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The Asian Institute of Technology exists to aid the technological development of the region through teaching, research and information dissemination. The first two of these constitute the principal activities of all universities, but AIT is unique in having an organized Documentation Center dealing specifically with subjects important for development but inadequately data-based, abstracted or bibliographed in the libraries of developed countries. Prominent amongst such subjects is the special structural engineering material (or method) known as ferrocement.

Engineers all over the world are using, and advancing the techniques associated with, ferrocement. This really is a technology appropriate to needs in developing countries combining, as it does, relative cheapness with ease of construction. Of course readers of “Journal of Ferrocement” need no introduction to that truism.

As this Anniversary Issue of the Journal goes to press, IFIC, after ten years of highly successful operation, is still the only one of its kind in either developing or developed countries. It is gratifying for AIT that its service, established to meet perceived needs in South and South East Asia, also is appreciated and sought for in developed countries. Interest comes from both universities and “the field” illustrating the success of the Center in aiding technology transfer by bridging the gap between academic and everyday life, often in rather undeveloped rural areas. AIT is proud to provide such a service, and wishes the Information Center, the Journal of Ferrocement, and all their clients and readers another decade as significant and as successful as the last.
The International Ferrocement Information Centre (IFIC) was founded in October 1976 at the Asian Institute of Technology under the joint sponsorship of the Institute’s Division of Structural Engineering and Construction and the Library and Regional Documentation Center. IFIC was established as a result of the recommendations made in 1972 by the U.S. National Academy of Science’s Advisory Committee on Technological Innovation (ACTI). IFIC receives financial support from the Government of Australia, Canadian International Development Agency (CIDA), Government of France, 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 publications, reference and reprographic services and technology transfer activities. All information collected by IFIC are entered into a computerized database using ISIS system. These information are available on request. In addition, IFIC offers referral services.

A quarterly publication, the Journal of Ferrocement, is the main disseminating tool of IFIC. IFIC has also published the monograph Ferrocement, Do it Yourself Booklets, Slide Presentation Series, State-of-the-Art Reviews, bibliography and reports. FOCUS, the information brochure of IFIC, is published in 16 languages as part of IFIC’s attempt to reach out to the rural areas of the developing countries. IFIC is compiling a directory of consultants and ferrocement experts. The first volume, International Directory of Ferrocement Organizations and Experts 1982-1984, is now available.

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

I am a V.S.O. volunteer working in Lombok on an appropriate technology project. I have written to you in the past concerning the use of ferrocement to build a biogas digester. Thank you for that information. I used that information in conjunction with other information to build a biogas unit in east Lombok. The biogas was a technical success however the government department who asked for it, are not using it as well as it could be.

Mr. Rob A. Dewhirst
Agricultural Engineer
Jl. Seruling V, No. 1
Lombok, NTB
Indonesia

Dear Editor,

Thank you for your encouraging remarks about our work. As you know we have made extensive use of your IFIC techniques and your most illustrative slides were shown to our trainees.

C.M. Mann
Director (Administration)
The Valley Trust
P.O. Box 33
Botha's Hill 3660 Natal
South Africa

Dear Editor,

I used to be principal of Emmanuel Secondary School, Ugboklo and while there I was in correspondence with you and you sent me some pamphlets etc. Now I am principal of a small day school [Otukpo, Benuel State] and my interest in ferrocement was revived.

The school and village of 1000 have no water supply or clean stream near them for half the year so there is a chronic water problem. I have made two ferrocement tanks from baskets, with a volume of about 250 gal., and now I am doing a 1000 gal., using bamboo.

We have just had an inspection and the inspectors were much impressed with the tanks and one at least intends making his own.

More than ever, with difficulty of importing metal, so with the high price of metal tanks, the ferrocement tanks could be a fine thing here.

Fr. V.J. O'Brien
Vicentian Community
St. Justin's Seminary, Ogobia
Benue State, Nigeria
Cracking Behaviour and Ultimate Strength of Ferrocement in Flexure

M.A. Mansur* and P. Paramasivam

The results of an investigation conducted on ferrocement to study the cracking behaviour and ultimate strength in flexure are reported. Based on the concept of plastic analysis, a simple method is proposed to predict the ultimate moment capacity of ferrocement. A comparison of the predicted ultimate moments with test data available with full details shows good agreement.

INTRODUCTION

As a result of extensive investigations, both analytical and experimental, carried out during the last two decades [1], various analytical models are now available to predict the fundamental mechanical properties of ferrocement. In case of flexure, ultimate strength models had been proposed by Logan and Shah [2], Johnston and Mowat [3], Rajagopalan and Parameswaran [4], Kumar and Sharma [5], Balaguru et al. [6] and Huq and Pama [7]. These methods are primarily based on the concept of conventional reinforced concrete analysis using the principles of equilibrium and strain compatibility. However, the basic differences are in the assumed compressive stress block, the stress-strain relationship for steel and the failure criterion, i.e., the maximum compressive strain in the matrix. Although simple and rational, these methods require a tedious trial and error approach unsuitable for direct design of ferrocement elements by manual computations.

In this paper, a simple method is proposed to predict the ultimate strength of ferrocement in flexure. The method is based on the concept of plastic analysis in which ferrocement is considered as a homogeneous perfectly elastic-plastic material. Simple equations are derived for direct design of a cross-section.

An experimental investigation has also been conducted to study the behaviour and strength of ferrocement in flexure. Galvanized woven mesh of square openings was used as reinforcement. The primary variables of the study were the volume fraction of reinforcement obtained by varying the number of layers of wire mesh and the water-cement ratio of the matrix while the specimen thickness was kept constant. The effects of these parameters on the cracking behaviour and ultimate strength are also discussed.

The results of the present tests as well as some of those available in the literature with full details are compared with the predictions of the method proposed herein. The proposed method gives good prediction of the ultimate flexural strength of ferrocement.

TEST PROGRAMME

The test specimens considered for the present study were 380 mm long, 100 mm wide and 25 mm thick. They were divided into three series—A, B and C—according to the water-cement

*Senior Lecturer, †Associate Professor, Department of Civil Engineering, National University of Singapore, Singapore.
ratio of 0.45, 0.50, and 0.55 of the matrix (corresponding cube strength, $f_{cu} = 56$ N/mm$^2$, 45 N/mm$^2$ and 38 N/mm$^2$). Ordinary Portland cement and natural sand passing through BS No. 14 sieve were used in the ratio of 1:1.5 for the matrix. Galvanized woven mesh of 8.5 mm square grids and 0.87 mm wire diameter (ultimate tensile strength, $f = 371$ N/mm$^2$) was used as reinforcement.

Series B consisted of three groups, each comprising of five specimens, in which the volume fraction of reinforcement was varied by varying the number of layers of wire mesh. Three, four and five layers of wire mesh were used to obtain 0.86%, 1.14% and 1.43% volume fraction of longitudinal reinforcement, $V_f$, respectively. These layers were equally spaced within the thickness with a clear cover of 3 mm on either face. The remaining two series, A and C, however consisted of only one group of five specimens each having four layers of wire mesh.

The specimens were cast on vibrating table using plywood moulds. They were demoulded the next day and cured underwater at ambient temperature for 14 days. The specimens were then air-dried in the laboratory before testing.

Tests were conducted in an Instron testing machine at a constant strain rate. Third-point loading was used over a simply supported span of 300 mm. Deflections were measured under the loading points and at midspan by using a set of linear variable displacement transducers (LVDT) as shown in Fig. 1. Two specimens from each group of five were tested primarily to study the cracking characteristics. A special setup, as shown in Fig. 2, was used for this purpose. The load was applied to the specimens in a vertically upward direction to facilitate easy identification of cracks and measurement of crack widths. In this case, the load was applied to the specimen in increments by a manually operated hydraulic jack. At each load increment, the number of cracks within the central 100 mm of the specimens was noted and the maximum width of each crack was measured by using a portable microscope with an accuracy of $\pm 0.02$ mm.

**DISCUSSION OF TEST RESULTS**

**General Behaviour**

The load-deflection curves of the specimens have indicated linear behaviour up to about the cracking load. As shown in Table 1, the observed first crack moment increases either with
an increase in the volume fraction of the reinforcement for the same grade of matrix or with
an increase in the grade of matrix for a fixed volume fraction of reinforcement.

<table>
<thead>
<tr>
<th>Test series</th>
<th>Vol. of long. steel (No. of layers) $V_f$ (%)</th>
<th>Experimental moments</th>
<th>$M_u$, test/$M_u$, calc.</th>
<th>$M_u$, test/$M_u$, calc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cracking $M_{cr}$ (Nm/m)</td>
<td>Ultimate test, $M_u$ (Nm/m)</td>
<td>British Code (1972)</td>
<td>Logan and Shah (1973)</td>
</tr>
<tr>
<td>A</td>
<td>1.14 (4)</td>
<td>550</td>
<td>1550</td>
<td>1.55</td>
</tr>
<tr>
<td>B</td>
<td>0.86 (3)</td>
<td>500</td>
<td>1250</td>
<td>1.37</td>
</tr>
<tr>
<td>C</td>
<td>1.14 (4)</td>
<td>540</td>
<td>1450</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>1.43 (5)</td>
<td>600</td>
<td>170</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>1.14 (4)</td>
<td>455</td>
<td>1350</td>
<td>1.18</td>
</tr>
</tbody>
</table>

After cracking, the load-deflection curves deviated from linearity and gradually became
almost horizontal as the applied load approached the ultimate value. Simultaneously, several
new cracks were formed at finite spacings. The specimens then maintained approximately the
same load level with increasing deflection, but the cracks continued to penetrate deep into the
specimens. At this stage, no crushing of the matrix was observed on the compression face.
Further increase in deflection was associated with a drop in the applied load. Finally the
specimens collapsed due to fracture of the steel reinforcement.

The typical cracking patterns of the specimens at ultimate load, but before fracture, are
shown in Figs. 3 and 4. It may be observed that the number of cracks depends on the matrix
grade as well as on the volume fraction of reinforcement. A weaker matrix gives more cracks
(Fig. 3) perhaps due to its higher ductility. Similarly, a higher volume fraction of reinforcement
provides better crack control mechanism by the formation of a larger number of well-distributed
cracks (Fig. 4).

![Fig. 3. Cracking patterns for different matrix grade. ($V_f = 1.14\%$).](image1)

![Fig. 4. Cracking patterns for different $V_f$ (water-cement ratio = 0.5).](image2)
Crack Width

In the present study, a special set-up (Fig. 2) was used to facilitate observation on cracking and measurement of crack widths. All cracks which appeared at every loading stage were identified and the maximum width of each crack across the width of the specimen was measured to determine the maximum and average crack widths.

Figs. 5(a) and 5(b) show respectively the load vs. maximum and average crack width curves of the specimens for different matrix grades as obtained by varying the water-cement ratio; the volume fraction of reinforcement being held constant at 1.14%. It may be noted that within the service load level (ultimate load /1.7), both the maximum and average crack widths decreased with an increase in the water-cement ratio, i.e., with a decrease in matrix grade probably because of higher ductility of a weaker matrix. However, as the load approached the ultimate value, cracks opened up more rapidly for the specimens with lower matrix grade (higher water-cement ratio).

![Graphs](image)

**Fig. 5.** Load vs. crack width curves for varying water-cement ratio ($Y_f = 1.14\%$).

The effects of the volume fraction of reinforcement on the maximum and average crack widths are shown in Figs. 6(a) and 6(b), respectively. It is obvious that a higher amount of reinforcement is more effective in crack control. Figs. 6(a) and 6(b) indicate that both the maximum and average crack widths decreased with an increase in the volume fraction of reinforcement throughout the entire loading range.

Ultimate Strength

The experimental ultimate moments of the specimens as summarized in Table 1 clearly indicate the effects of the two major parameters considered in the present study. It can be seen that the ultimate moment increases with an increase in either the volume fraction of reinforcement or the grade of matrix as expected.

The results of the present tests are compared with the predictions of the method proposed by Logan and Shah [2] and the British Code [8] method for conventional reinforced concrete in which the partial safety factors of material strength are assumed as unity. Both the methods
are based on the principle of equilibrium and strain compatibility. The main differences are in the assumed stress-strain relationships for the matrix and steel, and the ultimate compressive strain (failure criterion). When using Logan and Shah's method, a factor of 0.8 was used to convert the cube strength of the matrix to the corresponding cylinder compressive strength.

The comparison of the experimental and predicted ultimate moments is shown in Table 1. Although both the methods significantly underestimate the flexural strength, the method proposed by Logan and Shah [2] appears to give a relatively better prediction. For the five groups, each comprising of five specimens, the average ratios of the test to calculated ultimate moments according to the British Code, and Logan and Shah's method are 1.32 and 1.23, respectively.

**PROPOSED METHOD**

As indicated earlier, the available methods use a trial and error procedure to locate the neutral axis and hence to calculate the bending moment capacity of a ferrocement element. Since several layers of reinforcing meshes are usually involved in ferrocement, these methods are not suitable for hand computation. A simple method to calculate the ultimate moment of ferrocement is presented herein.

**Assumptions**

The proposed method is based on the concept of plastic analysis with the following assumptions:

1. Plane sections before bending remain plane after bending;
2. Perfect bond exists between the steel and the matrix;
3. Skeletal steel which is primarily required for stability of the element during casting is ignored;
4. Ferrocement, matrix (mortar) reinforced with uniformly distributed fine wire mesh, is considered as a homogeneous ideally elastic-plastic material having different stress-strain and strength characteristics in tension and compression.
Consider the stress-strain characteristics of the matrix. Similar to reinforced concrete flexural theory, it is reasonable to assume zero tensile strength for the matrix. In compression, the stress-strain relationship depends on a variety of factors. However, for the present analysis, the rectangular-parabolic stress-strain relationship as recommended in the British Code (1972) for concrete may be assumed with a partial safety factor of unity. As shown in Fig. 7, the parabolic portion of the curve may be idealized by a straight line giving the bilinear stress-strain relationship as indicated by the solid line. The factor of 0.67 allows for the difference between the bending strength and the cube crushing strength, $f_{cu}$, of the concrete.

In case of ferrocement, studies conducted in direct compression [9, 10] have shown that neither the ultimate strength nor the stress-strain characteristics differ significantly from those of the reinforced matrix if the reinforcing meshes do not provide any confinement to the matrix. Hence, the bilinear relationship shown in Fig. 7 is equally applicable to ferrocement.

Fig. 7. Idealized stress-strain curve for matrix. Fig. 8. Idealized stress-strain curve for ferrocement.

