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Discussion of the technical materials published in this issue is open until October 1, 1985 for publication in the Journal.

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The Editor, Journal of Ferrocement, IFIC/AIT, G.P.O. Box 2754, Bangkok 10501, Thailand.
The International Ferrocement Information Center (IFIC) was founded in October 1976 at the Asian Institute of Technology under the joint sponsorship of the Institute’s Division of Structural Engineering and Construction and the Library and Regional Documentation Center. The IFIC was established as a result of the recommendations made in 1972 by the U.S. National Academy of 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all over the world, IFIC attempts to collect information on all forms of ferrocement applications either published or unpublished.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 and IFIC’s reference and reprographic services. All information collected by IFIC are entered into a computerized data base using ISIS system. These information are available on request. In addition, IFIC offers referral services.

A quarterly publication, the Journal of Ferrocement, is the main disseminating tool of IFIC. IFIC has also published the monograph “Ferrocement", Do it Yourself Booklets, Slide Presentation Series, State-of-the-Art Reviews, bibliography and reports. FOCUS, the information brochure of IFIC, is published in 15 languages as part of IFIC’s attempt to reach out to the rural areas of the developing countries. IFIC is compiling a directory of IFIC consultants and ferrocement experts.

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 (14-16 January 1985) and a Short Course on Design and Construction of Ferrocement Structures (8-12 January 1985). 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.
Technology by itself is not the answer to the problems of modern man. It is when technology is linked to the economic, social and cultural needs of man that it can respond to and symbolize the hope of modern man for a better tomorrow.

Ferrocement is proving to be such a technology. It can be harnessed to respond to the need of varied users to improve the user's quality of life. Ferrocement has been successfully adopted for housing; storage facilities; irrigation; sanitation and water supply structures; and for marine transportation. In this issue ferrocement is shown to strengthen older structures and as a medium for sculpture.

Ferrocement as a medium for sculpture proves its versatility and the unlimited dimension to which it can be used. In “Blue Heron” by G. Galbraith and “Isadora” by F. Nassaux the properties of ferrocement have been used to advantage to communicate the ideas of the sculptors. These pieces of art exhibit grace and strength with appearance of lightness. Ferrocement in art is an exciting development, something quite different from the technical uses. It opens a new horizon, an application to enrich and illuminate our lives.

The Editor
Study on Ferrocement with Prestressed Bars

Wang Kai-Ming*

The paper deals with the working principle of ferrocement with prestressed skeletal bars, according to the advantageous effects of the components which are acting mutually. The results of its mechanical properties are analysed. On the basis of the analysis, the paper presents a method of calculating the strength of members, which has been proved through extensive testing and can be used in the design of products. The applied structural examples in this paper show tangible technical and economic benefits of ferrocement with prestressed skeletal bars. The development and application of such products should be further pursued.

INTRODUCTION

Ferrocement with prestressed skeletal bars has the merits of both ferrocement and prestressed concrete. It is a highly effective thin walled structural material with wide prospects. As the technology of tensioning mesh wire is very complex, the tensioning of skeletal bars is now a reasonably effective approach for using prestressed technique in ferrocement. The results discussed in this paper pertain to the working principle, the tests of mechanical behaviour, the method of calculating the strength of members and its applications.

ANALYSIS OF WORKING PRINCIPLE

In ferrocement with prestressed skeletal bar, the dispersed elastic reinforcement restricts the deformation and crack of mortar and strengthens the bond of its internal structure so that it improves the behaviour of mortar and establishes a favourable condition for using prestressing techniques. Prestressed skeletal bars, strengthened through tension, is highly effective in reinforcing the material and also enables the mortar to be in advantageous compressive state. The prestressed technique reasonably modifies the working program of the components to bear external load so that the mechanical behaviour is further improved.

A series of experiments indicated that the mechanical behaviour of the composite material depends on the deformation characteristics of components working jointly. Based on data of tests conducted, the graph of the working principle of ferrocement with prestressed skeletal bars is shown in Fig. 1. The two effects as seen from Fig. 1 are discussed below:

Effects of Dispersion of Reinforcement

The advantageous effects of dispersion of reinforcement include: increasing the elongation from \((\varepsilon_r - \varepsilon_a)\) to \((\varepsilon_f - \varepsilon_a)\); raising the load capacity of mortar corresponding to the elastic limit and \((\varepsilon_r - \varepsilon_f)\) stage; and enhancing the degree of utilization of the reinforcing materials [1].

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Effect of Prestressed Bars

The advantageous effects of prestressed bars include: moving the load-deformation curve of the skeletal bar upward and raising the first point in tension from O to $N_t$; retarding the loading where the deformation curve of mortar and mesh wire begins from O to $\varepsilon_o$, etc.

The favourable effects of prestressing and dispersion of reinforcement can also be seen from the contrast in Fig. 2 which shows the working characteristics between ferrocement with prestressed skeletal bars and other materials. Both these effects as stated above increase cracking load capacity, deformation modulus and elongation value considerably. Obviously, if the prestress value is too low or the content of mesh is too little, the material will lose its superior behaviour and perform like ordinary ferrocement or prestressed concrete. A comparison between the theoretical analysis and experimental results is shown in Fig. 3. It can be seen that the working principle is validated by the experiment.
Curve In Figure:
1 — Total deformation curve;
2 — Deformation curve of skeletal bar;
3 — Mesh wire deformation curve;
4 — Mortar deformation curve.

total deformation curve; 2 — Deformation curve of skeletal bar; 3 — Mesh wire deformation curve; 4 — Mortar deformation curve.

Symbol In Figure:
\( N_f' \) = Cracking load of ferrocement with prestressed skeletal bar;
\( N_f'' \) = Cracking load of ferrocement with skeletal bar;
\( N_t'' \) = Cracking load of prestressed reinforced concrete.

Fig. 2. Comparison of properties between ferrocement with prestressed skeletal bar and other materials.

TESTS ON MECHANICAL PROPERTIES

The experimental investigation was carried out for two types of specimens. The specimens for tension were 650 mm long, 200 mm to 300 mm wide of variable thickness while the specimens for flexure were 300 mm long, 110 mm wide and also of variable thickness. The woven meshes and the prestressed skeletal bars were uniformly distributed over the section with a
Curve in Figure:
1 - Load-strain curve of ferrocement with prestressed skeletal bar (specimen section area equals 36 cm²)
2 - Load-strain curve of prestressed skeletal bar (bar section area equals 1 cm², stretching control stress equals 0.75R₂)
3 - Load-strain curve of mesh wire (wire section area equals 0.52 cm²)
4 - Load-strain curve of mortar (mortar tensile strength equals 37 kg/cm²)
--- Testing curve ---
------- Curve of analytical calculation -------

Fig. 3. Comparison between analytical calculation and testing result.
(1 Kg = 9.8066 N; 1 Kg/cm² = 0.0981 MPa; 1 cm = 10 mm)
cover of 3 mm. The pretensioning method of prestressing was used. The tensile tests were carried out in a Universal Testing Machine.

All the specimens in flexure were simply supported over a span of 900 mm maintaining 300 mm moment region. A special test rig was devised such that the loading could be applied with the tension face on top to facilitate clear observation and measurement of cracking behaviour.

The strains on the tensile and compressive region were measured by electric resistance strain gauge and by means of a mechanical extensometer. The deformations were measured by deflectometers with a precision of 0.001 mm or of 0.01 mm. The crack widths were measured by a micrometer microscope with a sensitivity of 0.001 mm.

Mechanical Behaviour in Axial Tension

The characteristics of the axial tensile specimen and its testing results are shown in Table 1. As is shown in Table 1, the prestressed skeletal bar enables mortar to be in compression so that the tensile strength of ferrocement with prestressed skeletal bars is greatly increased. Similar to ordinary ferrocement, both the coefficient of reinforcement dispersion ($\beta$) and tensile strength of mortar are important factors influencing tensile strength. An enhanced

<table>
<thead>
<tr>
<th>No. of specimen</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength of mortar, MPa</td>
<td>34.73</td>
<td>35.61</td>
<td>43.56</td>
</tr>
<tr>
<td>Tensile strength of mortar, MPa</td>
<td>3.53</td>
<td>3.63</td>
<td>4.48</td>
</tr>
<tr>
<td>Wire diameter, d, mm</td>
<td>0.9</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Grid, mm</td>
<td>12×12</td>
<td>8×8</td>
<td>8×8</td>
</tr>
<tr>
<td>Mesh content, G, kg/cm³</td>
<td>325</td>
<td>338</td>
<td>338</td>
</tr>
<tr>
<td>Coefficient of reinforcement dispersion, $\beta$ = G/d, kg/m²-mm</td>
<td>361</td>
<td>563</td>
<td>563</td>
</tr>
<tr>
<td>Diameter of skeletal bar, mm</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Bar space, mm</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Type of reinforcement</td>
<td>2-1-2</td>
<td>3-1-3</td>
<td>3-1-3</td>
</tr>
<tr>
<td>Stretching control stress</td>
<td>0.75R⁺</td>
<td>0.75R⁺</td>
<td>0.75R⁺</td>
</tr>
<tr>
<td>Strength, MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First visible crack</td>
<td>15.40</td>
<td>18.25</td>
<td>22.66</td>
</tr>
<tr>
<td>Crack width 0.05 mm</td>
<td>17.07</td>
<td>21.19</td>
<td>28.94</td>
</tr>
<tr>
<td>Rupture</td>
<td>24.13</td>
<td>33.06</td>
<td>40.22</td>
</tr>
<tr>
<td>Modulus of deformation ($10^4$) MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elastic stage</td>
<td>3.14</td>
<td>3.00</td>
<td>3.35</td>
</tr>
<tr>
<td>First visible crack</td>
<td>3.02</td>
<td>2.16</td>
<td>2.03</td>
</tr>
<tr>
<td>Crack width 0.05 mm</td>
<td>2.48</td>
<td>1.97</td>
<td>1.30</td>
</tr>
<tr>
<td>Rupture</td>
<td>1.86</td>
<td>1.38</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Note: 1. $G$ = obtained from calculation according to subtracting the depth of prestressed bar;
2. 2-1-2 expresses: 2 layers of mesh, one layer of bar, 2 layers of mesh;
3. $R⁺$ = standard strength of prestressed bar.
Feature of Specimen:
1. Stretching control stress equals 0.75R;
2. Mortar tensile strength equals 45.7 kg/cm²;
3. Coefficient of reinforcement dispersion equals 563 kg/m-mm.

Fig. 4. Relationship between modulus of deformation and stress. (1 kg/cm² = 0.0981 MPa)

$\beta$ value has more influence in restraining crack and improves the working state in tension before rupture; and mortar strength influences both crack resistance and first-crack strength of the material favourably.

Experiments show that the advantageous effect of prestressed skeletal bar increases the modulus of deformation rapidly (Fig. 4). The maximum modulus of deformation is in a stress zone of 9.81 MPa-14.72 MPa, i.e. it remains in this stage before producing a great plastic deformation. In ferrocement with prestressed skeletal bars, the prestressed bars are thinner and spread uniformly, so that the uniform prestress value can be established effectively. The testing results indicate that the cracks on the specimen are spread uniformly, in addition, the closing ability of cracks on discharge is considerably increased. It has been further proved that the prestressed technique used for ferrocement is valid and reasonable.

**Mechanical Behaviour in Flexure**

The characteristics of the flexure specimen and its testing results are shown in Table 2. Similar to tension, the mechanical behaviour in flexure is influenced by the reinforcement characteristics, mortar strength and prestress value. But unlike in tension, the position of prestressed bars has an effect on behaviour too. A comparison of specimen No. 2 with No. 3 in Table 3 shows that as the position of No. 3 is near the tensile zone, its strength, elongation
Table 2. Characteristic of specimen and test result in flexure.

<table>
<thead>
<tr>
<th>No. of specimen</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 (ord.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength of mortar, MPa</td>
<td>58.86</td>
<td>58.86</td>
<td>58.86</td>
<td>58.86</td>
</tr>
<tr>
<td>Wire diameter, (d), mm</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Grid, mm</td>
<td>8.8</td>
<td>8.8</td>
<td>8.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Mesh content, (G), kg/cm(^3)</td>
<td>266</td>
<td>306</td>
<td>306</td>
<td>306</td>
</tr>
<tr>
<td>Coefficient of reinforcement dispersion, (\beta = G/d), kg/m(^3)-mm</td>
<td>443</td>
<td>437</td>
<td>437</td>
<td>437</td>
</tr>
<tr>
<td>Diameter of skeletal bar, mm</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Distance from prestressed bar to edge of compressive zone</td>
<td>1(\frac{1}{3}h)</td>
<td>1(\frac{1}{2}h)</td>
<td>1(\frac{1}{3}h)</td>
<td>1(\frac{1}{2}h)</td>
</tr>
<tr>
<td>Ratio of prestressed bar (%)</td>
<td>31</td>
<td>41</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>Type of reinforcement</td>
<td>9-1-5</td>
<td>3-1-3</td>
<td>3-1-3</td>
<td>3-1-3</td>
</tr>
<tr>
<td>Stretching control stress</td>
<td>0.65(R_f)</td>
<td>0.65(R_f)</td>
<td>0.65(R_f)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strength, MPa</th>
<th>First visible crack</th>
<th>Crack width 0.05 mm</th>
<th>Rupture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.03</td>
<td>44.15</td>
<td>69.06</td>
</tr>
<tr>
<td></td>
<td>27.00</td>
<td>32.96</td>
<td>44.83</td>
</tr>
<tr>
<td></td>
<td>32.37</td>
<td>35.90</td>
<td>47.87</td>
</tr>
<tr>
<td></td>
<td>9.76</td>
<td>14.22</td>
<td>34.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elongation value (10(^{-4}))</th>
<th>First visible crack</th>
<th>Crack width 0.05 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16.5</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>15.7</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>18.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modulus of deformation (10(^{-4}))</th>
<th>First visible crack</th>
<th>Crack width 0.05 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.47</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>1.96</td>
<td>1.77</td>
</tr>
<tr>
<td></td>
<td>2.44</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>0.93</td>
<td>0.78</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rupture</th>
<th>(\sigma_p) MPa</th>
<th>(E_p) (10(^4)) MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>44.83</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Note: 1. All of tensile strength of mortar equal 40 kg/cm\(^2\); 2. \(h\) = depth of specimen section; 3. The strength obtained from calculation of testing moment and elastic resisting moment; 4. The others are the same as before.

Table 3. Comparison of mechanical behaviour in flexure.

<table>
<thead>
<tr>
<th>Varieties of specimen</th>
<th>Prestressed (No. 2)</th>
<th>Ordinary</th>
<th>Ratio of increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First visible crack</td>
<td>(\sigma_f) MPa</td>
<td>26.98</td>
<td>9.76</td>
</tr>
<tr>
<td></td>
<td>(\varepsilon_f) (10(^{-4}))</td>
<td>15.7</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>(E_f) (10(^4)) MPa</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td>Crack width 0.05 mm</td>
<td>(\sigma_{0.05}) MPa</td>
<td>35.90</td>
<td>14.22</td>
</tr>
<tr>
<td></td>
<td>(\varepsilon_{0.05}) (10(^{-4}))</td>
<td>21.6</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>(E_{0.05}) (10(^4)) MPa</td>
<td>1.77</td>
<td>0.78</td>
</tr>
<tr>
<td>Rupture</td>
<td>(\sigma_p) MPa</td>
<td>44.83</td>
<td>34.53</td>
</tr>
<tr>
<td></td>
<td>(E_p) (10(^4)) MPa</td>
<td>1.37</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Note: \(\sigma\) = strength; \(\varepsilon\) = elongation value; \(E\) = modulus of deformation.
Fig. 5. Comparison of stress-strain curve.

