

SOUTH PACIFIC COMMISSIONFOURTH TECHNICAL MEETING ON FISHERIES

Noumea, New Caledonia

(21-29th October, 1970)

Ferro-Cement Shell Hull Construction for Fishing Boats

By F.S. Hespe, B.E.(Syd.), M.Cons.E.Aust., F.I.E. Aust.

SYNOPSIS

Ferro-cement is, by nature of its unique properties, unsurpassed as a material for fishing boat construction. It will not rust, rot, warp nor distort in any way; it is impervious to ultra-violet and salt water deterioration and is highly resistant to abrasion. As a material it has high modulus of elasticity, compressive and tensile strengths. It is incombustible and fire resistant.

Economic studies have shown that maintenance costs of ferro-cement hulls are of the order of 1/12th those of steel hulls of equivalent size and age. Moreover, the capital cost of ferro-cement hulls is in the order of 15% less than that of equivalent steel hulls. Again, ferro-cement is more resistant to accidental damage than other forms of construction and when damage is incurred it is relatively simple and inexpensive to repair.

Natural conservatism and other contributory factors have nevertheless mitigated against the greater use of ferro-cement in fishing boat construction. Particularly, the fact that methods of construction commonly in use have made it difficult to match the hull weights of other materials in vessels of less than 35ft. in length.

This paper briefly describes the design philosophy, the hull forms and construction methods used by a Sydney firm to produce ferro-cement fishing boats which actually have a weight advantage over other materials at 25 ft. and are of equivalent weight at 20 ft. Pleasure boats of less than 20 ft. L.O.A. can be produced with equivalent hull weights to timber boats.

Production techniques developed by the firm allow for semi mass-production of high quality hulls with a finish equal to the best fibre-glass or high quality carvel built timber. It would be possible to set up small factories at suitable locations in the Pacific area and train the indigenous population to operate the necessary tools. Nevertheless, it is emphasised that ferro-cement construction calls for highly developed technical skills and professional guidance.

Dear Sirs,

Reference is made to your letter of 10/10/20.

The information requested is as follows:

1. The total number of employees is 100.

Yours faithfully,

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COMMISSION DU SUD PACIFIQUE4^e ASSEMBLEE TECHNIQUE DES PECHERIES

Nouméa, New Caledonia

(21-29eme Octobre, 1970)

CONSTRUCTION DES COQUES NAUTIQUES EN FERRO-CEMENT POUR BATEAUX DE PECHE

Par F.S. Hespe B.E. (Syd.), M. Cons. E. Aust., F.I.E. Aust.

SYNOPSES

Le ferro-cement par ces propres caractéristiques, est à présent le meilleur matériau pour la construction de bateaux de pêche. Il ne se rouille pas, ne se carie pas, ne se gondole pas, ni ne se déforme d'aucune façon, il ne peut pas être affecté par la détérioration due aux rayons ultra-violet et de l'eau de mer, et de plus il résiste à l'abrasion. En tant que matériau il a un pouvoir considérable d'élasticité, de compression et d'extensibilité. Il est aussi ininflammable, et résistant au feu.

Des études économiques ont prouvé que les frais d'entretien des coques en ferro-cement sont par rapport aux coques en acier de même taille et de même âges, de l'ordre de 1/12eme. De plus le prix des coques en ferro-cement est de 15% moins cher que celui des coques en acier. D'autre part le ferro-cement résiste mieux aux avaries qui peuvent être occasionnées accidentellement, que les autres matériaux de construction. Ces avaries étant de toutes façons relativement simples et peu coûteuses à réparer.

Néanmoins, les habitudes de conservatisme, ainsi que d'autres facteurs, se sont conjugués contre un usage plus répandu, du ferro-cement, dans la construction de bateaux de pêche. En particulier le fait que les méthodes de construction habituellement en usage ont rendu difficile l'équilibrage du poids des coques en d'autres matériaux sur des bateaux de moins de 12 mètres de long.

