International Journal of Engineering Research and Advanced Technology (IJERAT)

DOI: http://dx.doi.org/10.7324/IJERAT.3166

E-ISSN : 2454-6135

Vol.3 (12) Dec -2017

Performance Evaluation of Polymer Modified Ferrocement Mortar

D. Raj Kumar [1] and B. Vidivelli [2]

Assistant Professor [1], Professor [2]

Department of Civil and Structural Engineering

Annamalai University

Annamalainagar - 608 002

Tamilnadu

India

ABSTRACT

The use of ferrocement as a repairing material continues to attract researches. The idea of addition of polymer in ferrocement is gaining attention recently. In spite of the excellent characteristics of ferrocement, their application on building repairs requires special concentration, since this material differs from other conventional repair materials. This article presents the strength results for mortars containing different amounts of polymer and meshes indicating the applicability of these mortars as a repairing material. To complement this study, the important material properties of polymer modified ferrocement mortars, were investigated and the optimum polymer cement ratio of mortar along the volume fraction of meshes were suggested. Addition of polymers increases fluidity of mortars and also the workability due to dispersing effect of polymer particles, action of the surfactants contained as emulsifiers and entrained air in the mix. Such improvements justify its study towards its applications in rehabilitation, repair and strengthening cases. The combination of polymer with ferrocement also results in excellent properties, which are ideal for repairs requiring high performance.

Key words: *Polymer, Latex, Ferrocement, Mortar, Mesh, Volume Fraction.*

1. INTRODUCTION

Researches about the polymer mortar composites have been earnestly initiated since 1970's and the researches about development and application for a new material have been continuously carried out. Furthermore, nowadays when people's attitude for protecting the existing structure is gradually strengthened, development and usage of the sustainable repair materials are strongly required by the environmental factors like the global warming due to carbon-dioxide and the construction wastes. Based on the point of view, many researches were ongoing with the mortar polymer composite to develop the new related materials and their research results are being utilized in various fields. Ordinary Portland cement is recognized as the most widely used building material even though the cement concrete and mortar has a number of limitations such as low flexural strength, low failure strain, susceptibility to frost damage and low resistance to chemicals. These properties can be improved by using polymer modified concrete or mortar. The types of polymers generally used in modifying mortars and concretes are either thermoplastic or thermosetting resins which can be classified into three broad groups, namely liquid resins, latexes and water soluble homopolymers and copolymers (Limaye and Kamath, 1992). In the preparation of the polymer modified mortars, copolymer latexes are usually employed as cement modifiers to vary mortar properties (Ohama et al (1991). However, plain concrete or mortar is a brittle material with low tensile strength and high possibility of crack development. In normal strength cement based materials, it is believed that cracks and large pores that govern the physical and mechanical properties mainly occur in the interfacial zone between aggregates and hardened cement paste. Therefore, if polymer is used to improve the microstructure towards physical and mechanical performances of cement mortar, it will be more effective to increase concentration of polymer within interfacial zone than having a uniform distribution of polymers in the whole composite, in consideration of strengthening the weakest part of the materials (Okba et al 1997). Previous studies state that the oxygen diffusion resistance of the polymer modified mortars is superior to that of unmodified mortar with an increase in the polymer cement ratio Ohama and Demura (1991). Mineral admixture often has the effect on the brittleness of mortar (Zeng et al 2003). In order to enhance the tensile mortar capacity and to avoid brittle failure, investigations are being carried out on the introduction of additives to plain ferrocement. Generally admixtures are used in concrete or mortar in order to increase workability, accelerate time of initial set, reduce bleeding and segregation, reduce permeability, reduce shrinkage, accelerate the rate of strength development, increase strength and durability, increase bond between old and new concrete and reduce the cost of concrete by reducing cement content for a given strength and workability. A polymeric admixture, or cement modifier, is an admixture which consists of a polymeric compound that acts as a main ingredient for the modification or improvement of mortars and concretes properties such as strength, deformability, adhesion, water proof and durability. Polymer latex is a colloidal dispersion of small polymer particles in water, which is obtained by the emulsion polymerization of monomers with emulsifiers. Hence, additives are now an essential component of modern repair works with use of ferrocement. In modern world ferrocement is a dominant repair material for bridges, tunnels, dams, canals, high-rise office buildings, low rise commercial structures, residential buildings, seaports, harbor structures, airport taxiways, power plants, drinking water and waste-water treatment facilities, floating structures, etc. India is a developing country with very fast growing economy and experiences the need of application of stronger, durable and economic materials to meet the challenges facing local construction industry. Therefore, how to produce the polymer modified ferrocement with required polymer content and volume fraction of mesh with high flexibility becomes an urgent and significant task of material researchers. The paper deals with important material properties of polymer modified ferrocement, to improve their mechanical characteristics and durability.