Curve 1 — prestressed specimen; Curve 2 — ordinary specimen.

Fig. 6. Comparison of modulus of deformation.

(1 kg/cm² = 0.0981 MPa)
value and deformation modulus relevant to each stage are all increased markedly. In order to prevent an early fracture of mortar in the compressive zone and to utilize fully the strength of reinforcement, high strength mortar should be used.

The excellent properties of ferrocement with skeletal bar can also be seen from the comparative test results between prestressed specimen No. 2 and ordinary specimen. The change of its working characteristics and increased degree of mechanical behaviour are shown in Figs. 5 and 6.

DESIGN CALCULATIONS

Based on the analysis of working principle and test data, ferrocement members with prestressed skeletal bars can be designed using the following method:

**Basic Calculations**

**Member in Axial Tension**

The strength related to elastic limit, first crack and crack width of 0.05 mm can be calculated using the following formula:

\[ K \sigma \leq \sigma_{li} = \sigma_{cr} + \varepsilon \sigma_{cr} + \varepsilon \mu + \sigma_r \mu, \]

where
- \( K \) = safety factor of member;
- \( \sigma \) = tensile stress produced by axial force, kg/cm²;
- \( \sigma_{li} \) = tensile strength of corresponding stage of ferrocement with prestressed skeletal bar, kg/cm²;
- \( \sigma_{cr} \) = tensile strength of corresponding stage of ferrocement, kg/cm², calculated according to reference (2);
- \( \varepsilon \) = strain of corresponding stage of ferrocement, determined according to reference (2);
- \( E_y \) = elastic modulus of prestressed bar, kg/cm²;
- \( \mu \) = percentage of reinforcement of prestressed bar;
- \( \sigma_r \) = stress of prestressed bar subtracted by the loss of prestress (if the location of the total resultant force of the prestressed bar is not on the axis of the centre of gravity of the section, the eccentric moment of the prestressed bar can be calculated as a simplex force and then check the strength).

**Member in Flexure**

Load capacity related to elastic limit, first crack and a crack width of 0.05 mm can be calculated using the following formula:

\[ KM \leq \gamma W_{cr} \sigma_{li} \]

where
- \( K \) = safety factor of member;
- \( M \) = moment of force under external load, kg-cm;
- \( \gamma \) = coefficient of plasticity (for elastic limit \( \gamma = 1.0 \), for first crack and a crack width of 0.05 mm, \( \gamma = 1.9 \)).
\( W_f \) = elastic resisting moment of section against tensile edge, cm^3;
\( \sigma_{ii} \) = tensile strength of corresponding stage calculated using equation (1).

**Member in Eccentric Tension**

Tensile stress at the tensile edge of the member related to elastic limit, first crack and a crack width of 0.05 mm can be calculated using the following formula:

\[
\frac{M}{W_f} \pm \frac{N}{A} \leq \frac{\sigma_{ii}}{K}
\]

where
- \( N \) = axial force under external load, kg;
- \( A \) = cross sectional area of member, cm^2;
- \( \sigma_{ii} \) = tensile strength of corresponding stage calculated using formula (1);
- \( M, \gamma, W_f, K \) have the same meaning as in equation (2).

**Member in Axial Compression**

Compressive strength of axial compressive member can be calculated using the following formula:

\[
K\sigma \leq \sigma_{wa} = \psi (1 + n_1\mu_g + n_2\mu_y) (R_a - \sigma_{so})
\]

where
- \( \sigma_{wa} \) = compressive strength of ferrocement with prestressed skeletal bar, kg/cm^2;
- \( \psi \) = longitudinal flexural coefficient, determined in reference to prestressed concrete structure.
- \( \mu_g, \mu_y \) = percentage of mesh wire and prestressed bar respectively;
- \( n_1, n_2 \) = ratio of elastic modulus of mesh wire and prestressed bar to that of mortar respectively (the elastic modulus of mortar can be taken approximately as 75% that of concrete);
- \( R_a \) = ultimate compressive strength of mortar prism, kg/cm^2, \( R_a = 0.9R \) (cube strength of mortar);
- \( \sigma_{so} \) = pre-compressive stress subtracted by the losses of prestress (if the location of the total resultant force of the prestressed bar is not on the axis of the centre of gravity of section, the larger value should be taken).

**Member in Eccentric Compression**

Compressive stress at the compressive edge of the member can be calculated using the following formula:

\[
\frac{M}{W_o} + \frac{N}{A} \leq \frac{\sigma_{wa}}{K}
\]

where
- \( W_o \) = elastic resisting moment of the member against the compressive edge,
- \( \sigma_{wa} \) = compressive strength of prestressed bar, calculated using equation (4), where \( \sigma_{wa} \) at inspecting point should be taken.

The meaning of other symbols is same as before.
Determination of Loss of Prestress

1. The prestress losses related to deformation of anchorage, heating, curing and relaxation of stress can be determined in reference to prestressed concrete structure.

2. The value of shrinkage and creep of mortar is more than that of concrete, the prestress losses due to shrinkage and creep can be taken as 150% of that of concrete.

Determination of Safety Coefficient

Safety coefficient should be chosen on the basis of importance of the member and performance characteristics of the structure used. As a certain safety coefficient has been used in the tensile formula in this paper, the safety coefficient used for calculating tensile stress in axial tension, flexure and eccentric tension can be taken as 80% of that of the concerned demand, otherwise, it should be determined by using the specification concerned.

Comparison with Test Data

Using the formulae presented in the paper, parameters for the prestressed specimens No. 1 and No. 2 in Table 1 have been calculated. These values along with the test data are shown in Table 4. A comparison of the results with test shows that the errors are negligible.

Table 4. A contrast between calculating results and testing values.

<table>
<thead>
<tr>
<th>Force varieties</th>
<th>No. of specimen</th>
<th>Dimension section mm</th>
<th>Cracking axial force (RN) or moment (N-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calculating results</td>
</tr>
<tr>
<td>Axial tension</td>
<td>1</td>
<td>300 × 12</td>
<td>60.09</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>300 × 12</td>
<td>67.74</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>300 × 12</td>
<td>74.76</td>
</tr>
<tr>
<td>Flexure</td>
<td>1</td>
<td>300 × 25</td>
<td>806.30</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>230 × 16</td>
<td>247.70</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>230 × 16</td>
<td>330.87</td>
</tr>
</tbody>
</table>

EFFECT ON APPLICATION

Ferrocement with prestressed skeletal bars has been produced in China successfully. Since its trial production, prestressed barges, tugboats, fishing crafts and agricultural boats have been produced gradually. Especially in recent years, prestressed agricultural boats have been widely used in the south of China and has brought favorable technical and economic results (Table 5).

As shown in Table 5, all kinds of boats made of ferrocement with prestressed skeletal bars have numerous merits such as saving in material, decrease in weight of the boat and increase in crack resistance. Prestressed agricultural boat that is now more widely used has also very tangible effects through savings in working days, decreasing cost, promoting quality of product and improving behaviour of product under use etc. (3).
Table 5. Techno-economic effect of prestressed ferrocement boats.

<table>
<thead>
<tr>
<th>Varieties of product</th>
<th>5 ton agri. boat</th>
<th>6 ton agri. boat</th>
<th>40 HP fishing craft</th>
<th>40 HP tugboat</th>
<th>60 ton barge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestressed member</td>
<td>shell, other plate</td>
<td>shell, other plate</td>
<td>shell, bulkhead</td>
<td>shell</td>
<td>shell</td>
</tr>
<tr>
<td>Percentage decrease in weight %</td>
<td>12.2</td>
<td>11.6</td>
<td>20</td>
<td>18.2</td>
<td>30.8</td>
</tr>
<tr>
<td>Percentage saved in steel %</td>
<td>38.2</td>
<td>15.6</td>
<td>-</td>
<td>-</td>
<td>13.7</td>
</tr>
<tr>
<td>Percentage increase in strength %</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>100</td>
<td>-</td>
</tr>
</tbody>
</table>

CONCLUSION

The main conclusions derived from the research reported here are as follows:

1. The working principle of ferrocement with prestressed skeletal bars has been analysed. The results of the research present a theoretical basis for controlling and enhancing properties of the product as well as drawing up the method of calculating the strength of members.

2. Better mechanical behaviour of ferrocement with prestressed skeletal bars such as higher crack load capacity, larger modulus of deformation and favourable cracking behaviour has been proved by the experiment presented above. The test results indicate that it is a highly effective thin walled structural material with a promising prospects.

3. The method of calculating the strength of members presented in the paper has certain theoretical and experimental foundations. The results obtained from these formulae are in conformity with the actual working condition in practical engineering structures. Therefore, it can be used directly for designing products.

4. The application of products made from the superior material show that these products have numerous merits, viz., simple building technology, better structural properties and improved technical and economic effects etc., thus its development and application should be further investigated.

REFERENCES


Experimental Study of Ferrocement as a Seismic Retrofit Material for Masonry Walls

A.M. Reinhorn* S.P. Prawel* and Zi-He Jia*

The existence in earthquake prone regions of many older masonry buildings, built before any provision for earthquake loading was required, presents one of the most serious problems facing the earthquake engineer today. This problem has generated a wide range of research directed to both the retrofit and repair of such structures. The research reported in this paper has to do with testing the suitability of a thin ferrocement overlay for such an application. A total of seven specimens were constructed and tested to destruction in diagonal tension. Two of these were bare brick masonry and the remainder had a ferrocement overlay with various amounts of steel reinforcement. The results of the testing indicate the suitability of ferrocement as a retrofit (strengthening) material.

INTRODUCTION

One of the most serious problems facing the earthquake engineer today is the very large number of older masonry buildings in earthquake prone regions that were built before any provision for earthquake loading was required [1]. These structures are usually constructed from brick or concrete block and in older cases stone. The units are tied together by a cement mortar mixture and in some cases, steel or other reinforcement.

While there are several types of masonry structural elements within a building, the most used and subject to earthquake damages is the load bearing wall. These elements are solid planes which are designed primarily to carry the vertical loads within the structure. In a seismic event, however, they must also carry any in-plane or out-of-plane horizontal loads resulting from the earthquake.

The high risk of earthquake damage to such older masonry walls, particularly when unreinforced and the potential for a great loss of life has made the masonry structure the subject of a wide range ongoing research. One area that is very active is that of defining methods whereby these structures can be strengthened or upgraded in lateral load capacity to satisfy modern seismic design codes. These retrofit measures are, in many cases, equally effective in the repair of damaged masonry.

REVIEW OF RETROFIT PROCEDURES AND RECENT RESEARCH

Several procedures have been found to be effective in the retrofit of load bearing walls. The choice depends largely upon the type of wall or the damage it has received. For damage in the form of relatively small cracks, injections of epoxy, epoxy-ceramic foams or a cement grout has been found to be effective. The cost however, is often high because of the adhesive and it is limited mostly to repair. For upgrading, two procedures have received considerable attention. The first of these involves transferring most of the load to a new composite wall

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consisting partly of the old masonry wall and partly of a new reinforced concrete wall. The new wall is constructed by removing one or more wythes of masonry and replacing the volume with a heavy coat of pneumatically applied concrete. While this type of upgrading is effective, it usually requires a great deal of preparation work and often adds considerably to the weight of the structure which, in turn, may lead to foundation adjustments.

The second of these retrofit procedures involves a thin bonded coat of reinforced cement to one or both sides of the masonry unit. These overlay procedures have been found to be very effective with the resulting composite wall developing at least the original in-plane shear strength of a damaged unit. When used with undamaged masonry the shear strength is usually doubled. The out-of-plane resistance is also substantially improved as is the composite ductility. Surface coating procedures are also attractive from a construction standpoint requiring very little surface preparation, very little forming and little highly skilled labor [2]. There are several cases reported in the professional literature in which reinforced plaster coatings were used successfully to upgrade existing masonry structures [3, 4].

For the reasons cited, surface treatment procedures for masonry retrofit and repair are considered by many to be among the most promising of all. They have therefore been the subject of a considerable amount of research activity. Experiments on the behavior of plastered walls carrying in-plane shear forces were carried out by Schneider and Dickey [5], Sheppard and Tercel [6], Meli et al. [7], Jabarov et al. [8], Tso et al. [9], Clough et al. [10] and Cagley [11]. Reference 3 reports of masonry walls coated with either reinforced plaster or fiberglass strengthened mortar which were tested with monotonic cyclic loads or by simulated earthquakes. In most cases, the shear strength was doubled by the coating process, and the ductility increased.

Information on the behavior of externally coated masonry can also be drawn from static and dynamic tests performed on regular reinforced masonry walls. Such tests have been conducted by Pristley et al. [12], Blume (quoted by Meli) [7], Williams [5], Meli [7], and Gulkas [13] who showed that the shear failure mechanism is more brittle than the flexural mechanism. The reinforcement contributes to the control of a flexural failure but not as much to the shear strength. The shear ductility, however, is somewhat improved by the spacing of the reinforcing bars [14]. Most of the tests to determine the shear capacity used a standard diagonal split test or simultaneous lateral and vertical loading. The split test however had a definite advantage in that it isolates the shear effect. One additional procedure for retrofit involves the use of external bracing and/or prestressed tendons or infilled walls. These methods are not considered here. For a detailed discussion of the state-of-the-art in masonry retrofit and repair see reference [2].

FERROCEMENT AS A COATING MATERIAL

Among the available coating procedures a thin ferrocement overlay has been suggested as one having considerable promise for use with unreinforced masonry walls that need enhanced in-plane and out-of-plane strength and ductility.

Ferrocement, as it is usually used, is an orthotropic composite material having a high strength cement mortar matrix and reinforced with layers of fine steel wires in the form of a mesh. The mortar strength results in a high composite compressive strength of 5 ksi to 8 ksi (34.48 N/mm² to 55.18 N/mm²) as measured in flexure [15] which is dependent on the volume
ratio of reinforcement (0.5% to 5%), the mesh type and its orientation [16]. The most significant properties of the composite are its ductility and its high tensile strength which ranges from 500 psi to 2000 psi (3.45 N/mm² to 13.48 N/mm²) for most commercially available mesh. The tensile cracking strength is dependent on the amount of reinforcement, its distribution within the matrix and on its orientation with respect to the load direction. Its performance has been found to improve, to a point, with the degree of subdivision in the mesh as defined by the specific surface of the mesh [15]. Several recent publications [15, 17] summarize in detail the basic information relating to the behavior of ferrocement. No data could be found, however, on the in-plane shear behavior of ferrocement. It is worthwhile to note that ACI committee 549 [15] has recently called for test data on in-plane shear and on combined shear and normal stress for ferrocement.

