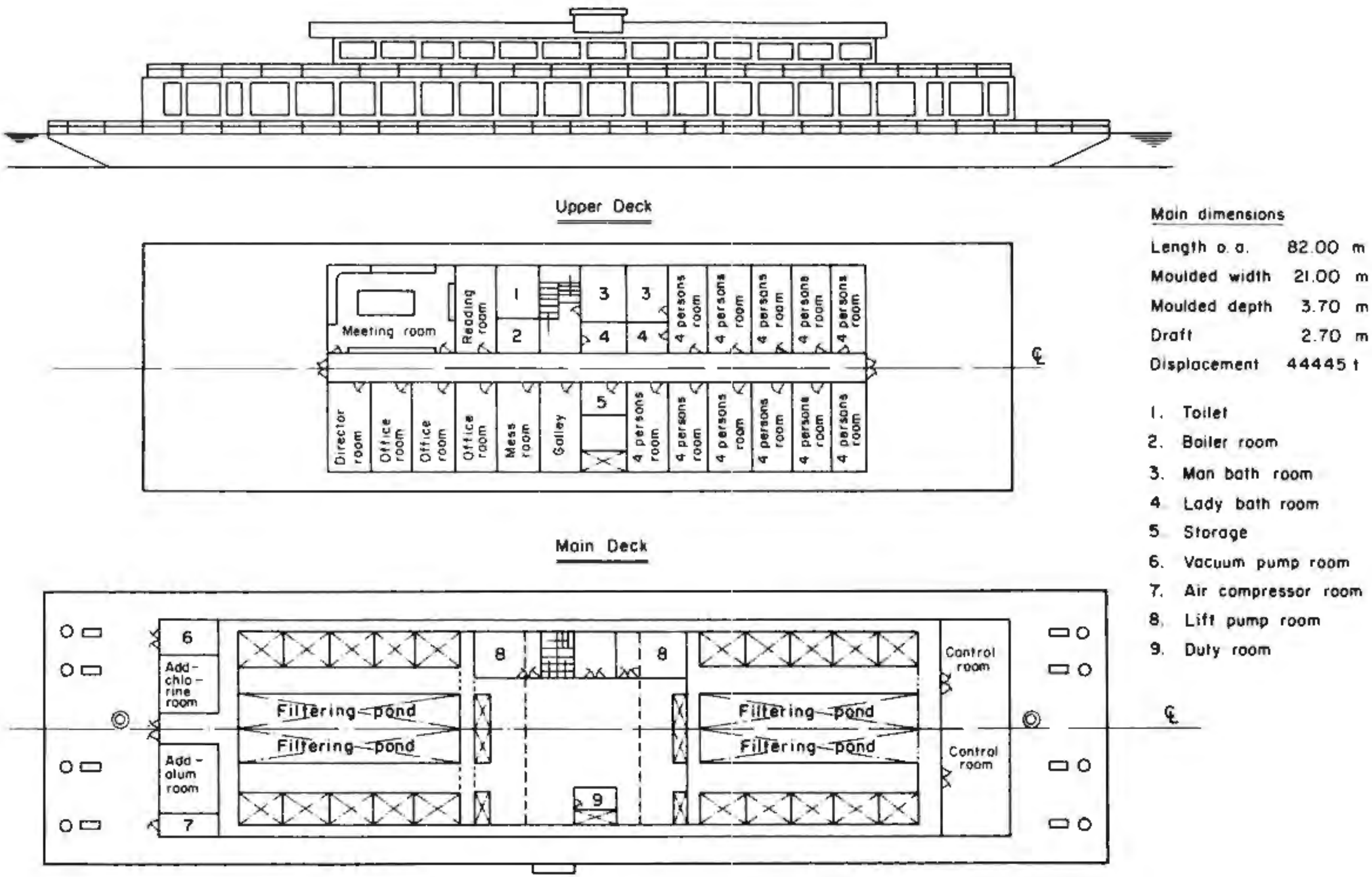


Fig. 2. General arrangement.

Fig. 3. Main deck.

Fig. 4. Pipes inside the hull.

Fig. 5. Pump room.

Anti-break strength limit	Rf = 2.1 MPa
Modulus of elasticity	Eh = $29\text{x}10^3$ MPa
Maximum crack width	0.1 mm
Reinforcing steel	
Class I No. 3	Rg = 235.4 MPa
Class II No. 16	Rg = 333.5 MPa

Design strength for ferrocement

Mortar anti-pressure strength	39.2 MPa
Wire mesh (Cold drawn low-carbon one, 0.9 mm–1.2 mm diameter)	
Ultimate tensile strength	441.45 MPa
Maximum crack width	0.05 mm

The hull should be designed considering wave force. The bending moment and shearing force should be determined under no load and full load conditions. The maximum bending moment should be calculated under the hogging conditions at no load and at sagging conditions at full load. For the 50 thousand t/d ship the maximum bending moment at no load hogging was 24.2 MNm and at full load sagging was 52.0 MNm. The maximum shearing force is 2.94 MN. The required number of steel reinforcement due to bending was checked according to the third working state of reinforced concrete beams. The strength of the steel reinforcement for the deck and bottom were also determined considering hogging and sagging conditions. The steel reinforcement for the bottom board also include reinforcement for bilge stiffeners and longitudinal members. Reinforcement for side plate and longitudinal bulkhead were checked against longitudinal bending, shear stress, and water pressure; and shearing strength along the longitudinal bulkhead and effect of local loads respectively. The steel reinforcement of the main hull is shown in Table 1.

Table 1 Steel Reinforcement of Main Hull.

Location	Thickness/ section	Steel reinforcement Longitudinal	Transverse
Bottomboard	80 mm	14 of 2 mm ϕ @ 100 mm	8 of 2 mm ϕ @ 100 mm
Deck	80 mm	8 of 2 mm ϕ @ 100 mm individually	8 of 2 mm ϕ @ 100 mm individually
Side Plate	80 mm	8 of 2 mm ϕ @ 100 mm individually	8 of 2 mm ϕ @ 100 mm individually
Bottom longitudinal frame	130 mm x 320 mm	18 of 4 mm ϕ (hooped reinforcement 6 mm ϕ @ 100 mm)	18 of 2 mm ϕ
Frame	130 mm x 300 mm	18 of 4 mm ϕ (hooped reinforcement 6 mm ϕ @ 100 mm)	18 of 2 mm ϕ
Deck longitudinal frame	100 mm x 250 mm	16 of 4 mm ϕ (hooped reinforcement 6 mm ϕ @ 100 mm)	16 of 2 mm ϕ

To improve working quality and reduce the berth period, prefabrication of specific members are recommended. The weight of prefabricated members should not exceed 9000 kg. The joints are formed by overlapping outstanding reinforcements. The length of overlap should not be more than 10 times the diameter of reinforcement. The prefabricated members are: side board, deck longitudinals, all of longitudinal and transverse bulkheads, the longitudinal and transverse baffle plates of precipitating pond and filtering pond. The sections cast in site are: bottom board and frame, deck board and longitudinal continual girder.

