Vol. 9, No. 1, January 1979

JOURNAL OF FERROCEMENT

Published by the

IFIC

International Ferrocement Information Center

in Collaboration with the

New Zealand Ferro Cement Marine Association

JOURNAL OF FERROCEMENT
Volume 9, Number 1, January 1979

CONTENTS

Discussion of the technical materials published in this issue is open until **July 1, 1979** for publication in the Journal.

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. The IFIC was established as a result of the recommendations made in 1972 by the U.S. National Academy of Sciences's Advisory Committee on Technological Innovation (ACTI). IFIC receives financial support from the **United States Agency for International Development (USAID), the Government of New Zealand 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all over the world, IFIC attempts to collect information on all forms of ferrocement applications either published or unpublished.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 publication and on request through IFIC's reference and reprographic services. Address all correspondence to: The Director, IFIC/AIT, P.O. Box 2754, Thailand.

SUBSCRIPTION RATES

The Journal of Ferrocement is published quarterly by the International Ferrocement Information Center (IFIC), Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand in association with the New Zealand Ferro Cement Marine Association (NZFCMA), as from July 1977.

The annual subscription rates are : (A) subscribers from U.S.A., Canada, European countries, Australia, New Zealand and Japan*: Individual US$25 and Institutional US$50: (B) subscribers from other than above countries : Individul US$15 and Institutional US$30; and (C) supporting subscribers US$100.

*Rates applicable to members of the New Zealand Ferro Cement Marine Association(NZFCMA)are as in (B).

EDITORIAL

With this January issue we wish once more to underline that throughout 1979 we will continue trying to improve and to develop the contents of the Journal of Ferrocement and more generally speaking the activities of the International Ferrocement Information Center, to better meet the needs of the various types of ferrocement users.

The publication in our Journal of high level technical papers has been criticized. In fact, the existence of such papers proves that ferrocement has reached an "adult" status as a construction material and this ought to please all ferrocement "supporters"! Therefore, we believe that what could be criticized is not the presence of very technical papers, but the fact of not finding *in addition* more practical papers and notes. As stated in previous editorials every effort is being taken to develop that practical component of the Journal, in cooperation with our readers, correspondents and anyone working with ferrocement either specialists or "amateurs".

In that respect we can add here that, considering the considerable potential of ferrocement as a construction material for developing countries, one of the main objectives of IFIC as a whole is to help in transferring ferrocement technology at the level of little educated rural users. Therefore, IFIC is undertaking a number of actions aiming at providing extension officers with the means needed to efficiently promote ferrocement applications, such as brochures translated in many local languages, sets of slides, a series of simple "Do it yourself" booklets on some ferrocement applications (grain storage bins, water tanks, biogas holders, canoes, etc.), organization of training sessions in ferrocement construction, etc. The practical applications of ferrocement considered as an "appropriate technology" to be used for and by the rural users is truly a major concern for IFIC, even if not yet properly reflected in the contents of the Journal.

The Editors

ADVERTISING RATES

Full page	US$70
Half page	US$40
Quarter page	US$25

These rates are for one number and include the cost of plate making. A reduction of 20 per cent for two numbers and 30 per cent for four or more numbers will be allowed.

All enquiries relating to advertising in this Journal should be addressed to:

The Editor, Journal of Ferrocement
International Ferrocement Information Center
Asian Institute of Technology
P.O. Box 2754
Bangkok, Thailand

FEES FOR IFIC SERVICES

The fees for photocopying are:

	Subscribers to the Journal	Others
A. Photocopy		
Xerox	US$0.15/page	US$0.20/page
Microform/Printer	US$0.20/page	US$0.25/page
B. Microforms		
Microfiches (60 page)	US$2.00/fiche	US$4.00/fiche
Microfilm	US$0.007/page	US$0.015/page

The fees for Reference Bibliography Services will be based on the following hourly rates.

Hourly fee	US$3.00	US$6.00

AIT M.Eng. Thesis & Doctoral Dissertation:	US$20.00/copy
AIT Research Report:	US$ 8.00/copy

(For each request a service charge of US$2.00 will be added)

Surface postage is free.

Recent Developments of Ferrocement in North America*

Gajanan M. Sabnis†

Although ferrocement has been used as a material of construction for various applications in many countries, only recently there has been growing interest especially in the Western hemisphere to use it as a structural material. The distribution in a concrete matrix of continuous fine reinforcement compared to conventional larger size rebars, gives ferrocement several advantages, which were recognized for quite some time in many developing countries without the support of vigorous analysis. Recent work with this material and novel applications have caused considerable research in North America; a committee was formed by ACI on Ferrocement. This committee sponsored a symposium at Toronto in April, 1978, the proceedings of which will bring out the State-of-Art on the topic with an extensive bibliography. Based on the recent experience in North America the following topics are discussed in this paper:

a) basic definition of ferrocement

b) useful structural properties

c) special properties in view of recent research

d) recent applications, and

e) further potential of Ferrocement in Civil Engineering

INTRODUCTION

The material 'Ferrocement' is certainly not a new material of construction. Similar to many other materials, it has been used for a long time in developing countries for a number of applications. As the technology developed, so did the interest of engineers to look into the material science of Ferrocement; this has resulted in the re-evaluation of this material in North America as a 'building material'; and a formal investigation so that the engineers may use it through their ingenuity in new applications.

The National Academy of Sciences (NAS) published a first report of Ferrocement NAS [1] in 1973, along with the panel's recommendations for its usage and more importantly, established the International Ferrocement Information Center (IFIC) in 1976 at the Asian Institute of Technology, Bangkok. In North America, the American Concrete Institute (ACI) established committee 549 on Ferrocement in 1974 with the following mission:

> "To study and report on the engineering properties, construction practices, and practical applications of Ferrocement and similar materials; develop standards and safeguards for ferrocement construction".

The above events have drawn, in the last few years, considerable attention from various individuals and organizations to improve this 'technologically' dormant but very useful

* Adapted by consent of the author with minor changes from the Proceedings of the International Conference on Materials of Construction for Developing Countries (August 22-24 1978, AIT, Bangkok).

† Associate Professor of Civil Engineering, Howard University, Washington, D.C., U.S.A.

material and explore all its potentials in engineering applications. In this paper, an attempt is made to report briefly on the activities in North America, related to ferrocement starting from its definition to its potential uses by the engineering profession.

DEFINITION OF FERROCEMENT

As the material 'Ferrocement' was used for a long time in boat building and similar allied structures rather than in structural applications, a rigorous engineering definition of ferrocement was not followed. Within ACI Committee 549, a considerable discussion on its definition evolved and it was agreed to group together various available definitions from many sources to come up with a concise and accurate definition that may be acceptable to the engineering profession. Some definitions considered by the committee are presented here:

Bigg [2] has discussed the problem of definition in detail. He points out that according to the American Bureau of Shipping it is:

> "A *thin, highly reinforced* shell of *concrete* in which the steel reinforcement is distributed widely throughout the concrete, so that the material under stress acts approximately as a homogenous material. The strength properties of the material are to be determined by testing a significant number of samples. . . ."

Although at first glance, the above definition seems an acceptable one, it brings about a number of questions on the words italicized therein, which may have different meanings of ferrocement to different people. Bigg [2] goes on to discuss various aspects of ferrocement, suggests various ways of defining it, such as a composite material and points out how the available engineering approach for composites of fiber reinforced concrete may be used to come up with a definition of ferrocement.

As a two component composite, made up of reinforcement and mortar (matrix) Bezukladov [3] defined it in terms of the ratio of the surface area of reinforcement to the volume of the composite. In this manner, ferrocement is separated from the conventional reinforced concrete. Somewhat arbitrarily, he assigned the specific surface greater than 2 cm^2/cm^3 to ferrocement which then behaves more or less as a homogenous material. Less than 2 cm^2/cm^3 is considered reinforced concrete.

Shah [4] in discussing different materials of construction, defined ferrocement in a manner similar to Bezukladov. He called it a composite made with mortar and a fine diameter continuous mesh as reinforcement, with which has higher bond due to its smaller size and a larger surface area per unit volume of mortar. Accordingly, this ratio may be as mush as ten times that which is observed in conventional reinforced concrete; this results in failure of ferrocement in tension by the actual breaking of wire mesh and a much higher cracking strength in the matrix.

As a composite, certain characteristics of ferrocement may thus be summarized as follows:

a. Since the wire mesh (reinforcement) is much stronger in tension compared to the matrix (mortar), the role of the matrix is to properly hold the mesh in place, to give a proper protection and to transfer stresses by means of adequate bond.

b. Compression strength of this composite is generally a function of the matrix (mortar) compressive strength, while the tensile strength is a function of the mesh content and its properties.

c. It follows from (b) above that the stress-strain relationship of ferrocement in tension may show either a complete elastic behavior (up to fracture of reinforcing mesh) or some inelasticity depending upon the yielding properties of the mesh.

d. Since the properties of this composite are very much a function of orientation of the reinforcement, the material is generally anisotropic and may be treated as such in the theoretical analysis.

The above discussion indicates the variety of approaches that have been made in a structural definition of ferrocement. It became apparent to the ACI Committee that the first task should be to define Ferrocement as a construction material. Accordingly, the following definition was adopted:

> "Ferrocement is a type of thin wall reinforced concrete construction, where usually a hydraulic cement is reinforced with layers of continuous and relatively small diameter mesh. Mesh may be made of metalic materials or other suitable materials."

In the remaining part of this paper, this definition will be used to discuss the properties of ferrocement and its development in North America.

PROPERTIES AS BUILDING MATERIAL

Traditionally, ferrocement has been viewed as a material for boat building rather than for housing applications. Its use, however, was extended to many types of structures in the eastern hemisphere. As such, little scientific information on its engineering properties was available. This is not to say that the intent here is to make a simple material used by unskilled labor, more complex, but only to provide additional information on its engineering properties in order to make ferrocement a universal material of construction.

The main properties recently studied in North America include:

1. Tensile Behavior (or alternatively, Flexural strength)
2. Cracking Behavior
3. Impact Strength
4. Fatigue Strength
5. Compressive Strength

Since, ferrocement is basically composed of reinforcement and mortar one may be tempted to compare it with reinforced concrete. However, from the earlier discussion the material differences are quite clear. Structural properties also differ mainly due to the fine dispersion of reinforcement in ferrocement. Most researches in recent years both in North America and elsewhere have concentrated to investigate these properties; the discussion of properties in this paper is based on the report of ACI 549 [5] and that presented by Batson, et al [6].

TENSILE BEHAVIOR

Unlike reinforced concrete, tensile behavior of ferrocement is considerably different. This is mainly because the reinforcement is spaced closer and uniformly than in reinforced concrete and its smaller diameter results in a larger specific surface area. This in turn affects cracking behavior (finer and more number of cracks) in ferrocement.

Tensile behavior is characterized by cracking (first crack), toughness elongation and ultimate strength of the specimen. Naaman and Shah's [7] work has indicated that the stress level at which the first crack appeared and the crack spacing were a function of the specific surface of reinforcement as indicated in Fig. 1. Toughness and elongation as measured by the area under the load-elongation curve, indicated that the toughness provided by a single layer was increased by increasing the number of layers of reinforcements. The ultimate load of the ferrocement specimen was the same as the load carrying capacity of the reinforcement in that direction; this should be expected since the load is carried by the reinforcement itself, after the mortar is cracked.

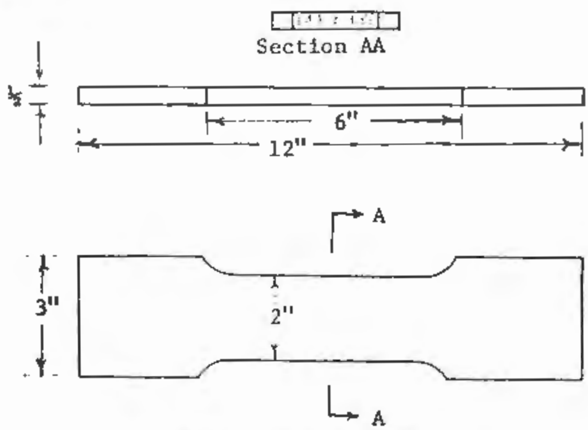


Fig. 1a. Tensile specimen (Ref. 12).

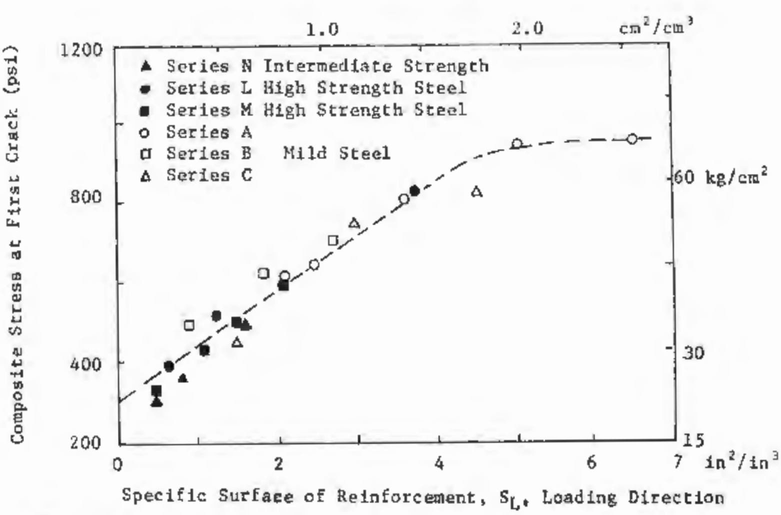


Fig. 1b. Stress at first crack vs. specific surface of reinforcement (Ref. 7).

FLEXURAL STRENGTH (BEHAVIOR IN BENDING)

In some applications ferrocement may be subjected to flexural stresses. In such cases, one must consider the method and manner in which its behavior in flexure may be predicted. Needless to say that compared to an average reinforced concrete beam (which is generally under-reinforced), the ferrocement beam due to several layers of wire mesh tends to be over reinforced. It is therefore important to insure that indeed ferrocement will not fail similarly to an over-reinforced concrete beam. Analytical and experimental evaluations are reported by Johnston and Mowat [8], Logan and Shah [9], Balaguru et al [10] and Pama, et al [11].

It is interesting to note that flexural strength of a ferrocement beam can be calculated using the conventional method of analysis of reinforced concrete. The load deflection relations shown in Fig. 2 clearly indicate this. The figure also shows that increasing the amount of reinforcement does not significantly increase the cracking moment of the beam, indicating that cracking behavior is different from the cracking behavior in tension as discussed in the earlier section (Fig. 1b). It should also be noted from Fig. 2 that there was no sudden failure as might be expected in the "over-reinforced" reinforced concrete beam.

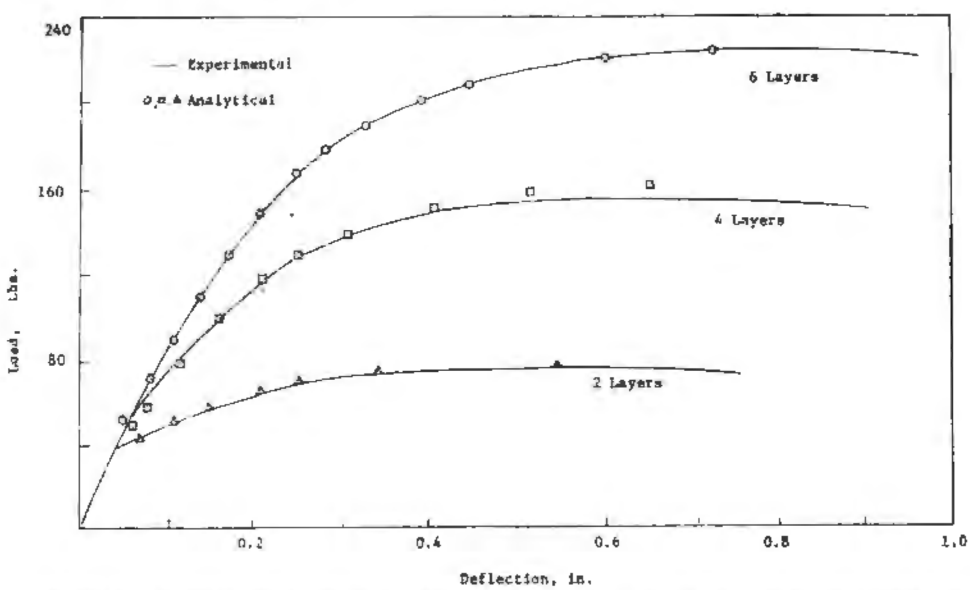


Fig. 2. Comparison of experimental and analytical load-deflection curves for ferrocement specimens (Ref.10).

