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Performance of polymer modified ferrocement in mortar

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Abstract— **Ferrocement is a highly versatile reinforced composite material suitable for several applications such as roofing and flooring elements, water tanks, boats, other building elements like doors, lintels etc., because of its durability, crack resistance and cost effectiveness (ACI 549, 1997). Ferrocement has very high tensile strength to weight ratio and superior cracking behavior (ACI 318, 2008). In the developing countries like India, china, Japan etc., Ferrocement is being extensively used in the applications of (a) Housing (b) Marine (c) Agricultural (d) rural energy and (e) repair and rehabilitation. Large number of experimental and analytical studies has been reported in the area of Ferrocement flexural elements.**

In this paper the behavior of a 500×100×20 mm beam containing mortar Ferrocement elements were studied. Mechanical Properties of all Ferrocement specimens were studied by analyzing the overall behavior change by addition of 0%, 5%, 10%, 15% and 20% of SBR polymer in Ferrocement for 7 & 28 days. From the study it was observed that, the engineering properties such as Flexural strength and tensile strength of different Ferrocement sections were found to improve with the increase in the percentage of volume fraction.

***Keywords*: Ferrocement, SBR Polymer; Mechanical Properties**

I. INTRODUCTION

There is a great demand for building materials these days. All the building materials are nonrenewable resources; hence they must be properly conserved and effectively used. To avoid the use of coarse aggregates and to reduce the thickness of elements, the Ferrocement technology is used in this study. To improve the strength of Ferrocement elements, a synthetic SBR polymer material namely "Styrene butadiene rubber" in latex forms. The engineering properties like compressive strength, and the flexural strength were determined for the cement mortar (by varying the percentages of cement as 0%, 10%, 15% and 20 % of the total volume of specimens). In addition to this, the impact studies were conducted on polymer modified Ferrocement beam of size 500mm X 100mm X 20mm to find the influence of SBR polymer in different proportions. Ferrocement scaled models were made according to the results obtained from the impact test conducted. In order to cope with the problem of thickness, one of the options currently suggested is to develop Ferrocement elements. This technique provides not only the thickness but makes the element lightweight as well. Presently, it has gained Polymers can be divided into 3 main structures named linear polymers, branched polymers, and cross linked polymers. Linear polymer consists of monomers that are linked in a long chain. Branched polymers have another chain that is bonded to the long molecular chain. These chains are formed with the presence of monomer from reactive group. Cross linking polymers have two or more chains that are linked by short side chains. A more complex link will gives us a three dimensional structure while lowly linked chains will give a two dimensional structures.

The incorporation of polymers into mortar system requires compatibility between both polymer and aqueous solutions. Polymer may be added in a dispersed, powdery, or liquid form into the fresh mortar. Among the few types of polymer-modified mortars are latex-redispersible polymer powder, water-soluble polymer, liquid resin, and monomer-modified mortar. Of these, the latex-modified mortar is the most widely used cement modifier. In the polymer-modified mortar, aggregates are bound by monolithic phase and polymer phase interpenetrate. This co-matrix phase results in an improved properties of polymer-modified mortar compared to ordinary mortar (Ohama, 1995).

II. EXPERIMENTAL BEHAVIOUR

The study was aimed to present the effects of polymer addition on compressive strength, and flexure strength on Ferrocement beams.

Objectives

- To determine the workability of the fresh polymer modified mortar with different polymer cement ratio..
- To obtain the compressive strength of ordinary mortar with polymer modified mortar with constant and varied water cement ratio.
- To obtain the flexure strength, tensile strength and corresponding deflection or elongation of the polymer modified Ferrocement beams.