Watertightness test was performed. The reinforced concrete has no problem. However, the cast in situ ferrocement water tanks have seepage problem.

CONCLUSION

The 50 thousand t/d water treatment plant has exceeded the design weight but just satisfied the design requirement of draft (d = 2.70 m). In water treatment plant ship, weight is an important factor as it affects the draft. Increase in draft will reduce the siphone pressure head and may cause failure.

Based from performance, ferrocement is suitable for small water treatment plant ships while reinforced concrete is good for bigger ships. This application is now widely developed in China.

Songkla Lake Fishing Boat

Sukda Konganum*

The Songkla Tinsulanond Fishing College investigated the possibility of building low-cost fishing boats. Consultants of the college recommended the use of ferrocement as a construction material. The transfer of the technology to students of the college is presented.

INTRODUCTION

Fishing plays an important role in the economy of Songkla, a southern province in Thailand. The Songkla Tinsulanond Fishing College was established to help the fishing industry in this province. In addition to its regular course, the college has provided training on trawl fishing and conducts research on relevant topics.

To further encourage fisherman, the college investigated the possibility of building low-cost fishing boats. Assistance was requested from the Ayuthaya Boatbuilding College and the Committee on Planning, Cooperation and Establishment of Industrial and Shipbuilding Center. Consultants from these institution recommended ferrocement boats as the solution.

This paper describes the construction of the first fishing boat at Songkla Tinsulanond Fishing College under the supervision of the author.

DESIGN AND CONSTRUCTION

The ferrocement fishing boat, weighing 800 kg, costs Baht 8000 (US$ 320). The 5 m long, 1.2 m wide and 0.90 m deep boat was constructed in 15 days by five students with assistance from two ferrocement resource persons and two carpenters. The design of the boat was based from locally available traditional fishing boat.

The lofted drawing of the ferrocement hull consists of a body plan, profile and half breadth (Fig. 1). Using these plans, the frame was made for all stations with 9.53 mm diameter steel bars. For the keel, 6.35 mm diameter bars were used. A numbering system was used to assist in the final assembly of the armature (Fig. 2).

Five layers of wire mesh were used. Two layers of welded mesh were place outside and three layers of hexagonal mesh inside the armature. The mesh were draped from the deck downwards and pulled constantly to maintain tension to obtain a fair shape hull. The five layers were tied together at 75 mm spacing longitudinally as well as vertically (Fig. 3).

The cement, sand and water ratio was 1:3:0.4. Plastering was started from the keel bottom. The matrix was pushed from outside to inside to ensure complete penetration. Both surfaces were smooth finished maintaining the same thickness. The completed hull was cured for 28 days (Fig. 4).

* Ayuthaya Boatbuilding College, Ayuthaya, Thailand.

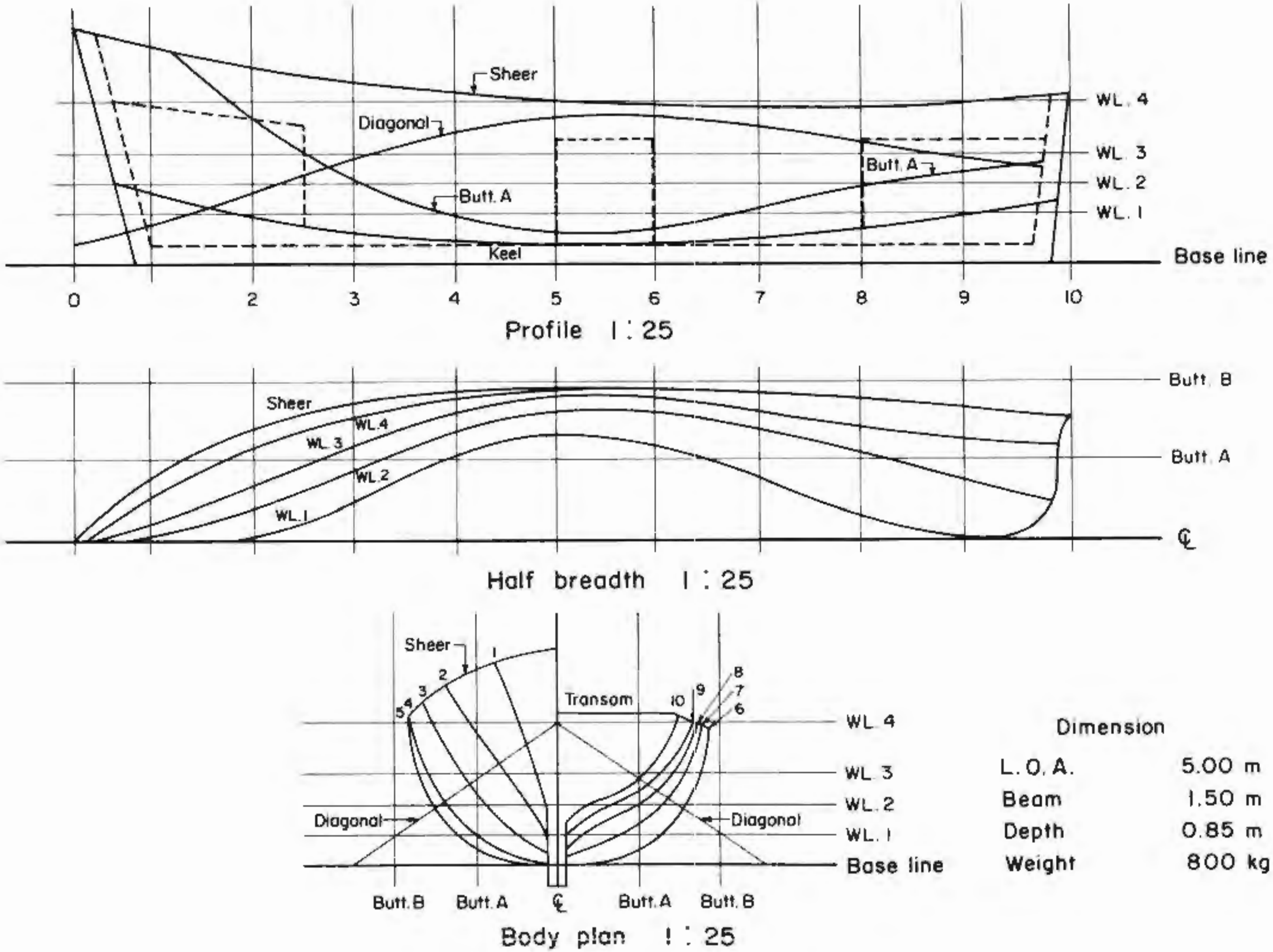


Fig. 1. Plans for the ferrocement hull.