COMPRESSIVE STRENGTH

Compared to the other strengths discussed above, the high compressive strength of mortar contributes primarily to the compressive strength of the ferrocement composite. Although the reinforcement may have some influence on the compressive strength, recent studies reported by ACI Committee 549, [5] indicate that certain types of reinforcement have a beneficial effect. For example, the use of welded wire mesh would increase compressive strength due to the lateral restraint provided by the welded transverse wires, while the use of hexagonal mesh or expanded metal may weaken the composite due to longitudinal splitting. Fig. 3 shows observed relationships between compressive strengths and steel content for columns reinforced

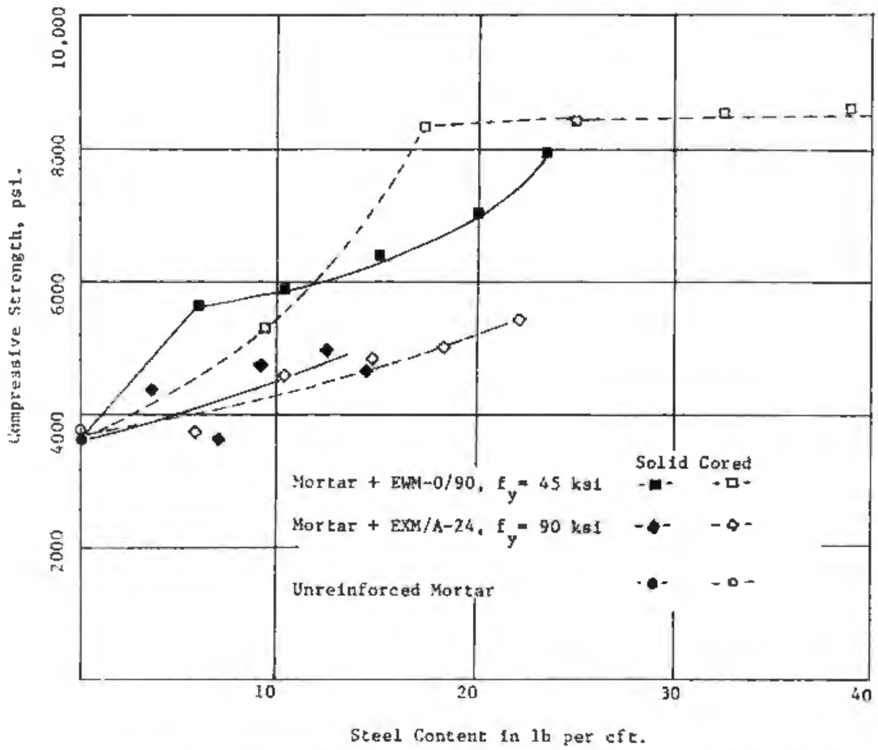


Fig. 3. Relationships between compressive strength and steel content for columns reinforced with expanded metal and welded mesh (Ref. 14).

with expanded metal and welded wire mesh. It should be mentioned here that in general a rectangular mesh with greater amount of transverse reinforcement is more cost effective in increasing compressive strength (by creating triaxial stress conditions) than the addition of longitudinal reinforcement.

IMPACT AND FATIGUE STRENGTH

Impact and fatigue strengths may be looked upon as special properties. Impact strength is a useful parameter in applications related to offshore structures. Fatigue strength may play an important role in restricting the use of ferrocement in structures subjected to such a loading as in bridges. Results of recent works are presented here.

Shah and Key [12] tested 9 in. square and ½ in. thick ferrocement slabs using a specially designed impact tester. The slab reinforcements had different tensile strengths and different layers to give a variation in the specific surface. Impact strength was defined as the energy absorbed by the specimens when struck by a swinging pendulum dropped from a constant height. The damage was measured by the relative flow of water through the damaged surface for a fixed energy absorbed (600 lb in.); it indicated that the higher the specific surface of the meshes and the higher the strength of the mesh, the lower the damage due to impact loading. This is shown in Fig. 4. These observations are also consistent with those in the tensile tests described earlier.

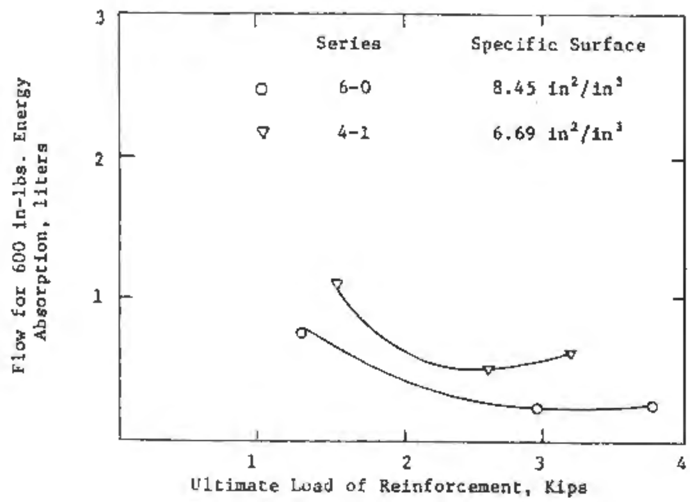


Fig. 4. Effect of specific surface and ductility of reinforcement on impact damage (Ref. 12).

Balaguru et al [13] have recently completed an extensive investigation on the flexural fatigue properties of ferrocement beams reinforced with square woven and welded meshes.

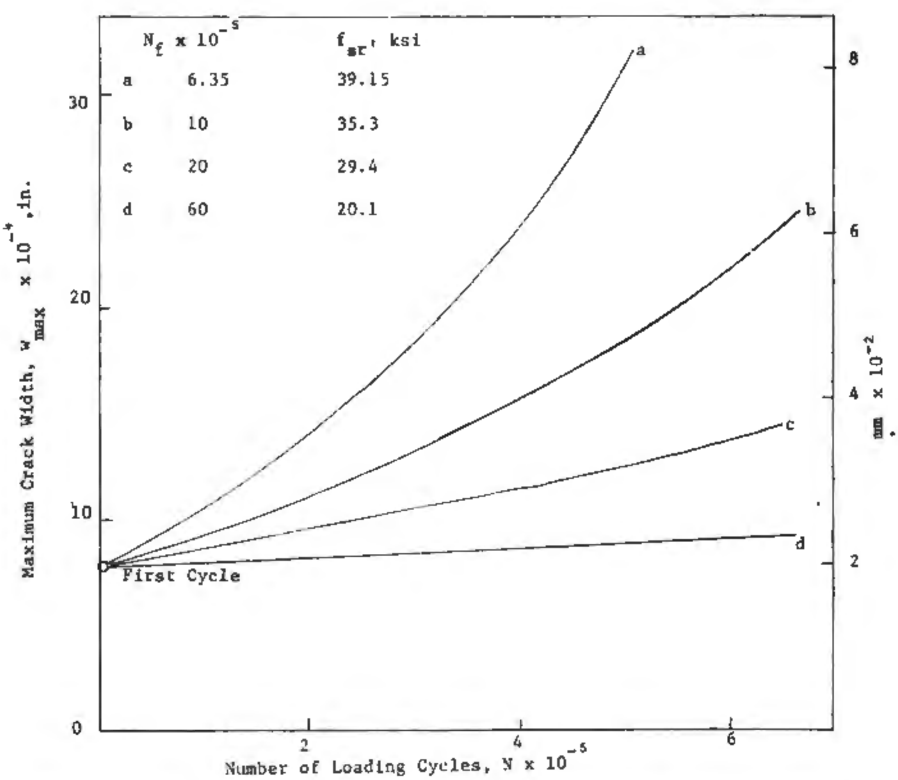


Fig. 5. Typical crack width increase in flexural beams under cyclic loading (Ref. 13).

A regression analysis of the observed data between the stress range f_{sr} in the outermost layer of steel mesh and the number of cycles to failure N_f led to the following relation:

$$f_{sr} = 152.3 - 19.5 \log_{10} N_f$$

f_{sr} being in ksi.

The same equation, if written in S.I. units, gives:

$$f_{sr} = 1051. - 134.4 \log_{10} N_f$$

where f_{sr} is in MN/M^2.

It was generally observed that deflections and crack widths, for the same load, increased with the number of loading cycles according to an exponential law. The effect was especially significant for low values of N_f as shown on Fig. 5.

WATER (OR LIQUID) RETAINING CAPACITY

Another special property to be noted is that of water retention when application of ferrocement is considered in liquid storage tanks. The important aspect here is small crack widths so that leakage may be minimal. Work by Shah and Naaman [14] indicated that crack widths in ferrocement for the same steel stress are smaller than in reinforced concrete by order of magnitude this making it a better choice on material for water retaining structures.

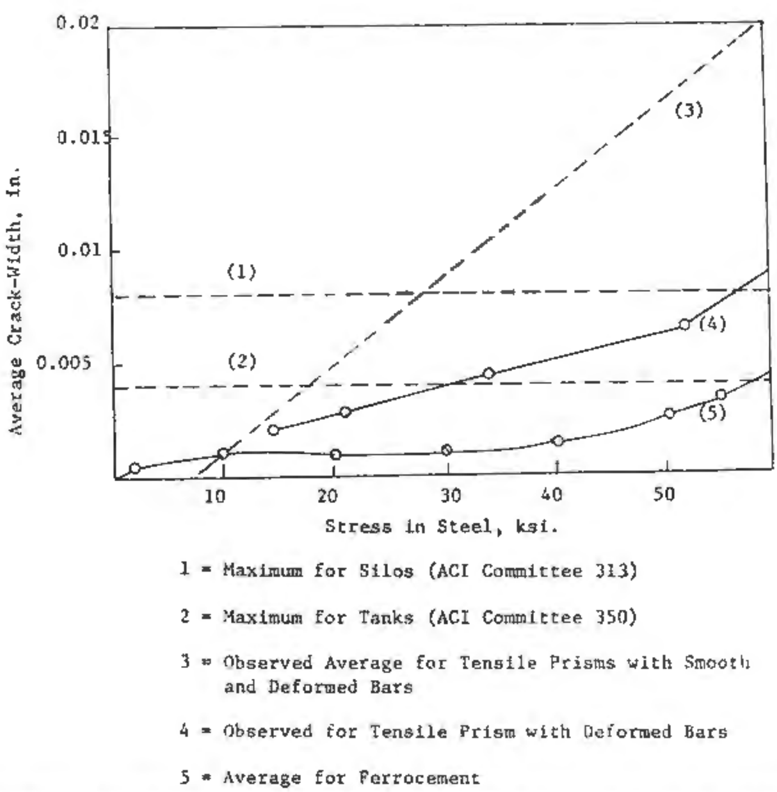


Fig. 6. Comparison of average crack-width vs. steel stress for ferrocement and reinforced concrete (Ref. 18).

Tests were conducted on cylindrical vessels with internal water pressure to investigate this impact. The results shown in Fig. 6 indicate clearly that the crack width in ferrocement is much smaller than the 0.004 in. (0.01 mm) recommended by ACI Committee 350, Sanitary Engineering Structures even at substantially high stresses. Furthermore, due to the well dispersed, finer reinforcing mesh the vessel behaves much better at the ultimate load level pressure in that failure is much more gradual and no incipient bursting is observed as in tanks made from other materials. Naaman and Sabins [15] have provided some recommendations on using ferrocement for water tanks.

IMPROVEMENT OF FERROCEMENT PROPERTIES

Attempts have been made recently to improve the properties of ferrocement. Notable improvement is reported by Atcheson and Alexander [16] in their work using fibers with ferrocement. Fibrous concrete has also been found to have good structural properties. Combining the two types of concrete, the above authors demonstrated the fibrous ferrocement of equal or better performance may be produced by using larger aperture steel mesh and fibers, thus removing the restriction from ferrocement to have closely spaced wire meshes.

Other possibilities of improving the properties of ferrocement exist such as using polymerization techniques, which have been demonstrated to improve properties of reinforced concrete to a great extent. As the technology progresses toward the economic use of polymerization, it is hoped that more related research will be reported to encourage its application in ferrocement.

RECENT APPLICATIONS

There have been many applications of ferrocement all over the world, both in developing and developed countries. The particular aspect of using the reinforcing cage as the stiff formwork itself, is an important advantage of ferrocement for use in complex shape structures, in which the cost of forming is sometimes prohibitive. Its use can be beneficial not only in habitats or building structures, but also in art structures. Recent applications of ferrocement are discussed in References [17-20]. They range from low cost housing in Mexico [18] to Fishing vessels in Canada [19] and prefabricated thin domes in Quebec, Canada [20]. Naaman and Shah [21] also present many other potential applications. Other possiblities exist for ferrocement applications, in off-shore structures such as buoys, deep submersibles and vessels for transportation of liquid gases.

CONCLUSION

This review paper presents some recent developments of ferrocement in North America. The excellent properties of the material should open the way to a great number of possibilities in industrialized countries. The recent analytical as well as experimental evaluations of the many properties of ferrocement make it eligible as a construction material similarly to other construction materials presently used.

REFERENCES

1. NAS, "Ferrocement: Applications in Developing Countries", National Academy of Sciences, Washington, D.C., February 1973, 90 pages.
2. BIGGS, G.W., "Definition of Ferrocement", Report prepared for SNAME Task Group HS-6-4, April 1972, 28 pages.
3. BEZUKLADOV, V.F., et al, "Korpusa Dudov iz Amotsementa" (Ship-hulls made of Ferrocement), Leningrad, 1968, 817 pp. (English Translation: NAVSHIP's Translation No. 1148, NTIS-AD680042).
4. SHAH, S.P., "New Reinforcing Materials in Concrete", J. ACI, Vol. 71, May 1974,-.257.
5. ACI 549, FERROCEMENT, "State of the Art Report" to be published in the Journal of ACI, 1975.
6. BATSON, G.B., SABNIS, G.M. and NAAMAN, A.E. "Survey of Mechanical Properties of Ferrocement as a Structural Material", (Part of Ref. 17).
7. NAAMAN, A.E. and SHAH, S.P., "Tensile Tests of Ferrocement", J. ACI, Vol. 71, May 1974,-.257
8. JOHNSTON, C.D., and MOWAT, D.N., "Ferrocement-Material Behavior in Flexture", Proc. ASCE, Structural Division, October 1974, p. 2053.
9. LOGAN, D. and SHAH, S.P., "Moment Capacity and Cracking Behavior of Ferrocement in Flexure", J. ACI, Vol. 70, December 1973, p. 799.
10. BALAGURU, P., NAAMAN, A.E. and SHAH, S.P., "Ferrocement in Bending-Part I: Static Non Linear Analysis". Report No. 76-a, Dept. of Civil Engr'g., University of Illinois at Chicago Circle, August 1976, 85 pages.
11. PAMA, R.P., INTARAGUMHAENG, V., and PAUL B.K. "A Study of Tensile cracks and Bond-Slip in Ferrocement", (Part of Ref. 17).
12. SHAH, S.P. and KEY, W.H., Jr. "Impact Resistance of Ferrocement", Proc. ASCE, Structural Division, January 1972, p. 111.
13. BALAGURU, P., NAAMAN, A.E. and SHAH, S.P., "Ferrocement in Bending-Part II: Fatigue Analysis" Department of Materials Engineering, University of Illinois at Chicago Circle, Report No. 77-1, Oct. 1977, 246 pp.
14. SHAH, S.P. and NAAMAN, A.E., "Crack Control in Ferrocement and Its Comparison with Reinforced Concrete", Presented at the symposium on "Practical Control of Cracking in Concrete Structures" held at the Fall Convention, ACI, New Orleans, La., October 1977, 24 pages.
15. NAAMAN, A.E., and SABNIS, G.M., "Tentative Guidelines for the Use of Ferrocement in Some Structural Applications", Proceedings of International Contercure on Materials in Developing Countries" (Ed. Pama R.P. et al), pp 677-688, 1978.
16. ATCHESON, M. and ALEXANDER, D., "The properties of Fibrous Ferrocement" Presented at the symposium on "Ferrocement-Material and Applications" held at the Annual Convention, ACI, Toronto, April 1978, 34 pages.
17. SABNIS, G.M., "Ferrocement-Material and Applications", Proceedings of the symposium held in ACI Annual Convention, Toronto, April 1978.