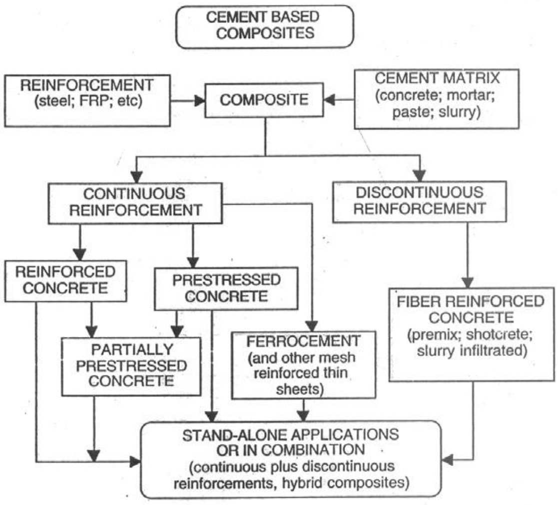


Fig2 Structural Concrete Family (Naaman, 2000)

The main aim of study is to find out the optimum value of polymer in Ferrocement mortar and its effect on the properties of mortar. The polymer modified Ferrocement beams were casted to find flexural and tensile strength. Prior to evaluate these parameters the flow value of controlled as well as polymer modified mortar. Its effect was studied on flexural and tensile of Ferrocement samples having a square wire mesh inside it.

III. TESTING

First Phase: - Compressive Strength

The first phase of testing will include investigation of compressive strength of polymer modified mortar for variations in polymer content (0 to 20%) (SBR Latex). Compressive strength is the major test done during this study the cubes were tested on UTM installed in concrete structure laboratory. The compressive strength was calculated by following formula:

$$f = F/A$$

Where:

f = Compressive strength (MPa) F= Ultimate load (N)

A = Cross-sectional area perpendicular to loading direction (mm^2)

The first phase of testing will include investigation of compressive strength of polymer modified mortar for variations in polymer content (0 to 20%) (SBR Latex). Mortar cubical specimens of size 70.6mm will be cast for checking the compressive strength.

Polymer	SBR				
%age	0	5	10	15	20
cubes	3	3	3	3	3

Second Phase: - Flexural Strength

Flexural strength is a measurement that indicates a material's resistance to deforming when it is placed under a load. The values needed to calculate flexural strength are measured with rectangular samples of the material placed under load in a 3 or 4 point testing setup. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength is defined as a material's ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress The transverse bending test is employed, in which a rod specimen having a circular cross-section is used to fracture the beam sample under three point loading.. The size of the sample was chosen as 160*40*40 mm. The rate of loading was fixed as 2.65KN/m. The effective length of the beam is taken as 120 mm. the sample includes the different percentages of mortar detailed in the second phase of experimental outline. It was found that the flexure strength of the polymer modified mortar increases as compared to the unmodified mortars. The maximum strength is achieved by SBR is 7.26 n/mm². The flexure strength of the beam under three point loading can be finding out by the bending equation or by the formula as given below:

$$\sigma = 3F.L/2\ B\ D^2$$

The flexure strength of the beam under third point loading can be finding out by the formula as under:

$$\sigma = F.L/\ B\ D^2$$

Where σ = stress at the outer fiber, F = the load (force) at the fracture point (N), L = the length of the support span (mm) b = width (mm) and d = is thickness (mm)

Investigation of flexural strength of polymer modified mortar for variations in polymer content (0 to 20%) (SBR latex). Mortar specimens of size 40x40x160mm will be cast for checking the flexural strength.

Polymer	SBR				
%age	0	5	10	15	20
No. of specimens	3	3	3	3	3

Third Phase: -Flexural Strength of Ferrocement Beams

The research program encompasses the investigation characteristic of polymer modified Ferrocement elements. The tests include determination of load and deflection characteristics when subjected to static flexure. The structural properties of Ferrocement were determined from the test specimens, 100 mm x 500 mm x 20 mm, reinforced with 2 and 3 layer of square mesh of diameter 0.48 mm and opening 7. 98 mm. A four-point loading was used over a simply supported span of 400 mm to determine the load-deflection properties. The samples were demoulded after 24 hours and then cured in water for 28 days. The Ferrocement specimens were tested at to the ages of 28 days. The flexural test was conducted on UTM as shown in fig. The specimen was subjected to a static load at the loading points. In the middle of the tensile face of Ferrocement specimen dial gauge were also used to measure the static deflection at the centre.