Fig. 2. The completed armature.

Fig. 3. The students with the ferrocement hull ready for plastering.

Fig. 4. The plastering of the ferrocement hull.

Fig. 5. Students of Songkla Tinsulanond Fishing College testing the boat.

CONCLUSION

The technology for building a ferrocement hull can be easily learned. Students of Songkla Tinsulanond Fishing College are now building ferrocement fishing boats (Fig. 5). After three years the fishing boats have had no problems.

Development of Ferrocement Boats in China: 1958–1988*

A Pictorial Presentation

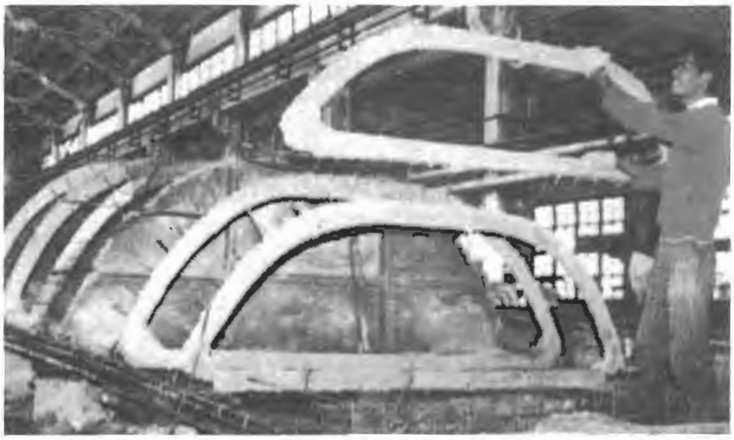
CONSTRUCTION PROCEDURE

A view of the factory.

The wire mesh used for the construction is also produced in the factory.

Tieing the wire mesh into required width.

* Excerpt from "Concrete Vessels in China (1958-1988)", with permission of the publisher. Publication sent by Mr. Zhang Xiaoyang, Shanghai Ship & Shipping Research Institute, Ministry of Communications, China.



Positioning of the frames.

Placing the wire mesh over the ferrocement armature.

Plastering the cement mortar by high frequency equipment.

Close-up of the high fequency grouting equipment from the hanging trolley.

Close-up of a portable high fequency fibrating plastering board.

Completed ferrocement hulls.

FERROCEMENT BOATS (1958–1988)

The first ferrocement sampan.

Ferrocement vessels for irrigation and drainage.

A 5000 t ferrocement floating dock.

A ferrocement hold-barge fleet.

A 3000 t sea boat.

COMMITTEES AND FOREIGN GUESTS

Annual meeting of the Chinese Network on Scientific Information of Cement Boat.

United Nations sponsored a seminar on Ferrocement in Asia and the Pacific Region.

Korean experts visiting the manufacturing site of tap water boats.

Mr. Ioms, an American expert on ferrocement boats, visiting a cement boat factory.

TIPS FOR AMATEUR BUILDERS

This section provides illustrated information and details of construction to help the user to construct ferrocement structures quickly, easily and economically.

The Distribution of Trim Ballast[*]

S.S.Z. Ray[+]

Often, due to variations in the construction or finishing of a boat from the calculations of the designer, when the boat is first floated it does not float at the designed water line. There are monographs in books such as Skene's *Elements of Yacht Design* which give the additional ballast required per inch (25.4 mm) of additional immersion required to obtain the correct position of the boat in the water.

To obtain best roll and handling charactristics, an often-overlooked rule of thumb is that for typical hull shapes, one-fourth of the added ballast should be located roughly at the water line. For slender hull shapes, use one-sixth instead of one-fourth. For beamy hulls, use one-third instead of one-fourth.

It is not difficult to add trim ballast in a distributed manner. One-eighth inch (3.175 mm) thick lead sheet may be glued to the hull with polysulfide rubber in pieces appropriate and concealed behind paneling, cabinets, etc. It should also be distributed rather evenly fore-to-aft to avoid unstable pitch characteristics.

To obtain the amount of trim ballast required, hold a ruler between the length at waterline and beam at waterline measurements for your hull (Fig. 1). The required ballast weight per inch (25.4 mm) of immersion will be shown on the middle line. If the boat is higher at one end than the other, use the number given on the nomograph (per inch (25.4 mm)) times the difference in immersion depths fore-to-aft, distributed over the lightest half of the boat (the appropriate fraction at the waterline). The total amount of ballast should be calculated from the additional immersion required amid-ships. As you add weight at the bow, be particularly attentive to how the stern moves up as the bow moves down and distribute the ballast accordingly. Do this with water tanks full and all ground tackle aboard. Now take the boat out for a sail and see how she handles.

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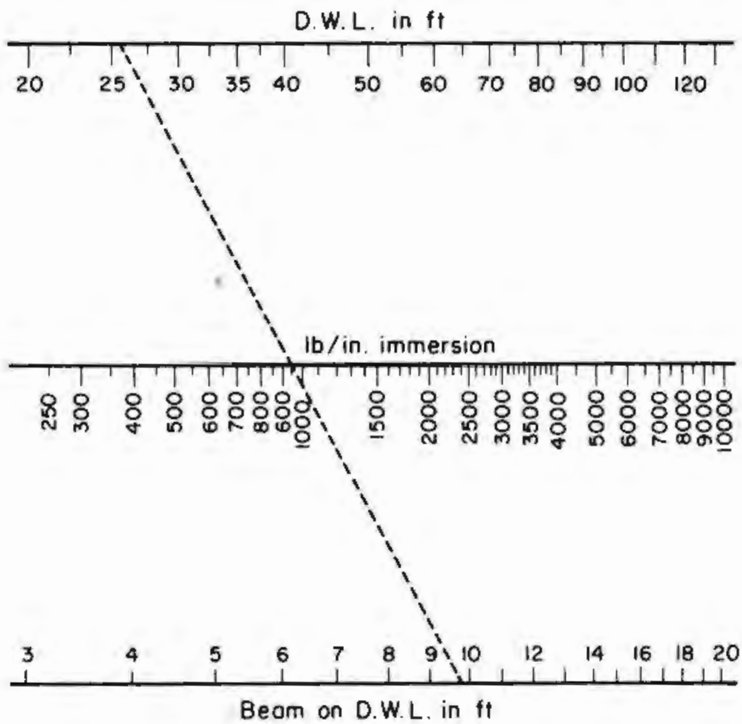
[*] Reprinted from "How to Finish Your Ferrocement Hull" by permission of the publisher.

[+] Master boatbuilder.