18. CASTRO, J.O., "Ferrocement Applications in Low Cost Housing in Mexico", (Part of Ref. 17).

19. GREENIUS, A.W., "Ferrocement for Canadian Fishing Vessels", No. 80 TRS of the Industrial Development Branch, March 1975.

20. BRUN, P., LACHANCE, L. and PICARD, A., "Systems Resille-Coque et Prefabrication pour Voiles Minces en Ferrocement", Proceedings of IASS Conference, Vol. 2, June 1976, p. 989.

21. NAAMAN, A.E. and SHAH, S.P., "Evaluation of Ferrocement in Some Structural Applications", Proceedings of International Symposium on Lower Housing Problems, May 1976, p. 1069.

Criteria for Choice of Microreinforcement in Concrete Composites*

B.R. Walkus, A.+ Januszkiewicz+ and J. Jeruzal+

The paper presents an assesment of the suitability of steel wires and meshes used as microreinforcement in concrete composites. Criteria for choice of microreinforcement and the influence of scale effect on the strength of steel fibers are also determined.

THE CONCEPT OF CONCRETE COMPOSITES

In traditional composites [1] manufactured for cosmic engineering, aeronautics, electronics, etc., (i.e. metal composites or plastic-base composites), all fibers serve to transmit the load while weaker but more flexible matrix serves mainly to keep the fibers in proper position and to transmit the load onto them. Individual components should essentially have the following properties (Fig. 1):

a) reinforcing fiber - high strength, high Young's modulus,
b) matrix - good bond property, easy to manufacture,
c) composite - strength and young's modulus higher than in matrix.

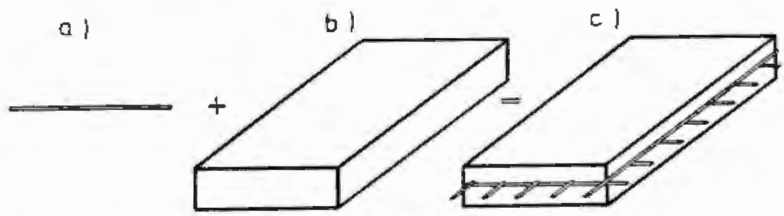


Fig. 1. Basic principle of concrete composites reinforced with steel fibers.
a) Reinforcing fiber - high strength, high Young's modulus,
b) Matrix - good bond, easy manufacturing,
c) Composite - strength and Young's modulus higher than those of matrix.

In the case of concrete composites the situation is opposite. Concrete matrix reveals characteristics of a brittle material and microreinforcement restrains the extent of microcracking occuring in the matrix. Under these conditions the advantages of concrete composite follow mainly from eliminating the defects of material structure (which is a result of dispersion of microreinforcement, aggregate dimensional restriction as well as special manufacturing techniques) and from the fact that in matrix weaker joints can be substituted by reinforcement.

Microreinforcement in concrete composite does not utilize its full strength under normal service conditions. As a result strength of the microreinforcement is not of basic importance. Essential requirements however are; good interaction with the matrix, i.e. good bond with

* Adapted by consent of the author with minor changes from the Proceeding of the International Conference on Materials of Construction for Developing Countries (August 22-24, 1978, AIT, Bangkok). Institute of Civil Engineering, Technical University of Lodz, Poland.
+ Institute of Civil Engineering, Technical University of Lodz, Poland.

concrete and the possibility of its easy distribution in the matrix during the manufacture of the composite. These properties depend on the material (steel, glass, etc.), type of microreinforcement (arranged and unarranged), its geometry (diameter, cross-section), arrangement in the composite (one way and two way arrangement, number of layers, spacing between the fibers, etc.) and dispersion (coefficient K). One way and two way continous steel microreinforcements were subjects of further studies.

GENERAL CHARACTERISTICS OF CONTINUOUS ARRANGED MICROREINFORCEMENT

While classifying steel microreinforcement various aspects can be considered, namely:

a) direction of arrangement
b) size of fibre diameter
c) shape of the fiber cross section
d) type of the surface
e) strain and strength properties
f) distribution in matrix
g) techniques of processing the microreinforcement - it concerns only the two-way arranged fibres (reinforcing meshes).

Taking into account the direction of arrangement the following continuous fibers can be distinguished:

a) one-way arranged
b) two-way arranged
c) three-way arranged

Three-way arranged continuous fibers (spatial mesh) have not been produced so far and thus still lie in the sphere of postulates and as such will not be considered here.

Microreinforcement used in concrete composites is made of wires of 1.0 mm diameter and in some cases up to 1.2 mm (decisive factor is a possibility of proper distribution in matrix and retaining the adequate value of coefficient K).

Taking into account various forms of the cross section (circular, semi-circular, flat, square, etc.) the considerations are restricted to the wire of circular cross section. The reasons for that are strength and technology, namely:

a) along the circular surface there is an even bond stress distribution
b) at the same time circular wires provide the maximum clearance between the reinforcement
c) circular shape ensures better infiltration of concrete mix

Microreinforcement can be produced as fibers with or without protective coatings, and as straight or undulated fibers. Fibers with protective layer (e.g. tinned) are more expensive and have no special effects on the properties of the composites, while continuous wires with a layer ensuring better bond have not been manufactured yet. Undulated wires are prefered to straight ones due to their superior bonding properties.

As it has been mentioned earlier, wires of high strength are not used in concrete composites because the strength of microreinforcement is not fully utilized in concrete composites.

Mesh in a continuous two way arranged microreinforcement can be square, rectangular. hexagonal, trapezoidal or any of the other available shapes. The most popular, reinforcing mesh manufacturing techniques are: weaving, welding, braiding and twisting.

Taking into account the same properties in both directions, especially in the range of basic studies, one should use reinforcing woven mesh of linen splice (Fig. 2a and 2b) as well as welded reinforcing mesh (Fig. 2c). Twisted mesh (Fig. 2d) which is often used for hull manufacturing, e.g. for yachts, is not included in the group of continuous arranged microreinforcement because of the shape of mesh (hexagonal mesh) and properties (e.g. strength) which differ significantly according to direction of the acting force (in direction of twist 107.2 N.cm, perpendicular to twist 37.5 N/cm of mesh width). Braided mesh (Fig. 2e) which has convex weave as related to the planes limiting the wire thickness can be used in special cases, i.e. assuming wide mesh spacing in concrete matrix and small mesh size. Continuity of the fibers is also controversial.

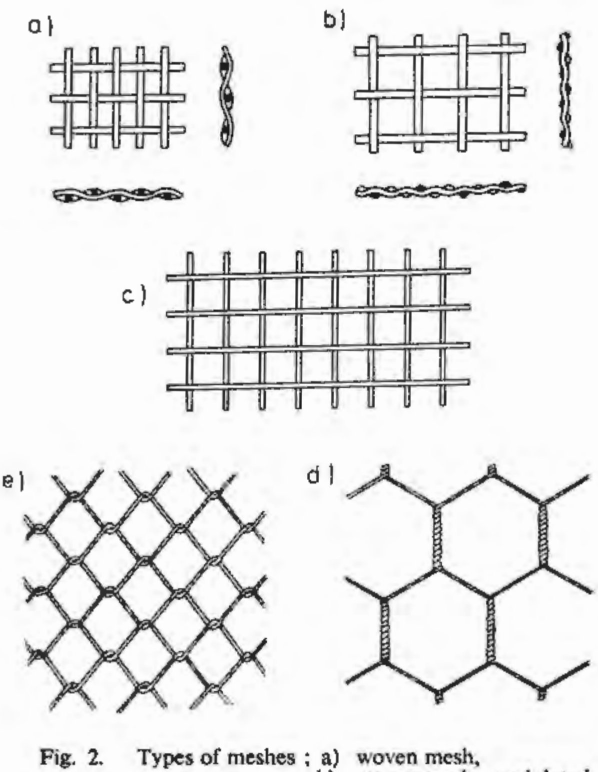


Fig. 2. Types of meshes ; a) woven mesh,
b) woven mesh - undulated wires,
c) welded mesh,
d) twisted mesh,
e) plaited mesh.

Distribution of fibers in the composite is determined by specific surface K which expresses the ratio of bond surface of the fibers to the volume of composite. It is expressed as cm^2/cm^3, i.e. cm^{-1} [2]. It is determined according to the direction of fibers and direction of acting force. Thus for the continuous one-way arranged fibers specific surface $K_1 = K_x$, for two-way arranged under uniaxial load $K_1 = K_x$, too, while under biaxial load $K_2 = K_x + K_y$.

According to the tests specific surface K_x must be in the range

$$1.0 \leq K_x \leq 1.5 \text{ cm}^{-1}$$

The lower limit assures that the material has extended microcracking phase and the upper limit is the resultant from arrangement of fibers and casting limitations.

Specific surface K depends upon the fiber diameter, spacing between fibers and percentage of microreinforcement, relationship between them can be expressed as [2].

$$\mu = 0.25 \; d \; K_x \qquad \ldots\ldots\ldots \quad (1)$$

where d = fiber diamater in cm

The relationship shown above is plotted in Fig. 3 for three values of specific surface K_x (lower, mean and upper). From Fig. 3 it follows that the composite with arranged microreinforcement evenly distributed in the cross section should have the percentage of reinforcement in one direction, in the range.

$$1.25 < \mu < \quad 4.5$$

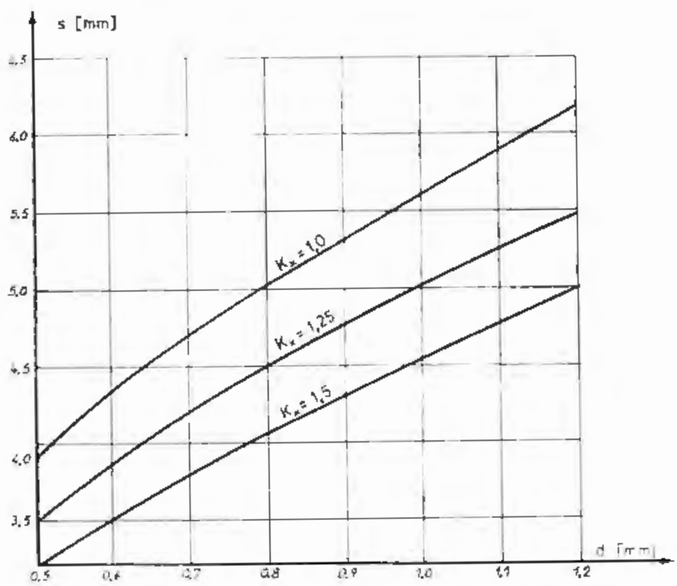


Fig. 3. Relationship between percentage of microreinforcement, wire diameter and coefficient K_x.

The cross section of such a composite is shown in Fig. 4. Following the notations assumed in Fig. 4 we can obtain

$$\mu = \frac{\pi d^2}{4bh} \, n \qquad \ldots\ldots\ldots \quad (2)$$

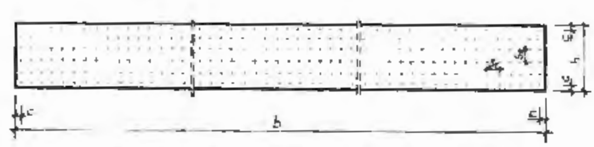


Fig. 4. Matrix saturated with fibers.

The number of fibers, n, is

$$n = \frac{(b + S_1 - 2c)\ (h + s_2 - 2c)}{s_1\ s_2} \qquad \text{.........} \quad (3)$$

Assuming that the components $(s_1 - 2c)$ and $(s_2 - 2c)$ are very small as compared with the cross section dimensions (b, h) we obtain

$$\mu = 0.25\ \frac{\pi d^2}{s_1\ s_2} \qquad \text{.........} \quad (4)$$

Comparing Eq. (1) with Eq. (4) we obtain

$$K_x = \pi\ \frac{d}{s_1\ s_2} \qquad \text{.........} \quad (5)$$

This relationship is plotted in Fig. 5.

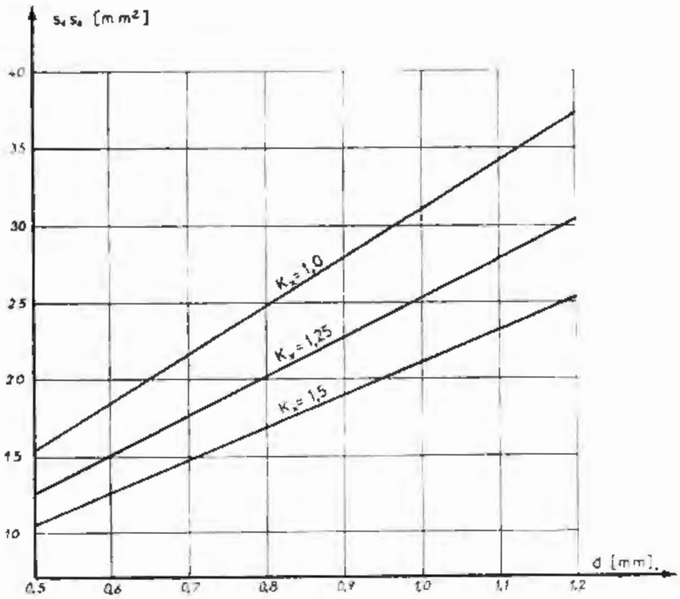


Fig. 5. Relationship between spacing product, wire diameter and coefficient K_x.

When microreinforcement is distributed ideally in the matrix i.e. when the spaces between fibers in both direction are equal $(s_1 = s_2 = s)$, Eq. 5 assumes the form:

$$K_x = \frac{\pi\ d}{s^2} \qquad \text{.........} \quad (6)$$

This formula is plotted in Fig. 6. It follows from Fig. 6 that optimum spacing of particular fibers should be in the range 3 mm $\leq s \leq$ 6 mm, according to fiber diameters. Further restraints of spacing results from technical criteria imposed by industrial practice, thus, it means that the diameter of grain of the aggregate should not exceed 1/3 space between fibres.

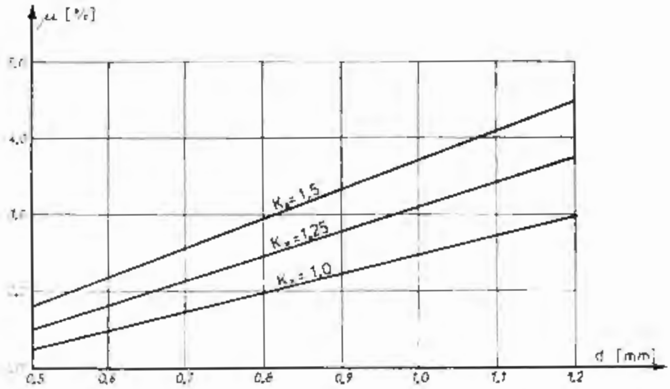


Fig. 6. Relationship between wire spacing wire diameter and coefficient K_x for perfect saturation of the matrix with wires.