Cette breve, étude décrit la philosophie du dessin, la forme des coques et ces méthodes de construction utilisées par une firme de Sydney pour la production de bateaux de pêche en ferro-cement, qui actuellement ont un avantage quant au poids sur les autres matériaux pour un bateau de 9 mètres et sont d'un poids équivalent à celui des bateaux de 7 mètres. Les bateaux de plaisance de moins de 7 mètres peuvent être produits avec des coques d'un poids équivalent à celui des coques en bois.

Les techniques de production mises en oeuvre par cette Société, permettent une production en demi-série de coques de haute qualité avec une finition égale à la meilleure qualité des bateaux en fibre de verre, ou en bois. Il serait possible de monter de petites usines en des endroits favorables, sur la côte du Pacifique, en apprenant à la population locale à utiliser les outils nécessaires.

Néanmoins, on doit mettre l'accent sur le fait que la construction en ferro-cement requiert une habileté technique hautement développée, ainsi qu'une direction professionnelle compétente.

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1. INTRODUCTION

- (i) A great deal has been written in recent years of the historical background to the use of concrete and ferro-cement in naval architecture. It is not proposed here to dwell again on this well trodden path; those who wish to acquaint themselves with the history of the subject are referred to the bibliography at the end of this paper.
- (ii) The kernel of the matter insofar as ferro-cement is concerned is that the great Italian engineer, Pier Luigi Nervi, took the idea of finely dispersing the reinforcing steel in reinforced concrete and developed the material to a marked degree for use in his structures.

Nervi himself obliquely applied the material to naval architecture - obliquely, because as far as the author understands Nervi has never developed the theme he commenced with "Irene", "Toscana", "S. Rita" and his own "Nennele".

It is indeed a pity that he has not done so because, without doubt, he is still the master of the material he perfected.

- (iii) The majority of workers in the field of ferro-cement in naval architecture have either adhered strictly to Nervi's original methods and materials or have varied the basic concept in detail only. Very briefly this method consists of setting up frames (usually of tubular section) in much the same manner as for timber or steel construction; then placing successive layers of wire mesh over these frames and longitudinal stringers (usually of solid round section). The meshing process is necessarily protracted and the resulting form needs considerable tying and fairing before it is ready to receive the cement mortar matrix. Application of the mortar is either by trowel or spray against a backing strip held by workers on the inside of the hull.

* Mr. Hespe is Managing Partner in the Sydney, Australia, firm of The C. Hulls Co., which specialises in ferro-cement hull construction.

- (iv) The practical limitations of this method, as well as a conservative approach by designers in the material has given rise, for the most part, to grossly overweight hulls. To be reasonable, it must be said that a conservative approach to a new material is not to be scoffed at, and the practical limitations referred to are very positive in their effect - nevertheless the result has been as stated, heavy hulls.
- (v) The implications of course are obvious; it has been taken for granted that ferro-cement is of use only in heavy displacement vessels of length greater than 30'0", and it has even been assumed that the initial cost of a ferro-cement hull will be greater than one of conventional construction. Both assumptions are false.
- (vi) A great deal of emphasis has been placed on the flexural strength and modulus of elasticity of ferro-cement when considering its application to naval architecture - and indeed it enjoys very high values for both these properties; which may be utilised to the full. However, it is the materials compressive and tensile strength and its monolithic nature that must be exploited if full benefit is to be derived from its use in the construction of fishing boats and other vessels. To this end the writer's Company has for some years been examining the problem of the use of very thin sections from both the theoretical and practical standpoints.
- (vii) The immediate end product has been a 20'0" L.O.A. fast fishing launch with a hull thickness of 3/8". The prototype is fitted out for pleasure fishing (or sport fishing as it is sometimes called), and is powered by a 4 cylinder Perkins diesel engine developing 37 continuous H.P. @ 3000 r.p.m. The hull form is round bilged with a moderately flared bow, and firm bilges and a flat run aft. The latter is important in the light of further comment regarding planing hulls later in this paper.