Connect points on top and bottom lines with straight line. Read answer on middle line.

Note : 1 lb = 0.454 kg
1 in. = 25.4 mm
1 ft = 0.3048 m

Fig. 1. Nomograph for lb/in. immersion in salt water.
(1 lb/in. = 0.1751 N/mm)

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This list includes a partial bibliography, with keywords, on ferrocement and related topics. Reprints and reproductions, where copyright laws permit, are available at a nominal cost (see page 319).

All information collected by IFIC are entered into a computerized database using CDS/ISIS System. Stored information can be retrieved using keywords, author names, titles, etc. Specialized searches are performed on request.

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composite materials / Young's modulus

FAST LOOKUP

INFC and IFIC Databases

The INFC and IFIC databases will save your time and effort in finding current information on ferrocement and related construction materials. These databases are created and maintained by the International Ferrocement Information Center (IFIC), Asian Institute of Technology, Bangkok, Thailand using UNESCO's Computerized Documentation Service/Integrated Set of Information Systems (CDS/ISIS).

The highly specialized construction materials included in the databases are directed to answer the needs of the low-income people in the developing countries. They cover ferrocement, the form of reinforced concrete which uses hydraulic cement mortar, and closely spaced layers of continuous and relatively small diameter wire mesh reinforcements; and related construction materials, such as steel fiber composites, bamboo fiber composites, natural and organic fiber composites, and polymer composites.

IFIC regularly reviews over 100 journals, magazines, newsletters, digests and bulletins, in addition to numerous monographs, reports, conference proceedings, theses, and materials supplied directly by ferrocement builders and researchers. From these publications, articles on ferrocement and related construction materials are identified, abstracted, indexed, and entered into the bibliographic databases.

Each record contains primary information: author, title, source, abstract and keywords; and secondary infromation: availability, date, language and type of publication.

INFC and IFIC databases contain over 3,500 records and these are expanding at the rate of 300 records per year. From these records, IFIC provides computerized biliographic search services for requests on particular aspects of ferrocement technology and related materials at the following rates:

Subscriber:	US$ 40.00	per contact hour
	US$ 10.00	upto 50 references
	US$ 00.07	for each additional reference above 50
Non-Subscriber:	US$ 60.00	per contact hour
	US$ 15.00	upto 50 references
	US$ 00.10	for each additional reference above 50

Precise description must accompany requests for search service so as to minimize costs. Requests (particularly for letter and telex requests) must include the following: (a) brief but clear summary of the research topic; (b) list of keywords and synonyms; (c) expected number of references; (d) cost limitations; (e) output specifications (date and language restrictions); and (f) degree of urgency of the request. The search print out contains a list of references, which may include abstracts if requested.

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NEWS AND NOTES

FIN NEWS

University of the Philippines

Miss Lavon Mary G. Abis, participant of the 1988 Trainer's Training on Ferrocement Technology and affiliated with the Building Research Service, National Engineering Center, University of the Philippines, has been actively involved with technology transfer activities.

The last week of February 1989, she conducted in Calaca, Batangas, a demonstration/ training on the use of fly ash (from the National Power Corporation's coal-fired thermal plant) for hollow blocks and bamboo-reinforced concrete pavements. The bamboo was used as an alternative because the fly ash was mixed with sea water (to aid the immediate transport of the ash to the ponds surrounding the plant) and contains salt sprays. The jointing methods at the intersections of the bamboo slats spaced 300 mm on center were either tied with ordinary straw cut in 300 mm lengths or nailed with 25.4 mm nails. Results of the first month construction inspection were favorble because no visible cracks were observed.

The Building Research Service will also start a Productivity Study for the Construction Industry Authority of the Philippines, DTI. This would be a study of representative construction firms productivity levels and recommend productivity enhancement guidelines plus a manual for a firm's self-assessment. This will be funded by the World Bank.

Demonstration house using coco-timber truss-frame system.

The University of the Philippines has also two (2) demostration houses–one using coco-timber truss-frame system which is fabricated using gang-nail metal plate connectors and rice hull ash-lime block walls both for low-income family housing, which are both under the Department of Science and Technology–U.P. Program "A".

She has been invited by Prof. Jose de Castro, FIN (Philippines) coordinator, to lecture and design a seminar for the Association of Structural Engineers of the Philippines (ASEP) entitled tentatively "Structural Applications of Ferrocement." This is scheduled for August of this year.

(Information and photograph from Ms. Lavon Mary G. Abis, Building Research Service, National Engineering Center, University of the Philippines, Diliman, Quezon City 1161, Philippines.)

REFERENCE CENTER NEWS

Philippine Council for Industry and Energy Research and Development (PCIERD)

The Philippine Council for Industry and Energy Research and Development (PCIERD), as part of its on-going activities on research and development in the application to industry, energy and infrastructure, will be undertaking a research project on ferrocement technology for the local shipbuilding industry. The project involves the construction of a prototype ferrocement boat. This project will be implemented by the *Maritime Industry Authority* (MARINA) in cooperation with the *Philippine Shipbuilders and Repairers Association* (PHILSAR).

In connection to this, the Council held a *Seminar on Ferrocement Technology* on 7 June 1989 which coincided with MARINA Day.

The topics discussed were the basic principles of ferrocement and its wide applications. These included the raw materials, the mechanical properties and the proper construction techniques. A short slide presentation was also included.

The target participants were Maritime Industry Authority; Philippine Shipbuilders and Repairers Association; and the Confederation of Inter-Island Shipping Organization.

The resource persons were Ms. Lavon Mary G. Abis, U.P. Building Research Service; and Engr. Edgardo P. Santibanez, PCIERD; participants of the Trainer's Training on Ferrocement Technology conducted by IFIC in 1988.

(Information from Edgardo P. Santibanez, Science Research Specialist II, Energy and Utilities Systems Technology Development Division, Philippine Council for Industry & Energy Research & Development.)

CUBA

A Ferrocement Swimming Pool

A 12.5 m x 25 m ferrocement swimming pool was built for the People's Camping Base "Presa Mamposton". It has a depth ranging from 0.70 m to 2.10 m. This swimming pool was constructed in two months by unskilled labours and the cost is lower than those constructed out of reinforced concrete.

(Information and photograph from Mr. Fidel Delgado, Chief, Technical Information Center, Centro de Informacion Tecnica, Cuba.)

Swimming pool under construction.

BANGLADESH

Rainwater Catchment for Rural People

The Department of Farm Power & Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh is initiating a project on rainwater catchment for the rural areas of Bangladesh.

Three locations have been selected. In each location, five ferrocement tanks will be constructed having capacity of 10.5 m^3. This tank will be able to supply water for a family of six members for a period of five months.

(Information from Dr. Md. Daulat Hussain, Head, Department of Farm Power and Machinery, Bangladesh Agricultural University.)