At initiation of cracking in reinforced concerete elements subjected to tension, stresses in the reinforcement vary along its length. In extreme cases the stress in the reinforcement at the cracked section reaches its strength in tension, while at other sections its value is lesser than the elastic limit. The length of fibers as a result depends on the bond between concrete and steel. In case of a good bond between the two, the length of the fiber need not be much different from the maximum crack width while in case of a poor bond, the fiber should be much longer.

In ferrocement elements subjected to tension, high intensity of cracking, i.e. occurence of numerous cracks of small widths, is observed. When proper value of specific surface is maintained ($K_X \geq 1.0$ cm^{-1}) cracks occur on every second transversal wire [3] and thus effectively working length of oblong wires (when concrete does not follow the deformation of steel) is $l = 2a$, where a is the mesh size. To investigate the strength of such a short wire is inconvenient. Hence, it is recommended that in order to determine the strength of mesh reinforcement one has to carry out laboratory tests on specimens of gauge length l_0 = 100 mm.

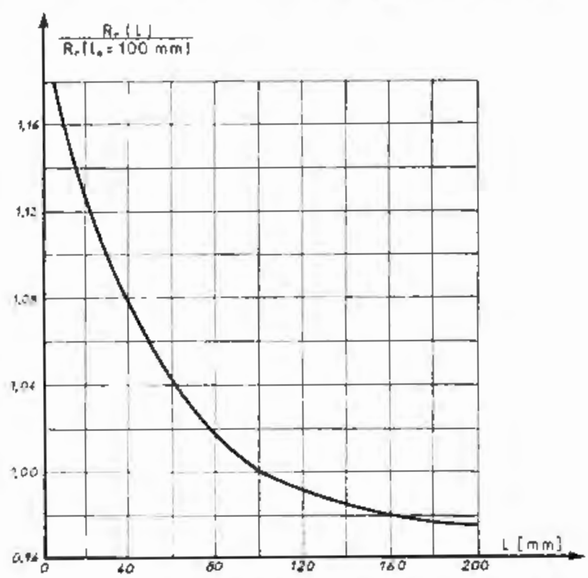


Fig. 7. Influence of the gauge length on the strength of wires of woven meshes.

On the basis of laboratory tests [3] a diagram of changes of tensile strength of mesh reinforcement as function of gauge length has been plotted (Fig. 7). It follows from Fig. 7 that tensile strength of microreinforcement of gauge length l_0 = 100 mm differs maximum about 16% from the strength determined on shorter gauge lengths.

Taking into account the fact that a ferrocement element usually has several layers of reinforcing meshes and consequently a considerable number of wires, their effect on the tensile strength was determined (Fig. 8). As the total number of extended wires increases, the tensile strength decreases. In the extreme case it is smaller by 15% when compared to strength of a single wire, i.e. about the same as strength increase resulting from testing the specimens on a smaller gauge length.

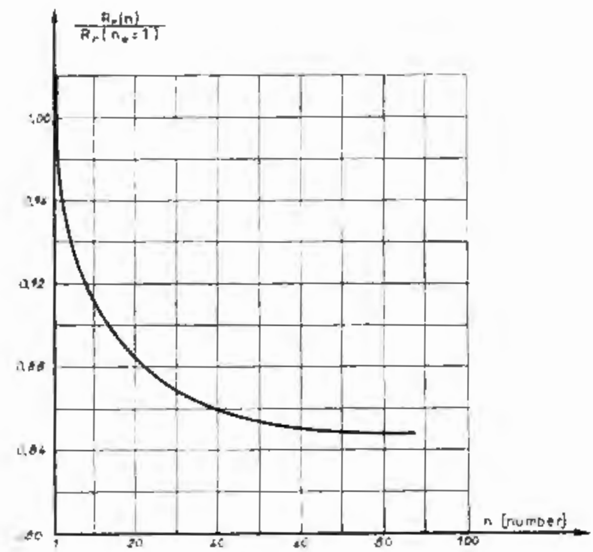


Fig. 8. Influence of the number of simultaneously tested wires on their tensional strength.

Taking into consideration the above mentioned factors which caused changes in the tensile strength, it seems purposeful to carry out tests of microreinforcement (reinforcing meshes and wires) using a gauge length, l_0 of 100 mm.

CONCLUSIONS

The following remarks are the result of the studies and tests carried out so far:

1. Circular fibers of diameter up to 1.2 mm of small strength and extensibility and increased bond to matrix should be used as arranged continuous steel microreinforcement.

2. Fibers distributed in matrix should satisfy the following condition.

$$1.0 \leq K_x \leq 1.5 \text{ cm}^{-1}$$

which results the optimum percentage of microreinforcement in the range

$$1.25 \leq \mu \leq 4.5\%$$

3. While distributing fibers in the matrix equal spaces between the fibers in both directions in cross section should be retained. The spaces should range from 3 to 6 mm.

4. The basic gauge length $l_0 = 100$ mm is recommended for the determination of tensile strength in microreinforcement of concrete composites (reinforcing meshes and wires).

REFERENCES

1. SZUMER, A., "Metal composites", (in Polish), Basic Problems of Contemporary Technics, Vol. XIX, Panstwowe Wydawnictwo Naukowe, Warszawa 1975.
2. WALKUS, B.R., "Investigation of Cracking Behavious in Tensioned Ferrocement Elements", (in Polish), Inzynieria i Budownictwo, No. 7/1966.
3. WALKUS, B.R., "Influence of Mesh Size on Strength of Ferrocement Reinforcement", (in Polish), Archiwum Inzynierii Ladowej, Vol. XV, No. 4/1969.

Small Capacity Ferrocement Bins For Foodgrain Storage*

P.C. Sharma†, S. Gopalakrishnan†, N.V. Raman‡ and G.V.S. Kumar†

In this paper, the work carried out at the Structural Engineering Research Centre, Roorkee (India) on the development of prefabricated small capacity ferrocement bins for the use of farmers to store foodgrains has been presented. Details of ferrocement bins, casting process developed, assembly of bins, cost estimates and advantages of the ferrocement bins have been outlined.

INTRODUCTION

In India, about 70 percent of the total foodgrain production is stored by farmers in rural areas at micro-level and the rest 30 percent is taken over by the governmental agencies like Food Corporation of India and Warehousing corporations for storage at macro-level and for public distribution. It is estimated that a minimum of 10 percent of total foodgrain production in the country is wasted every year due to unscientific, imporper storage methods and inadequate storage facilities. This accounts for a yearly loss of about Rs. 1000 crores (approx. 1250 million US Dollars) in terms of money value. This colossal loss of foodgrains, if avoided or brought down considerably, could feed a minimum of about 50 million people. With 70 percent of the grain stored in villages, the answer to this problem is to develop and promote scientific and inexpensive methods of foodgrain storage at the rural level. Keeping this in view, the research carried out at the Structural Engineering Research Centre, Roorkee (India) has resulted in the development of $\frac{1}{4}$, $\frac{1}{2}$, 1, 2 and 3 tonne ferrocement grain storage bins for the use of farmers in rural areas. The process developed and patented by the Centre for the production of ferrocement bins has been released to the industry through National Research Development Corporation of India (NRDC), New Delhi [1] and these bins are now available in the Indian market.

FERROCEMENT BINS DEVELOPED BY THE STRUCTURAL ENGINEERING RESEARCH CENTRE (SERC), ROORKEE (INDIA)

The ferrocement bins developed by the Centre are cylindrical in shape and are assembled out of prefabricated components viz. reinforced concrete base slab, ferrocement wall unit and dome-shaped ferrocement roof units. A manhole is provided in the roof unit for loading and an outlet is provided in the bottom-most wall unit for unloading the grain. Synthetic rubber gaskets are provided both at the inlet and the outlet to make the bins air-tight. Locking arrangements are provided for the inlet and the outlet openings. The external surface of the bin is painted with bituminous aluminium paint which acts as an additional protective layer to the bin to make them damp-proof and to avoid corrosion of reinforcement in corrosive climates. The sizes of the various components of the bins have been so selected that these units can be easily transported and the base, wall or roof of even a 3 tonne bin can be easily handled and erected manually by 4 or 5 persons. The R.C. base slab of 1, 2 and 3 tonne bins,

---

* Published also in the Proceedings of the International Conference on Materials of Construction for Developing Countries (August 22-24, 1978, AIT, Bangkok).

† Scientist, Structural Engineering Research Centre, Roorkee, India.

‡ Deputy Director, Structural Engineering Research Centre, Roorkee, India.

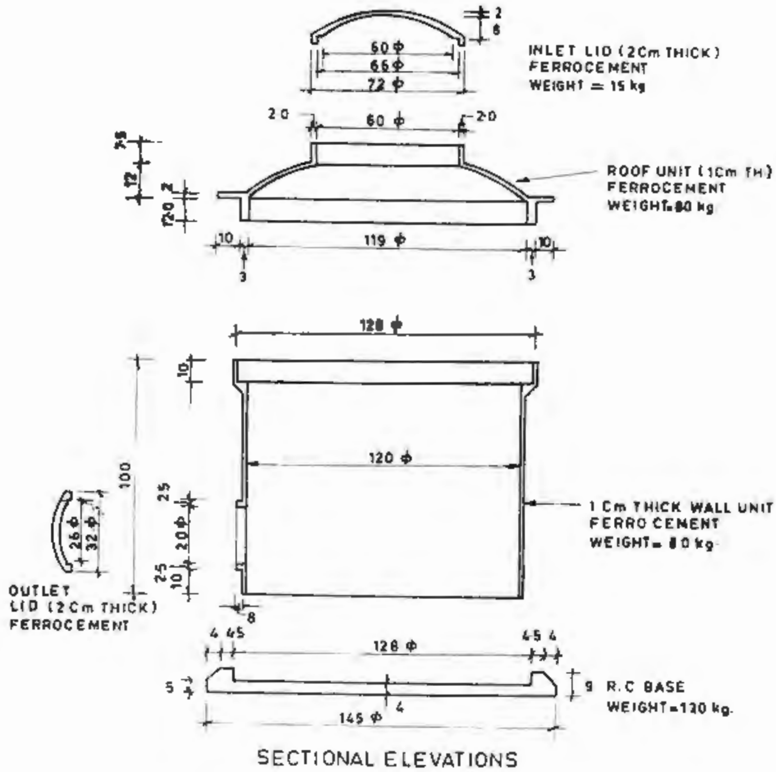


Fig. 1. Pre-fab units for bins upto 3 tonnes capacity.

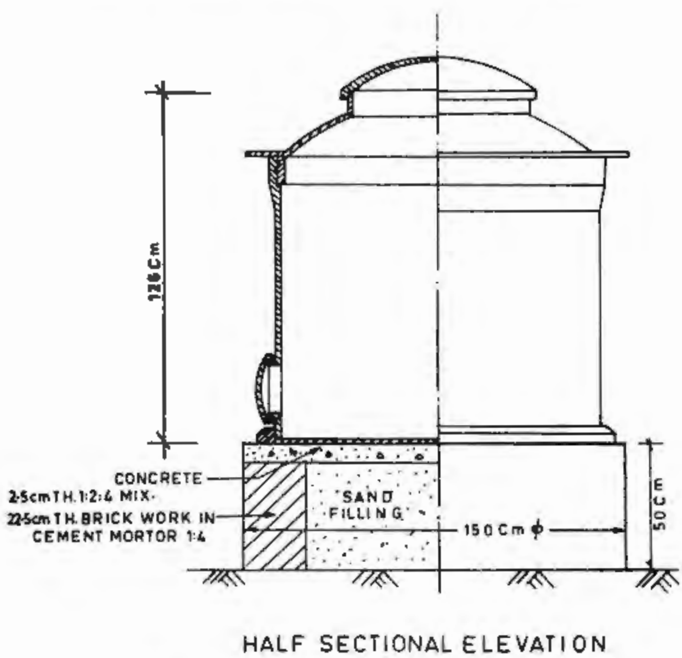


Fig. 2. 1 Tonne capacity (outdoor bin).

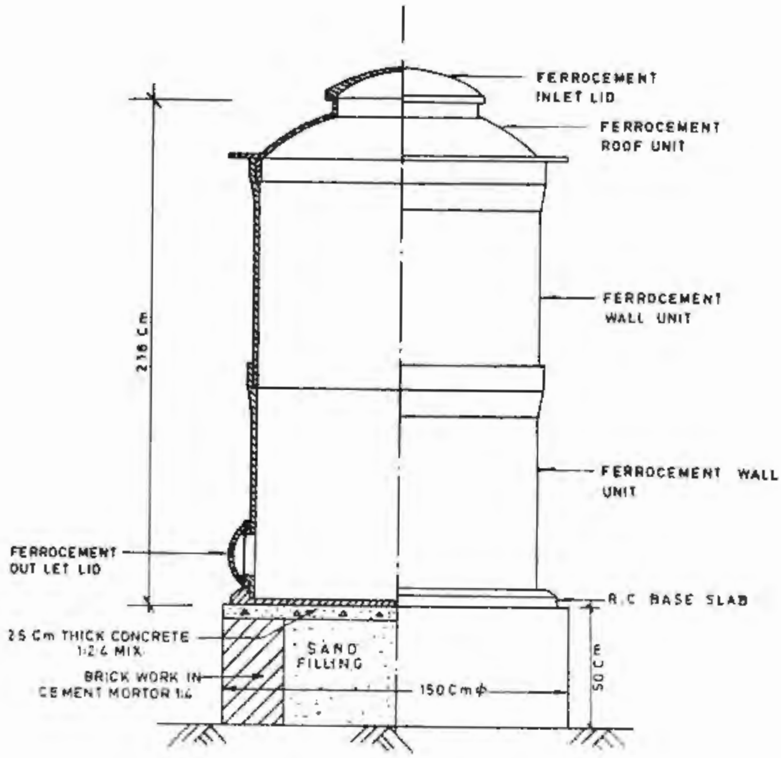
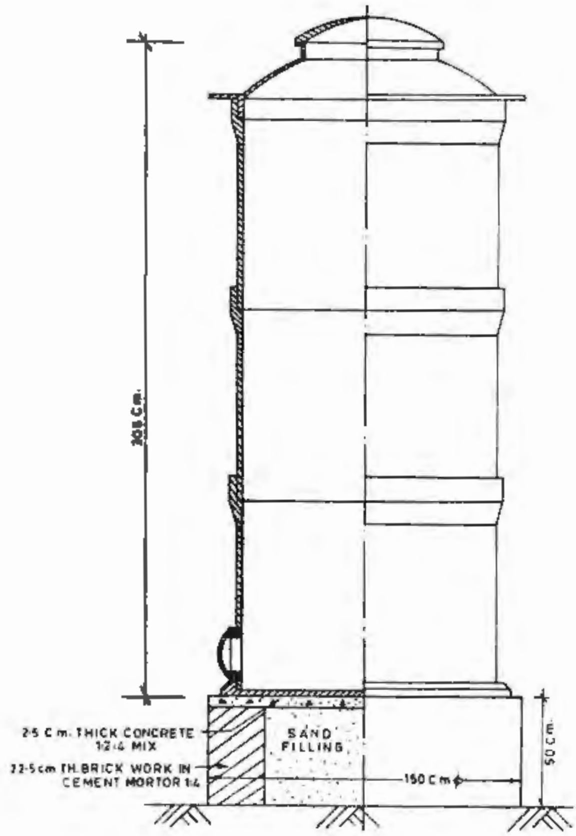


Fig. 3. 2 Tonne capacity (outdoor bin).

which is the heaviest of the prefabricated components, weighs about 120 kg. only. The cylindrical shape is preferred for the wall unit, because it is suitable for mass production at the factory level. The geometrical details of the prefabricated components used in the erection of 1, 2 and 3 tonne bins are given in Fig. 1. Depending on the individual consumer's requirement 1, 2 or 3 tonne bin may be assembled by erecting one, two or three cylindrical ferrocement wall units (having 120 cm diameter) one over the other and filling up the joints with cement mortar mixed with water proofing/damp proofing chemicals. The details of 1, 2 and 3 tonne bins are given in Figs. 2, 3 and 4.