In tension, the stress-strain relationship may again be idealized as bilinear [7, 10, 11]. It has been found that the ultimate tensile strength of ferrocement corresponds quite closely to the tensile load carrying capacity of the reinforcing element, i.e., the product of the ultimate tensile strength, $f_u$, and the cross sectional area, $A_s$, of the steel effective in the direction considered. The corresponding tensile strength $\sigma_{tu}$ is

$$\sigma_{tu} = A_s f_u (b t) \quad \text{(1)}$$

where $b$ and $t$ are the width and thickness of the ferrocement element. Therefore, the stress-strain relationships of ferrocement in direct tension and compression are as shown in Fig. 8.

Analysis

In a ferrocement element subjected to bending, the various layers of reinforcing meshes may be arranged in several different ways. They may either be uniformly distributed throughout the cross section or be lumped together in the tensile zone, or both in the tensile and compression zones as shown in Figs. 9, 10 and 11, respectively. All three cases have been considered for the present analysis.

Case 1: In this case, steel reinforcements are uniformly distributed throughout the cross-section of the element (Fig. 9a). When subjected to pure bending and as the applied moment
approaches the ultimate value, the distribution of stress across the thickness will be as shown in Fig. 9(c). According to the assumed material behaviour, the outer fibers will deform plastically, while the region near the neutral axis still remains elastic. At higher strains, the elastic core diminishes; the stresses in the core then contribute very little to the resisting bending moment because of their short lever arm. Hence, at collapse, the stress distribution as shown in Fig. 9(c) may be assumed without unduly impairing the accuracy. If the neutral axis depth at plastic collapse is \( x \), the compressive and tensile stress resultants may be written respectively as:

\[
C = \sigma_{cu} bx \tag{2}
\]

\[
T = \sigma_{tu} b(h - x) \tag{3}
\]

where ‘\( h \)’ is the overall depth of the section; \( \sigma_{cu} \) is the ultimate compressive strength of the matrix which is equal to 0.67 \( f_{cu} \) and \( \sigma_{tu} \) is the ultimate tensile strength of the matrix as given by equation (1). In the present case, \( t = h \).

The depth of neutral axis may be obtained from requirement of equilibrium of forces in the horizontal direction, i.e., \( C = T \). Equations (2) and (3), therefore give:

\[
x = \frac{\sigma_{tu} h}{\sigma_{cu} + \sigma_{tu}} \tag{4}
\]

The moment \( M_u \) at collapse is then obtained by taking moment of ‘\( T \)’ about the line of action of ‘\( C \)’ as:

\[
M_u = \sigma_{tu} b(h - x) \frac{h}{2} \tag{5}
\]

Using equation (4), equation (5) reduces to:

\[
M_u = \frac{\sigma_{tu} bh^2}{2} \left[ 1 - \left( \frac{\sigma_{tu}}{\sigma_{cu} + \sigma_{tu}} \right) \right] \tag{6}
\]

in which \( \sigma_{tu} \) is given by equation (1) and \( \sigma_{cu} = 0.67 f_{cu} \).

**Case 2:** When the reinforcing meshes are lumped together in the tensile zone within a thickness \( t \) as shown in Fig. 10(a), the distribution of stress across the thickness at collapse will be as

![Fig. 9. Conditions at collapse when meshes are uniformly distributed throughout the section.](image-url)
shown in Fig. 10(b), following the same reasonings as for case 1. The ultimate moment capacity can then be easily obtained as:

\[
M_u = \sigma_u b t \left( h - \frac{t}{2} \left( \frac{\sigma_u + \sigma_{tu}}{\sigma_u} \right) \right) \tag{7}
\]

If \( t > (h - x) \) in which \( x = \sigma_{tu} t/\sigma_{cu} \), case 2 reduces to case 1.

\[x = \frac{(\sigma_{tu} + \sigma_{tu})}{(\sigma_u + \sigma_{tu})}; \text{ and} \tag{8}\]

\[
M_u = \sigma_{tu} b(t' - x) + \sigma_u b \left[ h - \left( \frac{x + t'}{2} \right) \right] \tag{9}
\]

in which \( \sigma_{tu} = A_{sf}/(b't') \) \( \tag{10} \)

**Case 3:** In this case, the meshes are lumped on either faces of the element within thicknesses of \( t \) and \( t' \) on the tensile and compression zones, respectively (Fig. 11). If the neutral axis lies within the thickness \( t' \), the stress distribution across the depth at incipient collapse is as shown in Fig. 11(b). The following expressions for \( x \) and \( M_u \) may be readily obtained by using the same procedure as for case 1.

\[
x = \frac{(\sigma_u + \sigma_{tu})}{(\sigma_u + \sigma_{tu})}; \text{ and} \tag{8}\]

\[
M_u = \sigma_{tu} b(t' - x) + \sigma_u b \left[ h - \left( \frac{x + t'}{2} \right) \right] \tag{9}
\]

in which \( \sigma_{tu} = A_{sf}/(b't') \) \( \tag{10} \)
where \( A' \) is the area of steel within the thickness \( t' \). It may be shown that when \( x > t' \), case 3 reduces to case 2 and, hence, equation (7) becomes applicable.

**Comparison with Test Data**

The strength equations derived above by using the concept of plastic analysis are used to compute the ultimate moments of the writers' specimens presented earlier in this paper as well as those reported by Logan and Shah [2]. The reinforcing meshes were bundled together in the tensile zone for the majority of the specimens tested by Logan and Shah. In addition, they have reported mortar strength based on 75 mm \( \times \) 150 mm cylinders. In order to include the size effect, a factor of 1/1.06 has been used to convert this strength to correspond to 150 mm cylinder compressive strength as recommended by Blanks and McNamara [12] and then a factor of 1/0.8 to convert it to 150 mm cube strength, \( f_{cu} \).

<table>
<thead>
<tr>
<th>Source</th>
<th>Test Series</th>
<th>Number of layers of wire mesh</th>
<th>Test ultimate moment, ( M_u ), test</th>
<th>( M_u ), test/( M_u ), computed</th>
<th>Logan and Shah (1973)</th>
<th>Present method</th>
</tr>
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<tbody>
<tr>
<td>Present test</td>
<td>A</td>
<td>4</td>
<td>155</td>
<td>1.25</td>
<td>1.25</td>
<td></td>
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<tr>
<td></td>
<td>B</td>
<td>3</td>
<td>125</td>
<td>1.33</td>
<td>1.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4</td>
<td>145</td>
<td>1.20</td>
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<td>Logan and Shah [2]</td>
<td>A'</td>
<td>8</td>
<td>242</td>
<td>1.06</td>
<td>0.96</td>
<td></td>
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<tr>
<td>and B</td>
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<td>1.20</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1.20</strong></td>
<td><strong>1.17</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>0.11</strong></td>
<td><strong>0.13</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Not considered in the calculation of average and standard deviation.
Table 2 shows a comparison of the test ultimate moments with the predictions of the present method as well as the method proposed by Logan and Shah [2]. For the 21 groups of specimens (result of series A' has not been considered because of large deviation), the average ratios of the test to calculated ultimate moments for the two methods are 1.17 and 1.20, respectively with corresponding standard deviations of 0.13 and 0.11. Therefore, the present method is equally satisfactory. However, it is much simpler than Logan and Shah's method and directly gives the ultimate moment capacity of a ferrocement element.

CONCLUSIONS

The following conclusions can be drawn from the analytical and experimental investigations reported in this paper:

1. Both first crack and ultimate moment increase with increasing matrix grade (decreasing water-cement ratio) and increasing volume fraction of reinforcement.

2. Lower matrix grade is more favourable with respect to cracking, that is, larger number of cracks appear with smaller maximum and average crack widths.

3. Higher volume fraction of reinforcement provides more effective control of crack width.

4. The method presented herein gives satisfactory predictions of the ultimate moment capacity of ferrocement. It can be directly used at least for preliminary dimensioning of a cross section. The entire range of behaviour can then be obtained by using more sophisticated methods of analysis available in the literature.

REFERENCES


First Ferrocement Windsurfer Race

Ch.J.A. Hakkaart

Development of the design and construction of a ferrocement windsurfer is presented. Design rules, construction procedures, materials and quantities are discussed. The windsurfers, designed and constructed based on the criteria prepared, performed very well during the first concrete-windsurfer race in 1985.

INTRODUCTION

The interest in thin-walled concrete structures is growing in the Netherlands during the last years, like it is in other countries. Also the interest in ferrocement structures is growing, which results in an increased application of ferrocement as a building material for small scale structures (boats, balconies), the yearly concrete canoe race and establishment of the ferrocement study group in 1983 as part of the activities of the National Study and Research Institute CUR-VB.

One of the first activities of this group was organizing a national ferrocement congress in 1984. There were several speakers at this congress, giving their views on the subject. The first ferrocement windsurfer, made by a student from Delft University, was shown. In a demonstration, this windsurfer proved to be efficient. At this congress the idea was born to arrange a concrete windsurfer race at the next concrete canoe race. In the winter of 1984/85, the design rules have been drawn up by the study group.

On 18th May 1985 the first concrete windsurfer race was held at Den Bosch, a famous city in the southern part of the Netherlands celebrating its 800th anniversary.

DESIGN RULES

On preparing the design rules it became obvious that the development of a concrete windsurfer requires more knowledge from designers and builders than that of a concrete canoe. The main cause is the totally covered volume, which increases the construction difficulties.

A second important aspect is the wall thickness. An increase in wall thickness results in an increase in self-weight and an increase in draft. The buoyancy of a windsurfer is limited by its volume. An increase in wall thickness may have an important effect.

The rules have been drawn up in such a way that both designers and builders were given much latitude so that competitive windsurfers for the race could be developed. To give an example, a number of the most important items are mentioned:

- The length of the windsurfer has to be between 3.5 m and 4.5 m.
- A maximum width of 1.0 m is allowed.
- The maximum length of the keel is 0.7 m and of the skeg 0.3 m below the bottom of the board. Both have to be demountable.
- Both board, keel and skeg have to be constructed in concrete with cement as matrix.

* Delta Marine Consultant, Chairman of the Dutch CUR-VB Ferrocement group.
— A floating body with a floating capacity of 1 kN plus self-weight of the board has to be used, to prevent sinking of the board when leakage occurs.
— Strength and stiffness of the board have to be given by the hull. However, a foam body is allowed, provided that it has no influence on the strength and stiffness of the board.
— All kinds of armouring are allowed.
— It is allowed to use other materials for keel housing, skeg, mast foot, mast and sail.

After inspecting the completed windsurfers, it appeared that slight modifications on the rules are desirable for the next years’ races.

Two windsurfers were presented, one built from ferrocement and one built from glass reinforced concrete (GRC). These two different concrete materials offer a good opportunity for comparing the results. A thorough investigation was made on the required shape, the construction materials and the construction method by the participating schools, Amstel H.T.S. of Amsterdam (GRC) and Chr. M.T.S. of Drachten (ferrocement).

Main Characteristics

Some main characteristics of both boards are given in Table 1. The difference in weight is mainly caused by the difference in wall thickness. This explains clearly the high self-weight of the ferrocement board in comparison with the GRC board.

<table>
<thead>
<tr>
<th></th>
<th>Ferrocement</th>
<th>Glass reinforced concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>3.89</td>
<td>4.05</td>
</tr>
<tr>
<td>Width (m)</td>
<td>0.68</td>
<td>0.60</td>
</tr>
<tr>
<td>Thickness (m)</td>
<td>0.24</td>
<td>0.16</td>
</tr>
<tr>
<td>Displacement (dm³)</td>
<td>320.0</td>
<td>220.0</td>
</tr>
<tr>
<td>Self-weight (kg)</td>
<td>ca. 69.0</td>
<td>ca. 39.5</td>
</tr>
<tr>
<td>Wall thickness (mm)</td>
<td>5.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

CONSTRUCTION

Both windsurfers were constructed in the same way. First the required floating body was shaped. Around this body the scale was constructed.

Soft foam plates were limed together to create the body. With the construction method used for both boards, it is hard to prevent the body from absorbing part of the external forces. However, at the end of the race in both boards, heel prints and hairline cracks were visible. This means that only a minor part of the forces is probably taken by the body.

The GRC board was made of one layer of glass. At heavily loaded areas, two layers were used. A thin layer of mortar was spread around the body before the glass was laid. With an additional layer of mortar the board was completed.

The ferrocement board was made of 4 bars (topside, downside and sides) and only one layer of mesh. The bars were welded together. A specially constructed aluminium keel housing and steel mast foot were fixed to those bars. First the mesh was laid, followed by placing the
mortar. This resulted in a situation in which the mesh was pushed to the body, preventing the mortar partly from surrounding the mesh totally and preventing an optimal functioning of the composite material. The discrete loading of the feet caused damage to the board. Probably a second layer of mesh is required to prevent this damage.

The keel and skeg for both boards were of the same sandwich construction as the board. They worked well during the race. However the GRC skeg was lost. The GRC keel, which had a positive buoyancy, showed numerous hairline cracks after the race.

For inspection of the board, a round 100 mm gap was constructed in the board with a transparent disc (Fig. 1). During the race, water had entered the board by the crushed heelprints, which could be seen through this inspection gap. This justifies the use of foam buoyancy to prevent sinking. A detailed outline of all parts is presented in Table 2.

![Fig. 1. Inspection gap with transparent disc in ferrocement windsurfer.](image1)

![Fig. 2. The ferrocement windsurfer (no. 36415).](image2)

<table>
<thead>
<tr>
<th>Table 2. Materials and Quantities.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ferrocement</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Reinforcement</td>
</tr>
<tr>
<td>4 x 4 φ mesh 0.8 φ-10/10</td>
</tr>
<tr>
<td>4 m²</td>
</tr>
<tr>
<td>Mortar</td>
</tr>
<tr>
<td>blast furnace 28%</td>
</tr>
<tr>
<td>sand 41%</td>
</tr>
<tr>
<td>perlite 21%</td>
</tr>
<tr>
<td>water 10%</td>
</tr>
<tr>
<td>w-c factor</td>
</tr>
<tr>
<td>Buoyancy</td>
</tr>
<tr>
<td>Lime</td>
</tr>
<tr>
<td>Mast foot</td>
</tr>
<tr>
<td>Keel housing</td>
</tr>
<tr>
<td>Paint</td>
</tr>
<tr>
<td>Total weight</td>
</tr>
</tbody>
</table>
Both windsurfers had a very good appearance. Their cover had a very smooth finish. In fact there was no difference with comparable homemade synthetic windsurfers. A competition in construction with concrete canoes (already built in the Netherlands during 9 years) could be won by the boards.