INDIA

Technology Mission on Drinking Water

Training of Resource Persons/Trainers in Ferrocement Technology

The Government of India has launched a Technology Mission on Drinking Water and Related Management for solving the problem of drinking water in the villages where water is not available. The Department of Rural Development, Ministry of Agriculture, Government of India, is a nodal agency for this Mission. The Council of Scientific and Industrial Research (CSIR) is collaborating by providing cost effective solutions for specific problems related to chemical, physical and bacteriological contamination, ground water exploration and related water management. Several techniques have been adopted for solving problems of excess iron, fluorides, salinity, turbidity, scientific finding of ground water and recharge of water sources, improving of traditional water sources, collection of rain water etc. Priority has been fixed for adopting rain water harvesting in those areas where enough rainfall is available. The Mission has approved ferrocement water storage tanks for collection of drinking water due to its low cost and ease in construction and maintenance. Problems of the water in the hills, islands and coastal belt of the country can be solved easily by adopting rain water harvesting through roofs and micro-catchment platforms. Ferrocement has been accepted for construction of water filters and tanks for these schemes.

The Structural Engineering Research Center (SERC) formerly at Roorkee and now at Ghaziabad has been entrusted with several projects, namely: (l) Organisation of training courses and demonstrations of construction techniques of rain water harvesting schemes and ferrocement water storage tanks at various locations in the country; and (2) Development of ferrocement structures such as check-dams, underground water barriers, water filters and large capacity water tanks etc. for water harvesting schemes.

The Center has already conducted ten training courses for field engineers, technicians, planners and volunteers drawn from Public Health Engineering Departments, Rural Development Departments and Voluntary Agencies. A set of lecture notes compiled in two volumes, have been prepared and is being provided to the participants. The 'Do It Yoursef' booklet on ferrocement water tanks published by IFIC has been included in Volume 2 of the lecture notes. A total of about 450 participants representing States of Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, Assam, Tripura, Nagaland, Meghalaya, Manipur, Karnataka and

Participants with the ferrocement water tank elements during training-cum-demonstration course at Shillong (Meghalaya), April 1988.

Casting of ferrocement water jar during training-cum-demonstration course at Dimapur (Nagaland), October 1988.

Demonstration of the casting of ferrocement water tank by skeletal cage system during training-cum-demonstration course at Gulbarga (Karnatake) in December 1988.

Andhra Pradesh have been trained by the Scientists of the Center. The syllabus for these courses include details for construction of rain water collection system using roof, platforms and hill slopes as catchment area, casting techniques for ferrocement tanks up to 10000 litre (10 m^3) capacities including sack mould method, skeletal cage making and plastering technique, segmental ferrocement tank construction (SERC patented process), semi-mechanised process (SERC patented process), tempformer system, pit lining method for underground tank construction and ferrocement lining over brick/stone masonry tanks.

A large number of ferrocement tanks and filters have been constructed during these courses in Manipur, Meghalaya, Nagaland, Madhya Pradesh, Uttar Pradesh, Tripura and Karnataka States.

The response to these training courses has been very encouraging and many States have taken up construction of rain water harvesting schemes and ferrocement tanks on large scale for solving the drinking water problem in their villages.

Ferrocement Applications Exhibited in India

Structural Engineering Research Center, Ghaziabad has been organising full scale demonstration of construction techniques and displays of construction methods of various ferrocement structures at the engineering/technological exhibitions in India. The following exhibitions have been organized:

National Zonal Seminar on Water Problems in Hill Areas, Nainital (September 1988)

The seminar was organised by Department of Rural Development, Government of India in collaboration with the U.P. Jal Nigam. Construction of ferrocement water tanks, roofing units, septic tanks, rain water filters, drainage units, man-hole covers etc., were demonstrated.

Large number of charts, models and actual structures were exhibited. A lecture-cum-slide show was organised explaining the advantages, economics, usefullness and construction techniques for ferrocement structures for solving various problems in hill areas. About 1,000 engineers, technicians, social workers and administrators attended. The Honorable Minister for Hill Development, U.P. Government, Shri R.K. Dhar, Principal Secretary and Coordinator, Hill Development, Government of U.P., Shri Pande, Secretary, Rural Development, U.P. Government, Shri Rajeswar Dayal and Shri Virendra Kumar, Chief Engineer, U.P. Jal Nigam visited the demostration.

National Seminar on Water Harvesting Systems and their Management, Bangalore (22–24 December 1988)

Department of Rural Development, Government of India organised this seminar in collaboration with the Public Health Engineering Department, Government of Karnataka held 22–24 December 1988. A large size stall was erected to display several ferrocement units and the construction techniques for ferrocement tanks, irrigation channels, man-hole covers, septic tanks etc. More that 2,000 engineers and contractors visited the stall. During one of the seminar sessions, a slide show was arranged to explain the potential applications and advantages of ferrocement structures. Demonstration of casting techniques for few structures was also organised for the benefit of the participants.

Ferrocement water tank by skeletal cage system during display/ exhibition at National Seminar on Water Harvesting Systems at Bangalore in December 1988.

Panchayat Raj Sammelan, New Delhi (25–30 January 1989)

Government of India organised this sammelan for Chairman of Municipal Bodies, Rural Development Officers, Heads of Rural Blocks, Panchayats etc. It was attended by 8,000 participants. During this sammelan a large display of various techniques for production of structures was arranged. About 3,000 delegates visited the stall and were acquainted with the benefits of the ferrocement techniques.

Vigyan Gaonki Oar (Science Towards Village), Gauri Ganj (Sultanpur), U.P. (4–15 March 1989)

Council of Scientific & Industrial Research (CSIR) and National Institute for Wasteland Development, New Delhi organised a big Science & Technology exhibition in rural area in Gauri Ganj, District Sultanput (U.P.) from 4th to 15th March 1989. The aim of the fair was to expose to new technologies useful in solving their problems. Most of the Indian Government Departments actively engaged in extension and R&D activities, scientific organisations and laboratories displayed their techniques in this fair which was visited by very large number of villagers, administrators and political leaders. SERC organised a display of ferrocement tanks, bins, irrigation channels, filters etc. The other items displayed in form of charts and models included man-hole covers, roofing units, wall pannels, septic tanks, mechanical casting methods for ferrocement structures and rain water harvesting schemes. For this fair, SERC, Ghaziabad developed a special display system on ferrocement which explains about this material in simple Hindi & English. An average 5,000 people visited the SERC demonstration every day. The simple technique of water jar produced with hesian cloth and rice husk was liked by most of the visitors.

(Information and photographs from Mr. J. Swarup, Scientist, Drinking Water Mission Project, SERC, Ghaziabad, India.)