EXPERIMENTAL STUDY

The study whose results are reported here in has to do with the efficiency of ferrocement coated masonry walls subjected to in-plane shear forces. The diagonal split or “blume” test [7] was chosen for the experimental determination of in-plane shear strength and deformation of the ferrocement plates, the bare masonry specimens and the composite units. The results of the ferrocement plate tests were reported by Jia [18] and showed that after the split of the mortar matrix, all diagonal tension is carried by the reinforcement. In most cases, the specimens tested in diagonal split ultimately failed in compression by crushing the concrete at the loaded corners. Because of this the full range of diagonal tension capacity was not realized. The cracking load in most cases was however, 50% to 70% greater than that expected from composite materials theory.

The masonry unit testing involved the compression behavior of two uncoated brick masonry specimens and five coated specimens, each having a different spacing of the reinforcing wires. In each case a square mesh was used. The specimens consisted of 25.5 in. x 25.5 in. (648 mm x 648 mm) panels of stack bond brick masonry, 8 in. (203 mm) thick. The five coated specimens were strengthened by a 1/2 in. (12.7 mm) thick layer of ferrocement with various amounts of galvanized welded wire fabric. The wire spacing in the mesh was varied from 1/8 inch (3.2 mm) to 2 in. (50.8 mm) and the coating thickness varied slightly to maintain the constant reinforcement volume ratio. Details of the specimen geometry are shown in Fig. 1 and the variables employed in Table 1. The basic properties of the component materials are given in Table 2. All specimens were built according to ASTM requirements and then cured for 14 days in a humidity controlled room and tested at an age of 28 days.

The ferrocement coating was applied 14 days after the construction of the masonry elements. The meshes were kept in place by 0.06 in. (1.52 mm) diameter tie wires which passed through the masonry at locations approximately 8 in. (203.2 mm) apart as shown in Fig. 1b. Spacers were placed between the reinforcement layers to control their position. The mortar was then passed between the meshes aided by a high-speed surface vibrator. Some difficulty was encountered in achieving perfect penetration of the mortar when using the finest mesh.

After proper curing, the specimens were tested using the diagonal split procedure in a 300,000 lb. (136.2 ton) universal testing machine. After placing the specimens in the testing machine, their vertical alignment was adjusted to eliminate any eccentricity. The load applied
Fig. 1. Specimens for experimental study.
(1 in. = 25.4 mm)
Table 1. Description of specimens.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>No. of specimens</th>
<th>Thickness</th>
<th>Mesh size</th>
<th>No. of layers</th>
<th>Wire size</th>
<th>Wire diameter in. (mm)</th>
<th>Surface ratio in.²/in.³</th>
<th>Volume ratio in.³/in.³</th>
<th>Yield ksi (kN/mm²)</th>
<th>Ultimate ksi (kN/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1-SBM</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SZ1-SBF</td>
<td>1</td>
<td>0.610&quot;</td>
<td>1/2&quot; x 1/2&quot;</td>
<td>2</td>
<td>#19</td>
<td>0.0418</td>
<td>0.00550</td>
<td>0.0181</td>
<td>92</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15.5)</td>
<td>(12.7 x 12.7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SZ2-SBF</td>
<td>1</td>
<td>0.610&quot;</td>
<td>1&quot; x 1&quot;</td>
<td>2</td>
<td>#16</td>
<td>0.0598</td>
<td>0.00562</td>
<td>0.0181</td>
<td>73</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15.5)</td>
<td>(25.4 x 25.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SZ3-SBF</td>
<td>1</td>
<td>0.610&quot;</td>
<td>2&quot; x 2&quot;</td>
<td>2</td>
<td>#14</td>
<td>0.0747</td>
<td>0.00438</td>
<td>0.0175</td>
<td>55</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15.5)</td>
<td>(50.8 x 50.8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SZ4-SBF</td>
<td>1</td>
<td>0.500&quot;</td>
<td>1/4&quot; x 1/4&quot;</td>
<td>2</td>
<td>#23</td>
<td>0.0269</td>
<td>0.00455</td>
<td>0.0181</td>
<td>89</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(12.7)</td>
<td>(6.4 x 6.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SZ5-SBF</td>
<td>1</td>
<td>0.500&quot;</td>
<td>1/8&quot; x 1/8&quot;</td>
<td>2</td>
<td>#25</td>
<td>0.0190</td>
<td>0.00454</td>
<td>0.0181</td>
<td>59</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(12.7)</td>
<td>(3.2 x 3.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Properties of materials.

<table>
<thead>
<tr>
<th></th>
<th>Size/composition in.(mm)</th>
<th>Strength psi(N/mm²)</th>
<th>Curing time days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricks</td>
<td>8 x 3\frac{1}{4} x 2\frac{1}{4} in. (203.3 x 88.9 x 63.5)</td>
<td>$f'_b = 9600$ (66.21)</td>
<td>—</td>
</tr>
<tr>
<td>Masonry mortar* (ASTM C 270-68)</td>
<td>TYPE N 1C:1L:3S</td>
<td>$f'_c = 1800$ (12.41)</td>
<td>28</td>
</tr>
<tr>
<td>Ferrocement mortar*</td>
<td>1C:2S W/C = 0.48</td>
<td>$f'_c = 3600$ (25.24)</td>
<td>28 (COMP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$f_L = 516$ (3.56)</td>
<td>28 (SPLIT)</td>
</tr>
</tbody>
</table>

* Cement: Portland cement type I; Sand: Natural-nominal size 1/8 in. (3.2 mm)

...to the specimen was measured by a calibrated load cell and changes in diagonal dimension by a ± 2 inch (50.8 mm) stroke LVDT. Details of the test set up are shown in Figs. 2 and 3.

TEST RESULTS

In each test, the specimen was subjected to increasing load increments and corresponding deformations recorded. At each increment of load the specimen was carefully inspected and
any observations recorded in the test log for that load. The load deflection curves for all specimens after adjustment for support deformations are shown in Fig. 4 and important points from these curves tabulated in Table 3. As can be seen from the figure, the bare masonry
Table 3. Stresses in the walls-psi (N/mm²).

<table>
<thead>
<tr>
<th>Specimen</th>
<th>State of stresses</th>
<th>1/8&quot; × 1/8&quot;</th>
<th>1/4&quot; × 1/4&quot;</th>
<th>1/2&quot; × 1/2&quot;</th>
<th>1&quot; × 1&quot;</th>
<th>2&quot; × 2&quot;</th>
<th>Bare</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>SZ5 (3)</td>
<td>SZ4 (4)</td>
<td>SZ1 (5)</td>
<td>SZ2 (6)</td>
<td>SZ3 (7)</td>
<td>B1 (8)</td>
</tr>
<tr>
<td>1</td>
<td>Proportional limit - equivalent section*</td>
<td>225 (1.55)</td>
<td>228 (1.57)</td>
<td>216 (1.49)</td>
<td>246 (1.70)</td>
<td>246 (1.70)</td>
<td>62</td>
</tr>
<tr>
<td>2</td>
<td>Ultimate limit - equivalent section*</td>
<td>243 (1.68)</td>
<td>240 (1.66)</td>
<td>240 (1.66)</td>
<td>265 (1.83)</td>
<td>259 (1.79)</td>
<td>126</td>
</tr>
<tr>
<td>3</td>
<td>Ultimate limit - ferrocement plate**</td>
<td>1054 (7.27)</td>
<td>1026 (7.08)</td>
<td>840 (5.79)</td>
<td>1022 (7.05)</td>
<td>977 (6.74)</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Ultimate limit - ferrocement-theory***</td>
<td>1049 (7.24)</td>
<td>1321 (9.11)</td>
<td>1330 (9.17)</td>
<td>1196 (8.26)</td>
<td>997 (6.88)</td>
<td>-</td>
</tr>
</tbody>
</table>

* Equivalent stress obtained as: \( P_1 / [(b + 2t) \times L\sqrt{2}] \)

** Ferrocement plate stress obtained as: \( (P_1 - P_{BARE}) / (2tL\sqrt{2}) \)

*** Theoretical values for composite [17]: \( f_{comp} = f_r + w_f \) (using values from Table 1 and Table 2)
specimens (B1-1 and B1-2) show a distinctly nonlinear load deformation curve over almost the entire load range while the coated specimens maintain an almost proportional pattern up to yielding. The uncoated specimens B1-1 and B1-2 were constructed using different inspection procedures. Specimen B1-2 with a lower control developed a slightly lower stiffness and ultimate strength. The coated specimens all showed a similar behavior. After cracking of the masonry between the ferrocement plates, indicated by internal noises, diagonal cracks developed in the ferrocement between the loaded corners on both sides of the specimen. These can be clearly seen in Fig. 3. Except for the specimen having a 0.125 inch (3.2 mm) wire spacing, the initial cracks spread over a wide diagonal band as the load was increased. Specimens with more closely spaced reinforcement developed cracks within the same wide band that were much more difficult to identify. After substantial cracking of the outside surface, separation between the masonry and the ferrocement developed leading to a complete dislocation of the plates. At this point, the ferrocement plates failed in compression by a local crushing at the loaded corners as did the separate plates studied by Jia [18].

Final inspection of the tested specimens showed that all of the tie wires connecting the ferrocement to the masonry had failed in tension and shear and no bond between the two parts remained at final failure. Specimens SZ5 with 0.125 in. (3.2 mm) mesh wire spacing showed a completely different behavior. After cracking in one narrow vertical band, no separation was observed between the ferrocement plate and the masonry. Final failure in the case involved a complete yielding and tensile failure of the mesh with the tie wires remaining in place. The mesh appeared to be cut along a single vertical line. Further inspection of this specimen revealed a number of voids in the mortar at the interface between the ferrocement and the masonry and in these locations the mesh was deformed in a shear type pattern.

DISCUSSION OF RESULTS

It is clear from the load deformation curves in Fig. 4 and the stress computations shown in Table 4 that each of the coated specimens developed a maximum strength which was approximately double that of the bare masonry specimens and that the strength reached was almost independent of the reinforcement spacing. This observation agrees with those of other investigators when studying the shear behavior of reinforced masonry [7, 19, 20]. The ultimate stress in the ferrocement plates, after deducting the ultimate strength of the masonry, in each case reached approximately 1000 psi (6.898 N/mm²) again essentially independent of the reinforcement strength and spacing. This can be explained by noting that all of the plates except those having the 1/8 in. (3.2 mm) mesh failed ultimately in compression by crushing the loaded corner. This did not allow for the development of a full diagonal tension failure as in specimen SZ5. This observation is supported by the theoretical tensile stresses listed in line 4 of Table 4 which are larger than the stress achieved in the ferrocement plates, except for the 1.8 in. (3.2 mm) mesh which did fail in diagonal tension.

Based upon these observations and the stress computations, it is apparent the two different failure mechanisms are possible. The first is a diagonal tension split of the entire composite section which involves yielding of the tensile steel and leads to large inelastic deformations. The second mechanism involves local crushing of the ferrocement coating at the loaded corners. This mechanism is the result of a total transfer of load from the composite section to the coating after the coating has separated from the masonry. Such a failure is characterized as a bond failure. The bond failure is brittle and sudden drops in load capacity are noted when the indi-
Table 4. Load-deflection data at critical points (adjusted) [18].

<table>
<thead>
<tr>
<th>Description</th>
<th>B1-1 Bare masonry</th>
<th>B1-2 Bare masonry</th>
<th>SZ1 (1/2 x 1/2)</th>
<th>SZ2 (1 x 1)</th>
<th>SZ3 (2 x 2)</th>
<th>SZ4 (1/4 x 1/4)</th>
<th>SZ4 (1/8 x 1/8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportional limit</td>
<td>Load (kN)</td>
<td>88.964</td>
<td>66.723</td>
<td>34.374</td>
<td>355.856</td>
<td>355.856</td>
<td>329.167</td>
</tr>
<tr>
<td></td>
<td>Disp (mm)</td>
<td>1.981</td>
<td>1.194</td>
<td>6.223</td>
<td>7.798</td>
<td>7.595</td>
<td>7.493</td>
</tr>
<tr>
<td>Maximum limit</td>
<td>Load (kN)</td>
<td>169.037</td>
<td>182.376</td>
<td>346.960</td>
<td>382.545</td>
<td>373.649</td>
<td>346.960</td>
</tr>
<tr>
<td></td>
<td>Disp (mm)</td>
<td>6.985</td>
<td>5.791</td>
<td>10.490</td>
<td>13.919</td>
<td>9.246</td>
<td>17.450</td>
</tr>
<tr>
<td>At bond failure</td>
<td>Load (kN)</td>
<td>266.892</td>
<td>382.545</td>
<td>373.649</td>
<td>N.A.</td>
<td>344.736</td>
<td>N.A.</td>
</tr>
<tr>
<td></td>
<td>Disp (mm)</td>
<td>19.660</td>
<td>15.189</td>
<td>9.246</td>
<td>(23.241)</td>
<td>19.888</td>
<td>N.A.</td>
</tr>
<tr>
<td>At 70% max. load</td>
<td>Load (kN)</td>
<td>242.872</td>
<td>267.782</td>
<td>261.554</td>
<td>242.872</td>
<td>245.985</td>
<td></td>
</tr>
<tr>
<td>At 50% max. load</td>
<td>Load (kN)</td>
<td>(175.70)</td>
<td>(175.70)</td>
<td>(175.70)</td>
<td>(175.70)</td>
<td>(175.70)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disp (mm)</td>
<td>173.480</td>
<td>191.273</td>
<td>186.824</td>
<td>173.480</td>
<td>175.704</td>
<td></td>
</tr>
<tr>
<td>At 20% max. load</td>
<td>Load (kN)</td>
<td>64.392</td>
<td>76.509</td>
<td>74.730</td>
<td>69.392</td>
<td>70.282</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disp (mm)</td>
<td>42.98</td>
<td>88.14</td>
<td>88.72</td>
<td>41.28</td>
<td>35.54</td>
<td></td>
</tr>
</tbody>
</table>
individual tie wires joining the ferrocement to the masonry fail. If the plates remain bonded to the masonry, as in specimen SZ5, the load transfer is over the entire interface surface which allows for the development of a diagonal tension failure mechanism. It is apparent therefore, that the anchors play a key role in the effective use of the ferrocement coating.

Table 5. Ductility of tested specimens.

<table>
<thead>
<tr>
<th>Load/resistance level</th>
<th>Mesh size</th>
<th>Load/Resistance level</th>
<th>Mesh size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/8 in.</td>
<td>1/4 in.</td>
<td>1/2 in.</td>
</tr>
<tr>
<td>1 Max. load</td>
<td>1.8</td>
<td>2.4</td>
<td>1.7</td>
</tr>
<tr>
<td>2 70% max. load</td>
<td>2.6</td>
<td>2.9</td>
<td>3.2</td>
</tr>
<tr>
<td>3 50% max. load</td>
<td>2.9</td>
<td>3.5</td>
<td>3.3</td>
</tr>
</tbody>
</table>

(a) Ductility of composition elements ($\Delta P_1/\Delta P_Y$)*

| Max. load | 2.3 | 2.8 | 1.7 | 2.4 | 1.6 |
| 70% max. load | 3.2 | 3.5 | 3.2 | 4.1 | 2.7 |
| 50% max. load | 3.5 | 4.1 | 3.2 | 6.5 | 3.1 |

(b) “Ductility” of composite elements with respect to base masonry deformations ($\Delta P_1/\Delta P_Y^M$)

* $\Delta$ = Deformation; $P_i$ = resistance level; $P_Y$ = yield resistance; $\Delta P_Y^M$ = yield deformation of bare masonry.