RACES AND CONCLUSION

The purpose of the concrete canoe/windsurfer day was not only a competition in construction of concrete windsurfers, but also a race with the self-made boards. Two races were sailed between four windsurfers:

- the aforementioned ferrocement and GRC boards
- the one-year old ferrocement board
- a standard polyester windsurfer

In both matches a concrete windsurfer won the race. In the first race the GRC board was the winner (Fig. 2) and in the second race the one-year old ferrocement windsurfer was the winner. The boards were sailed by different sailors in both matches.

In May 1986, the second concrete windsurfer race was held in Dordrecht, Netherlands. This time there were six concrete boards: four from the Netherlands, one from Belgium and one from Poland. For this race, all parts of the board had to be of concrete, except for the mast.

So, this is again an example that ferrocement used in thin concrete structures are competitive with conventional building materials.
Spatial Component and Systems of Ferrocement

S. Yomtov*, A. Tibbi* and E.Z. Tatsa**

A method of construction based on components of single or double curvature is presented. The structures are based on a sandwich shell type section efficient in load transfer, waterproof and with adequate thermal insulation. A catalogue of shapes leading to a wide range of possible applications is shown. The method is suitable for both do-it-yourself and industrialized construction.

INTRODUCTION

Construction with reinforced concrete components of single or double curvature may lead to significant economic advantages provided that a practical manufacturing process is developed so that the efficiency of the system or component in load transferring is exploited. Presently used materials in civil engineering structures (reinforced concrete) enable only construction of large curved components like single or combinations of shells of revolution or hypars. The precondition for efficiency is the ability to do away with complex formwork which by itself when used for large units is an expensive construction problem.

Two well-established methods which avoid the classical use of formwork for reinforced concrete shells are based on inflated forms. These are:

a. The Binishells (Italian) method in which the whole structure or a part of it, which is a complete shell of revolution with a circular, elliptic or parabolic cross-section is cast on a horizontal surface and immediately lifted to its final shape while the concrete is still wet and kept between two flexible "plastic" sheets.

b. The Domecrete (Israeli) method in which the flexible form is inflated into shape before the steel bars are arranged and the concrete is cast on top.

The first of these two approaches has proven to be efficient for shells of revolution with a base diameter of 15 m - 36 m (single or combinations of up to six units). The smaller diameter shells with a floor area of about 170 m² are suitable for housing and hotel units while the large diameter shells are mostly used for storage buildings and sport halls with up to 4500 spectators. The second method has gained considerable success in structures with spans of up to about 15 m in various shell type shapes. Both methods encounter a number of problems:

2. Thermal insulation must be added after hardening of concrete.
4. Openings are made after hardening of the shell (Binishells method).
5. All elements of the Binishells method are of double curvature and it is either impossible or difficult to get other (cylindrical for example) shapes.
6. It is impossible to prefabricate lightweight units.
7. The two methods have quite high technological standard and require a skilled team to operate and supervise.

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** Faculty of Civil Engineering, Technion - Israel Institute of Technology, Haifa 32000, Israel.
The approach proposed in this work overcomes the above difficulties and problems, and facilitates low-cost, efficient and high quality construction of structures made of shell type components and systems for a wide range of applications. The method is based on a typical shell cross-section which is a sandwich made of two 10 mm - 15 mm skins parted by a layer of 20 mm - 60 mm flexible polystyrene boards. The thickness of the core depends on the thermal insulation requirements. The skins are mechanically connected by "shear nails" (Fig. 1).

Fig. 1. Typical section and stages of construction of flower packing shed.

SHAPES OF COMPONENTS AND SYSTEMS

Fig. 2 shows a selection of possible configurations for components and systems. All of these are simple to manufacture in a free form process. Therefore the functional and structural optimum shape may be obtained regardless of the usually inevitable question of how to construct economically. The variety of forms widened the range of possible applications of ferrocement. One- and two-way components and systems, and mixed combinations are shown. Some of these shapes have already been used and they are described in the following section.

APPLICATIONS

Analysis

A number of housing units and other applications have been built or are in the process of final design. Because of the complexity of the overall system, only estimates can be made in
Fig. 2. Possible configurations for components and systems.
In order to have some analytical verification. Generally, sandwich type structures should be analyzed for three modes of failure:

a. Material failure due to stresses exceeding the material strength.

b. General instability failure in which the whole shell fails with the core and skins acting together.

c. Local instability failure in which the skin buckles.

The basic dome unit used in the following applications provides adequate resistance against all three types of failure because of the following reasons:

a. The overall depth of the section (~70 mm) is relatively large in relation to the small span of the shell. This thickness is required for insulation purposes.

b. The skins (5 mm thick), which are relatively thick for a sandwich type section, together with the shear nails, prevent local buckling.

For example, the critical load for a 10.0 m diameter sandwich dome can be estimated from:

\[ q_{cr} = 0.366E \left( \frac{t_m}{R} \right)^2 \left( \frac{t_B}{t_m} \right)^{3/2} \]

in this case:

- \( R = 5.0 \) m
- \( t_m = 30 \) mm
- \( t_B = 51 \) mm
- \( E = 1962 \) MPa

therefore:

- \( q = 5.8 \) t/m²

The actual load on the shell is ~0.1 t/m², therefore a very high safety factor of 58 is provided.

In addition the effect of overturning moments due to wind loads has to be considered.

Thermal and shrinkage effects are of minor influence because of the dispersion of steel in the skin. No cracks have been noticed in the existing structures which have suffered temperature changes between \(-10^\circ\)C and \(+35^\circ\)C.

Projects Description

a. One-Family House — Tiberias Project

A 120 m² small family house is composed of four domes in three levels on a rocky hill. The four-dome combination enables an efficient “spiral” functional organization in which the whole area is fully utilized.

b. Extension of an Old One-Family House — Rosh Pina Project

In this case two domes were added to a small rectangularly shaped old house (Fig 3). The addition created new irregular spaces with very modest investment. The domes embrace the existing structure creating non-monotonous elevations in contrast to the whole neigh-
bourhood. The domes are very light and can be supported easily by the existing structure as necessary. In cases of addition to old structures it is essential that the final result will have an appearance of an integral unit. The embracing dome does it.

c. **Small Addition — Yarkona Project**

This addition to a living room was done in one week by the owner (Fig. 4).

d. **Architects Studio — Dalia Project**

The studio, which in fact is also a small family house, is built of a combination of 8.0 m and 4.0 m domes in a number of levels (Fig. 5). The innovative idea here is the suspended spherically shaped bedroom (Fig. 5d). The frame and mesh of the partial sphere were hanged from the main dome and the concrete was sprayed for both units together. The domes contain large windows which provide the feeling of a spacious house although the floor area is not larger than 52 m².

e. **Flower Packing Shed**

The structure is a combination of $2 \times (3/4)$ domes and $2 \times (1/4)$ domes, providing large entrances for tractors as well as efficient loading and storage. The partial domes are supported by very light steel trusses (Fig. 6). These shapes are suitable for industrialization.
Fig. 5. Dalia project.

Fig. 6. Flower packing shed: General view.
f. Watch-tower — Nahalal

The watch-tower is a composition of cylindrical shapes and two spheres; the ferrocement skin is stiffened by the stairs (Fig. 7).

Fig. 7. Watch-tower.

CONCLUDING REMARKS

In recent years ferrocement has rapidly won the recognition and popularity as a versatile construction material it undisputedly deserves. Beyond the technological advantages of ferrocement, the cultural aspects concerning one of the most important aspects of the modern industrialized society, namely, the relationship between people and their home emerges. In the modern world, orthogonal structures have come to be vastly predominant while curved forms are rare in spite of the clear superiority of the curved form over the flat one in many aspects like structural efficiency, volume containment, reduction of surface area and others. Industrialization favors the use of straight lines and angular intersections which are in many ways unnatural. The industrial applications of curved forms is difficult to carry out and therefore the more harmonious rounded shapes have been disappearing over the twentieth century. The particular attraction of ferrocement lies in the unlimited possibilities which it offers for shaping a structure without being dependent on sophisticated construction
methods. In this way the individual can become the master of his home not only by getting or buying one but by actually participating in the building process itself. Ferrocement can also be regarded as one of a series of materials like wood and metals enabling people to develop constructive hobbies used for improvement of the home and its surroundings. The construction procedure is easy to learn and therefore opens ways to overcome frustrations emerging from people’s inability to influence their close environment. Ferrocement technology as demonstrated here in is surely one of the leading materials.
Durability of Sulfur Impregnated Precast Ferrocement Elements

O. Yuzuqullu*

This is a study on the effect of sulfur impregnation on the durability characteristics of ferrocement and companion plain concrete specimens. Altogether 16 specimens, 130 mm square, 10 mm or 15 mm thick, were prepared and subjected to permeability and sulfuric acid attack tests. Eight of the above specimens were impregnated with elemental sulfur. Sulfur impregnated specimens were observed to be practically impermeable with a noticeable increase in strength together with an improved resistance against acid attack. Immersion of oven-dried units in molten sulfur appears to be most suitable for sulfur impregnation in precast ferrocement elements.

INTRODUCTION

Durability can be as important as strength when deciding the suitability of ferrocement for certain applications. If properly designed and carefully manufactured, normally, ferrocement is a durable material. Permeability of cement mortar of ferrocement plays an important role in its durability, since it controls the entry of water, liquids or other aggressive chemicals. If not properly plastered, thin concrete cover over the reinforcement allows easy penetration of corrosive liquids. Mortar application and mortar penetration inside the reinforcement seems to be one of the major problems in ferrocement construction. Techniques to ensure void-or cavity-free ferrocement plastering, and methods of inspection to detect voids and economical means of repairing voids [1] are needed.

In this study, sulfur impregnation of ferrocement units have been tested as an economical procedure for reducing the unfavorable effect of existing capillaries and voids on both permeability and strength with added improvement in acid resistance.

EXPERIMENTAL PROGRAM

Materials and Specimens

Unwashed natural sand and ordinary Portland cement was used to prepare the mortar. 

* Associate Professor, King Saud University, College of Engineering, Department of Civil Engineering, Riyadh 11421, Saudi Arabia.
Plain mortar or ferrocement specimens 150 mm square, and of thickness either 10 mm or 15 mm were manually cast in steel covered wooden moulds without vibration. Two different mixes were prepared; one with a water : cement : sand proportion of 0.5 : 1 : 2 and the other with 0.7 : 1 : 2. Two 150 mm × 300 mm cylinders and 50 mm × 50 mm × 50 mm cubes were secured from each mix for compressive strength determination. The reinforcement of the ferrocement specimens consisted of two orthogonal layers of expanded mesh having 10 mm × 25 mm openings (Fig. 1). The thickness of the specimens were either 10 mm or 15 mm. The designation of each specimen is given in Table 1.

Table 1. Specimen Designation.

<table>
<thead>
<tr>
<th>Normal specimens (no-impregnation)</th>
<th>Type</th>
<th>Water-cement ratio</th>
<th>Thickness (mm)</th>
<th>Reinforcement (expanded mesh)</th>
<th>Sulfur impregnated specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>P .5-1</td>
<td>Mortar</td>
<td>0.5</td>
<td>10</td>
<td></td>
<td>SP .5-1</td>
</tr>
<tr>
<td>F .5-1</td>
<td>Ferrocement</td>
<td>0.5</td>
<td>10</td>
<td>Two orthogonal layers</td>
<td>SF .5-1</td>
</tr>
<tr>
<td>P .5-1.5</td>
<td>Mortar</td>
<td>0.5</td>
<td>15</td>
<td></td>
<td>SP .5-1.5</td>
</tr>
<tr>
<td>F .5-1.5</td>
<td>Ferrocement</td>
<td>0.5</td>
<td>15</td>
<td>Two orthogonal layers</td>
<td>SF .5-1.5</td>
</tr>
<tr>
<td>P .7-1</td>
<td>Mortar</td>
<td>0.7</td>
<td>10</td>
<td></td>
<td>SP .7-1</td>
</tr>
<tr>
<td>F .7-1</td>
<td>Ferrocement</td>
<td>0.7</td>
<td>15</td>
<td>Two orthogonal layers</td>
<td>SF .7-1</td>
</tr>
<tr>
<td>P .7-1.5</td>
<td>Mortar</td>
<td>0.7</td>
<td>15</td>
<td></td>
<td>SP .7-1.5</td>
</tr>
<tr>
<td>F .7-1.5</td>
<td>Ferrocement</td>
<td>0.7</td>
<td>15</td>
<td>Two orthogonal layers</td>
<td>SF .7-1.5</td>
</tr>
</tbody>
</table>

P : Plain mortar; F : Ferrocement; S : Sulfur impregnated ferrocement.

Sulfur Impregnation Procedure

After 38 days of curing at room temperature, all the specimens were oven-dried for 24 hours at 110°C. Eight of the total 16 specimens were then immersed in molten sulfur for 8 hours at 110°C.

Testing

Three series of tests were conducted on the specimens:

a. Permeability Test: Fig. 2 shows the apparatus used for the permeability test. It consists of graduated bottomless plastic container which is attached on the surface of the specimen with a waterproof epoxy glue. Each container was filled with tap water to zero level and the water was freely allowed to penetrate the specimen. The drop in water level was used as a measure of permeability. Daily readings were recorded for 10 days.

b. Acid Attack Test: Acidic environment usually exists in agricultural and industrial wastes [2]. Sulfuric acid is particularly corrosive. The main objective of these tests was to study the degree of protection against acid attack, which could be provided by sulfur
impregnation when the specimens were subjected to a sulfuric acid solution. Acid attack test was performed only on the 15 mm thick specimens. For this purpose the specimens were soaked in a 10% sulfuric acid solution for 20 hours.

c. In-Plane Compression Strength Tests: Both the 15 mm thick specimens exposed to sulfuric acid and the 10 mm thick companion specimens not exposed to acid attack were subjected to in-plane compression tests (Fig. 3). The average compressive strengths obtained from the standard cylinders and cubes were $f'_c = 24.3$ MPa and $f'_c = 27.4$ MPa corresponding to the two mixes with water-cement ratio of 0.7 and 0.5, respectively.

TEST RESULTS

Permeability Test Results

The results obtained from these short-term permeability tests are shown in Figs. 4 and 5. It is observed that there is a distinct (manifold) reduction in permeability when sulfur impregnation is used. All the sulfur impregnated specimens have almost the same negligible amount of permeability independent of their thickness, water-cement ratio and the presence of reinforcement; whereas non-impregnated companion specimens showed considerable variations in behavior as a function of the above-mentioned parameters. Although the number of specimens is very limited for a parametric study, it can be roughly stated that ferrocement elements are slightly more permeable than plain mortar and some increase in permeability can be expected with increased thickness and increased water-cement ratio.