UNITED KINGDOM

ITDG Takes on VSO Technical Training

During the past 18 months, ITDG has been carrying out the bulk of VSO's technical training courses for volunteers going overseas to work in educational institutions and with local non-government organization.

Courses are held at the Stoneleigh show ground, headquarters of the Royal Agricultural Society. Course participants have access to a full range of practical and tutorial facilities at the ground, where accommodation is also provided.

To date, a total of some 215 VSO trainees have been on four types of training course:

-The 11-day *Appropriate Technology Course*, which provides practical experience of a range of different tecnologies, such as low-cost building techniques, ferrocement water tank, appropriate water and sanitation, an overview of ambient energy (water, solar, biomass), rural blacksmithing and small-scale foundry work.

-The five-day *Natural Resources Course*, covering the cultural and social aspects of agricultural land use in developing countries.

-The eight-day *Carpenters' Handtools Course*, for qualified and experienced carpenters, to learn how to make a range to tools using local hardwoods.

-The 11-day *Blacksmithing Course* for trained metalworkers, which enables them to produce good quality forged tools so they can repair or make a range of domestic and agricultural implements.

ITDG's emphasis on the importance of training as a means of dissemination has led to an increase in the number and type of courses offered to other institutions as well. There has been a very positive interest from universities in the UK carrying out diploma or post-graduate courses for overseas students.

(Intermediate Technology News, March 1989.)

Improving the Performance of Flat Roof Coverings

Modern building methods demand improved performance from flat roof covering materials, and over the last two decades many new products have been introduced. The Building Research Establishment (BRE) has a continuing programme of research to monitor the performance of these products as they appear, often working with companies in testing and development. The overall aim is to establish a basis for performance-based specifications for all types of membrane.

Mastic asphalt has been a successful weatherproof flat roof covering for years, but in recent winters there have been some cases of cracking in roofs where asphalt has been laid over thermal insulation. Failure is thought to be due to the faster rate of heat loss and greater range of temperatures in the asphalt layer. BRE has carried out laboratory tests of the effect of this thermal shock on samples of roof similar to those that failed, and is devising a test method for comparing different grades of asphalt to give an indication of in-service performance. The new polymer-modified asphalts perform considerably better at low temperatures. The indications are that they should prove satisfactory in service at temperatures down to -20°C. Tests and development work on these new products are being jointly funded by Permanite Asphalt Ltd.

In the work on bituminous membranes, BRE is developing methods for predicting service life, using laboratory techniques for simulating the effects of weathering and ageing in conjunction with measurements of resistance to flexural fatigue of built-up membrane sections. Conventional glass-fiber-based felts can be artificially aged by heating at 80°C and by using combinations of heat, water and uv radiation. However, the newer polyester-based felts are hardly affected by these procedures and should be proportionately longer-lived in service. The current programme also includes the new polymer-modified felts used for both traditional laying and 'torching on'.

Single ply polymeric roofing membranes have been used in the UK for some time now, primarily for very large roof areas. Tensile strength and fatigue tests at room temperature on naturally and laboratory-aged samples are showing very good performance, and the programme is continuing, with tests at -20°C planned. Attention will also be focused on the requirements for bonded joints: preliminary results, mainly for pvc materials with and without reinforcements, indicate that the jointing process can reduce fatigue resistance.

Data from all this work is being conveyed to BSI through BRE membership of committees, and through them to formulation of CEN standards.

(BRE News, February 1989.)

New Rapid-Hardening Cement Developed

BRE has developed a new rapid-hardening cement system based on calcium aluminates but without the inherent problems experienced with other cements of this type. Results of small-scale trials are showing promising results and the material offers potential for economies in precasting and in construction where rapid strength development is required.

A detailed and long-term investigation of the durability of the mortars and concretes made with the materials will have to be carried out before it can be used in production. BRE is now seeking partners from the industry to finance this development and subsequently to manufacture and market the cement under licence.

The new material, to be known as BRECEM, is based on mixtures of high alumina cement (HAC) and ground granulated blast furance slag (ggbs) or other pozzolanic or latently hydraulic materials. The addition of slag has modified the 'conversion' process in HAC so that BRECEM concrete should not be prone to the weakening and failure which affected some HAC concrete components in the 1970's.

Trials over a period of a year show that concrete produced from BRECEM has rapid initial strength gain, and is stable even in the hot and humid conditions which are so damaging to ordinary high alumina cements. The resistance to sulphates and other chemicals is expected to be as good as HAC concrete if not better.

BRECEM has been developed by a team led by the internationally-acclaimed BRE chemist Dr. A.J. Majumdar. Investigating the properties of new cementitious materials, they found that hydration of 50/50 mixtures of HAC and ggbs produces predominantly gehlinite hydrate, which does not undergo conversion, at the expense of the calcium aluminate hydrates produced in pure HAC which do convert.

The technology is covered by a UK Patent Application held by the British Technology Group, and patent applications have been filed in Canada, Belgium, France, West Germany, Italy, Netherlands, Spain, Japan and USA.

(BRE News, April 1989)

Site Test for Cement Content of Mortars

A rapid, on-site method of estimating the cement or lime content of fresh mortars has been developed by BRE, providing a practical method of quality control during building. A prototype kit, produced by the Scottish Laboratory, fits into a small tool box and gives accurate results in only two minutes.

The strength of mortar for brickwork or rendering is an important factor in the long-term performance of walls, but the precise mix specification is often not achieved on site. The new test, named BREMORTEST, makes this possible. It involves mixing an accurate weight of mortar into a standard amount of concentrated phosphoric acid, and measuring the resultant rise in temperature with an electronic thermometer. The rise is proportional to the amount of cement or lime in the mix. The prototype kit gives a rise of 28°C with a 1:4 by volume cement:sand mortar.

The test is suitable primarily for fresh mortars made with OPC and OPC/BFS blends. Limestone contents of up to 10% in the mix lead to only a small error in the result. The cement content of mortar containing lime, and of set uncarbonated mortar up to seven days old, can also be estimated, althought extra calibration is advisable in these cases.

(BRE News, April 1989.)

VIETNAM

Ferrocement Application in Ho Chi Minh

Mr. Do Kien Quoc, an AIT graduate from Vietnam has undertaken a number of projects to use ferrocement in Vietnam. Some of these are:

prefabricated ferrocement classrooms, high pressure ferrocement pipe for water supply, ferrocement sheeting for steel walls and ferrocement pipe manufactured by vibrator machine without skeletal steel.

(Reference and photographs from Mr. Do Kien Quoc, Department of Civil Engineering, Polytechnic University of Ho Chi Minh City, 268 Ly Thuong Kiet Street, Q. 10, Ho Chi Minh City, Vietnam.)

Prefabricated ferrocement classrooms.

High pressure ferrocement pipe for water supply.

Ferrocement pipe manufactured withoutskeletal steel.

