IMPROVEMENT IN DURABILITY OF FERROCEMENT USING FLY ASH AND SILICA FUME MODIFIED MORTAR

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Abstract
Ferrocement has proven itself as an excellent material for low cost housing. It has high degree of ductility and energy absorbing capacity and has been increasingly used both in terrestrial and marine environments as a structural grade material system, which competes favourably with reinforced concrete and other building materials. Success of ferrocement, as with other materials, depends largely upon its durability. Reinforcement corrosion is one of the most important criteria governing durability of the ferrocement since the diameter of the wire meshes used in ferrocement are much smaller as compared to the conventional reinforced cement concrete. In the present investigation an attempt has been made to modify the conventional mortar using fly ash and silica fume so that the dense matrix can be achieved. The strength properties as well as protection of the steel wire mesh against corrosion have been investigated.

Key Words: Ferrocement, fly ash, silica fume, partial replacement of cement, compressive strength, corrosion control.

1. INTRODUCTION

Providing low cost housing especially to middle and low income group both in rural and urban areas is a serious national problem. The magnitude and acuteness of the problems is obviously more pronounced in urban areas. Also the conventional construction materials are becoming excessively costly day by day. Innovative and low cost construction materials and techniques thereby become urgent need. Ferrocement may serve as one such alternative. It has proven itself as an excellent material for low cost housing. It has high degree of ductility and energy absorbing capacity and has been increasingly used both in terrestrial and marine environments as a structural grade material system, which competes favourably with reinforced concrete and other building materials (Hermosura, and Austriaco, 1994; Ramli and Wahab, 1994; Arif et al.1994; Naaman, 2006).

Investigations on the use of pre-cast ferrocement elements in low cost housing have proved the effectiveness of the material system under static conditions. The prefabricated ferrocement elements have also been used successfully in both residential and industrial buildings. It has been established in the studies reported that the ferrocement has performed well under almost all the loading conditions, whether it is tension, compression, flexure, shear, torsion, fatigue, impact or the dynamic loading. A large number of experimental and analytical studies dealing with ferrocement structural elements, having various shapes and sizes, subjected to different loading conditions are reported in literature. These studies have established the material worthiness for use in diversified applications and prove it to be a strong alternative to conventional construction material. Improvement in strength of ferrocement has also been suggested through the use of different types of wire meshes and modified mortar (Desai and Desai, 1988; Mathews et al. 1994; Rivas, 1994; Pande et al., 1997; Olvera, et al., 1998; Osorio and Rivas, 1998; Lau et al., 2001).

Ferrocement is an excellent material for use in house construction mainly for roofing because of its relatively low cost. Its ease in manufacture and fabrication by supervised local labourer using mainly indigenous materials further makes it an extremely good choice in pre-fabricated housing. If modified mortar has been used, the cost of the ferrocement elements can be reduced further (Pama, 1990; Arif et al., 2001). In the present study it has been attempted to address the problem of durable low cost housing in conjunction with the waste management. In the first part of investigation the compressive strength of mortar cubes prepared from cement replacement with the fly ash and silica fume were studied. In the later part of the investigation ferrocement cuboids were cast and tested for estimating corrosion resistance provided by the dense mortar.
2. EXPERIMENTAL PROGRAMME

Mortar mix ratios (cement:sand : 1:3.0) was chosen for the preparation of mortar cubes. In each mix cement was replaced with 5, 10, 15, 20 and 25% fly ash and silica fume. The water cement ratio was varied as 0.30, 0.35 and 0.40.

For the tests undertaken Ordinary Portland cement (43 grade) was used. The initial and final setting time was found to be 43 and 460 minutes. Locally available coarse sand has been used as fine aggregate. Fineness modulus of the sand was found to be 2.25. The properties of fly and silica fume are given in Tables 1-2. Potable water has been used for mixing and curing. Welded square wire mesh having average diameter of 1.42 mm and opening size 25.4mm were used for the preparation of ferrocement cuboids. Yield strength of the wire mesh was found to be 300 N/mm².

3. TESTING OF MORTAR CUBES AND FERROCEMENT CUBOIDS

Mortar cubes of 100×100×100 mm size were cast in triplicate with varying proportions of cement, fine aggregate, fly ash and silica fume. The water cement ratio was varied as 0.30, 0.35 and 0.40. These mortar cubes were tested for compressive strength. The details of the mix and the test results are given in Tables 3. For the corrosion tests ferrocement cuboid specimens of size 35 × 35 × 24 mm were prepared using best performing mortar mix in compressive strength test in both the categories. For the comparison cuboids without any additive (0% replacement of cement) were also prepared to serve as control specimen. Welded steel meshes were used as reinforcement in the cuboid specimens (Figs 1-2). These specimens were exposed to alternate drying and wetting cycle in accelerated corrosion testing simulator in the presence of 3.5% NaCl solution. After undergoing 60 wet and dry cycles of 24 hrs each the specimens were tested using AC Gill potentiostat (Fig.3). After the test the wire mesh was taken out by splitting the specimen for visual observation.