In the third phase, the following physical properties of Polymer Modified Ferrocement (PMF) by using two and three layered woven wire mesh will be investigated as per the relevant standards.

Flexural strength of Ferrocement:.

Polymer	SBR				
%age	0	5	10	15	20
No. of specimens	3	3	3	3	3

Specimen 500x100x20 mm (15.) X 2 = 30 (for 2 and 3 layers)

Phase Four:- Tensile test of Ferrocement

Tensile strength measures the force required to pull the member or a structural beam to the point where it breaks. The test includes determination of load and elongation characteristics when subjected to axial force. The 500 x 100 x 20 mm beams with 2 and 3 layers of Ferrocement at the bottom phase were casted to cover the tensile properties of the polymer modified mortar samples. The samples were tested in UTM machine. The sample was put into the jaw of the UTM machine. Then the tensile force was applied by gripping its edges properly. It was found that the breaking of the sample take place from the middle portion of the beam because the maximum stresses developed at the centre of the beam. The load elongation curve was plotted. The curve shows the linear variation first and then the elongation starts increasing. The results shows that when the beam have same polymer i.e. either VAE or SBR, the elongation in the two layered beams were found more as compared to the three layered Ferrocement beams. Ferrocement elements will be tested directly in tension in accordance with ACI Committee 549 standards.

Polymer	SBR					
%age	0	0	5	10	15	20
No. of specimens	3	3	3	3	3	3

Specimen 500x100x20 mm (15 nos.) X 2 = 30 (for 2 and 3 layers)

IV. DISCUSSION AND RESULT

To obtain the different parameter like compressive strength, flexure strength and tensile strength of mortar and polymer modified mortar it was necessary to find the ratio for each flow value and effect of polymer addition on workability of mortar. Hence flow test was conducted to fix such values and also to find out the water cement ratio at constant of mortar. Before conducting the test, all the specimens were checked for any kind of deformation such as broken edges and cracks. Then the specimens were placed at the center of the cleaned platens of the machine followed by the application of gradual and without shock loading. The samples were casted for each constant and varied w/c ratio i.e. 15 samples for each.

Compressive strength:

The compressive strength of the conventional mortar is 13.56 N/mm2 at constant water cement ratio. The compressive strength of the SBR polymer mortar decreases linearly up to 5 %. From 5 % to 10 % the compressive strength does not vary too much but after 10 % it again decreases linearly up to 20%. At 15 % the strength of each modified mortar is nearly equal but decreases continuously

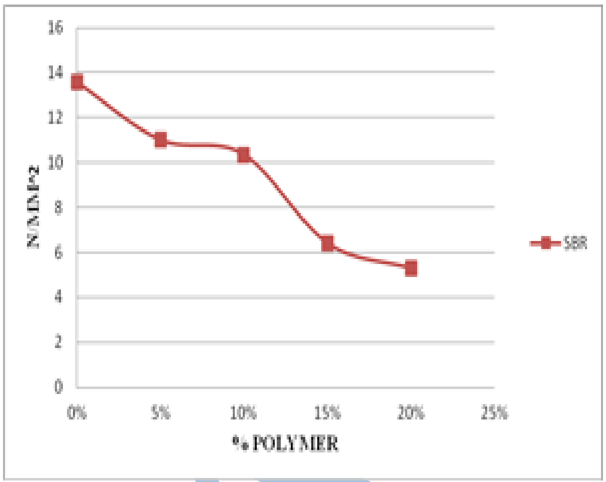


Figure: Compressive Strength Vs % Polymer after 7 days at constant w/c ratio.