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Ferrocement basic reference collection is available in the following IFIC Reference Centers. Each Center has a resource person who will entertain queries on ferrocement.

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Abstracts

FP124 FACTORS INFLUENCING THE DURABILITY OF FERROCEMENT

KEYWORDS: Carbonation, Corrosion, Cracking, Durability, Ferrocement, Reinforced concrete, Protection

ABSTRACT: Corrosion of the ferrocement mesh has affected several ferrocement structures. A knowledge of the factors influencing the durability of ferrocement is indeed vital. In this paper, the durability factors for reinforced concrete are first presented. Based on the discussion of reinforced concrete durability, the factors influencing the durability of ferrocement are set forth. The behaviours of reinforced concrete and ferrocement with regards to the phenomenon of durability differ only in the degree of protection provided by their assembly. The superior resistance of ferrocement to invading acid ions and gaseous CO_2 is probably due to the use of galvanized steel, fine grained well-graded sands, low water cement ratios, chemical neutralization by the alkalinity of rich mortars, and to compaction which is readily obtained as a consequence of the reduced mass of the ferrocement. In contrast, reinforced concrete uses coarse aggregate which makes void filling more difficult, lower cement ratios which may reduce the alkali content and greater mass which within the limits of economic constraint makes the probability of full compaction less likely.

REFERENCE: Alexander, D. 1989. Factors influencing the durability of ferrocement. *Journal of Ferrocement* 19(3): 215–222.

FP125 FERROCEMENT FISHING BOAT

KEYWORDS: Boats, Construction, Cost, Ferrocement, Indonesia

ABSTRACT: The demand for fishing boats to strengthen the growth of offshore fisheries is increasing, as a result, there is a need to identify alternatives to wooden boats. The DTC-ITB has developed six types of ferrocement boat to answer this need. The ferrocement fishing boats developed by DTC-ITB did not only serve as an excellent alternative to wooden boats but the technology is also found to be appropriate for the Indonesian Development Plan.

REFERENCE: Oemar Handoyo. 1989. Ferrocement fishing boat. *Journal of Ferrocement* 19(3): 223–227.

FP126 FERROCEMENT FLOATING DOCKS: A SOLUTION FOR THE MARINA IN CAYO LARGO DEL SUR

KEYWORDS: Construction, Docks, Ferrocement, Floating docks, Cuba

ABSTRACT: An economical solution for the construction of light berths for pleasure crafts is described. This solution as applied to Cayo Largo del Sur, more than 100 km far from the main Island of Cuba, increases in importance since it greatly reduces the transportation volume of construction materials in relation to the traditional berths. Some construction details, the general dimensions of the facilities, and the harmonization of the structures with the environment are shown.

REFERENCE: Pajon Brache, R. 1989. Ferrocement floating docks: A solution for the marina in Cayo Largo del Sur. *Journal of Ferrocement* 19(3): 229–234.

FP127 FERROCEMENT SHEETING FOR STEEL HULL

KEYWORDS: Boats, Corrosion, Ferrocement, Hulls, Sheeting, Steel, Vietnam

ABSTRACT: A new technique using ferrocement for lining steel hull is presented. The construction procedures in treating a steel vessel with corrosion problems is described, as applied to a 20 m long and 5 m wide steel vessel in Vietnam. It was shown that this method is economically feasible and could also be employed to wooden vessels to protect them from the attack of shipworms.

REFERENCE: Do Kien Quoc. 1989. Ferrocement sheeting for steel hull. *Journal of Ferrocement* 19(3): 235–238.

FP128 FERROCEMENT VESSELS IN CHINA

KEYWORDS: Barges, Boats, Ferrocement, Marine applications, Production, Ships, Trawlers, Vessels, China

ABSTRACT: For over three decades, ferrocement vessels have been widely produced and adopted in the People's Republic of China. Its field of application has extended widely as well. Experimental researches have been conducted to develop mechanized methods of construction of the vessel, due to the steady growth of production need. The modern production methods have improved the quality of the vessels. Several vessels, with their varying applications, are presented in this report. These ferrocement vessels have proved to be technically and economically satisfactory.

REFERENCE: Editorial Group–Shanghai Ship and Shipping Research Institute; Jiujiang Experimental Building Yard of Concrete Vessels; and Jiujiang Design and Research Institute of Concrete Vessel Engineering. 1989. Ferrocement vessels in China. *Journal of Ferrocement* 19(3): 239–249.

FP129 FERROCEMENT FOR WATER TREATMENT PLANT SHIP

KEYWORDS: Design, Ferrocement, Ships, Water treatment, China

ABSTRACT: The technique of producing fresh water in cement ships has been developed in China since 1970. These ships are referred to as water treatment plant ships and they are used to supply fresh water to medium and small sized cities as well as large and medium sized industrial enterprises. The experience on the design and use of reinforced concrete and ferrocement for this type of ship is discussed. It was concluded based from performance that ferrocement is suitable for small water treatment plant ships while reinforced concrete is good for bigger ships.

REFERENCE: Huang Youzhen. 1989. Ferrocement for water treatment plant ship. *Journal of Ferrocement* 19(3): 251–255.

FP130 SONGKLA LAKE FISHING BOAT

KEYWORDS: Boats, Construction, Design, Ferrocement, Thailand

ABSTRACT: The Songkla Tinsulanond Fishing College investigated the possibility of building low-cost fishing boats. Consultants of the college recommended the use of ferrocement as a construction material. The transfer of the technology to students of the college is presented.

REFERENCE: Sukda Konganum. 1989. Songkla Lake fishing boat. *Journal of Ferrocement* 19(3): 257–259.

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July 17–20, 1989: **Eighth International Conference on Alkali Aggregate Reaction, Kyoto, Japan.** Contact: Conference Services, The Society of Materials Science, Japan, 1-101, Izumidono-chou, Sakyou-ku, Kyoto 606, Japan.

July 24–26, 1989: **International Conference on Composite Structures, Paisley, Scotland.** Contact: Dr. I.H. Marshall, Department of Mechanical and Production Engineering, Paisley College of Technology, High St., Paisley, Scotland PA1 2BE.

August 1–2, 1989: **Structural Dynamics Symposium, Kuala Lumpur, Malaysia.** Contact: The Secretary, SDS '89, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Jalan Semarak, 54100 Kuala Lumpur, Malaysia.

August 8–11, 1989: **Fifth International Conference on Structural Safety and Reliability (ICOSSAR '89), San Francisco, U.S.A.** Contact: ICOSSAR '89 Secretariat, c/o ASCE, 345 East 47th St., New York, NY 10017-2398, U.S.A.