2. MATERIALS AND METHODS

2.1 Outline Of The Study

The objective of the study is to assess the effects on properties of polymer modified mortar in order to develop high performance mortar with high workability, strength and durability. All materials for preparing the mortar were obtained from local sources. Mixes were prepared with locally available fine aggregates passing through 4.75 mm IS sieve and ordinary Portland 43Grade cement conform to ISI specification. The fineness modulus and specific gravity of fine aggregates was 2.5 and 2.61 respectively. Water cement ratio of 0.4 is adopted for plain mortar and 0.3 for polymer modified mortars. A preliminary test program was set up to investigate the mechanical properties of polymer mortar and polymer modified ferrocement mortars by attachment of different layers of mesh reinforcement with volume fraction (Vr) towards 3.55%, 5% and 6.43% with influence of polymer modification on the properties of cement mortar. Different parameters were taken into account regards to the polymer cement ratio and volume fraction of reinforcement. Two types of polymer emulsion, acrylic rubber latex and styrene butadiene rubber latex was chosen and their basic properties were studied. Mortar specimens were prepared with cement sand ratio of 1:2 mixes with polymer cement ratios of 5%, 10 %, 15% and 20%, (mass of solid phase of polymer emulsion divided by mass of cement) to attain a fair high strength. Mortar cubes and cylinders were tested in axial compression for the estimation of mechanical strength using various empirical relationships primarily based on mortar crushing strength. Experimental test was also conducted on ordinary and ferrocement mortar specimens under two-point flexure with the aim to evaluate the flexure strength. Water absorption test was conducted on mortar cubes with different polymer cement ratios to understand the features in the reduced water absorption of polymer modified mortar. Tensile test was also conducted on steel meshes with three different volume fractions to evaluate the yield strength and the Modulus of Elasticity for polymer modified ferrocement mortars. Apart from improvement in mechanical strength characteristics, load strain behaviour shows significant improvement in load carrying capacity of these polymer-modified systems.

2.2 Investigations on The Use of Polymers In Mortar

Acrylic rubber latex and Styrene butadiene rubber latex are based on polymers with very high molecular weight and are absorbed onto the surface of hydrating cement particles. By breaking down the cement agglomerates the cement particles they become dispersed in water and a colloid is formed. The free water is released and friction between particles is reduced, allowing them to move easily subject to their physical properties. The physical properties related to the two different types of latexes are shown in Table 1.

Table 1 Physical Properties of Latex

Properties	AR Latex	SBR Latex
Stabilizer type	Non-ionic	Non-ionic
Appearance	Milky white	Milky white
Particle size	500mm	200mm
Total solids	44.5 to 45.5%	46.5 to 49.5%
Specific gravity @ 20^{O}C	1.054	1.010
pH @ 20^{O}C	8.6 to10.2	10 to 11
Viscosity @ 20^{O}C	29cP	10 to 12cP
Surface tension @ 20^{O}C	45dyn/cm	32dyn/cm

Influence of polymers on the mortars towards compressive, split tensile and flexural strength development was investigated in order to obtain the optimum polymer content with the influence of AR and SBR latex. The compressive and split tensile strength of polymer modified mortar was found by testing 100 mm size cubes as well as 100 x 200 mm cylinders and its flexural strength by testing 600 x 100 x 25 mm flexure specimens. The 28th day strength presented in Figure 1 & 2 is mostly the average result of the three specimens tested.