Although the actual failure mechanism did not allow for the full development of the ferrocement potential, the composite structure did develop a limited ductility which was totally absent in the bare masonry walls. The levels of ductility that were actually realized for various levels of strength compared to the yield deformation are shown in Table 5a. For medium size meshes, maximum ductility values range from 1.7 to 2.4 while at 50% of the ultimate the values are from 3.3 to 5.2. The smallest and the largest mesh, 2 in. (50.8 mm) and 1/8 in. (3.2 mm) developed less ductility.

When the deformations of the composite are compared to those of the base masonry (Table 5b) the “apparent ductility” reaches somewhat higher values. This is because the coating improves not only the ultimate deformation range but also extends the elastic range. When inelastic deformations did occur, between the breaks in the tie wire, (Fig. 4) the behavior was very close to that of an ideal plastic material.

Another important characteristic for seismic retrofit is the stiffness degradation. An ideal elastic-plastic material maintains its secant stiffness up to the yield point after which it decreases linearly as illustrated by the dashed line in Fig. 5. From the same figure it can be seen that the stiffness degradation of all of the coated specimens was very close to that of the ideal plastic case. It should also be noted from Fig. 5 that the stiffness degradation of the two uncoated specimens was much more rapid than those that were coated. At a deflection of 0.3 in. (7.62 mm) the stiffness of the coated specimens has double the value of the bare masonry and at 0.6 in. (15.24 mm), which was double the maximum deflection of the bare masonry, the
Fig. 5. Stiffness degradation of bare and ferrocement strengthened masonry. (1 in = 25.4 mm; 1 kip = 4.4482 kN)

Fig. 6. Stiffness degradation of ferrocement strengthened masonry vs. ductility. (1 in = 25.4 mm; 1 kip = 4.4482 kN)
stiffness of the coated specimens is seen to be reduced to the same value as that of the uncoated walls. Stiffness degradation vs. ductility curves (Fig. 6) indicate about 50 % reduction in stiffness at a ductility of 2 and 25% stiffness remaining at a ductility of 3. These values are within the acceptable range for the seismic design of walls considering inelastic story drift [21].

CONCLUSIONS

The experimental study involved several brick masonry walls coated with a ferrocement layer reinforced with various sized wire cloth meshes and two specimens of bare masonry. The study led to the definition of two failure mechanisms. A diagonal tension failure or a bond failure, the first being ductile and the second brittle. If one of the mechanisms develops, the other does not occur. The bond anchors between the masonry and the coating have a dominant effect on the development of these mechanisms. The strength, ductility and secant stiffness degradation of the coated walls have values nearly double those for an uncoated wall and the composite strength does not appear to depend on mesh size. Additional research is required, however, before suggestions for design procedure can be made. The development of complete bonding and the behavior of the composite- brick and ferrocement or block and ferrocement - under cyclic and simulated earthquake loads need to be determined.

ACKNOWLEDGEMENTS

The authors wish to thank the Department of Civil Engineering, State University of New York at Buffalo for the generous support received both in manpower and materials.

REFERENCES


Ferrocement was successfully used to build a 1.83 m sculpture of the great blue heron, the largest bird in Canada. Ferrocement was chosen for the following reasons: low-cost, durability, availability of materials, unlimited dimension, and simplicity of the building techniques.

INTRODUCTION

In 1973, I was introduced to ferrocement in Northern Canada when a close friend, Rick Puik, took on the task of building a 9.9 m sailboat. Though 2500 land miles (4203 km) from salt water, Rick had a dream of sailing the South Pacific. Within five years of making that decision, he had transported his boat through those land miles and sailed west from Vancouver Island, British Columbia to Hawaii where he is now living that dream.

My question at that time was why ferrocement for a boat. In later years, my reasons for its use in sculpture were the same as my friend: low-cost raw materials, strength, and simplicity.

As the iron rod and chicken wire of Rick's boat began to take shape, I was struck by the beauty of its geometric form and sense of strength, even at that stage of construction. This image stayed with me through the years to emerge in the fall of 1983 as the process through which I would accomplish a large ferrocement sculpture, the subject matter of the paper.

Most of my sculptures to that date had been of transportable sizes and I had worked in steatite (soapstone family), wood, clay, and bronze. The desire to do a large outdoor piece had me searching for possible mediums. Having ruled out the more traditional mediums of stone and bronze because of cost, I turned to ferrocement which filled all my requirements. At last, I was able to work with the long held image of grace and strength that I had found in Rick's ferrocement boat.

SCULPTURE IN FERROCEMENT

I chose as my subject the great blue heron that inhabits the river banks in the Cowichan Valley of British Columbia where I have my studio. I have spent many captivating hours observing this largest of our Canadian birds.

A one foot model of clay in the desired pose was the first step in the evolution of the sculpture that was to become "Big Blue". This accomplished, measurements were taken of the model and scaled up by a factor of six. The drawings and measurements were then lofted to a piece of 2.4 m x 1.2 m cardboard backed with plywood (Fig. 1).

* Sculptor, British Columbia, Canada.
This was an exciting, stimulating, energy generating time. It is the time this artist loves most, the reason creating art reaches out to me. Creativity in any field is the stimulus of discovery. To be totally involved in a project has its highs and lows, successes and disappointments, but it is exciting.

The second step was an estimate of the materials needed, their size and quantity (Table 1). Pipe was obtained from a local scrapyard along with copper wire and rod for exterior feather detail.

Step number three was to transcend the fact that I had no experience in welding. This was accomplished at Malaspina College in Nanaimo. The arts department under John Charnetski offers a course called free study for students who present a project for approval. If the project is accepted, use of the facilities are available from 9:00 a.m. to 5:00 p.m. Mondays to Fridays. Their facilities are extensive. I had done bronze in a previous semester. Arc and gas welding equipment were available.

The project involved building the armature or frame at Malaspina College and the wiring and cementing at my studio (Figs. 2 to 9). This arrangement was accepted and work began in earnest in the first week of September, 1983. The bird was completed in the last week of October 1983 (Fig. 10).
Fig. 2. Construction of body using 6.35 mm and 4.76 mm diameter rods and wooden frame to determine placement of legs to support body and distance between knees.

Fig. 3. Detail of metal strapping for the distribution and support of body weight using 31.75 mm pipe.

Fig. 4. Legs fitted into support pipes on body. Works on legs and feet completed later.

Fig. 5. Four to five layers of chicken wire mesh on body.
Table 1. Materials and quantities for “Big Blue”.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement*</td>
<td>Genstar Normal Portland # 10</td>
</tr>
<tr>
<td>Metal rod</td>
<td>4.8 mm and 3.18 mm rebar</td>
</tr>
<tr>
<td>Pipe</td>
<td>25.4 mm diameter</td>
</tr>
<tr>
<td></td>
<td>31.75 mm diameter</td>
</tr>
<tr>
<td>Chicken wire</td>
<td>25.4 mm holes</td>
</tr>
<tr>
<td>Copper</td>
<td>fine wire</td>
</tr>
<tr>
<td></td>
<td>bar stock</td>
</tr>
<tr>
<td>Metal strap</td>
<td>50.8 mm x 3.05 m</td>
</tr>
<tr>
<td>Angle iron</td>
<td>19.05 mm x 19.05 mm</td>
</tr>
<tr>
<td>Sand</td>
<td>med/fine washed</td>
</tr>
<tr>
<td></td>
<td>beach sand-fine</td>
</tr>
<tr>
<td>Laytex</td>
<td>Crete-fix</td>
</tr>
<tr>
<td>Resin</td>
<td>Bondo White Lightning</td>
</tr>
<tr>
<td>Plywood</td>
<td>tie wire</td>
</tr>
<tr>
<td>Wire</td>
<td></td>
</tr>
</tbody>
</table>

* Cement mix: Approximately 2:1 sand-cement with only enough water to allow it to be pushed through the wire and stiff enough to stand.

Fig. 6. Body and neck cavity stuffed with polyethylene.

Fig. 7. Scrap copper wired into place. Polyethylene was pulled up against wire frame to minimize cement thickness.
CONCLUSION

"Big Blue" (Fig. 11) was shown in May 1984 at the British Columbia International Symposium on Shellfish and Marine Biology Management at Nanaimo, and has now been installed in its permanent home in Centennial Park in Lake Cowichan, British Columbia (Fig. 12).
Fig. 11. "Big Blue".
The advantages of ferrocement in sculpture as I see it are:

1. Inexpensive – Compared to bronze, stone, plastics and wood, ferrocement is a much less expensive medium.
2. Availability – All materials used are usually close at hand.
3. Durability – It is a weather proof medium with strength that is well documented.
4. Dimension – It can be shaped as large or small as the artist wishes.
5. Simplicity – Little technical skills are required in using ferrocement.
White Ferrocement Used for Sculpture

M.K. Hurd*

Experimental sculpture in white ferrocement contains added polypropylene fibers for texture and supplementary crack control. Paper describes sculptor's design approach, materials, and techniques of fabrication.

INTRODUCTION

The cost of preserving their works in a permanent medium is a problem which has long troubled sculptors. This difficulty has always caused some restraint in the practice of art and at certain times has almost completely discouraged it. A few sculptors, such as Lorado Taft in the United States, have used cast concrete because it offered them both economy and plasticity along with durability and appearance comparable to that of stone. Seeking an expression of the plasticity of concrete, without the massive weight of conventionally cast material, sculptor Frederic A. Nassaux turned to ferrocement. Since ferrocement derives strength from the shell or folded plate shapes in which it is used, it is an obvious choice for sculptured forms which may then be made hollow.

DESIGN OF THE DANCING FIGURE

Structural engineering know-how and artistic intuition guided Nassaux's first effort at ferrocement sculpture. Although his previous artistic medium had been paint on canvas, Nassaux is by vocation and training a structural engineer. Thus, he was able to develop engineering calculations to be sure that his contemplated dancer would resist lateral forces. Anchored to its base with a single No. 9 bar (about 28 mm), the figure was designed to balance on one toe so as to place the least possible bending stress on the bar anchoring it to the base.

Nassaux decided to leave some of the body parts open to reveal the shell nature of the sculpture and to enhance the appearance of lightness appropriate to the subject. He estimates that the dancer weighs 300 pounds (136 kg). The cross-shaped support, which was cast solid, weighs about the same amount. The figure measures 6 ft (1.83 m) from the toe tip to the top of the head. Over all height of the outstretched hand is about 8 ft (2.5 m).

THE REINFORCEMENT SHAPED PRIMARY CONTOURS

Ordinary galvanized wire mesh was shaped around 1/4-in. (6 mm) ungalvanized mild steel rods, interconnected in an outline of the body forms, and tied to the single dowel projecting from the base. The sculptor used only his hands, a pair of pliers, and thin ungalvanized tie wire to put it all together. After completing the skeleton and checking its balance, he applied the white mortar which gave it substance.

MORTAR MIX INCLUDED POLYPROPYLENE FIBERS

Equal volumes of white portland cement and white silica sand were carefully mixed with water to keep the water-cement ratio at 0.4 or less. Nassaux used an air-entraining admixture

* Consulting Editor, Concrete Construction Magazine, Farmington Hills, Michigan, U.S.A.
White ferrocement was chosen by sculptor Frederic A. Nassaux for creation of the white danseuse *Isadora* in 1983. Ferrocement offered plasticity without the massive weight of conventionally cast concrete. Also, the artist could work directly in the permanent material, instead of preparing a mold for casting the figure. The work is hollow, and some of the receding surfaces were left open to provide an expression of lightness.

to improve durability, and a water-reducing plasticizing agent to get a workable material while keeping the water-cement ratio low. He measured these admixtures "by eye" in very small amounts because the mortar batches were small to keep pace with the artistic process.

The largest batches were about \( \frac{1}{2} \text{ ft}^3 (0.014 \text{ m}^3) \). Short polypropylene fibers were added to the mortar mix as an added measure of crack control—a sort of built-in insurance policy for the creative work. Typical polypropylene fibers used for concrete reinforcement are from 5 mils to 50 mils (0.13 mm to 1.3 mm) in diameter, made in bundles about the diameter of common twine, and cut to lengths about 1 in. (25 mm) or longer. During mixing, the movement shears these bundles into smaller bundles and individual fibers.

Mortar was applied to the wire mesh with trowels and thin shaped-metal sheets. The sculptor established the final surface form and texture using his bare hands and a soft 1-inch-
wide paint brush. This procedure opened the plastic fibers at the surface and produced a
texture which he found most satisfactory.

Although Nassaux reports no ill effects from contact with the cement mixture, workers
with ferrocement are generally warned against direct contact of portland cement mixes on the
skin.

WORK SCHEDULE AND CURING TIME

The sculptor had some trouble with the limited time available for shaping the medium.
This involved more than just the setting or hardening of the mix. Shaping and reshaping
altered the water-cement ratio and threatened to cause surface cracking that would spoil the
texture. There were a number of separate work sessions, and each part was wrapped in wet
cloths within an hour of final sculpting. Timing was critical; just enough time must elapse so
that the cloth would not adhere to the textured surface. The entire work had continuous moist
curing, from a minimum of 7 days up to as much as 30 days for some parts.

CONCLUSION

The sculpture, completed in 1983, is called Isadora, in memory of the famed modern
dancer Isadora Duncan (Fig. 1). It was placed in a plastic film enclosure for the first harsh
Michigan winter, and the texture seemed to improve with aging. Nassaux was so satisfied
with the medium that he has already completed another work, in ferrocement of course (Fig. 2).

Fig. 2. In this experimental low-relief piece, Nassaux used both black and white ferrocement mixes to define
the silhouette form. This also had supplementary reinforcement of polypropylene fiber.

ACKNOWLEDGEMENT

This article is based in part on information which appeared in Concrete Construction,
The Nature and Development of Ferrocement

D.J. Alexander*

In this address I seek to explore the nature of ferrocement in global fashion in order to reveal the factors inhibiting its development and to outline a direction of future development which is a journey away from its historical role as a low key, appropriate technology towards a place as an industrial material.

The single most distinguishing feature of ferrocement is the thin covers to the reinforcement accepted by its advocates as sufficiently protective against corrosion of the reinforcement. Although it is a fact that the effectiveness of the cover has been established by the wide-spread use of ferrocement, I know of no comprehensive explanation for this phenomenon!

An explanation has been sought in the close-spaced cracking regimes which results from the use of fine reinforcement where it is thought that cracks sufficiently narrow do not allow the ingress of water. Yet work in the field of cracking of reinforced concrete shows that moderate cracking and quite wide cracks have a minor influence on corrosion of substrate steel!