Sulfur impregnation had the positive effect of a good sealant. Since the pores and voids are almost filled with sulfur, water or other aggressive chemicals will not be able to penetrate through the specimen.
Fig. 4. Permeability test results (water-cement ratio = 0.5).

Fig. 5. Permeability test results (water-cement ratio = 0.7).
Weight loss after acid attack (g)

In-plane compressive strength (MPa)

Amount of impregnated sulfur (g)

Fig. 6. Acid attack and strength test results.
Acid Attack Test Results

After removing the specimens from the acid bath, visual inspection of the sulfur impregnated specimens clearly showed very little disintegration as compared to the companion non-impregnated specimens. This observation was also supported by the comparison of weight losses as given in Fig. 6a. Loss of non-impregnated specimens reached up to 5.8% whereas impregnated specimens had at most 1.4% loss.

In-Plane Compression Strength Test Results

Fig. 6b shows the test results obtained from the in-plane compression tests. In case of non-impregnated specimens, strength decreased almost in proportion with the weight loss (Figs. 6a and 6b) due to acid attack; whereas sulfur impregnated specimens were protected against acid attack due to the presence of sulfur. Besides, the increase in strength was observed to be directly proportional to the amount of impregnated sulfur (Figs. 6b and 6c).

CONCLUSIONS

The following conclusions can be drawn from the test results of this study:

1. Sulfur impregnation can improve durability of ferrocement precast units. This improvement can primarily be attributed to the significant decrease in permeability.
2. An indirect improvement in the freeze/thaw properties can also be expected because solid sulfur replaces the excess water.
3. Since cavities and voids are filled with sulfur, strength increases due to sulfur impregnation [3].
4. Sulfur impregnation procedure have broad applications in precast industry.
5. Sulfur is a considerably cheaper material than polymers, which are also used for impregnation of concrete [4].
6. Elemental sulfur, which was used in this study, is expected to deteriorate when exposed to moisture after a long period of time. For long-term durability, modified sulfur or some other technology [5] is suggested.
7. Further repeated number of tests are needed to reach quantitative conclusions as to the effect of different parameters.

ACKNOWLEDGEMENT

The support provided by the Research Center of the College of Engineering of King Saud University is highly acknowledged.

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The International Ferrocement Information Center (IFIC) is celebrating its 10th year anniversary this year, 1986. To commemorate this anniversary, the Journal of Ferrocement is presenting a series of papers on the early development of ferrocement in different parts of the world. These papers are based on personal experiences and recollections of persons who participated in this development.

Paper 1 traces the events that led to the establishment of IFIC with particular emphasis on the people, the problems and the sponsors.

Paper 2 gives special tribute to the 74 subscribers who have been with IFIC since the first issue of the Journal and to the only supporting subscriber to the Journal.
IFIC—Ten Years of Growth

L. Robles-Austriaco*

INTRODUCTION

A new building material is making its impact on architecture, engineering and construction. During the past ten years, ferrocement has clearly grown to a recognized construction material for many types of construction such as buildings, houses, boats, biogas digesters, gas holders, water tanks, swimming pools, sculpture pieces and others. These are concrete evidences that the International Ferrocement Information Center (IFIC) has achieved its objectives throughout its ten years of Service.

IFIC, THEN AND NOW

An international information service on ferrocement was first conceived by an Ad Hoc panel of the Board on Science and Technology for International Development (BOSTID) of the U.S. National Academy of Sciences (NAS). Following the release of the report of this panel, the Asian Institute of Technology (AIT) and NAS jointly sponsored a workshop which was held at the AIT campus Bangkok (Figs. 1-3). The workshop panel reiterated the urgent need for an information service. This led to the establishment of IFIC in October 1976.

IFIC published the first issue of the Journal of Ferrocement in July 1977 under the guidance of an international Editorial Board. Then, the Journal has only 82 subscribers. Now, the Journal has 328 subscribers in 66 countries; 60% of which are from developing countries. Of the original subscribers, 74 have been with IFIC for the last ten years.

*Editor, Journal of Ferrocement and Senior Information Scientist, International Ferrocement Information Center (IFIC), Bangkok, Thailand.
Then, the problem was to have enough papers for one issue. Now, the Journal continues to attract authors of papers on ferrocement and related materials. The backlog of papers result in a substantial increase in the number of papers of each issue. Papers are printed on an average of not more than six months after acceptance. This is a goal of utmost importance of IFIC—to disseminate the most current information on ferrocement and to continue to attract authors to submit their papers to the Journal.

In addition to adding more pages to the Journal of Ferrocement, IFIC has published, since 1979, a special issue a year on a particular application, and new sections such as Tips for Amateur Builders, Authors' Profile, List of IFIC Consultants, Ferrocement Experts, IFIC Reference Centers and Publications have been added.

To answer the needs of a great diversity of users, the repacking and dissemination of information on ferrocement had to be done equally in a very diversified way through different types of publications and audio-visual means. In addition to the classical types of publications such as monographs (Fig. 4), bibliographies, special reports and state-of-the-art reviews, IFIC
IFIC has introduced (1) *FOCUS*, an information brochure on ferrocement in 17 languages; (2) *Do-It-Yourself Series*, guide for non-technical people to build ferrocement structures and (3) *Slide Presentation Series*, audio-visual means to introduce the technology and its applications.

Then, IFIC used manual retrieval system to provide information to users. Now, all information collected at IFIC is entered into a computerized database. As a result, the retrieval is faster and more dependable. IFIC provides computerized search services for specific information requests on particular aspects of ferrocement technology and related materials.
Fig. 10. Participants constructing ferrocement trough during the training course for Universiti Pertanian Malaysia, 1984.

Fig. 11. Participants of the Asia-Pacific Symposium on Ferrocement at the University of Roorkee, India, 1984.

Fig. 12. Participants constructing a ferrocement element during the Short Course on Design and Construction of Ferrocement Structures, 1985.

Fig. 13. The “Ferrocement Park” at the Asian Institute of Technology (AIT), 1984.

Fig. 14. During the Opening Ceremony of the Second International Symposium on Ferrocement at AIT, Bangkok, 1985.

Fig. 15. Training course for villagers conducted by the Universiti Pertanian Malaysia, a member of the Ferrocement Information Network.
To promote the utilization and the transfer of ferrocement technology to the rural areas of developing countries, IFIC has undertaken activities such as organizing training courses, seminars, study-tours and symposia (Figs. 5-14). For these activities, IFIC acts as an initiator, identifying needs, soliciting funding, finding experts and bringing people together. Currently IFIC is organizing the Ferrocement Corrosion: An International Correspondence Symposium and the 1986 Ferrocement Inter-University Canoe Race, the first concrete canoe race in Asia.

To facilitate and accelerate the greater flow of information to users in developing countries, IFIC has established the Ferrocement Information Network (FIN) for Asia and Africa (Fig. 15) and IFIC Reference Centers in 50 selected institutions in developing countries (Fig. 16).

IFIC, believing that the engineers and the architects are the best transfer agents for ferrocement technology, has undertaken the Ferrocement Technology Curriculum Campaign. Invitation to teach ferrocement technology was sent to 528 universities throughout the world. As a result, 122 universities in 49 countries are now teaching ferrocement technology as a topic in one of the required courses in their undergraduate programs.

THE PEOPLE

IFIC has always been a people-oriented center. This is because IFIC was made possible by people. People with vision, who have freely given their talents and precious time. Dr. Jacques Valls and Dr. Ricardo P. Pama (Fig. 17) with Dr. Seng Lip Lee, then Chairman of the Structural Engineering and Construction Division, AIT worked for the establishment of IFIC in 1976. They were responsible for writing proposals and convincing people about IFIC. Dr. Valls has guided IFIC as director for more than 8 years. Dr. Pama and Dr. Lee has guided IFIC for the past ten years as associate director and member of the editorial board, respectively. Special mention is due to the past information scientists — Mr. Bishwendu Kumar Paul, Mr. V.S. Gopalaratnam, Mr. Caesar Singh, Mr. Sashi Kumar Kunnath; and to the administrative secretary of IFIC for ten years, Ms. Lalida Vichitsombat, for their great contribution to the success of IFIC.
The growth and success of the Journal of Ferrocement is a testimony to the effort of the past and present editorial board (Fig. 18) members: present members—Mr. D.J. Alexander, Professor A.R. Cusens, Mr. J. Fyson, Mr. M.E. Iorns, Professor S.L. Lee, Professor A.E. Naaman, Professor J.P. Romualdi, Professor S.P. Shah and Professor B.R. Walkus; past members—Dr. G.W. Bigg, Dr. G.L. Bowen, Mr. D.J. Eyres and Dr. Pisidhi Karasudhi Mr. D.G. Alexander, Professor A.R. Cusens, Mr. J. Fyson, Mr. M.E. Iorns, Professor S.L. Lee and Professor J.P. Romualdi have been members of the editorial board for ten years.
If we reflect on what contributed to the IFIC success, we have to salute the work of individuals—IFIC staff, editorial board members, correspondents, researchers, contributors, authors, extension workers and legions of ferrocement users—the dedicated men who have given countless hours of their time for the advancement of IFIC and ferrocement technology.

SPONSORS

IFIC will not be as it is without the financial support from The New Zealand Government (Fig. 15), United States of America Agency for International Development (USAID), Government of France, International Development Research Center (IDRC) of Canada, Canadian International Development Agency (CIDA) and the Government of Australia. They place their money in IFIC not expecting immediate return but rather more as a trust fund—building for a better future.
IFIC Salutes Its Special Subscribers

As the International Ferrocement Information Center celebrates its tenth year of service, IFIC salutes the very special subscribers—the 74 subscribers who has been with IFIC since the first issue of the Journal and the only supporting subscriber to the Journal. As a token of appreciation, IFIC has prepared a package of the 10th Anniversary publications for them.

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Mesh Types Commonly Used in Ferrocement

M.E. Irons*

INTRODUCTION

Ferrocement can include all thin-shell concrete structures containing one or more layers of reinforcement. The reinforcement can range from rods to finely woven fabrics and can include plastics or natural organic materials such as bamboo and jute.

Experiments by the US Navy [1] demonstrated a substantial increase in strength-to-weight ratio by eliminating rods and using mesh only. During the development of a high performance, impact-resistant planing hull, they found that rods were very inefficient as reinforcement. Because the rods were not loaded to take advantage of their strength, and the space between rods was filled with mortar which contributed to weight but not to strength. Rods are also undesirable because they act as stress concentrators. When prototype boats were tested, only the all-mesh hull survived the sea trials which included hull driven at 30 knots in choppy water.

When the most commonly available types of reinforcing steel are ranked by specific surface, rod is lowest, wire mesh is next, and expanded metal plaster lath is highest. When ranked in order of unit cost, rod is still lowest, but expanded metal lath costs less than any of the closely spaced wire fabrics. For all-mesh construction, metal lath is the most cost-effective, followed by welded mesh and woven mesh.

Builders who wish to use the superior ability of expanded metal lath to accept strain without cracking, [2] must keep its anisotropic character in mind and orient the layers in the laminate accordingly. This unequal strength in different directions is no greater than in many of the woods used in boatbuilding and may be used to advantage in the design, or strips of the lath may be placed at various angles like the veneers in plywood, to make the finished laminate more nearly isotropic.

Where tensile strength is important, the mesh should not be galvanized or welded since either operation anneals and weakens the wire. Galvanizing is unnecessary for wire embedded in rich mortar [3] and the zinc may react with any black iron present to form hydrogen bubbles unless the mortar is passivated by the addition of chromium trioxide or by other means.

* Ferrocement Laminates, 1512 Lakewood Drive, W. Sacramento, CA 95691, U.S.A.
ACTUAL SIZE PATTERNS OF MESH TYPES

Square Mesh

The commonly available meshes in welded or woven form are the 16 and 19 gauge meshes. Thinner wire meshes are woven.

Hex Mesh
Expanded Metal

Expanded metal lath is produced in large quantities for the plastering trade and is available in all industrially developed nations. Its lower cost and high specific surface compared to wire mesh makes it the most cost-effective reinforcement.

Expanded metal is a rigid non-raveling piece of metal which has been slit and drawn into an open mesh pattern in a single operation. It is stronger and more rigid than the original metal. Conventional mesh is in a diamond pattern.

Pattern

Expanded metal plaster lath 3.4 pounds per square yard (1.84 kg/m²) made from 24 gauge (0.023 in.) 9 in. wide sheet metal and expanded to 27 in. (0.7 m).

Expanded metal is generally designated by two numbers. The first number normally indicates nominal dimension, SWD (short way of design). The second number normally indicates gage with the exception of No. 9 and No. 10 expanded metal. Never add the word gage to style designation.
Style Designations

Random shearing—shear line falls at random points—diamonds not matched. Edge condition usually results in open diamonds. Tolerance: ± $\frac{1}{16}$ in (1.588 mm) for No. 9 styles or lighter; ± $\frac{1}{8}$ in. (3.175 mm) for heavier meshes. Bond shearing—sheared through bond resulting in closed designs.

CUSTOM-BUILT MESH

In many parts of the world, manufactured wire mesh is not available and represents a drain on foreign exchange to import. Bare wire is more generally available and costs much less to import, so on-site weaving of mesh for ferrocement makes good economic sense. Wire mats
of any size may be woven on a simple peg loom outdoors or on a frame or foot-powered loom indoors (4). On-site weaving also has an advantage over any standard manufactured mesh because the warp elements can be different in diameter, spacing, material, and tensile strength from the weft wires. This permits the mesh to be woven to a specification which will most economically resist the stresses involved in a particular section, no matter how small. A manufacturer cannot afford to adjust his machinery to produce small lots and still charge a reasonable price.

Custom weaving also facilitates research on the innovative use of reinforcing materials. In the past, builders were forced to use whatever mesh was available and were thus precluded from experimenting to find the best. This resulted in the “chicken wire” boats which brought ferrocement into disrepute as a hull material. Better mesh is now in use, but ferrocement is still limited to a few meshes manufactured for other purposes, and much research is needed to optimize reinforcing systems for various structures. For example, an ultra-thin high-tensile ferrocement might be achieved with a mesh having banding strap for the warp and wire for the weft.