CASTING PROCESS

The cylindrical ferrocement wall units are cast using the semi-mechanised casting process developed at the Centre [1]. In the casting process, a continuous winding of wiremesh from a wiremesh roll on to a cylindrical mould and simultaneous application of the cement mortar on the wiremesh as and when it is wound on the mould is achieved. This enables to have a high degree of compaction of mortar and good control over the thickness. This process is labour-intensive and does not require power or expensive machinery. A diagrammatic representation (elevation and plan) of the casting process equipment developed at the Centre is shown in Fig. 5. The process of casting consists of the following steps (Refer Fig. 5):



HALF SECTIONAL ELEVATION

Fig. 4. 3 Tonne capacity (outdoor bin).

1. The wiremesh roll for wall unit is mounted on spindle 'A' and the wiremesh roll for collar portion of the unit is mounted on spindle 'B'.
2. The mould for casting the cylindrical unit is mounted on stand 2.
3. The wiremesh is initially tied to the cylindrical mould.
4. The cylindrical mould is rotated in the forward direction as shown by arrow in Fig. 5 so that the mesh gets wound on the mould and moves along with the mould. When a sufficient portion of the wiremesh is wound on the mould, the rotation of the mould is arrested and rich cement mortar (1:2 mix) with water proofing/damp proofing chemicals is applied on the portion of the wiremesh wound on the mould. After the application of cement mortar, the mould is rotated further so that wiremesh gets wound on the mould and cement mortar is applied to the wiremesh in continuation of the portion on which cement mortar was already applied. Thus, the process goes on continuously and the application of cement mortar is done layer by layer on the wiremesh till the required number of layers of wiremesh are wound on the mould and the required thickness is obtained.

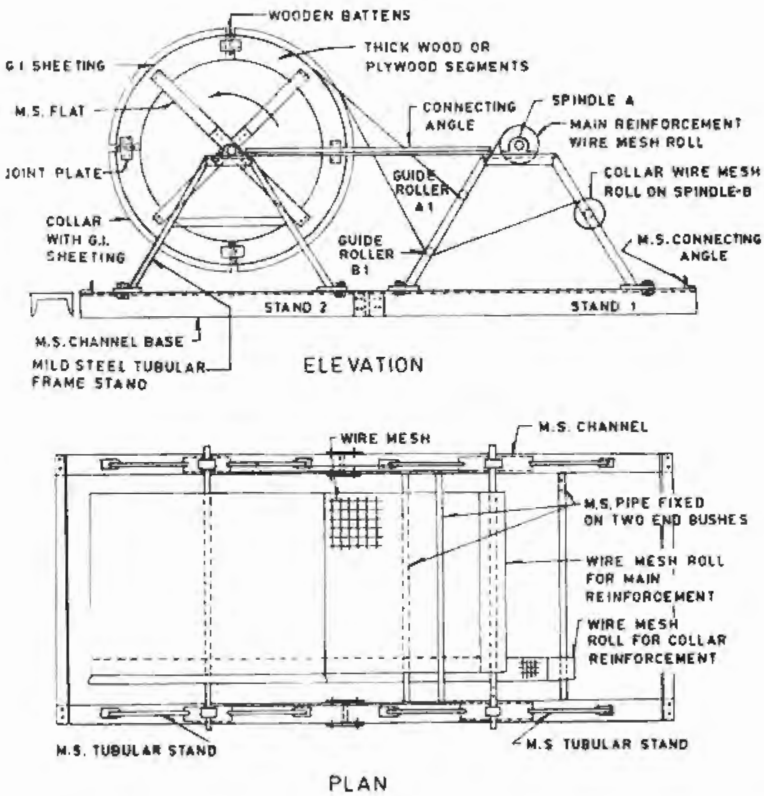


Fig. 5. Semi-mechanised casting process for producing cylindrical ferrocement units.

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

6. After 24 hours, the mould along with casting is removed from the casting process equipment and the unit is demoulded.

7. The wall unit is given a finishing coat of cement mortar on the inside surface and is cured for 14 days with water before it is used for assembling the bin.

The R.C. base slab and the dome-shaped ferrocement roof unit and the ferrocement lid for manhole in the roof unit are cast using suitable moulds. Centre has developed masonary moulds for these units which are cheap and have long life.

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

Figs. 6, 7 and 8 show a view of the ferrocement roof unit, ferrocement wall unit and R.C. base slab respectively.

Fig. 6. A view of ferrocement roof unit.

Fig. 7. A view of ferrocement wall unit.

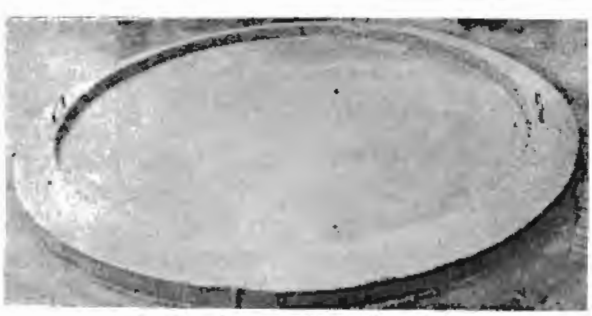


Fig. 8. A view of R.C. base slab.

ASSEMBLY OF FERROCEMENT BINS

After curing the precast components of the bins for 14 days with water, they are transported to the site and the bins are assembled.

Fig. 9. A view of $\frac{1}{4}$ tonne ferrocement grain storage bin.

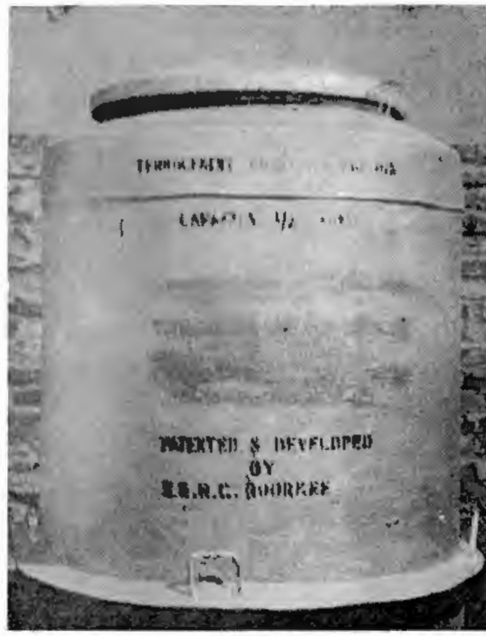


Fig. 10. A view of $\frac{1}{2}$ tonne ferrocement grain storage bin.

Fig. 11. A view of 1 tonne ferrocement grain storage bin.

Fig. 12. A view of 2 tonne ferrocement grain storage bin.

The joints are filled with cement mortar mixed with water proofing/damp proofing chemicals and the joints are cured for a further period of 7 days. After this period, the bin surface is allowed to dry and two coats of bituminous aluminium paint are given on the outside surface of the bins to make them damp-proof. Painting further improves the aesthetic appearance of the bins.

Figs. 9, 10, 11 and 12 show a view of $\frac{1}{4}$, $\frac{1}{2}$ 1 and 2 tonne ferrocement bins assembled, painted and ready for storing foodgrains.

ANALYSIS AND DESIGN OF FERROCEMENT BINS

The ferrocement bins were analysed and designed using the thin shell theory. Force due to dead load, live load, bin wall loads exerted by stored grains, temperature variations across the bin wall, wind load and perturbational effects due to fixty conditions at the joints caused by various loadings were taken into account in the analysis. The critical stresses for the design of the cylindrical wall unit due to direct vertical load and bending are well within the permissible stresses for the type of ferrocement used. Hence a minimum wall thickness and reinforcement have been adopted from practical considerations of erection and feasibility of casting. The details of the analysis and design of a 3 tonne ferrocement bin are given in a technical report prepared by the Centre [2].

EVALUATION TESTS ON THE BIN UNITS

(a) Tests for Water Proofing of Bin Units

The ferrocement units were coated inside with bituminous paint and were filled with water to observe any dampness in the walls or joints. No leakage or dampness was observed and their performance was found to be satisfactory.

A 2 tonne ferrocement bin without outlet hole in the wall portion was coated with coal-tar emulsion on the outer surface and was erected underground in a pit as shown in Fig. 13. The annular space between the outside surface of the ferrocement bin wall and the pit was filled with water to test the ferrocement bin for leakage and damp-proofness. The performance

Fig. 13. 2 tonne bin fully submerged in an underground tank during testing for damp proofness and leakage.

was observed over a period of four years. The joints and the wall units were found to be damp-proof and no corrosion of reinforcement took place. Based on these tests, two coats of bituminous aluminium paint on the outer surface of the bin are recommended to make the bin damp proof and to prevent corrosion of reinforcement.

(b) Load Testing with Grain

A 3 tonne ferrocement bin as shown in Fig. 14 was tested with wheat as filling material for different loading conditions viz. filling, filled and eccentric emptying conditions to ascertain the structural efficiency of the thin ferrocement walls to carry the bin wall loads. The test was repeated many times and strains at different positions on the bin wall were measured and the measurements showed that the loads exerted on the bin wall were much less than the critical values for the type of ferrocement used. The thickness and reinforcement provided for the bin wall were adequate and safe for the loads exerted on it. The grain unloading operation was smooth and presented no difficulties.

Fig. 14. 3 tonne bin under testing with wheat as filling material.

(c) Load Test on Roof Unit

The dome-shaped ferrocement roof unit, which was designed for a live load of 200 kg/m^2, was load tested and was found to be safe.

(d) Evaluation Tests to Ascertain the Suitability of Ferrocement Bins to Store Foodgrain

Ferrocement bins of 1 and 2 tonne capacities (both underground and above ground types) were erected at the Central Food Technological Research Institute (CFTRI), Mysore (India) by the Centre. Evaluation tests for studying the functional suitability for storage of foodgrain in these bins were conducted by the CFTRI to ascertain the following:

(a) Resistance against rodent and termite attack and impermeability to moisture from outside sources
(b) Evaluation for the retention of fumigants so as to offer suitable situation for the control of insect infestation arising out of the grain filled with initially infested stock
(c) Evaluation of the effect of ambient temperature on the inside bin temperature
(d) Initial curing time required for making the bin suitable for foodgrain storage

Results of the evaluation tests on the ferrocement bins conducted by the CFTRI, Mysore showed that:

1. Both the above ground and underground ferrocement bins are quite suitable for storage of foodgrains.
2. The bins are absolutely resistant against rodent attack, termite proof and impervious to moisture from outside sources.
3. Above ground and underground ferrocement bins are quite efficient in retaining the fumigant concentration to be effective against insects.
4. The internal surface of the bin should be fully dry and the grain should be dry before the grain is stored in the bin to avoid mould growth and caking.

COST ESTIMATES OF FERROCEMENT BINS AND COST COMPARISON WITH OTHER TYPES OF STORAGE BINS

The production cost estimate of ¼, ½, 1, 2 and 3 tonne ferrocement bins is given in Table 1, Cost comparison of the ferrocement bins developed at the Centre with other types of

Table 1 Cost Summary of Ferrocement Bins (December 1977 rates)

Capacity (wheat) tonne	Material cost in cluding 10% over head&2% storage charges Rs.	Cost of paint in cluding 10% over head&2% storage charges Rs.	Cost of gaskets including 10% over head and 2% storage charges Rs.	Cost of labour Rs.	Ammorti- sation cost of moulds Rs.	Supervision cost 5% on total cost Rs.	Net pro- duction cost Rs.
Indoor Ferrocement Bins							
1/4	46.75	5.61	25.20	20.89	4.84	5.17	108.46
1/2	116.23	8.76	29.12	25.83	5.63	9.47	194.85
1	191.80	21.00	29.12	27.04	6.97	13.80	289.73
2	263.61	35.56	29.12	39.27	11.02	18.93	397.51
3	335.42	50.12	29.12	51.50	15.07	24.06	505.29

Note : 1. Outdoor Ferrocement Bins (Production Cost) (i) Add supporting structure cost (approximately Rs. 30—for a 50 cm height brick masonry platform) to the cost of indoor ferrocement bins. (ii) 1/4t and 1/2t bins are meant for indoor use only

2. Underground ferrocement bins (Production Cost)
Add cost of excavation to the cost of indoor ferrocement bins
Cost of excavation for 1t bins Rs. 32.00
for 2t bins Rs. 42.00
for 3t bins Rs. 51.00

3. Rs. 9.10 = 1 US Dollar

bins developed by various agencies in India is given in Table 2. From the point of view of long term durability, minimum maintenance, protection against rodent attack and fire hazard, ferrocement bins developed at the Centre are economical when compared with other types of bins available in India.

Table 2. Cost Comparison of Various Bins

Material/Organization	Capacity (Wheat)					Remarks
	1/4t	1/2t	1t	2t	3t	
INDOOR BINS						
Ferrocement (SERC Roorkee)	108.46	194.85	289.73	397.51	505.29	Dec. 1977 rates
Metal (UP Agro. Industries)	-	220.00	350.00	-	-	1975 rates
Save grain and allied products (Delhi).	-	-	390.00	780.00	-	1975 rates.
Plywood (IPIRI, Bangalore)	-	165.00	245.00	350.00	450.00	1976 rates
OUTDOOR BINS						
Ferrocement above ground (SERC, Roorkee)	-	-	319.73	427.51	535.29	Dec. 1977 rates.
Ferrocement under ground (SERC, Roorkee)	-	-	321.73	439.51	556.29	Dec. 1977 rates.
Concrete (ACC. Secunderabad)	-	-	460.00	840.00	1100.00	1977 rates
Concrete semi-under-ground (CBRI, Roorkee)	-	-	400.00	-	-	1976 rates
Modified brick (CBRI, Roorkee)	-	-	-	-	1375.00	1976 rates
Brick pusa bin (IARI, Delhi)	-	-	-	467.00	-	1977 rates
Modified clay (CBRI, Roorkee)	-	-	275.00	-	-	1976 rates
Metal (IGSI, Hapur)	-	-	-	1450.00	1575.00	1971-72 rates
Plywood (IPIRI, Bangalore)	-	-	300.00	430.00	560.00	1976 rates

Note :

SERC ; Structural Engineering Research Centre, Roorkee India.
IPIRI ; Indian Plywood Industries Research Institute, Bangalore, India.
ACC ; Associated Cement Companies, Secunderabad, India.
CBRI ; Central Building Research Institute, Roorkee, India.
IARI ; Indian Agricultural Research Institute, New Delhi, India.
IGSI ; Indian Grain Storage Institute, Hapur, India.
Rs. 9.10 = 1 U.S. Dollar.

SAMPLES SURVEY REGARDING GRAIN STORAGE PRACTICES IN VILLAGES

A sample survey was conducted by the Centre in 29 villages around Roorkee to assess the existing grain storage practices prevalent in rural areas and to study the reactions of the farmers towards ferrocement bins developed at the Centre [3]. The farmers, who were interviewed, admitted that they did not have proper type of storage structures to store their foodgrain safely. They reported foodgrain losses varying from 10 per cent to 50 per cent during storage in traditional form of storage structures made of mud and wood which were susceptible to rodent attack, fire hazard and not suitable to carry out fumigation of foodgrain effectively. They desired to have ferrocement bins developed at the Centre and wanted subsidy in cost of bins and long term bank loans at easy lending rates to enable them to purchase ferrocement bins. As per the suggestions of farmers, $\frac{1}{4}$ and $\frac{1}{2}$ tonne ferrocement bins were also designed and developed at the Centre.