As corrosion is a chemical occurrence it is more likely to result from invading carbonation and chlorination of the material which carries acid radicals to the site of the reinforcing. The rate at which this invasion takes place, and hence the time taken to reach substrate steel, is linked with the porosity of the material which is governed by its density and permeability, so the first line of defence is imperviousness. A secondary and possibly very important factor in inhibiting diffusion is the pH of the material in which chemical interaction at the diffusion interface arrests the reactions, whilst there is further evidence that high pH environments promote the formation of insoluble and thereby protective oxides on the steel surfaces.

I mention these matters as relevant in establishing the conditions in which thin covers are effective and demonstrably acceptable.

This means that the dimensional characteristics of porosity, rate of diffusion, pH and other parameters controlling corrosion susceptibility should be specified for ferrocement (and probably beneficially for reinforced concrete also). At that point the material can be confidently used by engineers who may otherwise be concerned about thin covers. Except in this matter of covers, it has to be said, ferrocement performs broadly and predictably like reinforced concrete from which it is distinguished by the high surface area of its steel content. In this respect the tensile steel interacts with compressive concrete in strict compliance with reinforced concrete theory whilst crack spacing and crack width comply with bond theory and strain considerations except that in ferrocement, as in reinforced concrete, introduced notches may dictate crack spacing by a force majeure effect.

† Special Lecture delivered at the Second International Symposium on Ferrocement, 14-16 January 1985, Bangkok, Thailand.
* Alexander and Associates Consulting Engineers, Auckland, New Zealand.
In this context mesh reinforced ferrocement achieves fine crack regimes by means of its fine wire assemblies and by the notch effect of its transverse wires but similar results can be obtained from monofilament ferrocement resulting from bond length phenomenon alone!

Regrettably, mesh reinforced ferrocement suffers from the constraint of layering the mesh which results in interior layers being under-utilized and at the centre un-utilized except in its shear function. Effective use of reinforcing requires that the bulk of the reinforcing is concentrated near the surface as this type of configuration has a profound effect on the economy of use of the reinforcing steel. The difficulty of mesh reinforcement is to obtain sufficient steel near the surface.

In comparing reinforced concrete with ferrocement it is immediately evident that for traditional covers of the order of 37 mm used for reinforced concrete that a minimum slab thickness of 86 mm results. By the substitution of fine wires of the same gross area and reduction of covers to about 4 mm this thickness can be reduced to 45 mm without disturbing the dimensional relationship of tension steel versus compressive concrete upon which the flexural strength depends.

Furthermore in load conditions the steel stress in reinforced concrete is limited to 125 MPa to 140 MPa and not much advantage is gained by employing higher yield steel as increased and unacceptable crack widths occur with increased strain. This latter constraint is however dramatically altered with the introduction of the fine steel wire reinforcement which greatly reduces the spacings of the crack regimes, and consequently crack widths, so that the limitation becomes the point of yield of the outer layer mesh steel if this is mild steel at which point unacceptable crack widths develop. This occurs at approximately 350 MPa.

However when high tensile steel in mesh or monofilament form is employed in place of the usual mild steel meshes the allowable stress in the steel may be raised to as much as 500 MPa for similar crack width as yield does not occur. The original thickness of the reinforced concrete for equivalent flexural strength can now be reduced to a fraction of the 85 mm thickness often with an increased factor of safety as the yield of the steel will be approximately 1400 MPa i.e. well above its working range. On strength alone there is therefore no compelling reason for employing reinforced concrete in preference to ferrocement except on cost effective grounds, earthquake resistance, or fire rating where these are pervasive effects.

The cost effectiveness of ferrocement arises from manufacturing savings in aggregate, plant size and its capital investment, general handling and transport, and erection cost savings, resulting from the thinner and lighter section whilst those of reinforced concrete are its lower cost of placement of fewer reinforcing rods, lower unit cost of steel and lower precision requirements.

What militates against ferrocement at present is engineers' perception of the effectiveness of thin covers to steel. The fears engendered in these perceptions could be largely allayed if the properties controlling corrosion susceptibility could be incorporated within a code of practice and given numerical indices.

In comparing ferrocement with steel one must first explore the commercial limits of the strength of ferrocement i.e. yields which are approximately 100 MPa-110 MPa on a modulus base for high tensile wire reinforced ferrocement. This can be compared to 250 MPa for mild steel. However on an equivalent weight basis the ratio of modulus is 9 and therefore the flexural
Strength of ferrocement can be two to three times that of mild steel plate if high tensile steel reinforcement is used in conjunction with 100 MPa and upward compressive concrete.

It is for these reasons that high strength ferrocement can be substituted for mild steel plate in tanks, ships plate, for construction of ships, pontoons, barges and other offshore structures and in framing, posts, and cladding for commercial and domestic buildings with little weight penalty and given the correct, manufacturing infrastructural conditions. This substitution can be undertaken at reduced cost.

Infrastructure is about the industrial circumstance of production. Steel with its long history has developed steel making facility, foundry casting of shapes, rolling mill forming of sections and plate, and has implemented their fabrication and shaping with machines, cutting methods and welding techniques all non-existent in the beginning of the steel age and indeed deep into it.

This infrastructure is missing for ferrocement except where it is represented in the precasting and prestressing technology appropriate to reinforced concrete.

Ferrocement lies between the two technologies of reinforced concrete and steel. It is amenable to set piece casting methods provided reinforcement can be introduced and it is suited to the linear extrusion or rolling methods employed for producing steel plates or sections, albeit the cement mortar is linearly poured rather than linearly displaced, and it is this infrastructure that is necessary in order to produce cost effective steel equivalents and I refer here to long line casting techniques used in prestressing.
This section provides illustrated information and details of construction to help the user to construct ferrocement structures quickly, easily and economically.

Windows in Ferro Hull†

P. Finch*

MANY designs in ferro are flush-deckers with windows in the topsides. But, if the ones in the construction drawings look too expensive, unsightly, or difficult to make, you might like to consider the method I used.

Design

For the sake of safety, windows had to be small. After all, windows in the hull may be underwater when the boat is hard pressed. If you want to change the designed shape you might first offer up plywood blanks, remembering that the windows, which are recessed, will be larger—in this case one inch (25.4 mm) bigger all round—than the aperture itself.

† Source: Practical Boat Owner, February 1982. Published courtesy of the publisher.

* Boatyard Manager, Sales Manager and Broker, Frdk. C. Mitchell & Sons, Ltd., Parkstone, Poole Dorset, U.K.
Construction

I made a pattern of the aperture from \(\frac{1}{8}\) inch (3.2 mm) mild steel plate, and fixed it to a steel work surface. Mild steel bar (\(\frac{2}{3} \times \frac{1}{8}\) inch (19.1 \times 3.2 mm)) was then heated and bent round the pattern, hammered gently to shape where necessary. Having welded the join, more bar was tack welded at 90 degrees round the outside, finishing with a seam weld round the inside joint.

Lugs were welded on the outside edge which fits between the layers of mesh, and holes for bolts drilled \(\frac{3}{4}\) inch (3.2 mm) oversize to allow for galvanising. By the way, it is extremely important to remove all welding slag, as zinc will only stick to bare metal. Galvanising is charged by weight, so to avoid minimum charges, try and tack your frames on to someone else’s order!

Apertures

With the ports wired to the topsides, I drew round the outside with a felt tip pen and, wearing goggles, cut away the mesh with a mini-grinder. Cutting high tensile rod with a grinding disc is hard work, but a touch with welding rod produces a quicker cut without leaving razor sharp edges. But watch where the molten steel drops. (Users of polythene sheds, beware ……)

Installation

With the aid of a screwdriver, the lugs can be slid between the layers of mesh, leaving the ports \(\frac{1}{2}\) inch (3.2 mm) proud of the mesh on both sides. That provides a useful guide for the plasterers, as well as a smooth edge. It is also advisable to tie in the mesh round the lugs to grip the frames. We encountered no adhesion problems between steel and cement, but if you are worried use sealocrete. Sealocrete, an epoxy cement, sticks wet cement to virtually anything, and can be slopped round the frames just before plastering.

Finally, stainless steel frames, \(\frac{1}{8}\) inch (3.2 mm) bigger than the windows, were also made, and drilled at the same centres as the Perspex and ports, then bolted to the frames to finish off (Figs. 1-2). We bedded the Perspex on rubber gaskets and mastic, before tightening the bolts, and pinching it all together to make a watertight seal. Not only are these frames cheaper, they avoid the use of wooden blanks set in the hull, the removal of which often causes damage.

Fig. 2.
This list includes a partial bibliography on ferrocement and related topics. The AIT Library and Regional Documentation Center has these articles and books. Reprints and reproductions, where copyright laws permit, are available at a nominal cost (see page 329). 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.

Beginning with this issue of the journal, a new format will be used to classify bibliographic items appearing in this section. Each record will now be classified at two levels: a major and a secondary level. The new classification system is shown below:

<table>
<thead>
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<th>Major Level</th>
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<tr>
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<td>Material Properties</td>
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<td>Standards and Specifications</td>
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TERRESTRIAL APPLICATIONS
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- Water Resources Structures
- Storage Silos
- Sanitary Structures
- Miscellaneous Structures
- Construction Techniques
- General

PROTECTION AND RELATED TOPICS
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- Natural and Organic Fiber Composites
- Polymer Composites
- General

GENERAL TOPICS
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- Technology Transfer
- Miscellaneous Notes

We hope that readers will find this new format more useful and convenient for reference.

RESEARCH AND DEVELOPMENT

Material Properties


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IFIC NEWS

NEW EDITORIAL BOARD

The *Journal of Ferrocement* has a new Editorial Board effective July 1985. The members are selected in recognition of authoritative scientific work in the fields covered by the journal. The editorial board will have a tenure of two years, renewable.

The members of the editorial board are:

Mr. D.J. Alexander and Poore Consulting Engineers Auckland, New Zealand

Professor A.R. Cusens Head, Department of Civil Engineering, University of Leeds, Leeds LS2 9JT, England, U.K.

Mr. J. Fyson Fishery Industry Officer (Vessels), Fish Production and Marketing Service, UN/FAO, Rome, Italy

Mr. M.E. Jorns Ferrocement International Co., 1512 Lakewood Drive, West Sacramento, CA 95691, U.S.A.

Professor S.L. Lee Head, Department of Civil Engineering, National University of Singapore, Kent Ridge Campus, Singapore 5

Professor A.E. Naaman Department of Civil Engineering, The University of Michigan, 304 West Engineering Building, Ann Arbor, MI 48109-1092 U.S.A.

Professor J.P. Romualdi Director, Transportation Research Institute, Carnegie-Mellon University, Pittsburgh, Pennsylvania, U.S.A.

Professor S.P. Shah Department of Civil Engineering, Northwestern University, Evanston, Illinois-60201, U.S.A.

Professor B.R. Walkus Department of Civil Engineering, Technical University of Czestochowa Malachowskiego 80, 90-159 Lodz, Poland

Mr. D.J. Alexander
The duties and responsibilities of the editorial board as approved in the Editorial Board meeting held 14 January 1985 at the Asian Institute of Technology are:

To assist the editor in maintaining the quality of the papers appearing in the journal.

To assist the authors by offering constructive criticisms of their papers.

To respond to the editor’s request for advice within two weeks of receipt. If a referee finds himself unable to attend to a manuscript within this period, he should return the manuscript immediately without
comments in order to allow the editor to select another referee without delay.

To assist the editor in the collection of information for the journal by indicating sources of information.

**Ferrocement Information Network**

IFIC proposes to establish a Ferrocement Information Network (FIN) in Asia and Africa. The main objective of FIN is to facilitate and accelerate the greater flow of information to users in developing countries. In the proposal for the establishment of the network, the following were identified as functions of the network:

- Facilitates more effective reach to audiences in areas where otherwise users cannot be accurately identified.
- Ensures better coverage of the end-users in the local areas as the local center have a better knowledge of their respective users.
- Each network node will serve as a depository of documents on ferrocement and as a redistribution point within the country.
- Adapt specifications, design and language of IFIC publications to suit local needs.

These functions will be achieved through the following activities of the network members:

- Serving as a central resource for information about ferrocement and offering reference services.
- Collecting information on ferrocement within the country.
- Acting as a clearing house for local ferrocement publications.
- Offering user orientation in ferrocement.
- Conducting training courses at the local level in ferrocement use.

For 1985, IFIC proposes to start the project with five selected institutions in Asia. Membership in the network is by invitation and the criteria for selection are:

- Must be an institution in a developing country in Asia or Africa.
- Must have a civil engineering or architecture educational (undergraduate level) program or have undertaken extension work using ferrocement or must have an interest in utilizing ferrocement and potential ability to do so.
- Must have faculty active in ferrocement research and development or planning to become active in the near future.

IFIC has selected five institutions, one each from India, Indonesia, Singapore, Malaysia and the Philippines, for the pilot project.

**Ferrocement Corrosion: An International Correspondence Symposium**

IFIC is organizing an International Symposium on Ferrocement Corrosion by correspondence for 1986. The objectives of the symposium are:

- to provide an opportunity to review and update the existing knowledge on ferrocement corrosion.
- to discuss corrosion problems and recommended practices.

A Call for Papers will be distributed before 15 July 1985 and intending authors are requested to submit abstracts before 15 January 1986. A preliminary acceptance will be made on the basis of the abstract on 15 February 1986 and full-length manuscript will be required by 15 May 1986. Upon receipt of the manuscripts, IFIC will send them to all participants for comments and discussion. Participants must send their comments to IFIC before 1 September 1986. These comments will be sent to authors as soon as they are received and authors reply
to these comments must be received at IFIC before 1 November 1986. On the basis of the combined documents, IFIC shall publish a document on March 1987.

IFIC's Directory of Ferrocement Firms and Experts, 1982-1984

IFIC's Directory of Ferrocement Firms and Experts 1982-1984 is currently under preparation and is expected to be released on September 1985. The directory contains 226 entries presenting the capabilities and experience of each firm or expert. The format followed is:

A. Scientists/Designers — Nine categories of information constitute each bibliographical entry for each individual. Each category of information is designated by a number and within each category the following format has been employed:

1. (1) sex; year of birth; country of birth; nationality; marital status; mailing address,
2. (2) degree, institution; field of discipline
3. (3) current position, organization; duration; previous position only related to ferrocement, organization,
4. (4) [total number of papers published]; five latest papers on ferrocement and related materials,
5. (5) title of current research project, (date of completion),
6. (6) name of language followed by A B C or D or all
   A means “ability to deliver lectures and speeches”
   B means “ability to converse with ease”
   C means “ability to conduct a very small group or one-to-one conversation”
   D means “ability to use written materials for research in his own field”.
7. (7) IFIC Consultant; IFIC Resource Speaker,
8. (8) awards,
9. (9) structures completed; professional experience.

B. Builders/Consultants/Manufacturers — Seven categories of information constitute each entry for each organization. Each category of information is designated by a number and within each category the following format has been employed:

1. (1) address; telephone number; telex number; cable address; contact person,
2. (2) classification of organization; year of establishment; geographical coverage; location of production plants in operation,
3. (3) scope of activities,
4. (4) description of structures/product,
5. (5) mechanical properties; advantages; construction method; production system; number of structures; location; date of completion; unit cost,
6. (6) patent and license situation.