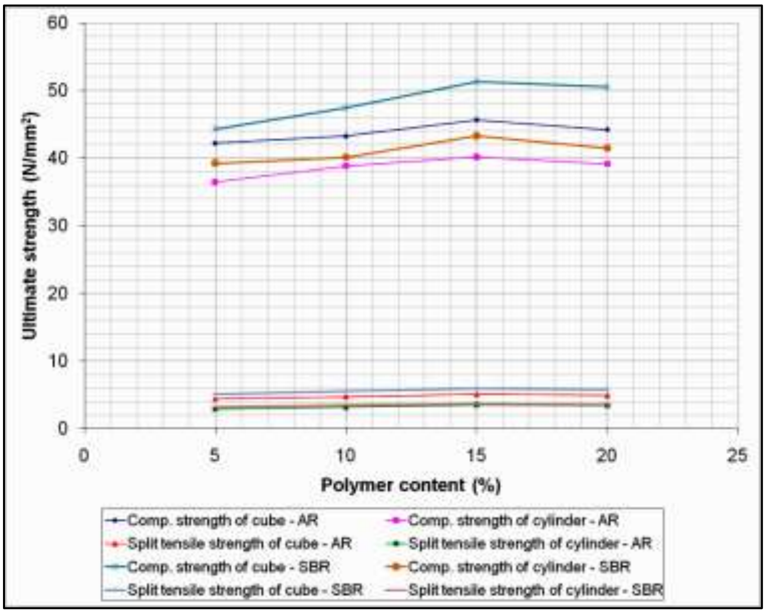


Fig. 1 Polymer content versus strength of polymer modified mortar specimens

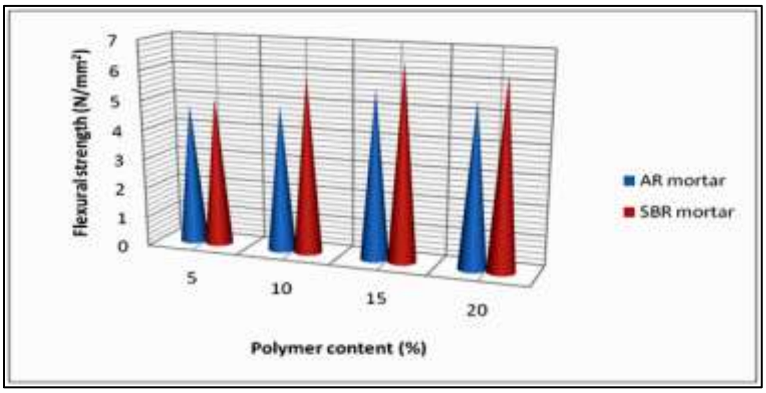
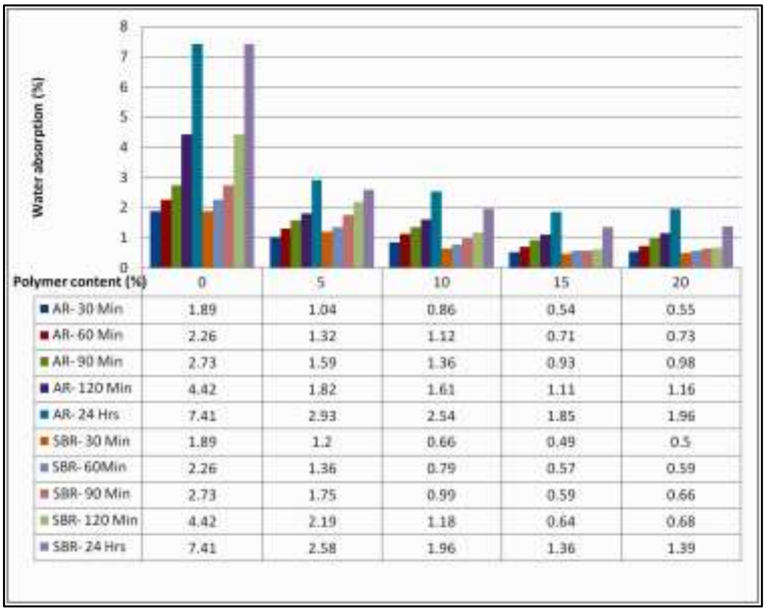


Fig. 2 Polymer content versus flexural strength of polymer mortar specimens

2.3 Water Absorption of Polymers Modified Mortar

Three control specimens and three polymer modified mortar specimens for each set, with size of 70mm x 70mm x 70mm were casted with cement sand ratio of 1:2 at various mixes. Water cement ratio of 0.4 was adopted for plain mortar and 0.3 for polymer modified mortar with polymer content such as 5%, 10%, 15% and 20% by weight of cement, moist cured for 28 days, subsequently dried in atmosphere and weighed (W_1). The dried specimens were immersed in water for the prescribed testing duration such as 30 minutes, 60 minutes, 90 minutes, 120 minutes and 24 hours. The weight of the specimen after immersion period is W_2. The change in weight (W_2 - W_1) expressed as percentage of initial dry weight which is the water absorption of all the specimens tested and is shown in Figure 3.