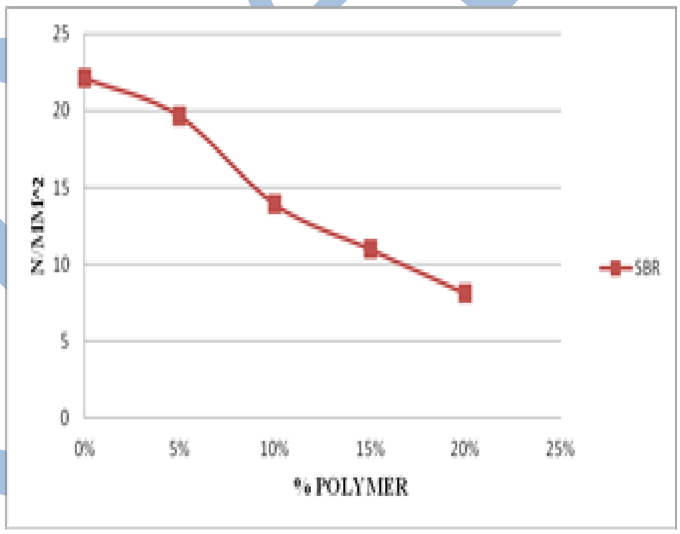


Figure: Compressive Strength Vs % Polymer at constant w/c ratio after 28 days

Compressive strength of SBR modified mortar increases with increase in polymer cement ratio up to 10 %. After 10 % the compressive strength starts decreasing up to 15 % of polymer cement ratio. After 15 % addition of SBR, there is no such effect of polymer addition in mortar and the curve becomes straight up to 20 %. The behavior of SBR modified mortar is concave upward up to 15 %. The graph and results for SBR modified mortars is shown in Figure: The compressive strength of SBR polymer modified mortar decreases at constant water cement ratio. The compressive strength of the SBR modified mortar increases at some extant at varied water cement ratio. This is due to the decrease in the water content at varied w/c ratio as compared to the constant w/c ratio. Due to decreases in w/c ratio the density of mortar increases. Hence the compressive strength of the polymer modified mortar is more for varied w/c ratio as compared to the constant w/c ratio.

Flexure Strength

The flexure strength and the further research are based on the constant flow value. The flexure strength of SBR mortar increases up to 15 % addition of polymer. SBR shows the flexural strength graph concave upward up to 15% and then it starts decreasing the strengths of SBR-modified mortar increase with a rise in the bound styrene content. A film of the bound styrene content is formed in the SBR modified mortar. The flexure strength of the dry films made from SBR latexes increases sharply due to the bound styrene content, and there is a positive correlation between the strength of the films and the flexural strength of SBR-modified mortars with polymer-cement ratios above 5 %. (Ohama, y et al. 1995).

Addition of SBR Up to 15 % act to strengthen the mortar microstructure but a further increase in the polymer content ratio leads to discontinuities in the microstructure which reduces the flexure strength further. As a result the flexure strength of the polymer modified mortar increased up to 15 % and then starts decreasing. The results shown in the diagram is shown in Figure.