REFERENCES

This list includes a partial bibliography, with keywords, on ferrocement and related topics. IFIC has these articles and books. Reprints and reproductions, where copyright laws permit, are available at a nominal cost (see page 518). Earlier parts of the bibliography have been published in the past issues of the Journal and are also available in the first volume of "Ferrocement and its Applications—A Bibliography" which contains 736 references compiled from the list. Copies of this IFIC publication can be ordered at a cost of US$2.00 per copy (surface postage included). For air mail postage, add an additional amount of US$2.00.

RESEARCH AND DEVELOPMENT

Material Properties


FAILRE / FERROCEMENT / FRACTURE / STRAIN / STRENGTH / TOUGHNESS
RESEARCH AND DEVELOPMENT

Standards and Specifications


BOAT / CONSTRUCTION / FERROCEMENT / MATERIAL / PROPERTY
Chile

General


BUILDING / CONCRETE / CONSTRUCTION / DURABILITY / HEAT / ROOF / WOOD / FRC
U.K.

CONSTITUENT MATERIALS

Mortar Preparation and Plastering


BOND / COARSE AGGREGATE / COMPACTIBILITY / COMPRESSION / CONCRETE STRENGTH / WATER-CEMENT RATIO
Iraq


CEMENT PASTE / PROPERTY / RHEOLOGY / SETTING TIME / SUPERPLASTICIZER
U.S.A.

Substitute Materials for Mortar Preparation

CEMENT / COMPRESSION / FLY ASH / MANUFACTURE / PORTLAND CEMENT / POZZOLANA / STRENGTH / TESTING
Tanzania

CEMENT / HOUSING / LOW COST / MANUFACTURE / POZZOLANA / PROPERTY

Ghana

COMPRESSION / HYDRATION / POZZOLANA / STRENGTH

Egypt

HOUSING / LOW COST / PREFABRICATION / ROOF / RHA

Pakistan

FLY ASH / MIX DESIGN / PORTLAND CEMENT / POZZOLANA / REINFORCED CONCRETE

Egypt

CEMENT / PERMEABILITY / POROSITY / PFA

U.K.

PRODUCTION / STRENGTH / PORTLAND CEMENT

Tanzania

CEMENT / MORTAR / SETTING TIME / STRENGTH / RHA

India

CEMENT / COMPRESSION / CONCRETE / CURING / FLY ASH / MIX DESIGN / STRENGTH

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CEMENT / CONCRETE / FLY ASH / READY-MIXED CONCRETE / SLAGS

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CONSTITUENT MATERIALS

General


COMPRESSION / CONCRETE / SETTING TIME / SLUMP / STRENGTH / SUPERPLASTICIZER
Singapore


ADMIXTURE / CONCRETE / COST / MIX DESIGN / SUPERPLASTICIZER
U.S.A.

TERRESTRIAL APPLICATIONS

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DEVELOPING COUNTRIES / FERROCEMENT / HOUSING / LOW COST / SANITARY

India


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Sanitary Structures


South Africa

PROTECTION AND RELATED TOPICS

Durability


Saudi Arabia

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CONCRETE / FIBER / FLEXURE / STEEL / STRENGTH / TESTING

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**BEAMS / CONCRETE / FIBER / STEEL / TORSION**


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**FIBER REINFORCED COMPOSITES**

**Bamboo Fiber Composites**


**BAMBOO / CONCRETE / DESIGN / DESIGN CRITERIA / ECONOMY**

U.K.

**Natural and Organic Fiber Composites**


**COMPOSITES / CRACK / FLEXURE / HOUSING / SHEAR / SISAL FIBER / STRENGTH / TENSION**

Kenya


**BAMBOO / CORRUGATED / GRAIN STORAGE / ROOF / SISAL FIBER / TILES / WALL**

Kenya


**CONCRETE / DEVELOPMENT / DURABILITY / MANUFACTURE / PROPERTY / ROOF / SISAL FIBER**

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**ABSORPTION / CORRUGATED / FIBER / FLEXURE / IMPACT / MORTAR / WATER**

Sudan

BAMBOO / CONCRETE / FIBER / HOUSING / LOW COST / ROOF
Egypt


CONCRETE / DURABILITY / IMPREGNATION / ROOF / SISAL FIBER
Sweden
IFIC NEWS

First Asian Concrete Canoe Race

The International Ferrocement Information Center (IFIC) and the Structural Engineering and Construction Division of the Asian Institute of Technology in collaboration with the Royal Thai Navy under the patronage of Her Royal Highness Princess Maha Chakri Sirindhorn, will hold a concrete canoe race in Bangkok in November 1, 1986 to commemorate the 10th anniversary of IFIC.

The first race of its kind in Asia, will be held in the lake of Muangthong Village 3 in the northern Bangkok suburb of Laksi. Engineering students from universities throughout Thailand were invited to participate in the race. They will compete for design, construction and actual paddling of canoes.

To generate interest on this activity, IFIC/AIT organized seminars and demonstrations for the media people and university students. The seminar and demonstration for the media were conducted in Thai language by Dr. Pichai Nimityongskul, Associate Professor of the Structural Engineering and Construction Division of AIT, last 26 August 1986. During the seminar, Dr. Nimityongskul explained the advantages and many applications of ferrocement. The construction of a ferrocement water tank was demonstrated after which the guests were invited for a ride in the ferrocement canoes (Figs. 1-2).

Dr. Nimityongskul also conducted the roving seminar to universities throughout Thailand. He discussed the mechanical properties of ferrocement, and design and construction of ferrocement canoes.
Reference Center News

Chile-Research Study on Ferrocement

Professor Sr. J.P. Covairuñas and Mr. Francisco Rosales of the Department of Construction Engineering, School of Engineering, Pontifica Universidad Catolica de Chile had undertaken a research study on ferrocement. The objective is to obtain technical specification for ferrocement construction, fabrication technique, typical curves and values for different material behaviour focusing on construction of ferrocement boats.

The research report based on this study is entitled “Specifications for the Construction of Ferrocement Boats and Material Properties (in Spanish)”. Pontifica Universidad Catolica de Chile is IFIC Reference Center and the resource person is Professor Dr. Carlos Videla C. (Information from Professor Dr. Carlos Videla C., Departamento Ingenieria de Construccion, Escuela de Ingeniería, Pontifica Universidad Catolica de Chile, Santiago, Chile).

AUSTRALIA

A Cook’s Tour on a Ferrocement Boat

Gween Skinner has used her own experiences—gained while cruising the South Pacific on the ferrocement yacht Swanhilde—as the basis for the book The Cuisine of the South Pacific. The tour comprised the islands of Papua New Guinea eastward to Marquesas Islands and from Tuvalu South to New Zealand. She describes the food in the South Pacific in details enhanced by photographs.


INDIA

Bagasse Ash as Pozzolanic Material

Bagasse is a waste product of sugar cane processing, which is sometimes used in paper- and board-making, although most is burnt as a fuel. The ash which is left after burning bagasse is of little use, except as a filling material for low-lying areas. In India alone, if all the bagasse were burnt, approximately one million tonnes of ash would be produced every year.

Chemical and microscopic analysis of ashes from boilers at sugar factories near Roorkee in India showed that they consisted of two-thirds to three-quarters silica, which was partly crystalline but mainly amorphous. Since it is known that amorphous silica is pozzolanic (it can react with lime at ordinary air temperatures), these ashes, mixed with high calcium-hydrated lime in various proportions, were used with sand to make 50 mm mortar test cubes. The 28-day wet compressive strengths were only 0.4 N/mm². However, if the ashes, were first ground to a fine powder in a ball mill strengths up to 3 N/mm² were obtained with the optimum lime: ash proportion of 1:2 by volume. The increase in strength may be due not only to the greater surface area produced by grinding, but also because the newly formed surfaces of the ash particles are free from the iron oxide coating which had been observed during microscopic examination on the original ash. Differential Thermal Analysis indicated that most of the lime had been utilized in reaction with the silica within one year.

The setting time of lime-ash mortars was slow, but could be accelerated by intergrinding 10% ordinary Portland cement and 4% gypsum with the ash and lime. If, alternatively, bagasse ash is used in an attempt to extend ordinary Portland cement, as other pozzolans occasionally are, any residual sugar...
in the ash may delay or prevent the setting of the cement.

Further information about this research can be obtained from S. Srinivasan, Publications Central Building Research Institute, Roorkee 247672, India.
(Source: Appropriate Technology, 12 (4) : 5).

KENYA

Sisal-Cement for Grain Bins

Sisal-cement bins have the advantage over metal bins because the temperature inside does not rise rapidly when the sun shines on the bin causing convection currents inside leading to condensation and crop deterioration. The advantage over traditional bins is that a sisal-cement bin can be made insect-proof, watertight and almost airtight (discouraging insect growth by build-up of carbon dioxide in the bin). The sisal-cement bin is cheaper than a metal bin.

Grain Bin using Sisal-Cement Soil-Block Walls

The bin is constructed on a damp-proof base consisting of blocks stacked to include air spaces covered by two layers of mortar separated by a layer of polythene. A pipe is included as the maize outlet (Fig. 1). The sisal-cement clad walls are built on this, and covered by a sisal-cement or metal lid that is also the maize inlet. If theft is a problem, then a mortar tunnel can be made over the outlet pipe, and a lockable door fitted at the other end (Fig. 2).

Construct 10 rows using 16 blocks in each row. In this case the walls are circular, when the blocks are touching on the inside of the wall, gaps will be left on the outside of the wall (Fig. 3). If these are a problem, either fill them with mud mortar or crumble the inner corners and edges of the blocks to reduce the gaps on the outside. After the first 10 rows, the walls should slope inwards (Fig. 4).
Conical Sisal-Cement Grain Bin Built Over Bamboo Frame

The frame is made using complete bamboo poles or sisal poles, and covered with polythene and a sisal mesh, plastered with sisal cement. Two thin coatings are used on the outside. When these have cured, the sisal poles or bamboo poles are removed, together with the polythene, and the walls are then plastered on the inside. The resulting shell structure is very strong because of its shape, even without the reinforcement of the sisal fibres whose presence is only necessary for the initial construction.

The bin uses the same foundation and roof as those described for grain bin using sisal-cement soil-block walls, although in these case larger diameter foundations are needed for the same size bin.


Sisal-Cement Water Jar

This technique for making a water jar is based on the method devised by Phromratanapongs “Water Jars of Cement Mortar”, in ‘Ferrocement, a Versatile Construction Material’, Asian Institute of Technology, Bangkok, 1976). In the original design, a mortar base is made first and allowed to set. A cloth bag is filled with sawdust and stood on the base. Layers of mortar, each very thin, are plastered onto the bag, each being allowed to harden before applying the next layer. This improved technique uses sisal-cement mortar and has three advantages: the bag can be placed on the wet mortar base before the latter has set, so that the walls can be a continuation of the base, eliminating the need for a joint which can lead to leakage problems; only two layers of mortar need to be used for the walls (possibly only one if the plastering is done very carefully); thinner walls can be used, thus reducing the amount of cement used and hence the cost.

NEW ZEALAND

Customised Reinforcing Mesh.

Construction companies and other users of reinforcing mesh will be able to achieve big savings on costs and wastage as well as faster construction time with a new prefabricated reinforcing mesh developed by Cyclone-CMI Ltd.

Cyclone-CMI has spent more than $1 million to upgrade its reinforcing mesh manufacturing capabilities and to engineer a new product called Customesh which is designed to meet the individual requirements of design engineers and building contractors.

New manufacturing machinery, imported from Switzerland, allows mesh specifications to be customised to suit particular jobs.

Until now it has been standard practice to allow for a lap wastage of 25% when calculating the area of mesh required for a slab. With Customesh the sheet type and dimensions are worked out from the plans. This enables the best sheet size to be chosen to fit the slab. Wastage can be significantly reduced, often below 18%, using this technique.

To get the best on-site placement, a detailed mesh layout plan is drawn up showing the orientation and placement of each sheet in the floor slab. The flexibility and fast change provided by the new Customesh manufacturing machinery means that the company can offer this detailing service for almost any size contract—even those with a floor area as small as 1200 m².

Customesh has a number of extra benefits over reinforcing bar. These include:

- tighter tolerance compared with hand placement of bar.
- less on-site supervision is needed because Customesh's reinforcing wires are mechanically spaced.
- increased construction speeds, shortening construction time.

- higher tensile strength (485 MPa yield strength) of the reinforcing wires gives a reduced steel mass.

Competitive building materials and techniques are required by the building industry in order to remain competitive and to stimulate growth. Customesh is one of such material that will minimise construction time while maximising accuracy.

Mt Roskill-based Cyclone-CMI is distributing design tables to outline the features of the product. Tables show options for the reinforcing wire cross sectional area, the weights of reinforcing wire for various spacings, and suggested Customesh equivalents to common bar diameters and spacings.

(Source: Customised Reinforcing Mesh. New Zealand Concrete Construction (May): 14).

Methods of Determining Cement Strength

The value of cement when employed as a structural material depends primarily on its mechanical strength in the set and hardened condition, i.e., a strength due to the cohesion of the particles of the cement and to their adhesion to the grains of sand or other aggregate with which they are mixed. Mechanical tests therefore play a most important part in determining the quality of cement, and every specification requires a certain minimum strength that must be attained under given conditions.

Strength tests take different forms: the specimen being subjected to tension (directly or indirectly), compression or bending (flexure).

Many countries, especially those in Europe, impose a requirement for the flexural strength as well as the compressive strength of mortar in their cement standards, but the most universally used test for determining the strength properties of cement is the compressive strength of standard mortars.
The material constitution of standard mortars for the purpose of determining cement strength varies somewhat according to the country involved. Water-cement ratios range from 0.40 to 0.60 and, in the main, mortars are of plastic consistency. An exception is the BS 4550 mortar cube test (which is used in New Zealand) where ungraded, virtually single size standard sand is used. In the latter test, the mortar is unworkable and is difficult to compact at high cement fineness. The test is also subject to error due to variations in effort applied during hand mixing.

There has been a move away from the use of extremely dry mortars having water-cement ratios 0.30 or less and where compaction has been achieved by tamping, towards the use of plastic mortars compacted either by hand tamping, vibration on a table, or the application of mechanical shocks. Australia and Indonesia were the only two countries which in 1980 were still using an extremely dry mortar to determine cement strength.

In 1964, New Zealand revised the New Zealand Standard for Portland Cement and issued as NZS 1844. The concrete cylinder test developed by the New Zealand's Ministry of Works engineers was included in the standard. The concrete cylinder test on machine mixed 8 in. x 4 in. concrete cylinder (water-cement ratio 0.50) is widely used throughout New Zealand, but the vibrated mortar cube test was designated the referee method. Although it is scarcely used by concrete manufacturers, the mortar cube test has remained the referee method.