2. FERRO-CEMENT AS A HULL MATERIAL

- (i) Hull deterioration is a major factor in the maintenance cost of fishing boats. Deterioration is caused by either (a) Mechanical, (b) Climatic or (c) Chemical and biological agencies.
- (ii) Mechanical deterioration can be either catastrophic (i.e. accidental and major) or daily wear and tear due to abrasion, bumping, flexure, and "working" due to high stresses in storm or other high loading conditions. Climatic deterioration can be due to warping and ultra violet deterioration in timber, rust in steel and again ultra violet deterioration in fibreglass. Chemical and biological agencies bring about rot in all its forms, marine borer attacks, rat and other infestations and finally fire, the sailors greatest foe.
- (iii) The properties of ferro-cement are such that it is highly resistant to all forms of hull deterioration. Its monolithic nature and high modulus of elasticity enable it to withstand impact loads to a marked degree; and the hardness of its sur-

face give it a resistance to abrasion exceeded only by steel itself. In a like manner a hull constructed in ferro-cement does not "work" - which is to say that no opening of seams or cracking occurs. Normal accidental knocks which might crack a plank in a wooden boat, tear a hole in a fibreglass boat or open a seam or at least dent a steel boat would in general have no other than a superficial effect on a ferro-cement boat.

- (iv) When a blow is of such a nature as to cause serious damage in other forms of construction it will shatter the cement mortar matrix of ferro-cement and depress the hull in the immediate area of the blow. The shattered mortar will however remain held in place by the wire mesh around which it has been cast and the result is that water can only percolate, as it were, through the interstices. This makes it possible for the crew to easily place a collision mat against the affected area. In most cases it would not even be necessary to do that. The shattering of the cement mortar matrix is a very important factor in the impact resistance of ferro-cement as it absorbs a very large amount of energy and hence localises the effect of the blow.
- (v) The mechanism of this type of failure is that the energy of the blow is dissipated by fragmenting the cement mortar matrix into a very great number of small pieces. Each fragment absorbs an increment of energy, and because of the very form of the material each element has to be completely fragmented before the residual energy from the blow is transmitted to the neighbouring elements. In such a fashion only very high energy blows have any but a minor effect on the hull, and high energy blows have their effect confined to relatively small areas.
- (vi) If a blow is such as to cause damage to a ferro-cement hull the necessary repair work is extremely simple and economical to perform. Where the damage is well below waterline it would be necessary to slip the vessel, but otherwise heeling to expose the damage would be all that would be necessary. It then remains to break out the damaged mortar using a hammer and dolly, straighten the deflected mesh (lapping in new mesh if any of the original wires are broken), and replaster the hole.
- (vii) Ferro-cement will not warp nor rust and is unaffected by sunlight or saltwater erosion. It is impervious to rot, marine borer or other infestations and will not become water-logged. Generally speaking it is unnecessary to paint ferro-cement, but in most cases it is thought desirable from the appearance point of view and because it is still necessary to paint below the waterline with an anti-fouling preparation.
- (viii) Insofar as fire is concerned, the material itself is non-combustible and is resistant to heat. In general terms it may be said that in all but a catastrophic fire involving a cargo of high calorific value where very intense heat is generated a ferro-cement hull will only sustain superficial damage. Where a complete burnout of great intensity is involved it is unlikely

4. that the hull would be suitable for general use afterwards although it is probable that it would be usable as a lighter in enclosed waters; and in any case, as long as the crew could sustain themselves until the hull cooled down sufficiently to get on board again, it would carry its crew to safety after the fire.

- (ix) The thermal conductivity of ferro-cement is quite low and hence the material does not give rise to condensation on deck-heads and hull surfaces - a point of major consideration in tropical climates. Again, this property is of value where refrigerated holds are concerned, as the hold can be built in sandwich fashion into the very hull and bulkheads - eliminating any maintenance whatsoever. Similarly the material's advantages in respect to wet holds (or fish tanks) must be obvious. In the latter case it is possible to have full flow fish holds incorporated in the hull without any of the dangers commonly associated with this feature in other forms of construction.
- (x) A telling commentary on the effectiveness of concrete and ferro-cement, from the maintenance point of view is the fact that an operator of a large fleet of barges in Manilla has indicated that over a four year return period the maintenance cost of his fleet of concrete barges (approx. ten in number) has been only 8% of the maintenance cost of an equal number of steel barges of the same age and general design. Add to this the fact that the concrete barges cost in the order of 15% less than steel barges of the same capacity and it is clear that the economic advantages of ferro-cement are very real indeed.