This directory is the result of the survey of the current status of ferrocement structures and manufacturers of ferrocement materials conducted by IFIC from 1982 to 1984. The aim of the survey is to provide communication and collaboration within the field.

The list price is US$ 15.00, however prepublication price (order received before 15 September 1985) is US$ 10.00 including surface mailing cost and for experts, builders and manufacturers listed in the directory the cost of each copy is US$ 5.00. For postage by air mail, an additional amount of US$ 2.00 should be added for each copy.

IFIC Reference Center in China

Two Chinese research institutes, the Building Materials and Concrete Research Insti-
tute in Beijing and the Suzhou Concrete and Cement Products Research Institute in Suzhou, agreed to have an exchange of information with IFIC and to be IFIC reference centers. IFIC will provide them with basic ferrocement reference collections under the IDRC grant to IFIC. The Institutes will provide a prominent location for the reference collection and will assign a ferrocement specialist as resource person to entertain enquiries on ferrocement in their area. The agreement was reached during the visit of Mrs. Lilia R. Austriaco, senior information scientist of IFIC and editor, *Journal of Ferrocement*.

Mrs. Austriaco visited the Building Materials and Concrete Research Institute and had a meeting with Mr. Chen Jinchuan, vice-director of the Institute and other ferrocement specialists from different research institutes in China. Research and development of ferrocement in China, Thailand and other countries were discussed.

She also discussed with Mr. Jiang Jiafen, director of the Suzhou Concrete & Cement Products Research Institute about ferrocement activities of the institute. This institute is very active on ferrocement and fibre cement research and applications. They have developed different methods of ferrocement construction such as: vibro-extrusion, vacuum dewatering and assembly of prefabricated sections by prestressing technologies.

Mrs. Austriaco also attended the 1985 International Symposium on Cement and Concrete held 14-17 May 1985 in Beijing, China. The symposium was attended by 213 participants from 12 countries. She presented a paper entitled "Ferrocement, a low-cost construction material".

**Special Student Discount**

IFIC is offering a special student discount for the monograph "Ferrocement" by Paul and Pama. Students may purchase these publications direct from IFIC by "class orders" and receive a special discount. A minimum order of 5 copies is required and must be ordered through their professor (please list professor’s name). If 10 or more copies are purchased, a free copy is supplied on request. The special price for such class orders is:

- 5 copies: US$ 37.50 (surface mail)
- 10 copies: US$ 45.00 (air mail)
- (plus one free) US$ 75.00 (surface mail)
- (plus one free) US$ 90.00 (air mail)

For further information contact:

IFIC/AIT
G.P.O. Box 2754
Bangkok 10501
Thailand

**VISITORS**

Dr. Pichai Taneerananon, head of the Department of Civil Engineering, Prince of Songkla University visited IFIC recently with three engineers from the Municipality of Phuket. The objective of the visit was to know more about ferrocement and how it can be
used for the projects of the Municipality of Phuket.

The guests in the Ferrocement Park.

INDIA

Research Project on Ferrocement

The University Grants Commission is funding a research project entitled “Study of Prefabricated Ferrocement Units for Economic Building and Rural Construction Work”. The grant for 3 years is Rupees 100,000.00. (US $ 8,517.90)

The project is to undertake a comprehensive literature review in three months and prepare a state-of-the-art report identifying gaps in the research and development in this field. Further work will be undertaken to complete a package to effect the transfer of technology suitably.

(Information from: Dr. S.K. Kau shik, professor of Civil Engineering, Department of Civil Engineering, University of Roorkee, Roorkee, 247667, U.P., India).

Workshop on Ferrocement Products, Design and Manufacture

The Indian Concrete Institute (ICI) in collaboration with the Structural Engineering Research Centre (SERC) Madras will conduct the Workshop on Ferrocement Product, Design and Manufacture on 28-30 August 1985 at SERC Madras. The workshop is sponsored by the Department of Science and Technology, Government of India.

The objectives of the workshop are to impart in depth knowledge and on-the-job experience to engineers and personnel who are engaged in construction activities and quality control. The topics for the workshop are: principles and composition of materials; properties of ferrocement; design parameters, tests; possible applications; products in development; linear elements, planks, 3D elements; service core units; kiosks; shells, lost forms, ferrocement as substitute for timber, polymerised ferrocement; demonstration on manufacture of selected products.

The workshop fee is Rs. 600.00 (US $ 48.00) per person. The fee will cover cost of technical literature, construction material used in training and the cost of lunch and refreshment during the workshop time. Members of the ICI or their nominees will be entitled to a 10% discount on the fee.

For further details, please contact

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Tel. 418012/412064
Telex. 041-6876 CSIR IN

NEW ZEALAND

Non-ferrous Metals

What precautions need to be taken when using non-ferrous metals in and around concrete?

The most common non-ferrous metals used in the building industry today are copper, brass, lead, zinc and aluminium.
Both lead and zinc are attacked by fresh concrete and mortar. Concrete that has dried out will not affect these metals. Partially embedded lead is susceptible to corrosion of the embedded section due to differential aeration. To counter this phenomenon, the embedded lead should be protected with asphalt, varnish or pitch.

Zinc, when embedded in fresh concrete, will corrode. However, this corrosion does not appear to continue. A dense film of calcium zincate protects the underlying material from further attack.

Aluminium is readily corroded by caustic alkalis, and the rate of attack is more rapid than that of lead or zinc. The corrosion products do not protect the metal from further attack as zinc does, and any damage will be more severe in areas where the metal has been bent, twisted or cold worked. If the metal is to be embedded in fresh concrete or to be in contact with wet concrete, (as in the case of aluminium windows), the aluminium should be protected with a coating of asphalt, pitch or bituminous paint.

Brass strips are sometimes used for control joints in highly finished slabs. The use of brass has been largely replaced by plastics. However, its resistance to chemical attack means it is particularly suited for protection against alkali exposure. A protective coating forms on the brass surface, and prevents further attack. Acidic ground waters do not attack brass, so its durability is practically unlimited even without a bituminous coating.

Cadmium plated parts will corrode severely when embedded in concrete. No protective film is formed as a by-product of the corrosion process (as in the case of zinc for example). Therefore, all cadmium plated parts embedded in, or in contact with, damp concrete should be protected with an unbroken film of bitumen, resin, pitch or similar materials.

Copper is corrosion resistant under most conditions. This metal will not be affected by embedment in fresh concrete, or by contact against hardened concrete. However, the presence of chlorides in the concrete can be detrimental.

Admixtures containing chlorides should therefore be avoided where the concrete comes into contact with copper or aluminium.

(Source: New Zealand Concrete Construction, October 1984 pp. 33).

PHILIPPINES

Pagtambayayong Foundation for Mutual Aid

The Pagtambayayong Foundation for Mutual Aid is engaged in cooperative housing resettlement, social credit and appropriate technology. It has organized three social credit organizations with 250 members and light housing cooperatives with 500 members. 420 members have already acquired land.

Construction of the houses have been slow because of the spiralling costs of materials. To lower cost of construction, Pagtambayayong ventured into verification of cheap and appropriate building technologies such as pozzolana cement, cimva-ram press in making soil cement blocks and fiber cement roof tiles. Six houses have been erected using soil cement block and the experiment on the fiber cement roof looks promising.

To help reduce costs of conventional building materials through bulk buying Pagtambayayong established a hardware store. Another support mechanism set up was the community credit program which provides loan at minimal interest to unemployed beneficiaries who have skills in running small enterprises.

Recently, the foundation has received a P 800,000.00 (US$ 44,444.44) grant from the US Agency for International Development (USAID) to handle a four-month subsidized building materials distribution program for low-income victims of a typhoon in Northern
Cebu. Seven hundred households will benefit from the project.


SWEDEN

Fiber Shotcrete System

Research and development work in Sweden has developed a unique steel fibre sprayed concrete production process, commercially known as ‘‘Econ fibre shotcrete’’ system. Through the combination of advanced fibre reinforcement technology, high quality concrete technology and technique of spraying, ‘‘econ fibre shotcrete’’ make possible the production of thin walled tough and durable flat and curved concrete products (Fig. 1).

Production process is basically a wet concrete spray method. A matrix is mixed and pumped to a spray nozzle, to which also are fed wires from bobbins placed on a wheel rack. Compressed air added at the spray nozzle ejects the matrix stream and powers an air motor cutting the wires and ejecting fibres. The fibre shotcrete is sprayed on reusable molds. (Fig. 2)

The wires used are indented and are delivered in 0.4 mm and 0.5 mm diameters, with or without zinc-coating. The length of the cut fibres varies from 20 mm to 200 mm depending on the products to be made, the situation where the spraying is made and the matrix properties. The strength of the wire is 1200 N/mm².

The mix design takes into account the specific requirements on a matrix for a steel fibre concrete, considering the local supply of raw materials. The matrix is normally of a high quality and has a maximum aggregate size of 4 mm. The use of superplasticizers, silica fume, polymers, etc. are taken into account. The matrix compressive strength most often developed is 100 MN/m², however, the matrix can be varied, depending on the situation, to developed a wide range of compressive strength.

‘‘Econ fibre shotcrete’’ can be used in precast production as well as for on site work. For most productions, first a thin unreinforced matrix layer is sprayed on the mould surface. Then follows simultaneous spraying of fibres and matrix until desired thickness is
achieved. The amount of fibres (Fig. 3) is typically between 0.5% and 1.5% by volume (between 1.8% and 5.5% weight) depending on the desired performance. In cases when fibres close to the surface should be avoided, a final unreinforced layer is sprayed. A total thickness of more than 100 mm can be built up without the use of accelerators. It is possible to add accelerators at the nozzle, but that is very rarely needed.

Fibre Volume

Fig. 3. Recommended fibre volumes for varying fibre lengths and diameters 0.4 and 0.5 mm, from a test production.

The sprayed layer thicknesses are measured with a gauge.

The fibre volume is measured and controlled through one or more of the following methods:

- negative weighing of the spools
- simultaneous and continuous measurement of the matrix and fibre flows, displayed at the gun (equipment optionally available)
- using an electromagnetic cover meter calibrated for “econ fibre shotcrete”

The end product is tested according to its function. Typically flexural strength and ductility are measured on beam specimens cut out from a separately sprayed specimen.

Typical applications of “econ fibre shotcrete” are: storage tanks, boat hulls (Fig. 4), shells and balcony (Fig. 5).

The needed thicknesses of the different layers are determined from statical analysis as well as from life length analysis concerning fibre corrosion. Thin walled cement based materials need close controlled and well defined curing processes e.g. if silica fume is used, moist curing is important and if certain polymers are used, dry curing is imperative.

The production of “econ fibre shotcrete” products are carried out under strict control, and the properties are properly tested. The matrix quality is normally evaluated from the compressive strength measured on cubes or cylinders according to normal standards.
Transfer of this system on a complete turn-key set up can be negotiated with

Ekdahl Technology hb
Embla4ven 4 5-182 63
Djursholm Sweden
tel. t (46) 8 753 2040
Telex : 40609 Aros S.

(Information sent by: Dr. Ake Skarendahl, Managing Director, Ekdahl Technology hb, Embla 4, 18263 Djursholm, Sweden).

UNITED KINGDOM

Admixtures for Concrete

In a well-produced guide to admixtures the Concrete Society and the Cement Admixtures Association (CAA) have jointly published an all embracing definition of an admixture as “a material, other than water, or Portland cement, which is added to a batch aggregate of concrete, mortar or grout during or immediately before mixing, in order to extend the properties of the concrete and/or make it more economical”.

This evidently covers a multitude of functions and to-be more specific, a table is presented (Table 1) relating the types of admixture to the effects on properties. Further useful ways of cross-analysing the uses of admixtures, proposed by Hewlett and Rixom, are by relating them to the stages in using concrete, and by beneficiary (Table 2).

Considered in terms of stages, the process of making concrete can be broken down into the following:

1. For making and transporting to point of placing, useful materials could be reaction modifiers, accelerating or retarding admixture;

2. For placing, compacting and finishing, one might usefully apply rheology modifiers, plasticisers, retarder/plasticisers, super-plasticisers, pumping aids;

3. For influencing in situ performance-bulk properties such as strength and durability, useful materials may be accelerators, air entrainers, super water reducers, gas forming and resin based;

4. For long-term appearance; admixtures may include cosmetic modifiers, damp proofers, water repellents and fungicides.

Considered in terms of main individual classes of admixtures, they show the following features: water reducers may be added to increase workability of concrete, to provide adequate workability with less water and therefore to produce greater strength in the set concrete, or to reduce both water and cement and thus give economies in mix design. They are generally salts of lignosulphuric acids, salts of hydroxycarboxylic acids, or low molecular weight polysaccharides.

Accelerating, and accelerating water-reducing admixtures, accelerate the setting and early development of strength in concrete. Normally they have been based on calcium chloride and calcium formate (with further constituents); but the use of calcium chloride is restricted in the UK and in many other countries to unreinforced concrete. The corrosive effects of chlorides on any adjacent metalwork is now well known. Accelerators improve early strength but have negligible effect on long-term strength unless they incorporate water-reducers and then the effect is related to the lower water/cement ratio.

Retarding admixtures also tend to incorporate water-reducing properties directly or by added constituents. If water-reducing retarding admixtures are used, the 28-day/strength may be some 10 per cent higher than that of the plain mix. The main areas of use are in large pours (preventing forming of cold joints, slowing down the rate of heating), with sliding formwork, in hot weather to compensate for the accelerating effect of the ambient heat, and in ready-mixed concrete to allow for
Table 1. From "Guide to chemical admixtures for concrete". Concrete Society and Chemical Admixtures Association, 1980.

<table>
<thead>
<tr>
<th>Desired property</th>
<th>Admixture type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water reducer</td>
</tr>
<tr>
<td>Setting and hardening</td>
<td></td>
</tr>
<tr>
<td>Accelerate rate of gain of early strength</td>
<td></td>
</tr>
<tr>
<td>Accelerate set</td>
<td></td>
</tr>
<tr>
<td>Retard set</td>
<td></td>
</tr>
<tr>
<td>Workability and other plastic properties</td>
<td></td>
</tr>
<tr>
<td>Increase workability without loss of strength</td>
<td></td>
</tr>
<tr>
<td>Increase frost resistance during setting</td>
<td></td>
</tr>
<tr>
<td>Reduce temperature rise</td>
<td></td>
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<tr>
<td>Reduce bleeding</td>
<td></td>
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<tr>
<td>Reduce segregation</td>
<td></td>
</tr>
<tr>
<td>Improve pumpability</td>
<td></td>
</tr>
<tr>
<td>Hardened properties</td>
<td></td>
</tr>
<tr>
<td>Increase final strength without increasing cement content or reducing workability</td>
<td></td>
</tr>
<tr>
<td>Improve durability and freeze-thaw resistance</td>
<td></td>
</tr>
<tr>
<td>Improve water-resistance</td>
<td></td>
</tr>
<tr>
<td>Alter colour</td>
<td></td>
</tr>
<tr>
<td>Improve bond</td>
<td></td>
</tr>
</tbody>
</table>

*Main application. **Secondary application.