ADVANTAGES OF FERROCEMENT BINS

Ferrocement bins possess the following advantages:

1. The bins are cheaper compared to steel, aluminium and reinforced concrete bins.
2. The bins are lighter than reinforced concrete bins.
3. The bins require little or no maintenance.
4. The condensation and moisture migration problems in the store foodgrain in ferrocement bins are much less than in steel bins.
5. Ferrocement bins are rodent proof, fire proof, damp proof and can be made air tight easily by sealing the inlet and outlet openings.
6. Any structural damage to the ferrocement bins can be easily repaired.
7. Ferrocement bins can be easily fabricated at the rural level. The fabrication technology is simple and can be easily acquired by the rural artisans.

VERSATILITY FOR DIVERSE USES

The know-how developed for the production of ferrocement bins can be diversified for the production of ferrocement water tanks and ferrocement biogas holders.

The Centre has recommended the ferrocement cylindrical units for the installation of small capacity water tanks for household and farm usage especially to meet the demands of hygienic water supply in rural areas. Fig. 15 shows a view of 600 litre ferrocement water tank suitable for use as overhead water tank in urban dwellings. Figs. 16 and 17 show a view of rural water storage scheme for 5000 litre and 10000 litre water storage respectively using ferrocement water tanks.

Using the above casting process, ferrocement biogas holders upto 2 cu m. capacity have been developed at the centre under a research project sponsored by the Department of Science & Technology, Government of India. Savings in the cost of biogas holders could be effected upto 50 percent with ferrocement gas holders in the place of mild steel biogas holders.

Fig. 15. A view of 600 litre ferrocement-water tank for use as overhead water tank in urban dwellings.

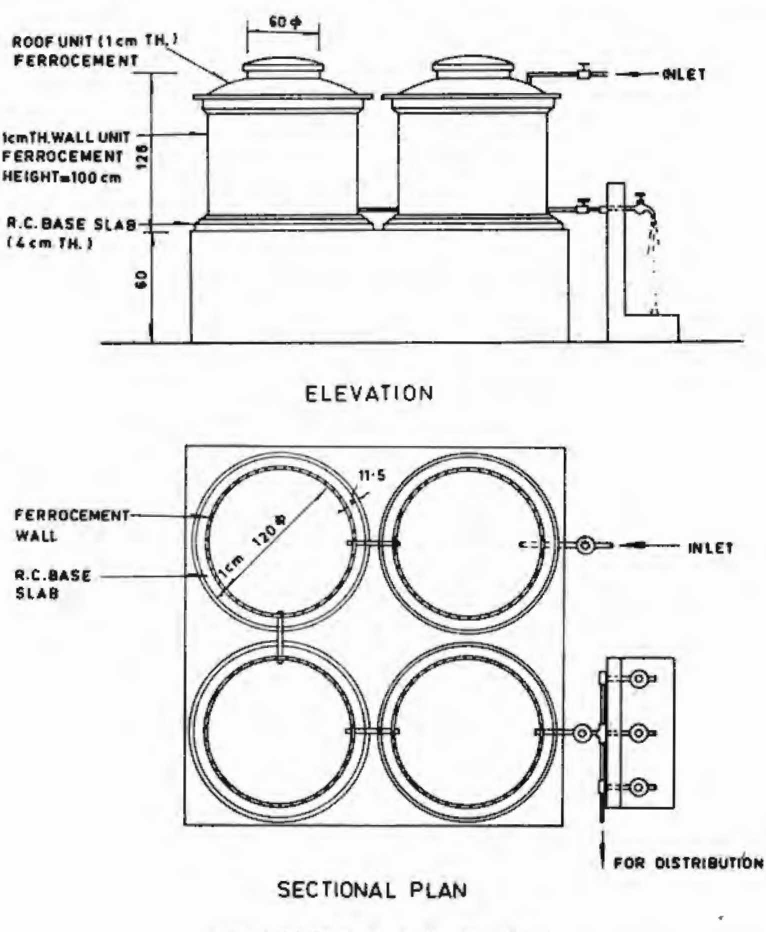


Fig. 16. Ferrocement water tanks for rural water storage scheme of 5,000 litre capacity.

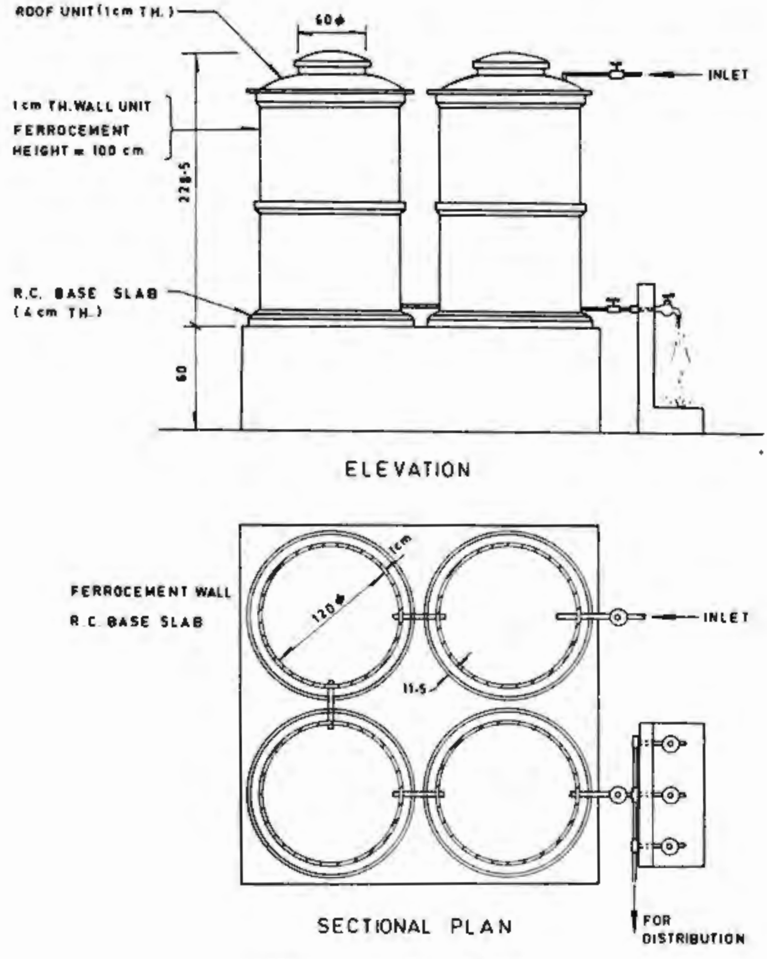


Fig. 17. Ferrocement water tanks for rural water storage scheme of 10,000 litre capacity.

ACKNOWLEDGEMENT

This paper is published with the permission of the Director, Structural Engineering Research Centre, Roorkee (India).

REFERENCES

1. G.V. SURYA KUMAR, P.C. SHARMA and S. GOPALAKRISHNAN "Improvement in or relating to precast ferrocement cylindrical units for use in structure like grain storage bins, water tanks, biogas holders and pipes", Patent application No. 75/DEL/76, Structural Engineering Research Centre, Roorkee (India).
2. S. GOPALAKRISHNAN, "Analysis and design of a 3-tonne capacity ferrocement bin", Technical Report, Structural Engineering Research Centre, Roorkee (India), December 1974.
3. S. GOPALAKRISHNAN, P.C. SHARMA & G.V. SURYA KUMAR, "Field Survey regarding grain storage in villages", Technical Report, Structural Engineering Research Centre, Roorkee, (India), January 1975.

Skinned Elements Made of Ferrocement for Building*

F. Bluger† and E.Z. Tatsa‡

The use of ferrocement ribbed plates as skinned elements for buildings is discussed. The load bearing elements of floor slabs may be of very light weight, and their sound-insulating properties provided by cheap materials. The ribbed slabs used as concrete casing need not be supported along the span. The walls may be built up of two ribbed elements and the space in between filled by insulating materials or by concrete cast-in-situ. The joints of the composite structure built of ferrocement elements are more reliable than traditional precast ones. The use of ferrocement skinned elements permits construction of efficient structures with the advantages of both precast and cast-in-situ systems.

INTRODUCTON

A large number of construction methods based on building with skins have been developed in recent years. This type of construction, which is of a semi-prefabrication nature where a part of the final element is prefabricated while the rest is cast-in-situ, reduces the weight of elements during handling and erection. In these methods at least one layer is precast, serving first as formwork for the casting of the additional concrete and later as a part of the composite element. Usually the precast element is made of reinforced concrete, approximately 50 mm thick, stiffened by steel trusses to avoid damage during handling and erection. In some methods the prefabricated layer may be prestressed.

All these methods do not enable to produce the great benefits which the idea of building with skins may provide.

The main reasons for this situation are:

a) The prefabricated element is a relatively thin reinforced concrete slab limited in span so that additional temporary supports are required when the concrete for the upper part is poured.

b) The final product is nothing else but a concrete slab and not a sandwich type construction where at least one of the layers may be so designed as to comply with performance specifications (Thermal and acoustic insulation, etc.).

c) The thickness of the precast part is relatively large in comparison with the depth of the section and therefore even if one tries to build a sandwich type product the room for the inner core may be insufficient and the distance between the skins must be enlarged. A thick element, which is uneconomical, is then obtained.

The aim of the proposed method is to provide multi-purpose skinned elements (slabs, walls, partitions) which simultaneously comply with performance specifications of various types (structural, acoustical, thermal, etc.). The elements are so developed as to be light even with long spans and easy to assemble into the final system (the building).

---

* Published also in the Proceedings of the International Conference on Materials of Construction for Developing Countries (August 22-24, 1978, AIT, Bangkok).

† Technion, Haifa, Israel.

‡ Visiting Associate Professor, State University of New York at Buffalo, U.S.A.

An efficient multi-purpose form of the skinned elements is the ribbed plate [1-2]. The thin mesh reinforcement of plates (ferrocement) may be varied according to the purpose for which the element is built.

FLOOR SLABS

Floor slabs must be primarily rather strong and crack resistant. The ribbed plate (Fig. 1) is suitable if its designated serviceability is maintained. For the purpose of crack prevention

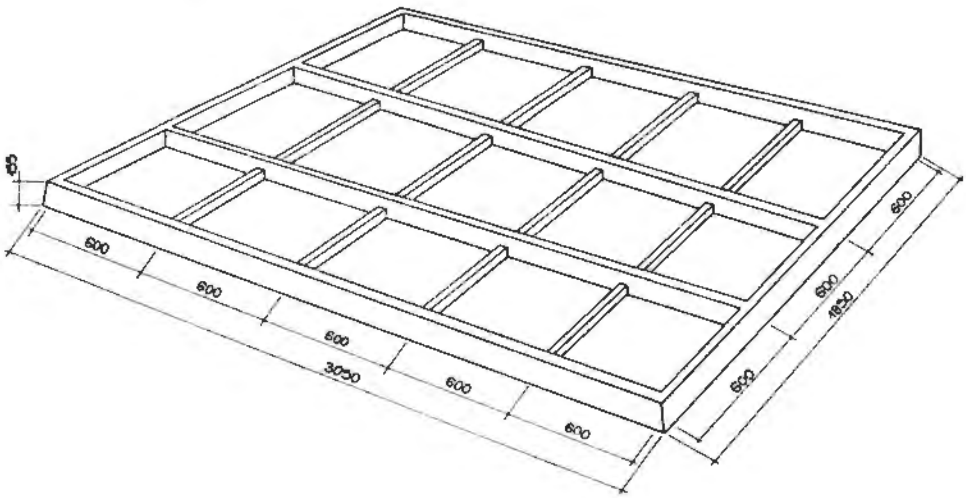


Fig. 1. Ribbed element for a floor slab.

in such elements, they are usually prestressed. The analysis shows that in the majority of cases this can be achieved by the use of a relatively strong concrete. With the use of thin mesh reinforcement the crack widths in slabs may be limited [3-5]. In this case it is not necessary to apply prestressing. In all cases the structural safety of plate elements between ribs must be provided. As a result, the plate between ribs must offer the required resistance to the design moment due to applied load. In general, two meshes are sufficient for structural safety (Fig. 2). These meshes are the longitudinal reinforcement of the ribs, as well.

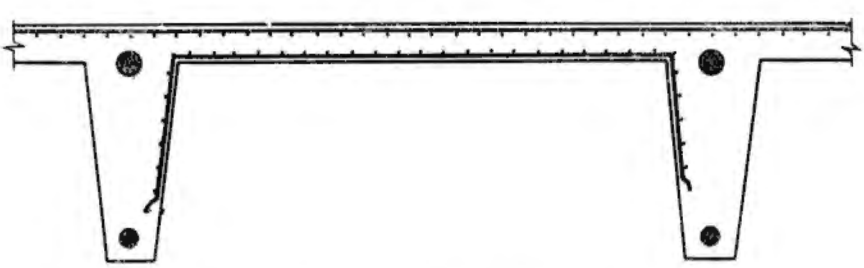


Fig. 2. Schematic positioning of two meshes in a ribbed element.

Such elements permit to complete the composite concrete constructions (Fig. 3). In so doing the negative bending moment may be taken on the support.

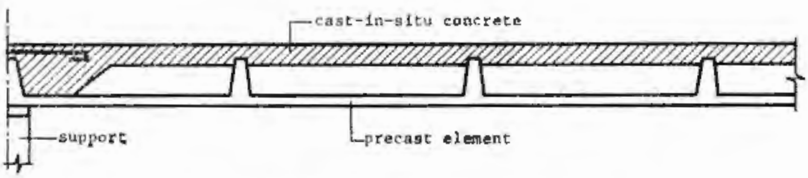


Fig. 3. The scheme of the composite floor slab.

In reference to well known structures [6], in which the precast plate is the concrete casing too, the ferrocement skinned element is very lightweight and, at the same time, a strong and rigid one, and it need not be supported along the span. The ribbed plates permit the use of any cheap insultation materials as alternatives to concrete in traditional floor slabs.

The performance specifications for the structural safety of floor slabs may be provided by common reinforcement of ribs and by mesh reinforcement of the plate. It should be remembered that design loads for structural safety analysis are taken as 1.5 times larger than for serviceability analysis, and that the characteristic concrete tensile strength is about 1.8 times larger than the design one. Consequently, it follows that the design stresses in a structure at the serviceability limit state are 3 times less than at the ultimate limit state. Because of this the serviceability of floor slabs may be provided by appropriate concrete tensile strength if the proper relationship between the slab thickness and distances between ribs are chosen.

The analysis of such elements shows that the optimal slab thickness is about 15-20 milimeters and the distance between ribs must be chosen as a function of the loads.

WALLS

Walls built up of two ribbed elements are well known (Fig. 4a). The use of ferrocement elements for these permits to build composite structures (Fig. 4b). Such walls may be load bearing elements as well as non-bearing ones. In the latter case the space between skinned elements may be filled by insultation materials. For exterior panels such materials may be light-weight cellular concrete. Thus we obtain a continual element of a wall.

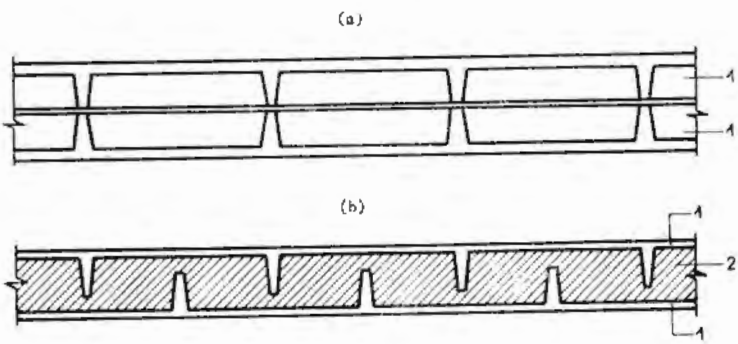


Fig. 4. Walls built of ribbed elements, (a) well-known structure, (b) ferrocement composite wall, 1-precast elements, 2-cast-in-situ concrete.