3. LIGHTWEIGHT FERRO-CEMENT HULLS - THE C. HULLS METHOD

- (i) As discussed earlier, it has hitherto been taken as axiomatic that ferro-cement hulls would not be possible without a weight disadvantage at lengths of less than 30' - indeed some writers have put the figure at 45'. The reasons for this assumption have been firstly, the fact that the method of construction generally used has made it all but impossible to reduce skin thicknesses below 5/8" at best and in the main 3/4", and secondly that most workers have been obsessed with either the 'beam and slab' theory of structural action or with an over sensitive idea of the degree of curvature necessary for 'shell' action.
- (ii) It is true that flat areas of hull are intrinsically unsound for ferro-cement construction, but this is equally so for other materials. Again, in the size hull we are discussing (up to 40' L.O.A.), no matter whether some areas of the hull are flat or not the complete structure still acts as a shell - not necessarily a curvilinear shell, but a shell nevertheless. There can be no doubt that it is palpably ridiculous to attempt to apply formal shell theory to hull design (except perhaps in the limiting condition at points of obvious stress concentration -

in fact the author has contemplated the assumption of a Prandtl type membrane as the limiting case but has derived little satisfaction from these essays) and recourse must be made to intuitive design and full scale testing.

- (iii) It must not be assumed from the foregoing that the author is advocating the use of guesssing (even of an educated type) instead of as rigorous a design approach as possible. Indeed the final intuitive and testing procedures would be quite worthless if they were not based upon an extensive and careful analysis of the stress conditions in the hull under consideration. Furthermore, the results of the intuitive design must be analysed carefully at every stage of testing.
- (iv) The point that is being made is that theoretical mathematical analysis can carry one just so far in the design of a small ship and that from there on certain engineering experience and intuition must be brought into play if the utmost is to be achieved in efficiency and economy. For example it becomes obvious to someone well versed in structures what the 'stress flow' is likely to be in a particular structure or member, and from this a decision can be made with regard to, for example, strengthening certain areas or the possibility of reducing others.
- (v) This briefly has been the approach taken by the author in developing the structural design and the production methods used by his Company to construct, in the first instance, a 20'0" L.O.A. motor launch and now to proceed with a 34'0" L.O.A. racing yacht; both with skin thicknesses of $3/8$ ".
- (vi) It might be asked at this stage; what has this to do with fishing boats? Indeed it has very much to do with fishing boats. Consider in the first instance a conventional displacement hulled trawler of small size - say 35'0" L.O.A. In a vessel of this type some 3000 to 4000 lbs. can be saved in hull weight between the conventional and the C. Hulls method of construction. This simply means that an extra $1\frac{1}{2}$ tons of cargo (fish) can be carried for the same operating cost, and as size increases so the total weight saving (but not necessarily the percentage weight saving) increases. Secondly, there exists a demand for planing hulls of up to 40'0" L.O.A. for fisheries such as the West Australian rock lobster fishery, the Victoria and Tasmanian scallop fisheries and the Pacific day tuna fishery. This type of hull would not be an economic proposition in the heavier construction normally used but would be entirely practicable using the techniques mentioned above.
- (vii) The author is at present investigating the design of a 35'0" L.O.A. hard chine hull (called a 'scooter' boat in Western Australia) for a tuna fisherman in South Australia, and a game fish enthusiast on the South Coast of N.S.W. This boat would have a service speed of about 17-18 knots and a maximum speed of 20-23 knots with a 150 h.p. diesel engine. When it is con-

sidered that this type of boat is at present being constructed in marine plywood, glassfibre reinforced plastics or aluminium it will be realised that significant advantages are to be obtained in terms of capital cost and maintenance when ferro-cement can be used instead.