Polymer content (%)	0	5	10	15	20
AR-30 Min	1.89	1.04	0.86	0.54	0.55
AR-60 Min	2.26	1.32	1.12	0.71	0.73
AR-90 Min	2.73	1.59	1.36	0.93	0.98
AR-120 Min	4.42	1.82	1.61	1.11	1.16
AR-24 Hrs	7.41	2.93	2.54	1.85	1.96
SBR-30 Min	1.89	1.2	0.66	0.49	0.5
SBR-60Min	2.26	1.36	0.79	0.57	0.59
SBR-90 Min	2.73	1.75	0.99	0.59	0.66
SBR-120 Min	4.42	2.19	1.18	0.64	0.68
SBR-24 Hrs	7.41	2.58	1.96	1.36	1.39

Fig. 3 Water absorption of polymer modified mortar

2.4 Meshes Employed With Polymer Modified Ferrocement

Figure 4 (a), (b) & (c) shows the three different types of meshes used with the mortar and the properties related to it are shown in Table 2. The amount of mesh reinforcement adopted is expressed in terms of volume fraction. The volume fraction of reinforcement is the ratio of reinforcement to the volume of composite.

(a) Woven wire mesh (b) Welded wire mesh (c) Twisted wire mesh

Fig. 4 (a), (b) & (c) Mesh reinforcement espoused for mortars

Table 2 Properties of Reinforced Mesh

Type	Shape	Fabrication mode	Gauge designation	Wire spacing in mm	Wire diameter in mm
Expanded steel meshes	Square	Woven	½ No. 20	4.23	0.88
	Square	Welded	½ No. 15	15	1.2
	Hexagonal	Twisted	½ No. 22	12.54	0.72

The arrangement of mesh reinforcement with volume fraction (Vr) of 3.55% contributes with 2 layers of welded mesh with 1.51%, 1 layers of woven mesh with 1.44% and 4 layers of twisted mesh with 0.60%. Also the mesh reinforcement with volume fraction (Vr) of 5% contributes with 2 layers of welded mesh with 1.51%, 2 layers of woven mesh with 2.88% and 4 layers of twisted mesh with 0.61% and the mesh reinforcement with volume fraction (Vr) of 6.43% contributes with 2 layers of welded mesh with 1.51%, 3 layers of woven mesh with 4.32% and 4 layers of twisted mesh with 0.60%. The experimental result obtained from the tension test on steel mesh is also shown in Table 3.

Table 3 Tension Test on Steel Mesh Reinforcement

Vr (%)	Yield stress N/mm^2	Ultimate stress N/mm^2	Youngs modulus (E_r) N/mm^2
3.55	351	679.22	1.996×10^5
5.00	352	683.42	2.00×10^5
6.43	366	698.80	2.032×10^5

2.5 Investigations on The Use Of Meshes And Polymers in Mortar

The objective of the study is to investigate the effect of addition of steel wire meshes and polymers on the properties of cement mortars. The optimum percentage of steel wire meshes expressed as volume fraction was estimated. In a hybrid, two or more types of meshes are joined together to give a combination of properties that cannot be attained in the original material. Hybrid composites are subdivided into two categories such as by using a combination of different sizes of the same steel wire meshes or combination of steel wire meshes of different materials with different modules of elasticity. In this study two different types of polymers such as Acrylic rubber latex and Styrene butadiene rubber latex are used. The purpose of reinforcing the polymer cement-based matrix with steel wire meshes is to increase tensile and flexural strength, impact resistance and fracture toughness of the mortar. Hence the expanded steel meshes such as woven wire mesh, welded wire mesh and twisted wire mesh are used for the study. The effect of three different volume fraction of mesh reinforcement on the properties of mortar towards compressive, tensile and flexural strength was investigated and is shown in Figure 5 and 6. The inclusion of polymers to primary reinforcement (steel wire meshes) in a hybrid improves compressive, tensile and flexural strength of the polymer ferrocement based mortars and these material can be used for structural repairs, thin precast concrete elements, subject to shrinkage or severe impact.