Time needed for delivery. But care is needed to prevent drying out before curing, otherwise there may be plastic cracking.

Superplasticisers are chemicals that very greatly reduce the amount of water needed for workability. They can be applied alternatively to give high level of workability at a given water level.

Air-entraining agents are organic surfactants, chemicals that lower the surface tension of water. They cause the mix to entrain a controlled quantity of air in uniformly dispersed and separate bubbles. Because they confer good freeze-thaw resistance on the concrete, they are used for pavings for roads and airfields. Reduced bleeding, improved workability and improved cohesion are also assets and these admixtures are used as an aid for pumping concrete at pressures below about 60 bar.

There are also many other admixtures applied for such functions as improving the
Table 2. Admixture/application/benefit chart. From a paper by Hewlett and Rixom at Ermco 83.

<table>
<thead>
<tr>
<th>Admixture type</th>
<th>Ultimate effect</th>
<th>Practical application and benefit</th>
<th>Beneficiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerators</td>
<td>Reduced setting times. High early strengths. Normal strength/time at low temperatures.</td>
<td>Offsetting low temperatures and cold weather. Early removal of forms and moulds. Improved production schedules. Reduced energy needs.</td>
<td>Client/User</td>
</tr>
<tr>
<td>Air-entraining</td>
<td>Improved workability. Improved consistence or “fattiness”.</td>
<td>Good freeze/thaw response. Offsetting poor sands and gap graded materials.</td>
<td>Client/User</td>
</tr>
<tr>
<td>Superplasticisers</td>
<td>Very high workability for a given water content. High water reductions for a given workability.</td>
<td>Facile concrete placing in difficult situations, i.e. closely spaced reinforcement, high early strength concrete, time and energy savings, non-shrink, non-bleed grouts.</td>
<td>User</td>
</tr>
</tbody>
</table>

bonding (synthetic polymer emulsions), colouring by pigments, and damp-proofing. Then there are materials that expand, usually by chemical reaction, and thus compensate for shrinkage, anti-bleeding materials, fungicides, corrosion inhibitors and anti-freeze additives. Standards are now available in Australia, Austria, Belgium, Canada, France, Germany, Italy, United Kingdom and U.S.A. There is also a Draft International Standard ISO 7690 “Definitions and classification of admixtures for concrete, mortars and grouts”.
For the UK, BS 5075: Part 1: 1982 covers accelerating admixtures, retarding admixtures and water reducing admixtures; Part 2: 1982 deals with air-entraining admixtures. Superplasticisers are the subject of a further Part scheduled for later publication.


Concrete Admixture

Concrete admixture have progressed in a decade from being objects of suspicion to a situation where they are being increasingly relied on to achieve results which would not be possible without them.

The range of concrete chemicals had itself grown rapidly, to incorporate not only plasticisers and air entraining agents, which were probably the first types to be adopted, but also products which would speed up or slow down the set, products which would make the concrete more or less workable, surface retarders to assist in preventing 'cold' joints, superplasticisers which make concrete flow readily into confined spaces, foaming agents, integral waterproofers, pumping aids for lightweight aggregate, formwork sealers, shotcrete accelerators and admixtures for glass reinforced concrete. Intensive research and development is continually adding new products to this list.

One of the most valuable and interesting developments in admixture technology has been the evolution of the superplasticiser. The first superplasticiser was launched on to the UK market exactly ten years ago. The new word which had been coined for a product which was to revolutionise certain areas of concrete technology took a little time to establish itself, but is now standard terminology in the construction industry.

This is the type of admixture which would make concrete perform in a way which no amount of juggling with mix designs could achieve on its own. It would produce stronger concrete with lower water/cement ratios, or even more importantly would give with normal water/cement ratios a concrete which was essentially self levelling without any tendency to bleed or segregate. Once convinced of the technical soundness of the product, the industry was quick to grasp the advantages in terms of lower placing costs of more workable concrete. At last, the hard work of the small nucleus of chemically-orientated companies had established that, from now on, there would be available to industry a growing range of consistent and reliable products which would significantly assist them in their work.

While the major use of superplasticisers is to be found in facilitating the laying of areas of open concrete, there are some interesting examples which demonstrate how the modern concrete chemical can make the impossible become possible. One such occurred in early 1983 constructing three pontoons, each 40ft long by 20ft wide (12.19 m x 6.10 m) and 8ft deep (2.44 m), for the Gosport/Portsmouth ferry. In shape, each was a concrete box with 4 in. walls encasing large blocks of polystyrene, with a concrete base and top which had to be absolutely level. Between 400 m$^3$ and 800 m$^3$ of concrete were involved.

The concrete would be one hour in the truck, plus pumping time. The works called for a mix containing a high content of sulphate-resisting cement which would in turn give a very fast setting time, unless some action was taken to retard the concrete. On the other hand, in order to flow into the narrow 4 in. walls, the mix must have excellent fluidity. To overcome these problems, the required retardation was provided by adding a plasticiser to the mix at a ratio of 140 ml/50 kg cement, while the problem of flow was solved by additionally using superplasticiser SPI at a ratio of 1 per cent by weight of cement.
The construction of bank vaults is an area of speciality concrete requirement. The Standard Chartered Bank at Bishopsgate required a concrete of exceptionally high flow characteristics to penetrate a complex and high level of reinforcement. Another plasticiser, in this case SP4, achieved the necessary flow at a dosage rate which varied between 3 kg/m$^3$ and 4.5 kg/m$^3$ according to the initial workability (slump value) of the concrete which was continuously monitored.

More recently still, a series of special problems involving the strengthening of bridges or platforms belonging to the London Transport Executive (LTE) has demanded a construction technique which is totally dependent on the flow characteristics of the concrete.

The first example arose at Ravenscourt Park Station on the London Underground system. An old platform needed to be strengthened. It was, however, in daily use and must if possible remain in service. The LTE decided on a method which involved building a new reinforced concrete slab directly underneath the old platform, which would remain in place.

To construct this slab, the contractor suspended reinforcement from the soffit of the original platform and erected formwork beneath it. A number of pump inlet valves were incorporated within the soffit at approximately 3 m centres. Concrete was to be pumped upwards, through each of these valves in turn, until the reinforcement and the brick piers supporting the old slab were totally surrounded.

To achieve the essential high level of workability, SPI was added on site immediately prior to placing at an average dosage of 3.61 t/m$^3$, the dosage being varied according to the slump reading of each batch, to give a flow rate of 55 cm-65 cm. This easily met the required pumping distance of 12 m. The mix design was 410 kg/m$^3$ of OPC to 1105 kg/m$^3$ of sand (net weight) and 1010 kg/m$^3$ of 10 mm aggregate.

(Source: "Admixtures Come of Age" Concrete, December 1984, pp. 13-15).

Concrete and Building materials Laboratory

A new laboratory to study the properties of concrete and building materials and to develop concrete technology has been opened by British Rail Research at the Railway Technical Centre in Derby.

Staff from the section advise on the maintenance, preservation and refurbishment of the vast number of buildings, bridges, tunnels and other structures throughout the British Rail system. They have also assisted and advised overseas rail administrations as far afield as Spain, New Zealand, Egypt, and Canada, gaining international recognition with the concrete industry.

In addition to their work with concrete, the team also provide a testing and advisory service for a variety of other building materials and structures, including stone and brickwork, flooring, roofing, and cladding.

The new laboratory houses a compression testing machine, flexural testing apparatus for quality assessment, and equipment for use in non-destructive detection of corrosion in steel reinforcement.

Considerable research has gone into improving the early strength development of concrete, especially for bridge decks and other situations where a return to normal rail traffic is required without excessive delays.

The section was also involved in the development of paved concrete track (PACT), where a solid track base replaces conventional stone ballast and which has proved particularly useful in tunnels and on overbridges.

As well as researching into new materials and uses, the laboratory staff are also involved
with the diagnosis and rectification of faults in existing structures.

Full details on services offered can be obtained from Trent House, Railway Technical Centre, Derby (tel: 0332 42442). U. K.

(Source: The Structural Engineer. Vol. 63A, No. 4, April 1985)

Concrete Reinforcement Corrosion Test

A device for determining whether concrete reinforcement is corroding has been developed by Taywood Engineering Ltd. The company has applied for a patent on the instrument which mounts electronic measuring equipment on a wheeled assembly, so that a thorough examination of reinforced concrete structures can be made quickly.

The technique, normally used in the early stages of examining for corroding rebars, works on the principle of corrosion potential. This involves a half-cell, such as copper/copper sulphate, being placed in contact with the surface of the concrete. An electrical potential can then be measured between the rebar and the copper rod of the half-cell. The magnitude of potential measured can be related to the probability of the rebar corroding.

Such copper/copper sulphate half-cells are commercially available and all that is additionally required to make a measurement is a high input resistance voltmeter, ideally with an input greater than 1000 MΩ. This in a simple tool for spot measurements, but it is neither efficient nor cost effective; increase the number of measurements required and the process is slowed down.

Taywood Engineering’s solution is to connect the half-cell to the concrete, using a wheel as a tip. This means the instrument can be drawn across the surface to give a continuous readout of the corrosion potential.

The prototype wheel is fitted with a rotary shaft encoder to measure the distance travelled. This is coupled to a modern chart recorder driven by a stepper motor and fitted with remote drive input, so that the linear movement of the wheel is directly related to the travel of the chart paper.

Also contained in the instrument’s electronics is a high-input resistance buffer amplifier as an interface between the half-cell and the chart recorder.

The wheel is 160 mm in diameter and has a foam rubber rim. A water-absorbent tip is in constant contact with the rim and is kept moist by a water chamber.

A silver/silver chloride half-cell is used in the wheel instrument and its silver chloride tip is kept in contact with the water inside the chamber. The electrical path of the full cell created by the wheel’s contact with the surface of the concrete is therefore rebar/concrete/water/silver chloride/silver.

The top speed at which the wheel can be drawn across concrete is currently 1 m/5 s, because of the limitations of the chart recorder’s speed. However, this is predicted to increase after modifications to the system of recording the distance travelled and the voltage output. Taywood Engineering is now considering both a simplified version of the instrument — without the distance measurement — and a more sophisticated model to record and log both distance and ‘potential’ data for computer analysis.

Full particulars are available from Taywood Engineering Ltd., 345 Ruislip Road, Southall, Middlesex UB1 20X (tel: 01-575 4390).

U.S.A.

Fiber Reinforcement Standard Approved

A new standard has been drafted by ASTM to determine toughness indices which reflect the behavior of fiber reinforced concrete under static flexural loading.

The standard, C 1018, Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Beam with Third Point
Loading), was developed by ASTM Subcommittee C09.03.04, a branch of Committee C-9, Concrete and Concrete Aggregates.

According to ASTM, this new test method enables evaluation of fiber reinforced concrete's flexural toughness in terms of areas under the load deflection curve obtained by testing a simply supported beam under third point loading. The ratios provided through use of the standard serve as toughness indices which identify the pattern of material behavior up to the selected deflection criteria.

ASTM said the indices are calculated by dividing the area under the load deflection curve up to a specified deflection criterion and by the area up to the deflection at which the first crack is deemed to have occurred.

The C09.03.04 chairman is Colin D. Johnston, University of Calgary, Calgary, Alberta, Canada, also a member of ACI Committee 544, Fiber Reinforced Concrete. The new standard may be ordered by contacting ASTM Customer Service Department, 1916 Race St., Philadelphia, Pa., 19103.

(Source: Concrete International, February 1985).

Worldwide Cement Contest Announced

Fuller International Inc., Bethlehem, Pa., has announced a contest to search for new uses of cement.

The contest with prizes of $20,000 is intended to seek out new and better ideas for the use of cement and promote growth of this vital basic industry. There will be two prizes, one for the most original idea and another for an idea that is closest to implementation. Entries will be judged by a distinguished international panel, members of which will be announced in the near future.

The company hopes that the QUEST contest will play a significant role, in a most creative way, to stimulate the industry's growth and progress.

(Source: Concrete International, February 1975).

ZIMBABWE

Sisal Cement Roofsheet

The Department of Appropriate Technology, Hlekweni Friends Rural Service Centre in Zimbabwe has recently published the Sisal Cement Roofsheet Manual by Kim Paamand. The technique presented in this manual was developed in the Centre since 1979. The manual presents: list of equipments and tools; the material to be used including the preparation of the sisal fibers; method of casting the moulds; method of casting, curing, storing and transporting the roofsheets and the range of products that can be made using the sisal-cement mixture developed.

Nigel Nicholson introduced the technique of producing sisal roofsheet to the Centre. Under the Department of Appropriate Technology of the Centre, a research and development team was formed with the mandate to improve the technique of construction and to lower the cost of production. The team members were David Ward, Andrew Ncube, Mark Moyo and Kim Paamand. The team modified the production equipment and was successful in lowering the cost of production equipment from US$350.00 to US$50.00. The size and shape of the sheets have been changed to give greater strength and ease of use. The failures of the first design in 1979 were the basis for the changes. The new shorter design, used for roofing of workshop, domestic houses, schools and animal shelters, has not developed any cracks.

This manual was written to supplement the "Sisal Cement Roofsheet Course" conducted by Hlekweni Friends of Rural Service Centre.

(Reference and information sent by Mr. Kim Paamand, Department of Appropriate Technology, Hlekweni Friends Rural Service Centre, P.O. Box 708, Bulawayo, Zimbabwe).
CALL FOR PAPERS

July 1986 Special Issue

on

Ferrocement Prefabrication & Industrial Applications

The Editorial Board, following the success of the special issues on Marine Applications, Housing Applications, Agricultural Applications, Prefabricated Ferrocement Housing and Ferrocement Water Resources Structures has decided to devote the July 1986 issue of the Journal to Ferrocement Prefabrication and Industrial Applications.

The gradual depletion of natural materials resources and the continuing advance of materials science and technology have generated many remarkable materials. Perhaps the most startling development has been in the synthesis of two or more components to produce materials having certain desired characteristics unobtainable in the individual components. The products of such synthesis are known as composites. Familiar composites are ferrocement, fiber reinforced concrete, glass reinforced polyester, etc.

Ferrocement and other related composite have been used successfully on a commercial scale using different fabrication techniques. IFIC aims to provide the opportunity in this field through the Journal of Ferrocement Special Issue on Ferrocement Prefabrication and Industrial Applications.

SUGGESTED TOPICS

- Innovative Applications
- Innovative material: mechanical properties and performance.
- Detailed construction information.
- Research and developments.

REQUIREMENTS

- Papers should pertain to precast ferrocement elements and related materials.
- Papers should be original.

DEADLINES

Submission of title and abstracts : 1 July 1985
Notification of preliminary acceptance : 1 September 1985
Submission of completed manuscript : 1 December 1985
Notification of final acceptance : 1 March 1985
FIRST ANNOUNCEMENT

FERROCEMENT CORROSION: AN INTERNATIONAL CORRESPONDENCE SYMPOSIUM

Objectives:

. To provide an opportunity to review and update the existing knowledge on ferrocement corrosion

. To discuss corrosion problems and recommended practices

Call for Papers

Papers are invited on all aspects of ferrocement corrosion. Intending authors are requested to submit two copies of the abstract in English of not more than 500 words before 15 January 1986. A preliminary acceptance will be made on the basis of the abstract and the final acceptance will be based on the full-length manuscript which will be required by 15 May 1986.