Permeability of Cement Pastes

Fig. 1 shows the variation of permeability with water-cement ratio for relatively mature cement pastes (degree of hydration = 93%) as measured by Powers et al (1). These data exhibit a marked increase in permeability as the water-cement ratio climbs much beyond 0.50.

This increase is associated with the distribution of capillary pores (which generally form the principal passageway for permeating fluids). At relatively low water-cement ratios, the capillaries within a mature paste are largely discontinuous with the result that the overall paste permeability reflects the extreme watertightness of the hydrated cement gel. As the water-cement ratio increases, so too does the relative volume of capillaries present within the cement paste system. Beyond water-cement ratios of 0.5 the likelihood prevails in practice of an interconnected network of capillary pores, the degree of interconnection being related to both the water-cement ratio and degree of hydration achieved. Table 1 shows the effect of age (active curing throughout) on the measured permeability of a cement paste having a water-cement ratio of 0.51(2).

Fig. 1. Permeability coefficient vs. water-cement ratio for mature pastes (1).

References

Table 1. Age vs. Permeability Coefficient, K, for a Cement Paste with \( w/c = 0.51 \)

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>( K ) (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh paste</td>
<td>( 10^{-5} ) Independent of ( w/c )</td>
</tr>
<tr>
<td>1</td>
<td>( 10^{-6} )</td>
</tr>
<tr>
<td>3</td>
<td>( 10^{-9} )</td>
</tr>
<tr>
<td>4</td>
<td>( 10^{-10} ) Capillary pores interconnected</td>
</tr>
<tr>
<td>7</td>
<td>( 10^{-11} )</td>
</tr>
<tr>
<td>14</td>
<td>( 10^{-12} )</td>
</tr>
<tr>
<td>28</td>
<td>( 10^{-13} )</td>
</tr>
<tr>
<td>100</td>
<td>( 10^{-16} )</td>
</tr>
<tr>
<td>240(maximum hydration)</td>
<td>( 10^{-18} ) Capillary pores discontinuous</td>
</tr>
</tbody>
</table>


SOUTHERN AFRICA

Catchment Tanks

In Matabeleland and Mashonaland, a large catchment tank programme has been run by the ecumenical organisation Christian Care. The work began in 1968, on the following:

1. Ground surface catchment tanks known as "water harvesters"; these are linked cylindrical tanks, typically of 9,000 litres capacity (Fig. 1); they have been built mainly in Mashonaland.

2. Ferrocement roof tanks of 9,000 litres nominal capacity (7,500 - 8,000 litres after subtracting dead storage etc.); the design has been used for many tanks built in Matabeleland, Mashonaland and Malawi.

The centre of Christian Care's tank-building operations in Matabeleland is Hlekweni, a rural training centre run by the Society of Friends near Bulawayo. By the end of 1972, this centre had been instrumental in building some 30 "open" ground surface catchment tanks and over 200 ferrocement roof tanks. At Hlekweni, an "open" type catchment tank constructed on Botswana principles (ITDG 1969) is being successfully used for irrigating a vegetable garden. The ferrocement tanks are Hlekweni's most outstanding contribution in this field.

The most common type of roof catchment tank in southern Africa is a cylindrical tank made of corrugated sheet steel with a galvanised finish. Apart from their high initial cost (Table 1), these tanks have a limited life because seams open up or corrode. Better installation can overcome this to some extent, but 5 years is accepted as a reasonable life by European farmers who have the knowledge and capital to ensure that all possible precautions are taken.

With this situation in mind, Mr. Roy Henson of Hlekweni devised a similar sort of tank but made of ferrocement, built around a cylindrical former of corrugated curved sections (Fig. 2). The former is removed after the outside layers of cement have been applied, and the tank is finished by plastering from the inside. A certain amount of building and plastering skill is necessary, but no complicated equipment is used. Some half-dozen craftsmen trained at Hlekweni built 210 tanks for householders in Matabeleland in two years (1971-72).

An interesting feature of this project is that all gutting and downpipes for the tanks are made from sheet metal in the workshop at Hlekweni. Gutters must be of generous cross section to cope with the intense rainfall occurring in tropical storms. The durability of the tanks has not yet been proven, because few have been in existence for more than three years. However, they should be able to out-
**Table 1. Costs and Labour Requirements of the Catchment Tanks.**

<table>
<thead>
<tr>
<th>Type of Tank</th>
<th>Nominal capacity</th>
<th>Self-help labour requirement</th>
<th>Hours work per 1,000 litres capacity</th>
<th>Cost (1973 prices)**</th>
<th>Cost per 1,000 litres capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roof catchment tanks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>retail prices of the galvanised type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of ready-made steel tank, excluding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gutters, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swaziland, 500 gallon</td>
<td>2,250</td>
<td>-</td>
<td>-</td>
<td>£18.20 T</td>
<td>£8.10</td>
</tr>
<tr>
<td>Swaziland, 1,000 gallon</td>
<td>4,500</td>
<td>-</td>
<td>-</td>
<td>£26.30 T</td>
<td>£5.26</td>
</tr>
<tr>
<td>Bulawayo, 2,000 gallon</td>
<td>9,000</td>
<td>-</td>
<td>-</td>
<td>£40.00 T</td>
<td>£4.00</td>
</tr>
<tr>
<td>Bulawayo, 2,000 gallon</td>
<td>9,000</td>
<td>-</td>
<td>-</td>
<td>£45.00 T</td>
<td>£5.00</td>
</tr>
<tr>
<td><strong>Roof catchment tanks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>installations complete with gutters.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Galvanised steel tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrocement tank, built with wage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>labour with some self-help.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swaziland, 500 gallon</td>
<td>9,000</td>
<td>2 x 15</td>
<td>2</td>
<td>£60 T,G</td>
<td>£6.00</td>
</tr>
<tr>
<td>Swaziland, 1,000 gallon</td>
<td>9,000</td>
<td>2 - 15</td>
<td>2</td>
<td>£37</td>
<td>£4.15</td>
</tr>
<tr>
<td>Bulawayo, 2,000 gallon</td>
<td>9,000</td>
<td>2 xx 100</td>
<td>11</td>
<td>£25 G</td>
<td>£2.80</td>
</tr>
<tr>
<td>Large concrete block-built tank</td>
<td>71,000</td>
<td>80 xxx 700</td>
<td>10</td>
<td>£104 G</td>
<td>£1.45</td>
</tr>
<tr>
<td>(Parker 1973)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Surface catchment tanks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Open&quot; type (e.g. as in Botswana -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ITDG, 1969)</td>
<td>45,000</td>
<td>45 xx 400</td>
<td>9</td>
<td>£30</td>
<td>£0.67</td>
</tr>
<tr>
<td>&quot;Beehive&quot; type (figures partly from</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swaziland Econo. Planning Office)</td>
<td>90,000</td>
<td>160 xxx 2000</td>
<td>22</td>
<td>£100 P</td>
<td>£1.10</td>
</tr>
<tr>
<td>Linked cylinder type (rough estimate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*All prices are as quoted in late 1972 or in August 1973 except the costing for the "open" tank which had been adjusted to 1973 prices from an estimate of £22 in 1967-68 quoted by ITDG (1969). Exchange rate assumed is £1 = R1.87.
Fig. 1. Ground surface catchment tanks.

Fig. 2. Constructing a ferrocement tank: a concrete foundation has been laid with the outlet pipe tap embedded in it, and two sections of the corrugated metal former or "form" are in position.

Table 2. Cost of Building Tanks.

<table>
<thead>
<tr>
<th></th>
<th>Ferrocement tank with locally made guttering</th>
<th>Galvanised steel tank with ready made guttering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank construction:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>materials...</td>
<td>£9.00</td>
<td>£45</td>
</tr>
<tr>
<td>tank cover...</td>
<td>£4.50</td>
<td></td>
</tr>
<tr>
<td>wages...</td>
<td>£10.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>£24</strong></td>
<td><strong>£45</strong></td>
</tr>
<tr>
<td>Guttering and downpipes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>materials...</td>
<td>£3.00</td>
<td></td>
</tr>
<tr>
<td>wages...</td>
<td>£3.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>£6</strong></td>
<td><strong>£8</strong></td>
</tr>
<tr>
<td>Transport...</td>
<td>£7</td>
<td>£7</td>
</tr>
<tr>
<td></td>
<td><strong>£37</strong></td>
<td><strong>£60</strong></td>
</tr>
</tbody>
</table>


last the galvanised tanks, and leaks should be comparatively easy to deal with by re-sealing the inside surface.

A breakdown of the cost of building a tank whose nominal capacity is 9,000 litres (useful capacity 7,500-8,000 liters) is set out in Table 2. The figures were worked out at an early stage in the project, and have been updated by the authors so as to be consistent with the 1973 price levels of Table 1.
SOUTH AFRICA

Triple-Purpose Mould.

The mould is used to build a ferrocement roof tank, a spring protection reservoir and the superstructure of the ventilated, improved pit toilet. It is constructed by bolting together curved sheets of corrugated galvanised iron into six vertical sections. These vertical sections are bolted together in turn to form either a circular mould, for roof tanks and spring protection reservoirs, or a spiral mould, for toilet superstructures. In the latter case, one of the broad vertical sections is removed, the bolts joining the remaining sections one to another are loosened, and the remaining five sections are bent inwards into the illustrated spiral shape.

Earlier attempts to use a mould comprising two vertical sections were not successful. Apart from the fact that this mould could not be used for toilets, great difficulty was experienced, firstly, in removing such a comparatively large piece of formwork from the inside of the first layers of plaster. Secondly, passing the half section of mould up and over the sides of the tank or reservoir was difficult and threatened the comparatively fragile first layers of plaster.

To stabilize the circular mould during plastering, horizontal struts are bolted onto brackets attached to the vertical lengths of timber between the vertical sections of corrugated iron (Fig. 1). It is more difficult, however, to stabilize the spiral mould. This can be achieved by temporarily wiring together two points (Fig. 2) at the base and top of the mould. This also assists in stabilizing the timber door frame during plastering. This door frame is not essential but can be used by the toilet owner to hang a half-door or a gate as an improvement.

Local experience suggests that householders are keen on such improvements. The improved toilet is, firstly, frequently used as a wash-house requiring increased privacy. Householders also sometimes request some kind of door to prevent strangers from using the toilet and goats from sheltering there. The door or gate should not impede the passage of air down the pedestal and up the vent pipe.

Fig. 1. Dimensions of mould.

Fig. 2. Plan of formwork for spiral VIP latrine.
The mould is not maintenance free. After each usage, care should be taken to rub down the outer surfaces with a hard brush and rag to remove the residual grains of the plaster. These surfaces should then be lightly oiled with SAE 30 or similar. Without this maintenance the outer surfaces become rough and increasingly difficult to detach from the plaster.

The advantages of this triple-purpose mould are self-evident. It is relatively cheap, built from standard size, generally available materials and can be disassembled and transported in the back of a small truck. It enables a rural dweller to apply one skill, that is the use of ferrocement, to three activities that are fundamental to rural development. A major disadvantage of ferrocement is the uneconomic delay between the application of the different layers of plaster. This can be shortened both by improved plastering techniques and by the use of two or three moulds used concurrently at different building sites.

Two sets of moulds, including the vent pipe and pedestal moulds, a set of the necessary tools come to $380 in 1985. Since the work requires two men, this represents job creation at an extremely low capital equipment input cost, transport excluded. As in so many instances of rural development, however, the simplicity or excellence of a proposed technology must be seen in the full human context of its use.


THAILAND

Cement Jars for Dry Villages

In remote villages, a campaign to solve the farmers’ water shortage has been urgently carried out during the past five years. At present, one million huge jars have been built all over the country to reserve water for use during the dry season.

Mr. Vongchan proudly displays jar number one million.

Mr. Sangvien Vongchan, 69, a farmer living in Bann Khumbucharoen, Nakhon Ratchasima Province, has built the one millionth jar. The village has 75 households and a population of 412, who face a water shortage problem, though there are natural pools in which people dig for. A problem arose when villagers brought their cattle to the water sources. The animals were dirty, especially so during the dry season; the local people drank the water and ended up with diarrhea.

In order to solve the water problem, the Integrated Rural Development Committee has taken part in a scheme to teach villagers how to build jars for storing rain-water for use during the dry season. During the past two years, poor villagers have turned to using jars which supply them with drinking water throughout the year.

Bann Khumbucharoen has 137 cement jars, or two per household. The main occupation of the villagers is farming. Lately, there has been a campaign to establish a vice-free village. The locals set rules to reduce the drinking of alcohol and gambling. For the purpose of spending their time in a more
profitable way, villagers joined together in activities such as; producing fertilizer from hyacinth, building cement jars, making shoes from tyres, and making bricks. Financial support came from the rural job creation project.

The Integrated Rural Development Committee of Nakhon Ratchatasima, launched the project to overcome a water shortage that has been causing the village hardship since 1980. The first jar was built on August 12, 1980, in Prachub Kirikan Province. At last count, in January 1986, the committee had overseen the building of 1,058,721 jars all over the country as part of a government project aimed at tackling the rural problems of poverty, illiteracy and disease.

Mr. Vongchan told The Nation that one jar could hold 1,600 litres of water. He spent 180 baht on it and finished it on February 6. He felt that the jar would be better used by all the villagers rather than keeping it as his own property, because they all helped to build it. He has refilled the jar three times since he finished it. The water from the pools was contained in the jars because it was summer and there was no rain-water. When the rain arrives, he will empty the container and store rain-water instead.

He expects to take about three months to consume the water. He is planning to make one more bigger jar to hold 2,000 litres—enough for the whole year.


UNITED KINGDOM

Admixture Manufacturers Index

There are numerous manufacturers of admixtures around the world, some offering an extensive range of products whilst others provide a more specialised service.

All companies are able to provide a technical advisory service to assist not only in the right selection and use of chemical admixtures but in development areas also. Concrete technology is advancing at a great speed, and much of the advancement is due to the close cooperation which the construction industry enjoys with the chemical admixture manufacturers. As new requirements become evident, the listed manufacturers will be only too willing to assist, if possible, in the research and development of an admixture which will satisfy the particular requirements.