- (viii) There are still a number of design decisions to be made which will be influenced by feedback information derived from strain gauge analyses of the 20' launch mentioned earlier.

A very detailed examination is being made of the critical stress condition at the chine. In this regard it was mentioned earlier that the 20' launch, which is now under test, has very firm bilges aft - in fact the radius of the bilges for a length of nearly 10 ft. is no more than four inches while the bottom and the topsides are for all practical purposes flat with a dead rise of about two inches. Strain gauge readings at these points seem to indicate that the reversal of stress between extremes of load (no immersion to minimal freeboard immersion) is by no means critical.

- (ix) We therefore now have a construction technique for ferro-cement hulls which will allow for the development of lightweight vessels in the range 15'0" L.O.A. to about 35'0" to 40'0" L.O.A. and which, in addition, will give considerable economic and weight saving advantage to displacement type vessels of considerably larger size. For the purpose of the present paper sufficient has been said of the structural philosophy behind the method - it remains to discuss some of the practical and constructional considerations.

4. PRACTICAL CONSIDERATIONS

- (i) The C. Hulls method of construction depends upon the use of a mould, and while this fact in itself may not be unique, the details of the mould and moulding system, the techniques employed in laying up the mesh, and other operations during construction, certainly are. The principles involved in the operation of the mould and the mould machinery are very sophisticated; while the mould proper can be either cheap and roughly finished for short run production or for vessels where cost is a major factor and interior finish not so important, or finished to a high degree of perfection for long production runs and for pleasure boats where interior finish is of some consequence. It is to be noted that in all cases the external finish is of very high quality (in fact is of such high surface finish that etching is necessary before painting) and is perfectly fair in shape.
- (ii) In regard to the matter of fairness of shape, it is here that another distinct advantage of the moulding technique lies. Whereas the pipe frame meshing method or its derivatives makes it well nigh impossible to prevent a 'quilting' effect in the mesh after tying and a 'waving' between frames, which is

reproduced to a greater or lesser degree in the finished product; moulding and the production techniques employed by the C. Hulls Co. ensure that the fairness of the mould is exactly reproduced in all hulls taken off the mould. To be objective, it must be said that almost complete fairness is possible to achieve using the pipe frame method, but this is always at the cost of many manhours of shaping and hammering which put it entirely outside the scope of a commercial operation - in other words it is really only suitable for amateur construction where labour costs can be written off in personal effort.

- (iii) Fairness of shape may be of little consequence in fishing boats insofar as appearance is concerned, but it does have an influence on the drag coefficient of the hull, and over years of service will add up to a considerable sum in fuel bills.

Exact repetition of internal surfaces is also of distinct advantage in the production of more than one vessel since production line procedures can be employed at the fitting out stage as well as during hull construction - this again offers distinct economic advantages.

- (iv) It is clear that for the construction of more than one vessel of the same design the mould method holds considerable advantages in economy over other methods - quite distinct from the technical and other advantages touched on before. Moreover, within a range of approximately ten feet in L.O.A. (for example for vessels from 35' to 45' say) the same mould machinery can be used, and moulds interchanged for various hull forms. Thus, even on a one off basis the C. Hulls moulding method is more economical than the traditional or pipe frame method.
- (v) The mould machinery referred to can be easily transported, so that it is quite practicable to set up a factory - even in a remote area - for the construction of relatively few hulls. All materials used in the construction of the mould proper and the hulls themselves come in small parcels so that transport again is no problem. Notwithstanding this it would normally be preferable for the mould itself to be built in Sydney and transported complete to the site of construction, except where runs of only a very few vessels were concerned. Again it must be emphasised that these remarks apply only to vessels of up to say 35'0" L.O.A.
- (vi) Where vessels of greater than 35'0" L.O.A. are concerned the economics are substantially greater, but it will be clear that a considerable production run would have to be guaranteed before the setting up of a local factory could be warranted.