Schedule

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ANNOUNCEMENT

THE FIRST EAST ASIAN CONFERENCE ON STRUCTURAL ENGINEERING & CONSTRUCTION

Imperial Hotel, Bangkok, Thailand

January 15-17, 1986

Co-sponsored by

ASIAN INSTITUTE OF TECHNOLOGY
OVERSEAS CONSTRUCTION ASSOCIATION OF JAPAN, INC.

under the Auspices of

Association of Structural Engineers of the Philippines, Chinese Institute of Civil and Hydraulic Engineering, The Consulting Engineers Association of Thailand, Engineering Institute of Thailand, Hong Kong Institution of Engineers, Indonesian Society of Structural Engineers, The Institution of Engineers, Malaysia, Japan Society of Civil Engineers, Korean Society of Civil Engineers, National University of Singapore, Tongi-Ji University, and University of the Philippines.

Conference Objectives: The First East Asian Conference on Structural Engineering and Construction (EASEC) aims at providing a forum for researchers and practicing engineers working in the East Asia and Pacific region to meet and communicate recent advances in the fields of structural engineering and construction.

After the first Conference, it is planned that more conferences of this theme will be held at intervals of two years. The official language of the Conference is English.

During this conference, the possibility of establishing a professional society of structural engineers in the region will also be explored. More than 200 delegates from most countries in Asia and Pacific are expected to participate in this Conference.

Call for Paper: All topics within the broad fields of structural engineering and constructions including super structures and foundation structures are invited. Provision will also be made for engineers to present papers on the practical as well as on the general professional aspects of structural engineering & construction in the region. Abstract of approximately 300 words should reach the EASEC-1 Secretariat by July 15, 1985.

Registration: The registration fee for all participants is Baht 1250 (US$ 1 is roughly Baht 27), and will be discounted to Baht 1000 if received before December 15, 1985. This fee will cover a volume of the Conference Proceedings, entrance to all technical sessions and official functions, daily lunches, as well as coffee service during the session breaks.

Post Conference Workshop: Immediately after the Conference, a 3-day Microcomputer Workshop on Structural Engineering Applications and Practice (M/SEAP) will be held at the Asian Institute of Technology.

For Further Details please write to:

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India

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Economic and Social Commission for Asia
and the Pacific (ESCAP)
Bangkok 2, Thailand

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6055 Flamingo Drive
514 Roanoke, Virginia
U.S.A.

Mr. Simcha Yom Tov
Kibutz Dalia 18920
Israel
This is a partial list of ferrocement experts in the current survey conducted by IFIC on the current status of ferrocement scientists, designers, builders of ferrocement structures and manufacturers of ferrocement materials. The aim is to provide communication and collaboration within the field. Entries were received from January 1, 1985 to March 31, 1985.

Guide to Format

A. Scientists/Designers—Nine categories of information constitute each bibliographical entry for each individual. Each category of information is designated by a number and within each category the following format has been employed:
1. sex; year of birth; country of birth; nationality; marital status; mailing address,
2. degree, institution; field or discipline,
3. current position, organization; (duration) previous position only related to ferrocement, organization,
4. total number of papers published; five latest papers on ferrocement and related materials,
5. title of current research project, (date of completion)
6. name of language followed by A B C or D or all
   A means “ability to deliver lectures and speeches”
   B means “ability to converse with ease”
   C means “ability to conduct a very small group or one-to-one conversation”
   D means “ability to use written materials for research in his own field”,
7. IFIC Consultant; IFIC Resource Speaker,
8. awards,
9. structures completed; professional experience.

B. Builders/Consultants/Manufacturer—Six categories of information constitute each entry for each organization. Each category of information is designated by a number and within each category the following format has been employed:
1. address; telephone number; telex number; cable address; contact person.
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3. scope of activities,
4. description of structures/product,
5. mechanical properties; advantages; construction method; production system; number of structures; location; date of completion; unit cost,
6. patent and license situation.
Douglas ALEXANDER

Mr. Alexander is an international consultant in the design and construction of motorized barges, tugs and fishing vessels, storage tanks and buildings, since 1960. Many ferrocement vessels were built following his design. Mr. Alexander pioneered the research and development of high tensile wire reinforced fibrous ferrocement. He has published numerous papers on the subject. His book ‘Widening Application of Ferrocement’ outlines the theory and practice of the high tensile wire reinforced fibrous ferrocement. He is also a member of the Editorial Board of the Journal of Ferrocement and a corresponding member of ACI Committee 549 on Ferrocement.

G. GALBRAITH

Mr. Galbraith is a sculptor. Collectors across Canada, the United States and Britain are among those who are sharing the spirit of his art. The broad response to Mr. Galbraith’s work is no doubt a reflection of his own varied and colourful background. He received his degree in chemistry from Paisley Technical Institute in Scotland and was connected with Suncor Canada as manager technical services for twenty years. In the late 60’s, Mr. Galbraith made his first steatite carving and though busy as a laboratories administrator through the 70’s, sculpture played an increasingly important role in his life. In 1977 Mr. Galbraith began his full time dedication to sculpture. In his relentless desire to express his feelings through form, he uses wood, metal, clay, bronze, stone and ferrocement as medium.

S.P. PRAWEL

Dr. Prawel received both his B.C.E. and M.S. degrees from the Georgia Institute of Technology, Atlanta, Georgia; his Ph.D. in Civil Engineering is from the University of Waterloo, Waterloo, Ontario, Canada. He has been a member of the Civil Engineering Department, State University of New York at Buffalo since 1958, teaching structural design, numerical methods and computer analysis of structures. Dr. Prawel also taught in the Architecture School of the same institution for several years. His research interests include studies of conflicting design philosophies, nonlinear computer methods in structural analysis and design, the development of ferrocement as a modern construction material with emphasis on seismic applications.
SCIENTISTS/DESIGNERS

BASUNBUL, Islam Ahmed
(1) M; 1950; Saudi Arabia; Saudi; m; Chairman, Civil Engineering Department, UPM No. 1895, University of Petroleum and Minerals, Dharam 31261, Saudi Arabia
(2) B.Sc., University of Colorado, U.S.A.; M.S. and Ph.D. University of California, U.S.A., Structural Engineering
(3) Assistant Professor and Chairman, Civil Engineering Department, University of Petroleum and Minerals, Dharam, Saudi Arabia; (1972-1973) Principal investigator for research project in developing ferrocement structural components for housing, University of California
(4) [8] “Fire Resistance of Ferrocement Load Bearing Walls” Research Report, University of California
“Mechanical Properties of Ferrocement” Research Report, University of California
“Strength Test of IHC-DUFTEC Wall Panels” Research Report, University of California
“Behaviour of Composite Concrete Beams” Research Report, University of California
(5) Study and design of ferrocement structural system (January 1986); Bond behaviour of reinforced concrete beams (1987)
(6) Arabic ABCD; English ABCD
(7) IFIC Consultant; IFIC Resource Speaker

GALBRAITH, Angus, D.
(1) M; 1932; Canada; Canadian; m; Box 518, Lake Cowichan, British Columbia, Canada VOR 2GO
(2) H.N.C. Paisley Technical College, Paisley Scotland; Chemistry
(3) Sculptor; (1958-1978) Manager Technical Services, Sunoco- (Tar Sand Developers)
(6) English ABCD
(7) IFIC Consultant; IFIC Resource Speaker

TANG, John Chow Ang
(1) M; 1946; Malaysia; Malaysian; m; No. 44 Jalan Radin Anum 2, Sri Petaling, Kuala Lumpur, Malaysia
(3) Managing Director, Structural Concrete Sdn. Bhd; (1976-1980) Research Student, Department of Civil and Structural Engineering, University of Sheffield
(5) Fibrous ferrocement as a shell structure for decorative fascia panels.
(6) English ABCD; German CD; Mandarin BCD
(7) IFIC Consultant; IFIC Resource Speaker
BUILDERS/CONSULTANTS/MANUFACTURERS

STRUCTURAL CONCRETE SDN. BHD.

(1) No. 44 Jalan Radia Anum 2, Sri Petaling, Kuala Lumpur Malaysia; 03-355519; MA 31754; ________; Dr. John Tang Chow Ang, Managing Director

(2) Limited Liability Company; 1981; Peninsular Malaya; 10 Milestone, Ipoh Road, Kuala Lumpur Malaysia

(3) Precast prestressed concrete fabrication and industrialized method of construction. Buildings, civil works and products

(4) Double storey bungalow using precast C-channel floor slab; Bank Negara extension (Phase III) using precast prestressed double tee beams and precast fascia; Eight flats on 47 Section 87A Town of Kuala Lumpur; Soya Sauce Factory, Selangor
A. REINHORN

Dr. Reinhorn received his first degree in 1968 and his Ph.D. in Civil Engineering from Technion-Israel Institute of Technology in 1978. In addition to being a lecturer at the same institution, he has designed and supervised the construction of several reinforced concrete and steel structures in Israel. Dr. Reinhorn is an assistant professor at the State University of New York at Buffalo since 1980 and is doing research in the behavior of ferrocement materials and masonry structures as well as active control of structures during strong ground motion.

WANG, K.M.

Mr. Wang is vice-director of Teaching Research Department of Building Structure, Northwest Institute of Building Engineering in Sian, People's Republic of China since 1982. Prior to this, he was director of Ferrocement Research Group, Research Institute of Building Materials in Peking, 1958-1966 and Head of Ferrocement Research Department, Soochow Research Institute of Cement Products, 1966-1981. Mr. Wang graduated from Qing-Hua University in 1958.

Z. JIA

Mr. Zihe Jia is a graduate of Beijing Institute of Civil Engineering and Architecture, in the People's Republic of China (1982). After completing his Master's degree in 1984, he started his Ph.D. studies at the State University of New York at Buffalo, where he is presently a candidate and a research assistant. Mr. Jia has taught and has undertaken research on theory of structures in China and in the U.S. His main interests are in the areas of structural dynamics and earthquake engineering, stability of structures and ferrocement and its applications in structural engineering.
Abstracts

JFP 55 STUDY ON FERROCEMENT WITH PRESTRESSED BARS

KEYWORDS: Compression, Eccentricity, Ferrocement, Flexure, Mechanical Property, Prestressing, Strength, Tension, Testing.

ABSTRACT: The paper deals with the working principle of ferrocement with prestressed skeletal bars, according to the advantageous effects of the components which are acting mutually. The results of its mechanical properties are analysed. On the basis of the analysis, the paper presents a method of calculating the strength of members, which has been proved through extensive testing and can be used in the design of products. The applied structural examples in this paper show tangible technical and economic benefits of products of ferrocement with prestressed skeletal bars. The development and application of such products should be further pursued.


JFP 56 EXPERIMENTAL STUDY OF FERROCEMENT AS A SEISMIC RETROFIT MATERIAL FOR MASONRY WALLS

KEYWORDS: Ferrocement, Masonry, Repair, Seismic Resistance, Strength, Tension, Testing, Wall.

ABSTRACT: The existence in earthquake prone regions of many older masonry buildings, built before any provision for earthquake loading was required, presents one of the most serious problems facing the earthquake engineer today. This problem has generated a wide range of research directed to both the retrofit and repair of such structures. The research reported in this paper has to do with testing the suitability of a thin ferrocement overlay for such an application. A total of seven specimens were constructed and tested to destruction in diagonal tension. Two of these were bare brick masonry and the remainder had a ferrocement overlay with various amounts of steel reinforcement. The results of the testing indicate a very high potential for this procedure to become a method of choice for retrofit-repair applications.


27-28 August, 1985: Tenth Annual Conference on Our World in Concrete and Structures, Singapore. Contact: John S.Y. Tan, Ci-Premier PTE Ltd., 150 Orchard Road 07-14, Orchard Plaza, Singapore 0923.

9-11 September, 1985: Third International Conference on Composite Structures, Paisley, Scotland. Contact: Mrs. MacDonald, Centre for Liaison with Industry and Commerce, Paisley College of Technology, High Street, Paisley, Renfrewshire, Scotland, U.K.


24-27 September, 1985: Seventh International Conference on Boundary Element Methods in Engineering, Lake Como, Italy. Contact: Miss. G. Dyer, CAES, 125 High Street, Southampton SO1 OAA, U.K.


25-27 September, 1985: First European Conference on Composite Materials, Bordeaux, France. Contact: Dr. A. Massiah, EACM, 2 place de la Bourse, 33076 Bordeaux, Cedex France.

2-6 December 1985: International Symposium on Cement-Based Composites: Strain Rate Effects on Fracture, Boston, U.S.A. Contact, Prof. S. Mindess, Dept. of Civil Engineering 2324 Main Hall, University of British Columbia, Vancouver, B.C. V6T 1W5, Canada.

14-20 December, 1985: International Colloquium Workshop on Concrete in Developing Countries, Lahore, Pakistan. Contact: M. Saeed Mizra, Department of Civil Engineering and Applied Mechanics, McGill University, 817 Sherbrooke St., W., Montreal, Quebec, Canada H3A 2K6.
21-25 April, 1986: 2nd International Conference on Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Madrid, Spain. Contact: Mohan Malhotra, CANMET, 465 Rochester Street, Ottawa, Canada K1A 0G1.

28-30 May, 1986: 8th International ERMCO Congress, Via Umberto Tupini, Rome. Contact: Organising Secretary, ERMCO'86, Associazione Nazionale Costruttori Edili, 16-18 Via Guttani, I-00161 Rome. or Secretary General, European Ready Mixed Concrete Organisation, Shepperton House, Middlesex TW17 8DN, U.K.

13-17 July, 1986: Third International Symposium on Developments in Fibre Reinforced Cement and Concrete, Sheffield, England. Contact: Mr. R.L. Wagstaffe, Conference Secretary, Material Research Ltd., Dell Road, Rochdale, Lancashire OL12 6BY, U.K.

2-4 September, 1986: Conference on Automated Composites '86, Nottingham, U.K. Contact: Dr. P.J. Hogg, Department of Materials, Queen Mary College, Mile End Road, London E1 4NS, U.K.

7-12 September, 1986: 8th European Conference on Earthquake Engineering, Lisbon, Portugal. Contact: Organizing Committee, 8ECEE, a/c Laboratorio Nacional de Engenharia Civil, Av. do Brasil 101, 1799 Lisboa Codex, Portugal.


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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
S.N. Iddings Civil Engineer, Ludlow Falls, Ohio, U.S.A.
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K. Sashi Kumar Senior Information Scientist, International Ferrocement Information Center, Thailand
D.N. Trikha Professor, University of Roorkee, India
M. Wieland Associate Professor, Asian Institute of Technology, Thailand
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This report is the product of the workshop “Intro-
duction of Technologies in Asia — Ferrocement, A Case
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The Journal of Ferrocement is published quarterly by the International Ferrocement Information Center (IFIC) at the Asian Institute of Technology. The purpose of the Journal is to disseminate the latest research findings on ferrocement and other related materials and to encourage their practical applications, especially in developing countries. The Journal is divided into four main sections:

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(c) Technical Notes
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