August 21, 1989: **Second Symposium on Concrete and Structures, Jakarta, Indonesia.** Contact: Engr. J.S.Y. Tan, Conference Organizer, 150 Orchard Road #07–14, Singapore 0923. Tel: 7332922; Telex: RS 33577 COMPA; Fax: (065) 2353530.

August 24–25, 1989: **Fourteenth Conference on Our World in Concrete and Structures, Singapore.** Contact: Engr. J.S.Y. Tan, Conference Director, 150 Orchard Road #07–14, Singapore 0923. Tel: 7332922; Telex: RS 33577 COMPA; Fax: (065) 2353530.

August 25–28, 1989: **Seventh International Conference on Composite Materials, Beijing, China.** Contact: Mr. Tu Dezhang, China Society of Aeronautics and Astronautics, 67 South St., Jiao Daokou, Beijing, China.

August 28, 1989: **Second Symposium on Concrete and Structures, Malaysia.** Contact: Engr. J.S.Y. Tan, Conference Organizer, 150 Orchard Road #07–14, Singapore 0923. Tel: 7332922; Telex: RS 33577 COMPA; Fax: (065) 2353530.

September 5–8, 1989: **The Second Beijing International Symposium on Cement and Concrete, Beijing, China.** Contact: Mr. Zhaoqi Wu, China Building Materials Academy, Guanzhuang, East Suburb, Beijing 100024, China.

September 6–8, 1989: **IABSE Symposium on Durability of Structures, Lisbon, Portugal.** Contact: Organizing Committee, 1989 IABSE Symposium, LNEC, Avenida do Brazil 101, P-1799, Lisbon, Portugal.

September 8–11, 1989: **NZCRA/NZCS Pacific Concrete Conference, Auckland, New Zealand.** Contact: The Secretary, New Zealand Concrete Society, P.O. Box 17-268 Karori, Wellington, New Zealand.

September 11–15, 1989: **10 Years of Progress in Shell and Spatial Structures: 30 Aniversary of IASS, Madrid, Spain.** Contact: Sr. D.A. de las Casas, Laboratorio Central de Estructuras y Materiales–Cedex, Alfonso XII, 3, 28014 Madrid, Spain.

September 18–20, 1989: **International Conference on Pumped Storage, Manchester, U.K.** Contact: Conference Office, Institution of Civil Engineers, 1–7 Great George St., Westminster, London, U.K. SW1P 3AA.

September 18–20, 1989: **International Conference on Recent Developments in Fiber Reinforced Cement and Concrete, Cardiff, U.K.** Contact: Dr. B. Barr, Conference Secretary, School of Engineering, University of Wales College of Cardiff, Newport Road, Cardiff, U.K. CF2 1XH. Tel: Cardiff (0222) 874000 Ext. 5692/4826; Fax: (0222) 371921; Telex: 498635 Ulibcfg.

September 18–20, 1989: **New Roles for the Engineer in a Changing World, Italy.** Contact: SEFITAL 1989, Presidenza della Facolta d'Ingegneria, Piazzale V, Tecchio 80, 1-80125, Naples, Italy.

September 19–21, 1989: **International Conference on Civil and Structural Engineering Computing, London, U.K.** Contact: Dr. B.H.V. Topping, Department of Civil Engineering, Heriot-Watt University, Riccarton, Edinburgh, U.K. EH 14 4AS.

September 19–21, 1989: **An International Conference on Engineering and Tourism, Malacca, Malaysia.** Contact: The Institution of Engineers, Bangunan Ingenieur, Lots 60 & 62, Jalan 52/4. P.O. Box 223, Jalan Sultan, 46720 Petaling Jaya, Selangor Darul Ehsan, Malaysia.

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October 4–6, 1989: **Third International Conference on the Use of Superplasticizers and Other Chemical Admixtures in Concrete, Ottawa, Canada.** Contact: H.S. Wilson, P.O. Box 3065, Station C, Ottawa, Ontario, Canada K1A 0G1. Tel: (61)996-5617; Telex: 053- 3117; Fax: (61) 952-2587.

October 16–17, 1989: **Expert Systems in Civil Engineering, Italy.** Contact: ISMES Secretariat–Continuing Education Seminars, Viale G. Cesare 29, I-24100 Bergamo, Italy. Telex: 301249 ISMES I; Fax: (Int + 3935) 211 191.

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November 8–9, 1989: **International Symposium on Architectural Precast Concrete Cladding–Its Contribution to Lateral Resistance of Buildings, Chicago, Illinois, U.S.A.** Contact: Sidney Freedman, Director, Architectural Precast Concrete Services, Prestressed Concrete Institute, 175 West Jackson Boulevard, Suite 1859, Chicago, Illinois 60604, U.S.A. Tel: (312) 786-0300; Fax: (312) 786-0353.

November 8–10, 1989: **Conference UK Corrosion '89, Blackpool, U.K.** Contact: Programme Coordinator, UK Corrosion '89, Exeter House, 48 Holloway Head, Birmingham, U.K. B1 1NQ.

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April 25–28, 1990: **The International Conference on Structural Engineering and Computation, China.** Contact: Prof. Gong Yaonan, Solid Mechanics Research Center, P.O. Box 85, Beijing 100083, China.

May 14–17, 1990: **International Symposium on Admixtures for Concrete: Improvement of Properties, Barcelona, Spain.** Contact: Prof. Dr. E. Vasquez, Departamento de Ingenieria de la Construccion, Escuela Tec. Sup. Inginieros de Caminos, Canales y Puertos, Jorge Girona Salgado 31, 08034 Barcelona, Spain.

May 20–22, 1990: **Second International Symposium on Applications of High Strength Concretes, California, U.S.A.** Contact: Prof. Weston T. Hester, 215 McLaughlin Hall, University of California, Berkeley, California 94720, U.S.A.

May 20–25, 1990: **13th International Congress of the Precast Concrete Industry–BIBM 90, U.K.** Contact: Concorde Services

Ltd., 10 Wendell Road, London, U.K. W129RT. Fax: 01-743-1010.

June 3–7, 1990: **FIP '90: XIth International Congress on Prestressed Concrete, Hamburg, U.K.** Contact: Dr. J. Dougill, FIP, The Institution of Structural Engineers, 11 Upper Belgrave St., London, U.K. SW1X 8BH.

September 3–5, 1990: **Concrete for the 90's, Australia.** Contact: Concrete for the 90's, GPO Box 1571, Sydney NSW 2001, Australia.

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November 23–28, 1992: **9th International Congress on the Chemistry of Cement, New Delhi, India.** Contact: The Secretary-General, 9th International Congress on the Chemistry of Cement 1992, National Council for Cement and Building Materials, M 10 South Extension II, Ring Road, New Delhi 110 049, India.

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3. Naaman, A.E., and Shah, S.P. 1972. Tensile tests of Ferrocement. *ACI Journal* 68(9): 693-698.
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