A vessel of this size would normally be built in Sydney and delivered on her own bottom to her prospective home port. Not the least consideration in this is the question of fitting out and the installation of main machinery, etc.

- (vii) It is often assumed by amateurs and unfortunately sometime expressed or inferred in the literature (such as exists) that ferro-cement construction is easy and the necessary skills are few. Indeed, it is perfectly true that under skilled direction and with proper professional guidance unskilled or semi-skilled labour can be employed (this is in fact another of the advantages of the material), but it cannot be stated too strongly that gross errors can be made only too easily in the manufacture of ferro-cement and that to embark upon the construction of a ferro-cement vessel without the fullest professional advice and assistance is to court disaster. In fact, for the amateur builder, except of course for the man with special skill or knowledge who is prepared to spend a lot of time acquiring the necessary information, and a great deal more time actually building his hull - ferro-cement is above all the material where the purchase of a professionally built hull to be fitted out in his own time is the ideal solution.
- (viii) So far, consideration has been given, in the main, to smaller fishing vessels only; it is perhaps appropriate to briefly mention vessels of a larger size which, while being perhaps fewer in number, are equally important - in fact, in the author's opinion more important - to the full development of fisheries in Australian and South Pacific waters.
- (ix) Larger displacement type hulls can be constructed to advantage using the C. Hulls mould method, the saving in hull weight previously mentioned being but one consideration. A cost saving in the order of 15% to 20% of the cost of the cheapest equivalent steel hull is currently achievable and construction time is dramatically reduced. For example a 50'0" trawler hull could be completed from bare mould to bare mould in two and a half weeks. At present a standard 48'0" L.O.A. modern stern trawler to the designs of Alan H. Buchanan and Partners is being offered and a market survey is being undertaken to determine another larger vessel (in the range 60' to 75') suitable for adoption as a standard hull. It will be appreciated that in these sizes a standard hull is essential since mould costs are considerable and must be written off over a number of hulls. Similarly, it is not envisaged at this stage that the larger vessels will be constructed outside Sydney.

5. APPLICATION TO THE SOUTH PACIFIC AREA

- (i) Before very briefly considering the application of the foregoing remarks to the South Pacific area (in which must be included Australia), the author wishes to make it clear that he is a consulting civil and structural engineer and not a naval architect nor yet a fisheries expert. However he has taken a particular interest in the construction and economics of fishing vessels ever since becoming actively engaged in the investigation, design and construction of ferro-cement hulls. It is hoped therefore that the following remarks will be of some interest; if

the conclusions drawn are old hat, or smack of special pleading, due apology is made; but every care has been taken to be entirely objective in considering the problems involved.

- (ii) One of the basic problems of the fishing industry, particularly at the individual or partnership level, is that it is capital intensive in a world where the manipulation of capital is becoming more and more centred in the hands of fewer and fewer large organisations which do not view the fishing industry as a source of attractive returns. To an individual fisherman, or small group of fishermen, his boat and gear represent a massive capital outlay which, in all but a very few cases, is entirely beyond his capacity to fund. Furthermore the sources of long term finance which are therefore so necessary to provide this capital are not always willing to provide it for such a purpose.
- (iii) The result of this has been that fishermen have been forced to resort to many unfortunate devices to reduce their capital outlay. First and foremost by building smaller, ever much smaller, boats than they really need (for example, in 1966 69% of all fishing boats in N.S.W. were less than 20' in length). Secondly, by reducing the specification of the boats they do build and by economising on gear and equipment; and thirdly, by not engaging a naval architect nor using properly prepared plans from which to build. Jan-Olof Traung, in his report to the Department of Primary Industry, Australia in 1966 "Problems with Fishing Boats in Australia" said, inter alia "Of the total of Australia's 9,426 vessels no more than perhaps 400 have been built from drawings. Most of those drawings have been of the most rudimentary kind showing only the lines and main construction details. Perhaps only 100 of the 400 boats have been built to a carefully worked out design prepared by an experienced naval architect. Actually the figure of 100 may be high". and again, "..... However, it is felt that most Australian fishermen are not yet convinced that the payment for such services (naval architecture) is a worthwhile investment".
- (iv) One would be disposed to imagine that a very similar problem exists throughout the entire South Pacific area.
- (v) The use of substandard boats - particularly those of poor design - has very adverse effects on the efficiency of the industry. Small boats cannot operate in weather which would not affect a larger vessel, their range is considerably less and their time spent on moorings much greater. Maintenance becomes a problem and not only makes inroads into the fisherman's working capital but into his fishing time as well.
- (vi) Operating costs, even disregarding maintenance, will always be high in a poorly designed or constructed fishing boat. For example fuel savings of up to 50% can be achieved by proper hull design and by matching propeller to engine, and both to the hull.