The use of composite concrete construction of walls enables to provide the continuity of the structural system as a whole. Of course, it is necessary to accomplish the appropriate joints.

JOINTS BETWEEN FLOOR SLABS AND WALLS

The horizontal joints are relatively weak zones of a structure and their bearing capacity is of paramount practical importance [7]. It depends to a large measure on the parameters of the mortar layers. As a rule, it is impossible to obtain correct layer thickness, and the inevitable thick layers cause the decrease of the wall bearing capacity.

The use of the ferrocement skinned elements as concrete casing in walls permits to avoid this disadvantage of precast walls (Fig. 5). The area of horizontal mortar joints in the section of the wall may be relatively small, and its influence on the wall bearing capacity is negligible.

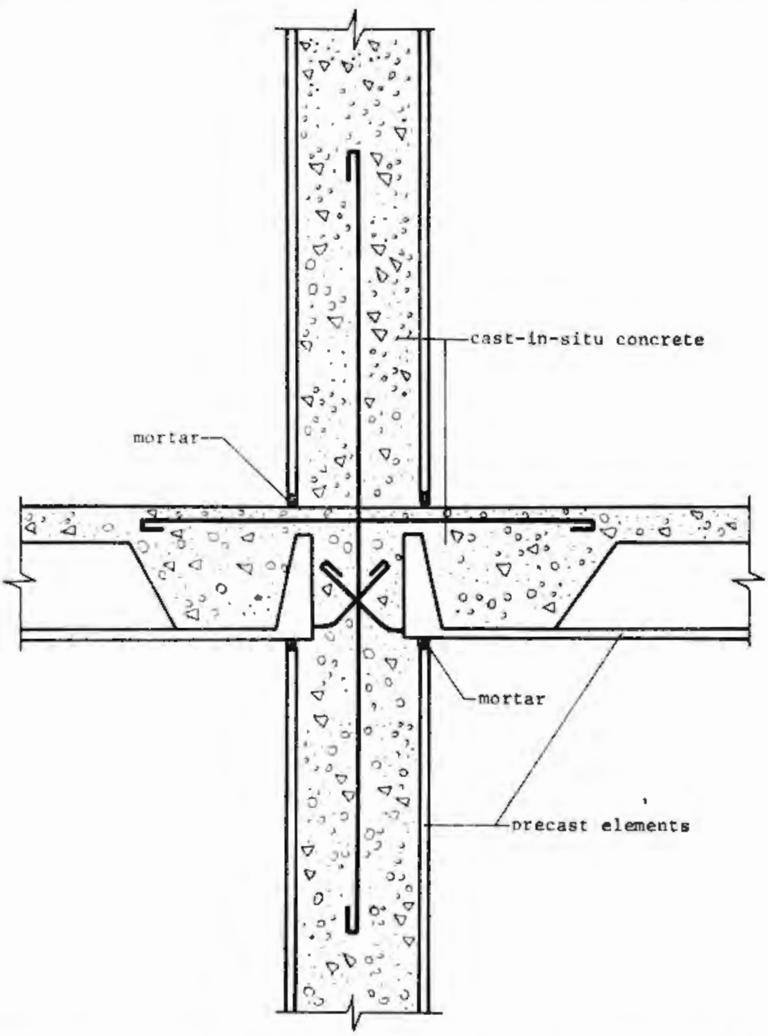


Fig. 5. Joint between a wall panel and a floor slab in the composite structure.

The tensile forces in joints are transmitted by steel. The reserve principle is provided by vertical bars (Fig. 6).

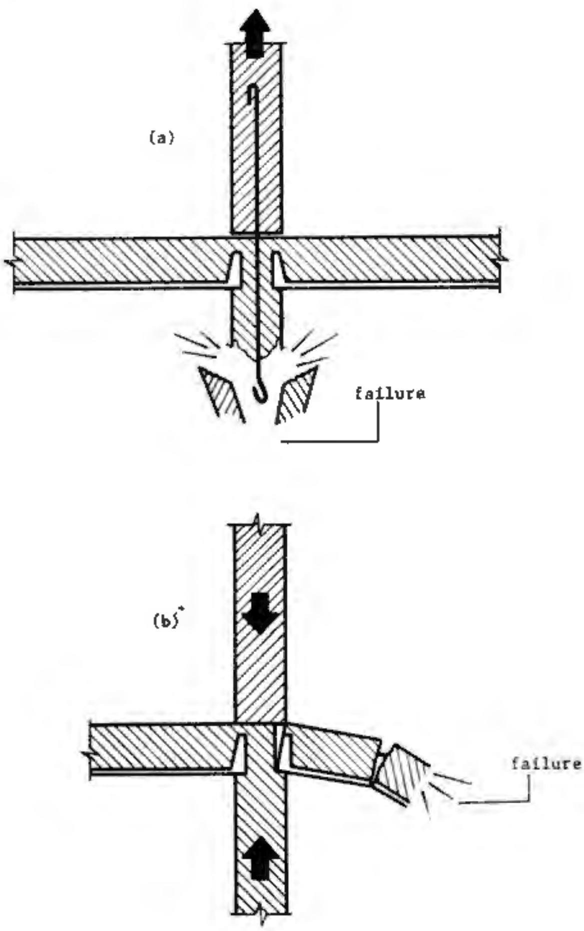


Fig. 6. The behaviour of the composite structure in case of a failure of one element, (a) wall failure, (b) floor slab failure.

The non-bearing walls may be connected to bearing elements by anchor bars connected to the floor sab (Fig. 7).

CONCLUSIONS

The use of ferrocement skinned elements enables the construction of efficient structures incorporating all the advantages of the precast and cast-in-situ systems. In so doing the precast ferrocement elements may be of lightweight than traditional ones.

The required acoustic or thermal-insulating properties may be achieved by filling of space between precast elements by different cheap materials.

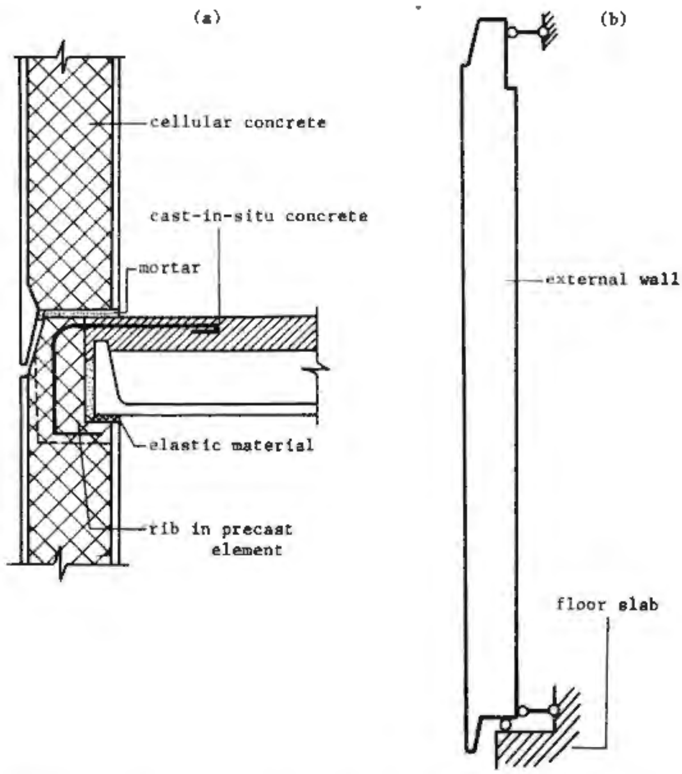


Fig. 7. (a) Joint Between external wall and floor slab, (b) Design model of an external one storey wall

REFERENCES

1. BLUGER, F., "Investigation of Bearing Capacity of Thin-Walled Reinforced Concrete Panels", Moscow, 1962 (in Russian), pp. 1-12.

2. TATSA, E.Z., REICHWERGER, Z., "Methods of Manufacturing Structural Elements of Ferrocement" (in preparation).

3. LOGAN, D., SHAH, S.P., "Moment capacity and cracking behaviour of ferrocement in flexure", Journal of the American Concrete Institute, Proceedings, Vol. 70, No. 12. December 1973, pp. 799-804.

4. LISSENKO, E.F., "Ferrocement Structures", Kiev, 1974, pp. 125-129 (in Russian).

5. JOHNSTON, C.D., MATTAR, S.G., "Ferrocement-Behavior in Tension and Compression, Journal of Structural Division, ASCE, No. ST5, May 1976, pp. 875-889.

6. HARTLAND, R.A., "Design of Precast Concrete", London, 1975, pp. 84-111.

7. BLUGER, F., "The bearing capacity of joints between walls and floor slabs in multistorey buildings", "Building Science", Edinburgh, Scotland, Vol. 10, 1975, pp. 271-276.

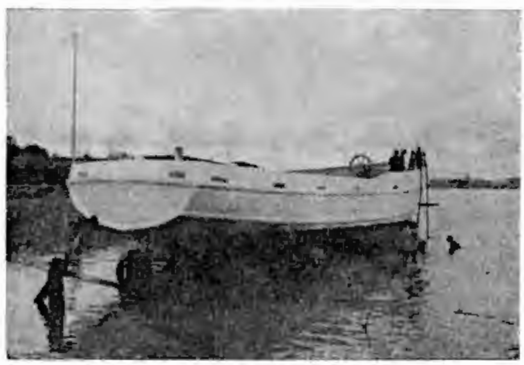
The Launching of a 22 Meter High Tensile Wire Reinforced Fibrous Ferrocement Tug for Log Hauling Duties

Douglas Alexander*

Photographs below depict the launching of the first of two tugs designed by Alexander & Poore of Auckland, New Zealand for log hauling and general cargo duties in Sandakan, Sabah where they were constructed.

Several new techniques have been employed in the construction of these vessels. Firstly, the traditional mesh form of ferrocement is absent but replaced with monolayers of 10 gauge high tensile wire encased in fibrous mortar. The result is a material decisively stronger in flexure and piercing resistance than the mesh form and less costly.

Next the normal practice of plastering the mortar into the fabric and floating the surface is replaced by a technique of vibrating the fibrous mortar from the inside of the vessel against thin plywood facings. These facings are removed some 12 to 20 hours later and the surface 'bag' washed and then kept moist for several days. This process is an inexpensive external moulding technique which can be applied to vessels of all sizes but especially to large vessels.



The vessels are also post tensioned within the skin to give a final stress of approximately 4 Mpa. Post tensioning has the effect of stiffening the ferrocement in its working range which does not however diminish its capacity to absorb impact. (It may be commented that it does not have this effect on mesh reinforced ferrocement.) When the vessel is finally post tensioned and the stressing anchors buttressed airspray equipment is used to apply the paint surfacing. This type of equipment is capable of applying high build coatings at a rate of 400 square meters per hour and cuts the painting time down to a few hours work.

* Alexander & Poore, Consulting Engineers, New Zealand.

As far as possible all the components of the vessels are constructed in fibrous ferrocement. This approach encompasses the deckhouse, the rudder plate, the funnel and the mast and such items as the ventilator cowls and bollard beltings and even the anchor. Experience has shown that fibrous concrete has a considerable abrasion resistance as illustrated by the towing bollards installed in a 600 tonne gross palm oil barge which has been in service for some 2½ years without significant wear occurring.

Ferrocement fuel oil tanks with a 20 tonne capacity occupy the bilge area in the forehold and engine room areas and freshwater is carried in the after hold bilges. The cargo hold themselves are commodious and designed to stow 90 tonnes of general cargo. At this capacity the draught aft is 2.75 meters and the free board 1 meter.

The first vessel was launched with its engine installed and completely outfitted except for the mounting of its deckhouse which had been prefabricated in readiness for erection. It entered the water and floated free at less than 1.5 meters draught aft or at approximately the same draught as that of a comparable steel vessel.

Material costs compare more than favourably with other materials averaging \$13.40 per square meter including the paint. This is about one third the cost of plate, scantlings, gas and electrodes and paint requirements of a comparable steel vessel.

Bibiographic List on Ferrocement: Part VII

This list includes a partial bibliography on ferrocement and related topics. The AIT Library and Regional Documentation Center has these articles and books. Reprints and reproductions, where copyright laws permit, are available at a nominal cost (see page no. iv). Please quote the serial number of the list at the time of request.

Earlier six parts of the Bibliographic List have been published in the last six issues of the Journal of Ferrocement (Vol. 7 and Vol. 8).

Also available now is the first volume of "Ferrocement and its applications -- a bibliography" which contains 736 references compiled from the list that have appeared in the last six issues of the Journal of Ferrocement. Unlike in this list the first volume includes a more detailed classification of the reference. Copies of this IFIC publication can be ordered at a cost of US $ 2.00 per copy (surface postage inclusive).

MARINE USES

M728 AKOL, J., "Keeping the Juba Boatyard Afloat", Appropriate Technology, Vol. 5, No. 2, August 1978, pp. 24-26.

M729. ALEXANDER, D.J. and ATCHESON, M.G.A., "Fibrous Ferrocement for Commercial Vessals", Journal of Ferrocement, Vol. 5, Nos. 2 & 3, 1976, pp. 25-48.

M730. ANON., "Ferrocement Boats", Concrete Quarterly, 117, July 1978, pp. 17-18.

M731. ARNOLD, S.R., "Concrete Afloat—British Style", Journal of the American Concrete Institute, Vol. 75, No. 10, October 1978, pp. N17-N18.

M732. PEDERSEN, H.P., "Ferrosement Som Byggemateriale for Mindre Fiskeog Lystbater", Fiskeriteknologisk Forskningsinstitutt, 1976, 33 pp. (in Norwegian).

M733. PEDERSEN, H.P., "Byggermaterialer for Fiskefartoyer", Trondhiem, Fiskeriteknologisk Forskningstitutt, 1976, 70 p. (in Norwegian).

MATERIALS AND RESEARCH

MR734. ANON., "Admixtures", Civil Engineering, September 1978, pp. 45-47.

MR735. ANON., "Concrete Pumping", Civil Engineering, September 1978, pp. 33, 35, 37.

MR736. BABCOCK, E.S., "The Effect of Precycling on the Strength of Ferrocement", Monterey, California, Naval Postgraduate School, 1975, 89 pp. (M.Sc. Thesis).

MR737. BENVENISTE, Y. and ABOUDI, J., "A 2-Dimensional Mixture Theory for Biaxially Fiber Reinforced Composites with Application to Dynamic Crack Problems", International Journal of Engineering Sciences, Vol. 16, pp. 615-636.

MR738. GAMBLE, W.L., "Analysis and Behaviour of Ferrocement in Flexure", Discussion, Journal of Structural Division, ASCE, Vol. 104, No. ST8, August 1978.

MR739. LATHAM, J.D., "Vibrated Concrete", Civil Engineering, September 1978, pp. 60, 61, 63, 65, 67.

MR740. PEDERSEN, H.P., "Utvikling Og Utprving Av Utstyr for Binding Av Ferrose. mentarmering Fartyseksjonen, Fiskeriteknogisk Fovskingstitutt, 1974, 20 pp. (in Norwegian).

MR741. RAICHVARGER, Z. and TATSA, E.Z., "Manufacturing Technologies of Structural Elements Made of Ferrocement", Journal of Ferrocement, Vol. 8, No. 4, October 1978, pp. 259-266.