Table-1

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
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</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Light grey</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.40</td>
</tr>
<tr>
<td>% Retained on 90µ IS Sieve</td>
<td>47</td>
</tr>
<tr>
<td>% Retained on 75µ IS Sieve</td>
<td>68</td>
</tr>
</tbody>
</table>

Table-2

Properties of silica Fume

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Grey</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Table-3

Compressive Strength of Mortar Cubes with Fly ash and Silica Fume

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Mix Proportions (C:FA/SF:FA)*</th>
<th>W/C ratio</th>
<th>Compressive strength of cubes at 28 days (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fly ash</td>
</tr>
<tr>
<td>1.</td>
<td>1.0:0.0:3.0</td>
<td>0.30</td>
<td>38.0</td>
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<tr>
<td></td>
<td></td>
<td>0.35</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.40</td>
<td>43.1</td>
</tr>
<tr>
<td>2.</td>
<td>0.95:0.05:3.0</td>
<td>0.30</td>
<td>32.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.35</td>
<td>45.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.40</td>
<td>45.2</td>
</tr>
<tr>
<td>3.</td>
<td>0.90:0.1:3.0</td>
<td>0.30</td>
<td>27.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.35</td>
<td>46.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.40</td>
<td>46.2</td>
</tr>
<tr>
<td>4.</td>
<td>0.85:0.15:3.0</td>
<td>0.30</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.35</td>
<td>46.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.40</td>
<td>47.3</td>
</tr>
<tr>
<td>5.</td>
<td>0.80:0.20:3.0</td>
<td>0.30</td>
<td>20.0</td>
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<td></td>
<td></td>
<td>0.35</td>
<td>48.7</td>
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<td></td>
<td></td>
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<td>47.0</td>
</tr>
<tr>
<td>6.</td>
<td>0.75:0.25:3.0</td>
<td>0.30</td>
<td>14.0</td>
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<td></td>
<td></td>
<td>0.35</td>
<td>36.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.40</td>
<td>35.1</td>
</tr>
</tbody>
</table>

C: Cement; FA: Fly ash; SF: Silica fume; FA: Fine aggregate

Fig.1 Specimen under preparation
4. DISCUSSION ON TEST RESULTS

An increase in compressive strength values as compared to the corresponding control has been observed in fly ash modified mortar for the w/c ratios 0.35 and 0.4. This increase is observed for cement replacement up to 20%. However with the w/c ratio 0.3 in the entire six mix ratios, the values are less than the control specimen. Also for the 25% replacement the values of the compressive strength has been observed to be lower than the control values.

Similar trend has been observed for the silica fume modified mortar for the cement replacement up to 15%. However the compressive strength values are substantially higher in case of silica fume modified mortar than the control as well as the fly ash modified mix. The increase in the compressive strength values for the most of the mixes may be attributed to the improved packing of the entire mass thereby providing a relatively dense matrix. However for other mixes where the values are lower than the control reason appears to be increased water demand due to increased surface area of the ingredients of the matrix.

It is evident from Tafel plot (Fig.4) that the substantial protection of reinforcement from corrosion has been achieved in modified mortar specimens. In both the specimen reduced corrosion current values as compared to the control specimen is suggestive protection of steel wire mesh embedded inside the modified mortar specimens. Visual inspection of the welded steel wire mesh used in the specimens and taken out by splitting the tested specimen, clearly indicates the onset of corrosion in control (Fig.5). A little stain mark can be observed in fly as modified mortar specimen’s mesh whereas silica fume modified matrix mesh is completely free of corrosion. This could be attributed to the dense mortar not allowing much ingress of chloride ion into the matrix which is responsible for the corrosion of the embedded steel.

5. CONCLUSIONS

It has been concluded from this study that if the matrix is properly modified not only the strength of the matrix is improved but the reinforcement used in the form of the wire mesh can also be protected from corrosion. This will definitely lead to improvement in durability thereby adding prolonged life to the ferrocement structural elements.
REFERENCES


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Dr. Sabih Akhtar is Associate Professor in the Department of Civil Engineering, Aligarh Muslim University (AMU), Aligarh, India. He has obtained his bachelor’s degree from B.U. in the year 1991, Masters in 1994 and Ph. D. in 2008 from A.M.U in the area of structural engineering.

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