- (vii) All of this may seem to be a rather long and drawn out way of arriving at what might be thought to be the obvious conclusion that capital cost, good design and low operating and maintenance costs are the three main areas in which improvement in the construction of fishing vessels is necessary. However it is sometimes illuminating to consider the reasons for the presence of a problem before attempting to solve it.
- (viii) The advantages of ferro-cement in regard to maintenance have been set out at length earlier in this paper; it need only be repeated here that the maintenance costs of ferro-cement vessels are of the order of 1/12th those of steel vessels.
- (ix) Series production, where design fees and tooling up costs are distributed over a number of vessels, offers significant advantages in the first two areas of improvement. It is possible, in fact it is absolutely essential, that a manufacturer of a range of series production vessels engages the services of a world ranking naval architect to produce the best possible design for the particular vessel or vessels concerned. In this way prospective purchasers are assured of the best in design, with all its attendant advantages in reduced operating costs, stability, safety and efficiency. In a like fashion the spreading of overheads, tooling, and mould costs over a number of boats reduces the selling price of each unit. At present the cost of a ferro-cement hull on the basis of moulded construction and for a specified minimum number of repetitions is between 15% and 20% less than the cheapest equivalent steel hull.
- (x) As mentioned earlier it is possible, using the techniques described in this paper to set up a factory in any specific location in the South Pacific and to produce high quality hulls on site. To achieve this, the necessary equipment and the professional, technical and managerial skills would be provided from Australia, but it would be possible, and highly desirable, to train local people in all facets of the operation. Indeed, if such a proposal were forthcoming, it would be appropriate to invite local capital participation and proceed on a joint venture basis.

6. CONCLUSION

- (i) In the South Pacific the effects of climatic and environmental deterioration on fishing vessels are such that one is lead to the almost inevitable conclusion that ferro-cement offers the best solution to the problem. If this solution can be achieved with economy and improved efficiency through good design so much the better.
- (ii) It has been the author's endeavour to present such a solution. If reference has been made to a specific process or a particular method it is because it has been hoped that this paper might be a practical contribution to the subject, and in such circumstances generalisation is impossible.

REFERENCES :

1. FOUIGNER, N.K. 'Seagoing and other Concrete Ships' - London. Henry Froude, Hodder & Stoughton.
2. 'Reinforced Concrete Ships' - The Architect and Building News Vol. 219, No. 24, 1961.
3. do. Vol. 219, No. 26, 1961.
4. 'Thin Walled Concrete Ships' - Journal A.C.I. Nov. 1949 and Feb. 1953.
5. NERVI P.L. 'Ferro-Cement' - Its Characteristics and Potentialities. CACA Library Translation No. 60, 1956.
6. ALEXANDER D. 'A Technical review of Ferro-Cement Construction - Commercial Fishing, 1967.
7. MAHAFFEY, P.I. 'Ferro-cement' - CACA Australia Tech. Memorandum TM8 - May, 1970.
8. COLLEN L.D.G. and KIRWAN, R.W. 'Some Notes on the Characteristics of ferro-cement'. Civil Engineering and Public Works Review Feb. 1959.
9. HESPE, F.S. 'Ferro-cement for Fishing Boat Construction' - Australian Fisheries, Dept. Primary Production, Canberra, June, 1970.