MORTARS

MO742. DETRICHE, C.H., "Analyse Expérimentale du Retrait de Couches Minces de Mortier Mesure Depnis le Moulage", Matériaux et Constructions, Research and Testing, Juillet - aoû t 1978, No. 64, pp. 247-259.

MO743. RILEM, "Tentative Recommendations of RILEM : 9", texts issued by 13-MR Committee on Mortars and Renderings, Materials and Structures, Research and Testing, Vol. 11, No. 63, May-June 1978, pp. 207-216.

PROTECTION AND RELATED TOPICS

PR744. FOWLER, D.W., PAUL, D.R. and YIMPRASERT, P., "Corrosion Protection of Reinforcing Provided by Polymer - impregnated Concrete", Journal of the American Concrete Institute, Vol. 75, No. 10, October 1978, pp. 520-525.

TERRESTRIAL USES

T745. ANON., "Miracle Domes from Italy", Civil Engineering, September 1978, pp. 73.

T746. OSTERGAARD, K.N., "The Ferrumbu", A Booklet on an improved grain storage structure for rural areas, issued with the help of the Danish International Development Agency (DANIDA), December 1977. (Also published in the Journal of Ferrocement, Vol. 8, No. 4, October 1978, pp. 239-248)

News and Notes

IFIC NEWS

Staff Farewells and Hellos

Mr. Bishwendu Kumar Paul, 27, of Bangladesh an alumnus of the Asian Institute of Technology (M.Eng. 1977), on completion of his 22 month contract as Research Associate with IFIC, left the Center in mid-September to take up a Doctoral degree in Structural Engineering (Materials) at the University of California, Berkeley. In his capacity as Research Associate, Mr. Paul has contributed a lion's share of efforts in establishing IFIC as the only international center for information related to ferrocement. He is also credited with co-authoring (with Professor R.P. Pama) the first ever comprehensive text on ferrocement, IFIC's first monograph. He can be contacted at: 2299 Piedmont Avenue, #417, Berkeley, California 94720, U.S.A.

Mr. Vellore Shroff Gopalaratnam, 23, of India also an alumnus of the Asian Institute of Technology (M.Eng. 1978) joined IFIC as a Research Associate in July 1978 on a 2 year contract. Specialized in Construction Management, Mr. Gopalaratnam takes over the yeoman task of expanding and improving IFIC's customer services. Besides having had some editing experience, he is well versed in programming--an asset which is likely to come of use when IFIC plans to create a computerised data-base for information storage and retrival (service expected to be available by mid 1979).

Mr. Prem Chandra Sharma, 39, of India joined IFIC as a Technical Specialist in September 1978 on a 3 month contract. In his capacity as a Technical Specialist, he is to initiate work on a series of "Do it yourself" booklets on ferrocement structures, that are to be published by IFIC in the near future. The first two in the series that he was entrusted with were booklets on Grain Storage Bins and Water Tanks. Since completing his engineering in Civil in 1958 from Roorkee, Mr. Sharma has worked with the Bhilai Steel Project and the Central Building Research Institute, Roorkee. While on his recent assignment he was on leave from the Structural Engineering Research Centre, Roorkee where he is a class I Scientist. Specialized in design, construction and errection technologies for prestressed and reinforced concrete structures besides ferrocement construction technology, Mr. Sharma has to his credit over 40 papers in various professional journals. His two patents for the process of production of ferrocement cylindrical units and process of production of roofing units using burnt hollow clay bricks are being used by various agencies in India. Mr. Sharma can be contacted at Structural Engineering Research Centre, Roorkee, U.P., India.

Dr. G.L. Bowen (B.S. (Alaska), M.S. (Stanford), Ph.D. (Minnesota) of the Department of Civil Engineering, University of Auckland, New Zealand, has after 18 months of commendable service to the Editorial Board of the Journal of Ferrocement opted to resign because of his present activities which no longer deal with ferrocement construction. The International Ferrocement Information Center greatly appreciates Dr. Bowen's efforts in trying to promote the use of ferrocement both in his capacity as a member of the Editorial Board and also as a faculty who has undertaken numerous research projects in the field. The Center also looks forward to a fruitful exchange of ideas even though he is no longer on the Editorial Board.

INDIA

Precast Segmental Units for Ferroecment Water Tanks and Grain Storage Bins

The Structural Engineering Research Center (SERC), Roorkee, has developed a simple method of construction of cylindrical water tanks and grain storage bins using precast ferrocement segmental units. Besides being easy to handle and transport, these can be errected even atop buildings whose terraces are otherwise inaccessable. Ferrocement cylindrical units of any diameter can be suitably divided into 4, 6 or 8 segments and cast with wiremesh and skeletal reinforcement projecting on both sides of the segment (see Fig. 1 below). After 10 days of curing the units can be transported to site for assembling.

Fig. 1. Precast segment unit with horizontal ribs.

Errection is carried out by lapping wiremesh of adjacent segments and sealing the joint with a rich mortar mix. Extra reinforcement could also be provided while errection, and the thickness of the joint in the wall could be increased, if so desired. The precast unit could be cast with extra reinforced vertical ribs or horizontal rings.

When mass produced these units could be vibrated with vibrodiscs or form vibrators mounted on a plank or a channel. Masonry moulds have been tried and found to be satisfactory besides traditional wooden frame moulds with galvanized iron sheeting.

Tanks built by this technique of capacities 2,500 liters and 6,000 liters have for the last 3 years been tested rigourously and have performed satisfactorily. The casting process has the flexibility to accommodate any type of reinforcement combinations like mild steel bars, galvanized iron wires, hexagonal wire mesh or woven square mesh.

These segmental units could alternatively be used as cylindrical roofing units, sheet piles or decorative wall pannels. Though thickness of the unit and reinforcement details could vary with the type of structural use these units are put to, a possible scheme of use has been presented in Fig. 2.

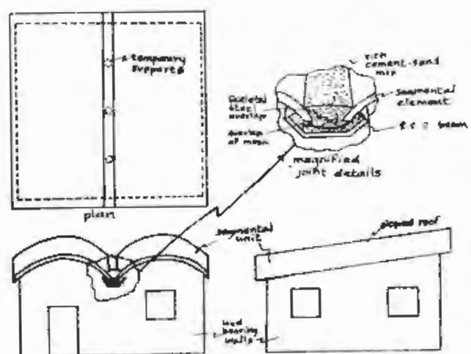


Fig. 2. Use of precast segmental units as roofing. Note that the figure is not drawn to scale.

Novel Method for Ferrocement Dome Construction

Sarabhai Technological Development Syndicate, Ahmedabad, with technical assistance from SERC (Roorkee and Madras) has constructed a ferrocement dome for a large

Fig. 3. Plastering the underside of the dome.

Fig. 4. Finishing the outside of the dome.

sized workshop at the B.M. Institute, Ahmedabad. The architect for the building, Mr. Gautam Sarabhai has developed a concept whereby a network of tubular frame is raised from various points by means of a pulley jack arrangement while the network is held firmly at the dome edges. This forms a skeletal steel framework for laying of mesh. After plastering this tubular network becomes an integral part of the dome. The dome thickness is around 25-30 mm. The first dome built successfully last year has highlighted the economic advantages of this technique. More domes of larger diameters are envisaged for the near future (see Figs. 3 and 4.)

(Report : P.C. Sharma, SERC, Roorkee)

INDONESIA

Rainwater Collection Tanks

Photograph shows a 12 m^3 tank which was completed recently in South Lombok for rainwater collection. More interesting perhaps is an experimental tank that has just been completed in which all metal and wire reinforcing was substituted with woven bamboo. The weave was spaced to allow 3-4 cm gaps between each strand of bamboo and was later plastered with cement mortar. The tank built with bamboo reinforcement is 1.7 m in height and 1.3 m in diameter with an approximate capacity of 1.7 m^3. Though it is too early for a proper evaluation of this method of construction, preliminary performance tests prove encouraging.

Fig. 5. A 12 m^3 capacity rainwater collection tank of ferrocement. Filter is attached to the inlet while protruding pipe at half the height serves as water inlet from tankers.

Dian Desa, a rural development organisation based in Yogakarta is doing a lot to promote the construction of ferrocement water tanks in Java. They have built about 20 tanks as a pilot programme in a dry area south of Yogya where they will be used as rainwater collection tanks. Encouraging results from the pilot project has lead to a UNICEF sponsored project to build 350 such tanks. The construction method being quick and simple is suitable for village-level application, using only bamboo matting as formwork. Two reports on this method of construction (in Bahasa Indonesia) could be obtained from UNICEF in Jakarta.

(Report ; Ben Young, VSO, Indonesia)

TUNISIA

Small Fishermen Test Ferro-Cement Prototypes

A new boat is being tested by fishermen off the shores of Tunisia. In many ways it is indistinguishable from their traditional wooden craft. Its size, shape and color are the same. But the new vessel has several characteristics which could make it the fishermen's choice for the future, thereby saving Tunisia costly wood imports. It is highly durable, impervious to rot or rust, immune to the attacks of water bores, eminently seaworthy even in storms, and easy to repair if damaged by collisions with rocks. It can be made almost entirely from locally-available materials, and the techniques of its construction are easily within the range of national skills.

The new craft is one of three ferrocement prototype fishing boats Tunisia is building in an effort to expand fisheries through the development of an alternative to the traditional vessel, more and more costly to construct. The project is supported by the United Nations Development Programme (UNDP) and the UN Food and Agriculture Organization (FAO), which have supported similar trials in other developing countries.

Tunisia has a growing fishing industry along her 1,500 kilometre Mediterranean coastline. Forty-five thousand tons of fish were landed in 1975. The 1977-81 Development Plan calls for an increase of nearly 100 per cent above this level, as part of an overall strategy for attaining food self-sufficiency.

Eighty per cent of Tunisia's fishermen--responsible for 40 per cent of the catch--are small in-shore fishermen who work within three miles of the coast from boats six to eight metres in length. In 1974, there were about 2,500 such boats in service, only 700 of which were motorized. The traditional boats are made of local eucalyptus, insufficiently strong to hold up well against punishing Mediterranean waves--or imported wood, which continues to rise in cost.

To build additional motorized boats, larger and stronger, and thus able to exploit the richer fishing grounds along the more turbulent northern coastline, the Government secured a world Bank/IDA loan of $2 million. Due to increased costs, however, it soon became clear that this would provide for the construction of less than 200 boats, rather than 335 as originally envisioned. This prompted the Government to explore the possibilities of ferrocement craft.

Patented by the French in 1855, ferrocement has been used for small commercial and pleasure boats by several countries, notably, France, Italy, Canada, New Zealand and the People's Republic of China. The basic materials required are steel for the frame, grillwork of chicken wire, sand and ordinary Portland cement. Though requiring precise skill, construction techniques are relatively simple and can be easily learned by workmen who build traditional boats. Mortar is applied to the grillwork in a thin layer with a special pressure applicator, care being taken to avoid exposure of the steel, so that there will be no possibility of rust or corrosion. The boat is then painted, and an occasional repainting is about the only maintenance required. Should damage occur, it can be easily repaired with epoxy resin or a reapplication of mortar, often with no need to remove the vessel from the water.

Savings of 25 to 30 per cent on hull costs are possible over classic methods used for vessel construction. The crafts are surprisingly lightweight, very strong, and unlike unreinforced cement the surface is not brittle. Their longevity is demonstrated by the fact that some ferro-cement boats built by the Italians in the 1940s are still in use.

In charge of the Tunisian project is Luc Spothelfer, a FAO specialist in ferro-cement from Switzerland. He has designed the three prototypes, trained workmen to build them, supervised all phases of construction and taken finished boats out for their maiden voyages. "The first prototype", he explains, "has been built in the traditional style so as not to shock the fishermen, who are very traditional. They are now testing it and seem to be quite pleased."

The second, now ready for its fishermen trials, has a few improvements which Spothelfer feels should make it the ideal vessel for their use. There is a larger working surface, a cabin which houses the steering wheel, and below board, a sleeping area large enough for two simple bunks, making overnight finishing expeditions possible.

Both of the prototypes are powered by 60 horsepower motors. Based on the fishermen's evaluations, the Government's National Fishing office will decide whether to put one or both into production.

All construction of the prototypes has been done by SOCOMENA, a parastatal Tunisian shipyard located in the port city of Bizerte. "The present workshop alone could turn out a boat every two months very easily", Spothelfer maintains. To interest private companies in construction, he is preparing a publicity campaign to demonstrate the prototypes in Tunisia's principal ports and naval workshops.

In addition to the motors, which would have to be imported in any case, only the wire mesh for the grillwork has been obtained from abroad. It comes from Belgium, and represents only 4 or 5 per cent of total costs.

If the ferro-cement boats are produced commercially in Tunisia, the one in traditional style, complete with motor, would cost about $ 18,000; the improved boat, around $20,500. They would be more economical than wooden boats because of their greater durability. To facilitate the purchase of new boats, the Government grants fishermen loans of up to 95 per cent, allowing eight years for repayment.

The third prototype, still larger in size (17 metres) is presently under construction. This will be used to fish for lobsters, which abound in northern Tunisian waters, but are now being exploited mainly by foreign fishermen. Equipped with the necessary chamber for storing the catch live, it will have the capacity to transport 2 or 3 tons of lobster. Launching and testing will be done later this year.

(Information courtesy: Mary Lynn Hanley, Division of Information, UNDP, New York.)

Abstracts

JEP14 RECENT DEVELOPMENTS OF FERROCEMENT IN NORTH AMERICA

KEY WORDS: Ferrocement, North America, Applications, Definition, Properties.

ABSTRACT: Although ferrocement has been used as a material of construction for various applications in many countries, only recently there has been growing interest especially in the Western hemisphere to use it as a structural material. The distribution in a concrete matrix of continuous fine reinforcement compared to conventional larger size rebars, gives ferrocement several advantages, which were recognized for quite some time in many developing countries without the support of vigorous analysis. Recent work with this material and novel applications have caused considerable research in North America; a committee was formed by ACI on Ferrocement. This committee sponsored a symposium at Toronto in April 1978, the proceedings of which will bring out the State-of-the-Art on the topic with an extensive bibliography. Based on the recent experience in North America the following topics are discussed in this paper:

a. basic *definition* of ferrocement
b. useful *structural* properties
c. *special* properties in view of recent research
d. recent applications

and

e. further potential of Ferrocement in Civil Engineerering.

REFERENCE: SABNIS, G.M., "Recent Developments of Ferocement in North America", Journal of Ferrocement, Vol. 9, No. 1, Paper JFP14, January 1979, pp. 1-12.

JFP15 CRITERIA FOR CHOICE OF MICROREINFORCEMENT IN CONCRETE COMPOSITES

KEYWORDS: Composites, Specific surface, Fiber, Yong's modulus, Crack width.

ABSTRACT: The paper presents an assessment of the suituility of steel wires and meshes used as microreinforcement in concrete composites. Criteria for choice of microreinforcement and the influence of scale effect on the strength of steel fibers are also determined.

REFERENCE: WALKUS, B.R., JANUSZKIEWICZ, A. and JERUZAL, J., "Criteria for Choice of Microreinforcement in Concrete Composites" Journal of Ferrocement, Vol. 9, No. 1, Paper JFP15, January 1979, pp. 13-20.

Air-Mailing Charges

As announced from the start, the subscription fees to the Journal of Ferrocement include mailing costs by *surface mail*.

Despite this during 1978 we did send the Journal by air mail at no extra charge because of delays in printing and our concern not to inconvenience our subscribers.

We are now in a position to bring out the Journal on time. Therefore, begining 1979 we shall send it by *surface mail* except for subscribers who wish to receive it by *air mail* at the following axtra costs :

Additional cost for air mailing Journal of Ferrocement (U.S.S.)

	Asia & Pacific	America, Africa & Europe
For the entire year (4 issues)	6.00	8.00
For one issue	1.50	2.00