BIM BV, (The Netherlands).
Calder Colours (Ashby) Ltd. (United Kingdom).
Cementa AB, (Sweden).
Cementation Chemicals Ltd. (United Kingdom).
Cementone-Beaver Ltd. (United Kingdom).
Chemische Fabrik Gruenau GmbH. (West Germany).
Cormix Limited (United Kingdom).
Cugla by (The Netherlands).
Dow Construction Products. (United Kingdom).
FEB (United Kingdom).
Fosroc International Limited. (United Kingdom).
Kerner Greenwood & Co Ltd. (United Kingdom).
MC Bauchemie Muller GmbH Co. (West Germany).
Master Builders, (U.S.A.).
Asbestos Poses No Threat to the Public

An exposure of 0.0005 f/ml, which is the measurement obtained in asbestos-insulated buildings, represents a mortality risk of 1 in 100,000 during a lifetime, based on 40 hours of exposure per week for 20 years. In contrast, exposure to cigarette smoke for more than seven hours a week means a cancer risk of 90 in 100,000 for a non-smoker.

Using such comparisons, Sir Richard Doll and Dr. Julian Peto presented their evaluation of the risks run by the public exposed to asbestos in a report published last May.

The report, entitled "Effects on Health of Exposure to Asbestos" was commissioned in 1982 by the Health and Safety Commission of Great Britain to bolster the adoption of regulations to control asbestos in the workplace. From that starting point, the authors examined the wealth of available data on asbestos exposure in the workplace, as well as in the environment, giving particular attention to the more complex aspects.

After summarizing the biological effects of asbestos, the report states that there is no scientific evidence of a relationship between the fibre and gastrointestinal cancers, since it was impossible to generate this type of cancer in laboratory animals. As for the risk of contracting cancer of the larynx, it is much lower than the average risk that may be associated with asbestos in the workplace.

The authors of the report also went on to emphasize the difficulties of evaluating the effects of asbestos exposure, citing the following reasons: the presence of several chemicals in the composition of asbestos; the fact that the physical properties associated with biological effects vary according to mineralogical type and fibre processing; and finally the fact that asbestos is used with other substances that may change its effects.

The United States Environmental Protection Agency (EPA) seems to be responding to opinion that removing asbestos from schools and other public buildings is not always the best solution. In a guide published in August 1985, the American agency recommends leaving asbestos-based insulating material in place when in good condition.
suggests a number of techniques to control and avoid eventual asbestos dust.

Furthermore, in a radical swing from its previous stand, the EPA recognizes in this guide that the presence of asbestos in a building does not necessarily endanger the health of the occupants.

(Source: Asbestos poses no threat to the public. Asbestos 1 (2): 8-9).

Effective Lining Systems

Reinforced guniting liners have been used in the renovation of sewers for many years. Their excellent performance has been well established, but the problem has always been that they were too heavy and that factor has imposed many restrictions on their use in sewer renovation. The Ferro-Monk system not only offers a solution to this problem but also provides many other advantages:

- Formed in any shape or size, segmental or complete sections
- Provides a smooth high density finish giving excellent hydraulic properties with low permeability and excellent durability
- High impact and abrasion resistance
- Excellent bonding with cement grout
- Designed to withstand grouting pressure without the need for temporary support thus eliminating problems of local debonding of the liners from the grout
- A competitive pricing structure
- Designed in accordance with the “Sewer Rehabilitation” manual

Designed either as a structural or non-structural protective coating the Ferro-Monk system has, inherent in its guniting process, the ability to bond extremely well to existing materials, without the use of chemical bonding agents, and forms a genuinely composite structure between the ferrocement and the old sewer lining.

The system reduces the erection time normally required for relining since the relining can progress from several manholes with minimal disruption to traffic.

Other advantages are:

- Because the lining follows the existing shape of the sewer the reduction in overall size is minimal
- Use of precast inverts avoids over pumping in low and moderate flows
- The problems generally associated with sharp bends and lateral connections are avoided
- Existing manholes can be used and also cost-effectively renovated
- Eliminates rebound and dusting problems commonly associated with guniting
- Conforms to variations in shape such as flat roofs, services, crossings, etc.
- The system is designed to allow spraying in all man entry sewers
- There are no hidden extra costs normally associated with the quantity of grout required

The constituents of Ferro-Monk linings are not new, in fact they are the traditional materials of the construction industry—steel and concrete. Their strength lies in the way the constituents are combined and also in the use of specially developed fabrication techniques. Ferro-Monk linings are thin shells constructed of reinforced concrete which provides a high cement content, low water-cement ratio, high density and superior mechanical properties.

Ferrocement Sewers and Tunnels Ltd. and Monk Tunnelling have combined to produce and market this extremely flexible and economical structural lining system. It has been developed to protect, stabilise and strengthen sewers, tunnels, shafts and other types of underground structures (Figs. 1-6).
Fig. 1. Precast units at the ferroconent factory.

Fig. 2. Precast lining to a 1.2 m high by 0.9 m wide sewer.

Fig. 3. Precast and in situ spray lining to a 1.4 m high by 1 m wide sewer.

Fig. 4. Fixing of reinforcing for in situ lining.

Fig. 5. In situ spraying of structural lining to 1.5 m high by 0.9 m wide sewer.

Fig. 6. Non-structural protective in situ lining to a 1.2 m high by 1.5 m wide sewer.
Effect of Energy-Saving Measures

An overall picture of energy use in the UK housing stock and how it is changing is being built up using BREHOMES, a model developed for the purpose at (Building Research Establishment) BRE. Between 1979 and 1984 there was a reduction in energy consumption per dwelling of about 12%, worth almost a billion pounds a year, despite a big growth in central heating and the increase in internal temperatures which resulted.

One of the main reasons for this fall is the application of energy conservation measures — BRE estimates that five billion pounds (at 1985 prices) has been spent in the last ten years. Some measures have been widely adopted: for instance, 83% of the housing stock now has loft insulation. Scope for further improvements in energy efficiency now centres on the wider uptake of other measures, particularly cavity fill, and on the installation of more efficient heating systems. A large proportion of the systems put in during the 1960s and 1970s are reaching the end of their useful life, and new high performance boilers offer the chance of improving efficiency by between 15% and 40%.

For more information contact: Building Research Advisory Service Garston, Watford WD2 7SR, Herts, WD6 2BL.

(Source: "Measuring effect of energy-saving measures" BRE News of Construction Research (February) : 1).

Energy Efficiency in Buildings

Building Research Establishment (BRE) is involved in a wide-ranging programme of research on energy-related problems. The aim of the work is to increase energy efficiency cost-effectively, but at the same time to make sure that the environment in the building is kept at a satisfactory standard and that possible side effects and health hazards are avoided. Research on housing covers studies of the effectiveness of energy conservation measures, including insulation, heating appliances, draughtproofing, schemes for domestic energy audits, and solar gains. Possible side effects such as condensation and mould growth and indoor air pollution, are also covered. Guidance on these issues will be included in the BRE draft for a new Code on energy efficiency in housing. Studies for non-domestic buildings include energy-saving through management and control systems, improved lighting design and use of daylight, advanced heat generators, and more economical ventilation.

(Source: "Research on energy efficiency in buildings" BRE News of Construction Research (February) : 1).

Testing Concrete Durability

There are two main reasons for investigating and testing concrete: to check compliance with a specification during construction, and to investigate performance after a period in service. The Concrete Society has been actively involved in both of these areas since its formation nearly 20 years ago and has contributed, directly and indirectly, to the revision and improvement of many British Standards.

During the 1960s and 1970s, the main emphasis was on improving testing procedures related to compliance checking and, in particular, on establishing clear guidelines on procedures for compressive strength testing of cubes. The performance of testing machines was also studied. Another important area was core testing, culminating in Technical Report
Concrete core testing for strength. An addendum to CSTR 11 is due for publication later this year, which takes account of recent research, particularly in relation to small cores (less than 100 mm diameter), and practical experience in the use of the original report.

In recent years, the Society’s interest in testing has shifted towards the investigation of performance in service, related commonly to deterioration of a structure and the need for ‘forensic’ investigation of the causes. The work on core testing pointed the way towards the interest in concrete ‘in the structure’ rather than test specimens, and towards the understanding that strength is an important criterion of concrete quality, but that durability of concrete in situ can be equally, if not more, important.

The forthcoming British Standards — the 200 series of BS 1881 — will help to establish guidelines on non-destructive test procedures and the advantages and limitations of the various tests. These will help engineers and testing specialists to ‘get the right numbers’. But what is also needed is advice on ‘what the numbers mean’ and this is where the Society, with its representation throughout the industry, can play a most effective role. Two current examples are permeability and chemical analysis.

Permeability covers a multitude of properties and mechanisms. A low permeability is probably better than high permeability concrete in general, but a distinction must be drawn between absorption and penetration of liquids, and diffusion of ions, all of which can be considered as types of permeability.

Chemical analysis of hardened concrete is a subject that is prone to misunderstanding and hence leads many engineers to doubt its usefulness in any situation. Yet it can, with skill and care at all stages of sampling, preparation and analysis, yield valuable information on the constituent materials, their nature and proportions, and on the changes to the concrete caused by environmental, or other agents.

In summary, the Society’s role in relation to testing concrete for durability is focused on the bringing together of experience of new techniques and approaches with the day-to-day needs of the industry, in order to produce practical guidance which will help to improve concrete durability.


Training Course in Appropriate Technology

A course in Wales to train development workers in alternative technology has been going on for four years. Since its establishment, the courses offered at Machynlleth in Wales have evolved in response to the needs of those who attend. One of the things the course teaches is problem solving and resourcefulness. Since all countries have different materials available and not available, no solution is universal and adaptation is easiest from a fertile imagination.

The 10-day course is designed to cover as many practical technologies as possible in the time given. These include:

- The use of indigenous building materials such as used stabilized soil.
- How to build a roof truss using round timbers and no nails or bolts, then test it.
- Methods of termite control.
- Use of ferrocement for building grain or water storage tanks.
- Potential in the use of water, wind and solar power generation.
- Practical appreciation of blacksmithing and small-scale foundry work.
- Sanitation — review of different methods.
of sewage disposal including the ventila­
ted pit latrine.

- Clean water supply — sources of pollu­
tion and simple methods of purification.

The actual syllabus for any course can be
adjusted to suit the needs of the volunteers,
and it is interesting to notice that this course
has proved equally useful to teachers, health
workers and administrators.

The Norwegian Overseas Development
Agency, NORAD, not only sends their
volunteer architects and engineers, but all
their volunteers on this course, amounting
to 60 people a year with a wide range of skills.

The use of this course by both technical
and non-technical volunteers illustrates the
value of people learning by practical methods
which make them much more aware of what
is possible, often with very little resources.

It is very encouraging to the course leaders
when volunteers write back from their pro­
jects confirming the relevance of what they
have learned on the course. This is further
strengthened by the commitment and support
from other practical development groups, who
have for many years been working in collabora­
tion with countries overseas in the
development of appropriate tools and pro­
ceses. What they add to the course is of
immense help since the volunteer can appreci­
ate first hand that again so much is possible
with so little. The whole philosophy of helping
people to help themselves is at the very
heart of the concept of appropriate technol­
gy.

(Source: King, R. 1986. Training course in
appropriate technology. Appropriate Tech­
nology 12 (4) : 17-18).

U.S.A.

Cast-in-place Construction vs. Industrialization

Multi — storey building construction, be­
cause of the many opportunities for repetition
that it offers, logically lends itself to an indus­
trialized approach — prefabricating building
components under factory conditions and as­
sembling them at the site with minimal field
work. During the last two decades, a wide
range of cost-effective building construction
schemes using industrialized or prefabricated
materials have been proposed and implemented.
The prefabricated components now range
from simple structural frame elements or
panels to complete room modules and box­
shaped living units.

Traditional cast-in-place construction,
however, continues to dominate the rein­
forced concrete, residential, multi — storey
building industry, although some elements
of the traditional building methods may lend
themselves to industrialization.

Undoubtedly it is the proper combination
of all materials and methods which lead to the
most efficient, economical and socially effec­
tive building. For investment-type buildings,
the measuring stick is invariably the total
cost, but social, aesthetic or functional
values also play important roles in the
final selection of a building design.

Why does the archaic cast-in-place method
of construction still compete so successfully
with the newer industrialized systems? Un­
doubtedly the weight of tradition, as well as
intellectual inertia on the part of engineers,
architects and contractors, has helped assure
the continued popularity and competitiveness
of cast-in-place construction. In addition, the
reluctance of labor to adapt to new building
systems has been influential. Unions in the
United States, for example, still require that
work be done on-site, although factory-cut
or prefabricated products might prove better
and cheaper.

Furthermore, building codes, in many
instances, have been restrictive and not
directly responsive to industrialized construc­
tion. And at the same time, huge capital
expenditures — from US$2 million to US$5
million—may be required to build and equip a central plant, along as well as a fairly large and continuous volume of construction to support it. In other words, cast-in-place construction requires a considerably smaller capital investment for equipment that has a high degree of mobility. Finally, there is the less tangible but equally significant advantage of inherent flexibility and the freedom of design that cast-in-place construction allows the engineer or architect. All of these factors have combined to make the process, at least for the high-rise structural frame, one of the most popular and economical forms of construction.

The industrialized approach, nevertheless, has been or can be cost-effective when combined with a cast-in-place, high-rise, reinforced concrete structural skeleton. During the last two decades, there have been significant developments and innovations in design and construction technology that have helped streamline the cast-in-place, residential construction process thus maintaining the competitive position of this method in relation to other forms of construction.

Two recent building types have become particularly popular. In both, prestressed precast hollow core slabs, (the most economical) are used. One type uses these slabs on concrete block bearing walls in buildings up to 10 storeys. In another, slabs with spans of 9 m-12 m and precast large panel walls are used to create precast buildings. Either the cross-wall type or the longitudinal type is used in precast buildings. This structural arrangement has proven reasonably successful in the United States.

In many countries, developing and developed alike, industrialization is still in its infancy. In the United States, 96% of all 4- to 15-storey buildings and 99% of those over 15 storeys are built with the traditional cast-in-place structural frame constructed by a variety of highly modern, sophisticated methods and equipment. The flexibility of design, the relatively low capital investment, the mobility of the required equipment, the huge investment in education, experience, and the production of accessories associated with it have helped to maintain cast-in-place construction as the backbone of high-rise reinforced concrete construction industry. And with the present rate of change within the industry, cast-in-place reinforced concrete is likely to dominate the high-rise residential building field for the near future.

But the current trend toward increased off-site component manufacture is a healthy trend in the building industry, and should be welcomed—not only for providing a competitive alternative to the traditional methods of construction, but for spurring improvements in the old system.

ACI to Publish Two New Journals

To keep pace with the tremendous growth in concrete information available for publication, the American Concrete Institute is responding with two new journals.