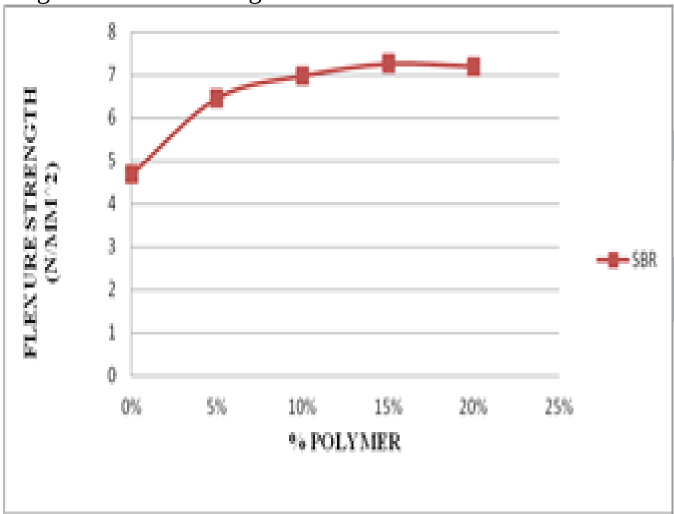
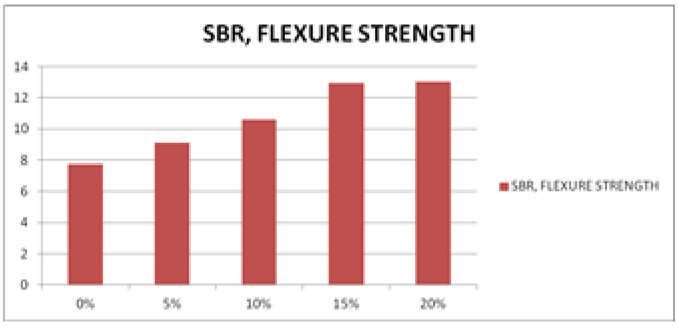


Figure: Flexure Strength Vs % Polymer at constant flow

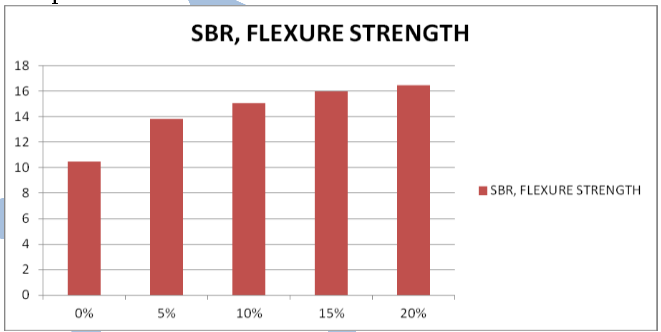
Flexural strength of Ferrocement Beam

The flexure strength of polymer modified Ferrocement samples increases up to 15 %. This is due to the dry films made from VAE and SBR latexes increases sharply due to the bound acetate styrene content, and there is a positive correlation between the strength of the films and the flexural strength of SBR-modified mortars with polymer-cement ratios. (Ohama y et al. 1995)

After 15 % the flexure strength of Ferrocement samples decreases up to 20%.SBR Up to 15 % act to strengthen the mortar microstructure but a further increase in the polymer content ratio leads to discontinuities in the microstructure which reduces the flexure strength further. The results show that the increase of polymer cement ratio up to 15 % increases the capacity of the member to take more loads. The flexure of mortar increases due to both cement hydration and polymer phase formation (coalescence of polymer particles and the polymerization of monomers) proceed well to yield a monolithic matrix phase with a network structure in which the hydrated cement phase and polymer phase interpenetrate. In the polymer-modified mortar and concrete structures, aggregates are bound by such a co-matrix phase, resulting in the superior properties of polymer-modified mortar and concrete compared to conventional. (Ohama Y et al, (1995)).



Flexure Strength Vs % Polymer for two layered mesh Samples.



Flexure Strength Vs % Polymer for three layer mesh samples

It was supposed that the results of maximum compressive strength out of these parameters will be adopted for further remaining works. The compressive strength of polymer modified cement decreases at constant water cement ratio. But at varied water cement ratio the compressive strength of polymer modified cement increases up to 10 % and then starts decreasing after 7 days. The flexure strength of SBR modified mortars increases. The compressive strength of the SBR polymer mortar decreases linearly upto 5 %. From 5 % to 10 % the compressive strength does not vary too much but after 10 % it again decreases linearly up to 20%. After 28 days the compressive strength of both VAE and SBR polymer mortar decreases cement ratio the compressive strength of controlled samples found more as compared to the polymer modified mortar samples. At 15 % the strength of each modified mortar is nearly equal but decreases continuously.

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