These two new journals will expand considerably the publishing power of the Institute and, beginning 1987, will replace the existing ACI Journal. Entitled respectively the ACI Structural Journal and the ACI Materials Journal, these new publications will bring to the membership a vastly improved information capability.

The decision to retire the existing Journal and replace it with the two new journals was reached by the ACI Board of Directors at its recent meeting in San Francisco. It was felt that this action would expand the information available to members through the publication of more papers. By concentrating the new journals into a structural journal and a materials journal, a member can choose, as part of his dues, whichever publication best satisfies his professional needs and avoid paying additional dues for information he may not require. The second journal would
then be made available for a modest subscription fee. To provide maximum service to the membership, abstracts from each journal will appear in the other, with copies of each paper available upon request for a nominal charge.

In approving the two new journals, the Board emphasized that it was their intent, that the Institute will be affording more opportunities for authors to submit high quality manuscripts for publication.

The change to the new two journal concept will not affect Concrete International: Design & Construction, published monthly and included as part of the members basic dues.

**Ferrocement Septic Tank**

Mr. Patrick McGinn used ferrocement septic tank for his trailer home (Fig. 1). His choice was dictated by high speed construction and the low cost of the ferrocement septic tank.

(Information from Mr. Patrick McGinn, Rt., 3, Box 33 Lamy, New Mexico 87540, U.S.A.)
ANNOUNCEMENT

FERROCEMENT CORROSION: AN INTERNATIONAL CORRESPONDENCE SYMPOSIUM

Objectives:
- To provide an opportunity to review and update the existing knowledge on ferro-cement corrosion
- To discuss corrosion problems and recommended practices

Call for Papers

Papers are invited on all aspects of ferrocement corrosion. Authors are requested to submit two copies of the full-length manuscript by 15 May 1986.

Schedule

IFIC receives comments from participants for authors 1 September 1986
IFIC sends comments to authors 1 October 1986
Authors send reply to IFIC 1 November 1986
Release of symposium Publication 1 March 1987

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CH. J.A. HAKKAART

Mr. Hakkaart obtained the M.Sc. degree in civil engineering from the Technical University of Delft, the Netherlands. In 1978 he started as a design engineer with Delta Marine Consultants, the Netherlands, where he was involved in the design of harbours, breakwaters and other marine infrastructure. During this period the interest for lightweight and alternative materials, like ferrocement started. From 1981-1986, he was a project engineer and subsequently project manager in the development of new construction methods, techniques and materials for the large storm surge barrier in the Netherlands (Easter Scheldt).

In 1983 the Dutch Concrete Institute (CUR-VB) started a committee “Ferrocement” for the stimulation and research of Ferrocement in the Netherlands. Since then he was the chairman of this committee. He is a member of the Royal Netherlands Institute of Engineers (KIVI). He has published two papers on marine operations and two papers on ferrocement. At present he is involved in the development and installation of new construction methods and materials for marine and onshore infrastructure.

M.A. MANSUR

Dr. Mansur is a senior lecturer of civil engineering, National University of Singapore. He obtained his B.Sc. Eng. and M.Sc. Eng. from Bangladesh University of Engineering and Technology, Dhaka and a Ph.D. in Structural Engineering from the University of New South Wales, Australia in 1979. His primary research interests are in the areas of torsion in concrete beams and frames, ferrocement and composite materials.

P. PARAMASIVAM

Dr. Paramasivam is an associate professor of the Civil Engineering Department at National University of Singapore, Singapore. He obtained a Bachelor of Engineering and Master of Science in Engineering with First Class honors in 1964 and 1966 respectively from Madras University and Doctor of Philosophy from Indian Institute of Technology, Kanpur in 1969. He worked as research associate at University of Calgary, Calgary, Canada before joining the National University of Singapore in 1971.
He has published several papers in the field of ferrocement and fiber reinforced materials, computer applications of static and dynamic analysis of building frames, finite element and grid framework model analysis of complex plate structures. He is a member of Institution of Civil Engineers, London, Institution of Engineers, India and Singapore.

**ELISHA Z. TATSA**

Dr. Tatssa is a civil engineer and a senior lecturer at the Faculty of Civil Engineering at the Technion, Israel Institute of Technology in Haifa. He obtained his D.Sc. Degree from the Technion. Dr. Tatssa has been a visiting faculty at the University of Sheffield, U.K. and the State University of New York at Buffalo, U.S.A. where he taught both in the departments of Civil Engineering and Architecture. His main fields of interest are in the development of structural components and systems. Among these are a housing system made of ferrocement, industrial buildings with active envelopes, sandwich road construction and peripherally stressed components. All these are now in various stages of applications. Many of his works have been described in about 25 professional papers. Dr. Tatssa is also active as consultant to firms in Israel, U.K. Italy, U.S.A. and Japan.

**ARIEL TIBBI**

Mr. Tibbi is an architect in Haifa, Israel. A graduate of the Technion, Israel Institute of Technology in Haifa in 1982, his main field of interest is in the design and construction of shells made of ferrocement.

**SIMCHA YOMTOV**

Mr. Yomtov is an architect in Kibbutz Dalia, Israel. He obtained his degree in architecture from the Technion, Israel Institute of Technology in Haifa. His main work and interest in recent years is in curved forms for housing systems. He has developed methods of construction enabling fast construction for one and two level buildings made of ferrocement. Another field in which he is deeply involved is planning and development of Arab Villages in Israel.
Abstracts

JFP 75 CRACKING BEHAVIOUR AND ULTIMATE STRENGTH OF FERROCEMENT IN FLEXURE
KEYWORDS: Cracking, Ferrocement, Flexure, Plastic Analysis, Moment Capacity, Strength, Ultimate
ABSTRACT: The results of an investigation conducted on ferrocement to study the cracking behaviour and ultimate strength in flexure are reported. Based on the concept of plastic analysis, a simple method is proposed to predict the ultimate moment capacity of ferrocement. A comparison of the predicted ultimate moments with test data available with full details shows good agreement.

JFP 76 FIRST FERROCEMENT WINDSURFER RACE
KEYWORDS: Canoe, Construction methods, Design, Ferrocement, GRC.
ABSTRACT: Development of the design and construction of a ferrocement windsurfer is presented. Design rules, construction procedures, materials and quantities are discussed. The windsurfers designed and constructed based on the criteria presented, performed very well during the first concrete-windsurfer race in 1985.

JFP 77 SPATIAL COMPONENTS AND SYSTEMS OF FERROCEMENT
KEYWORDS: Building, Construction Methods, Housing, Ferrocement, Sandwich Construction, Shell.
ABSTRACT: A method of construction based on components of single or double curvature is presented. The structures are based on a sandwich shell type section efficient in load transfer, waterproof and with adequate thermal insulation. A catalogue of shapes leading to a wide range of possible applications is shown. The method is suitable for both do-it-yourself and industrialized construction.

JFP 78 DURABILITY OF SULFUR IMPREGNATED PRECAST FERROCEMENT ELEMENTS
KEYWORDS: Chemical Analysis, Durability, Ferrocement, Impregnation, Permeability, Precast.
ABSTRACT: This is a study on the effect of sulfur impregnation on the durability characteristics of ferrocement and plain mortar. Altogether sixteen specimens, 150 mm square, 10 mm or 15 mm thick, were prepared and subjected to permeability and sulfuric acid attack tests. Eight of the above specimens were impregnated with elemental sulfur. Sulfur impregnated specimens were observed to be practically impermeable with a noticeable increase in strength together with an improved resistance against acid attack. Immersion of oven-dried units in molten sulfur appears to be most suitable for sulfur impregnation in precast ferrocement elements.
October 7-9, 1986: Joint Symposium on Use of Vegetable Plants and Their Fibers as Building Materials, Baghdad, Iraq. Contact: Dr. Mufid A. Samarai, National Center for Construction Labs., Tell Mohammad/Mousa Bin Nesser Sq., Baghdad, Iraq.

October 13-14, 1986: The Asia-Pacific Concrete Technology Conference '86, Jakarta, Indonesia. Contact: The Organisers, Institute of International Research, Suite 0803, Golden Wall Center, 89 Short Street, Singapore 0718.

October 27-30, 1986: Second International Conference on Concrete Technology for Developing Countries, Tripoli, Libya. Contact: Ali S. Ngab, Director of Organizing Committee, P.O. Box 13225, El-Fateh University, Tripoli, Libya.

October 18-31: World of Concrete Europe 86, London, U.K. Contact: World of Concrete Expositions (Europe) Ltd. PO Box 53, 28 Church Street, Rickmansworth, Hertfordshire WD3 2AG, U.K.

November 9-14, 1986: ACI Fall Convention, Baltimore, Maryland, U.S.A. Contact: P.O. Box 19150, Detroit, Mich., 48219, U.S.A.


January 14-16, 1987: Third International Conference on Rainwater Cistern Systems, Khon Kaen, Thailand. Contact: Secretary, Technical Committee, Third International Conference on Rainwater Cistern Systems, Faculty of Engineering, Khon Kaen University, Thailand 40002.


March 17-18, 1987: 3rd International Conference on Steel Structures, Singapore. Contact: Miss Peggy Teo, Conference Logistic and Services, P.O. Box 576, Orchard Point Post Office, Singapore 0923.
March 22-27, 1987: ACI Annual Convention “Concrete Quality”, Mexico. Contact: IMCYC, Insurgentes sur 1846, Col. Florida, Del. Alvaro Obregon 01050, Mexico, D.F. Telex CACEME 017-75715. OR ACI, Convention Department, P.O. Box 19150, Detroit, Michigan 48219, Telex 810 2211454

April 5-10, 1987: 3rd Int. Conf. on Creep and Fracture of Engineering Materials and Structures, Swansea, U.K. Contact: Dr. E. Wiltshire, Dept. of Metallurgy, University College of Swansea, Singleton Park, Swansea SA2 8PP, U.K.

April 27-May 1, 1987: Katharine and Bryant Mather International Conference on Concrete Durability, Vicksburg, Miss., U.S.A. Contact: John M. Scanlon, Waterways Experiment Station, Corps of Engineers, P.O. Box 631, Vicksburg, Miss., 39180-0631, U.S.A.

May 1987: Third International Conference on Structural Faults and Repair, London. Contact: Dr. M.C. Forde, Department of Civil Engineering, University of Edinburgh, The King's Building, Mayfield Road, Edinburgh EH9 3JL, Scotland.

July 20-25, 1987: The Sixth International Conference on Composite Materials, England. Contact: Mr. F.L. Matthews, Director, Center for Composite Materials, Imperial College of Science and Technology, Prince Consort Road, London SW7 3BY, England.


September 21-24, 1987: 5th International Congress on Polymers in Concrete, Brighton, U.K. Contact: Dr. B.W. Staynes, Department of Civil Engineering, Brighton Polytechnic, Cockroft Building, Lewes Road, Brighton BN2 4GJ, U.K.


November 4-6, 1987: Fourth International Conference on Durability of Building Materials & Components, Singapore. Contact: Prof. Lee Seng Lip, Head, Department of Civil Engineering, University of Singapore, Singapore.

January 6-9, 1988 International Conference on Composite Materials and Structures, Madras, India. Contact: Prof. K.A.V. Pandalai, Fiber Reinforced Plastics Research Centre, Indian Institute of Technology, Madras, India.
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Published  December 1985
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B  HOUSING BIBLIOGRAPHY
Specialized Bibliographies Vol. 1

Housing Bibliography includes all references available at IFIC on housing, constructed in-situ and prefabricated.

Published  December 1985
List price  US$ 2.00 Surface mail
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C  FERROCEMENT BIOGAS DIGESTER
Do it Yourself Booklet No. 6

W. Kanok-Nukulchai and L. Robles-Austriaco

This booklet, the sixth in the Do-It-Yourself Series, explains the construction of the ferrocement biogas digester developed at the Asian Institute of Technology. The construction procedure has been presented in easy to follow format. Introduction to biogas, design guidelines, operation and maintenance of the plant are also discussed.

Published  October 1985, flexicover edition, 41 pages.
List price  US$ 4.00 surface mail
           US$ 6.00 air mail
D  FERROCEMENT ROOFING ELEMENT
Do It Yourself Booklet No. 5
K. Sashi Kumar, P.C. Sharma and P. Nimityongskul

This is the fifth booklet in the Do-it-Yourself series published since 1979. A new format has been adapted in the presentation of the text. The construction procedure has been detailed in a simple step-by-step manner. The descriptive text is accompanied by corresponding figures thus enabling a clearer perception of the construction process. Also included are erection and installation procedure, post-construction operations, precautions to be taken and additional reading.

Published  June 1985, flexicover edition, 47 pages.
List price  US$ 4.00 surface mail
            US$ 6.00 air mail

E  INTERNATIONAL DIRECTORY OF FERROCEMENT ORGANIZATIONS AND EXPERTS 1982-1984

The 1982-1984 IFIC'S INTERNATIONAL DIRECTORY OF FERROCEMENT ORGANIZATIONS AND EXPERTS is your indispensable source for decision making when you need to select firms/experts for ferrocement related design, construction and engineering services.

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F  PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM ON FERROCEMENT

This proceedings contains the papers presented at the Second International Symposium on Ferrocement held at the Asian Institute of Technology, Bangkok, Thailand, 14-16 January 1985. The 65 well illustrated papers were contributed by authors from 17 countries. The papers were grouped into the following subjects: material properties; research and development; analysis and design; construction; housing applications; special structures; corrosion and durability; and ferrocement standards and technology transfer.

The proceedings provide an opportunity to review and update the existing knowledge and further understand the latest developments and progress made in ferrocement technology.

Published January 1985, hard bound, 788 pages
List price: US$ 60.00 (surface postage included)
LECTURE NOTES
SHORT COURSE ON DESIGN AND CONSTRUCTION OF FERROCEMENT STRUCTURES

This is a compilation of the lecture notes of the Short Course on Design and Construction of Ferrocement Structures held at the Asian Institute of Technology, Bangkok, Thailand, 8-12 January 1985. This publication contains every aspect of ferrocement from its historical background and constituent materials to the construction procedures. An important feature of the lecture notes is the design criteria for ferrocement including examples of analysis problems based from the “ACI Design Guide for Ferrocement.” The resource persons are:

D.J. Alexander   Principal, Alexander and Poore Ltd., New Zealand
G.B. Batson      Professor, Clarkson University, U.S.A.
P.E. Ellen        Principal, Peter Ellen and Associates, Ltd., Hong Kong
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003 FERROCEMENT, A VERSATILE CONSTRUCTION MATERIAL: IT’S INCREASING USE IN ASIA
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