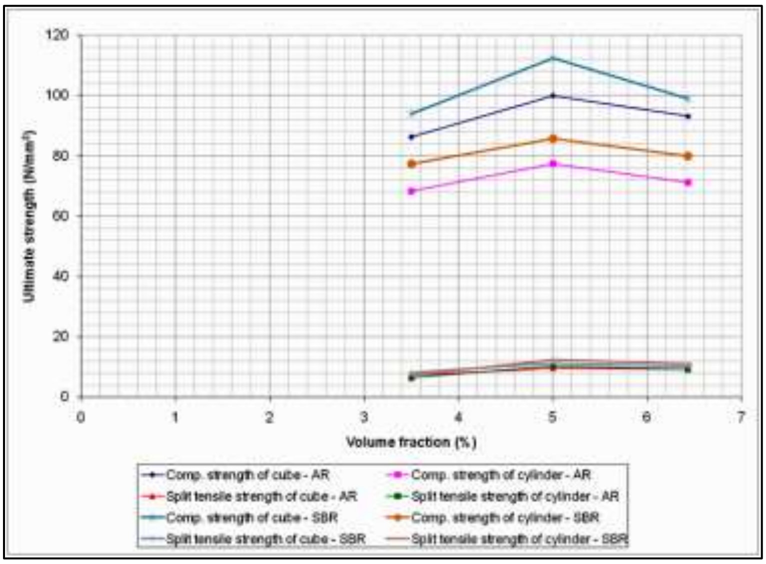


Fig. 5 Volume fraction of mesh versus strength of AR & SBR modified ferrocement specimens

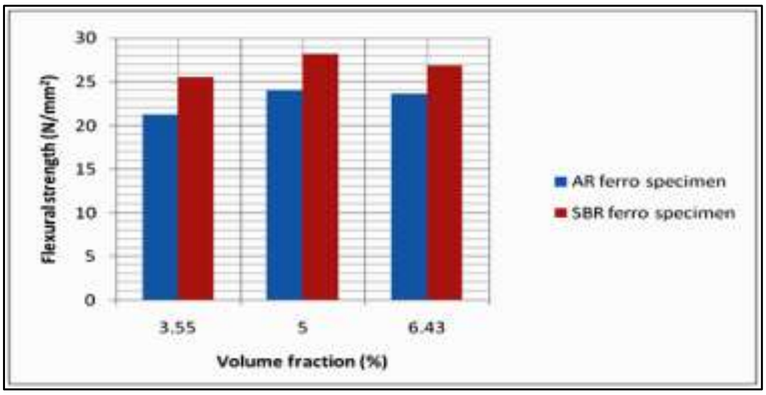


Fig. 6 Volume fraction of mesh versus flexural strength ferrocement specimens

2.6 Modulus of Elasticity of Polymer Modified Ferrocement Under Compression

Cylinder specimens were used to find the values of Modulus of Elasticity of ferrocement under compression and are shown in Table 4. The deformation of cylinder specimen's was measured with electrical strain gauges and deflectometers. According to IS 456: 2000, Modulus of Elasticity of concrete can be computed as $E_c = 5000\sqrt{f_{cu}}$. In this mode, unlike tension, the matrix contributes directly the ferrocement strength in proportion to its cross sectional area. The strength and amount of reinforcement were most appropriately defined in terms of stress and volume fraction of reinforcements.

Table 4 Modulus of Elasticity of Polymer Modified Ferrocement under Compression

S.No	Volume fraction (Vr) %	Type of polymer	Polymer content (%)	Ec (N/mm^2)
1	-	-	-	31292
2	3.55	AR	15	41349
3	5	AR	15	43982
4	6.43	AR	15	42198
5	3.55	SBR	15	43948
6	5	SBR	15	46300
7	6.43	SBR	15	44698

2.7 Behaviour of Polymer Modified Ferrocement Under Tension

Ferrocement is a highly ductile material and its behaviour in tension is contributed by mortar and also by mesh reinforcement. The tensile strength was obtained through 100 x 200 x 25 mm tensile specimens, which was designed in accordance with ACI 549R-97. The strain gauge was attached to the specimen and was kept vertically under UTM and the strains were measured at regular loading interval. The tensile specimens along with test setup are shown in Figure 7. The load-strain profile established from the experimental values with three different volume fraction of reinforcement for meshes towards AR ferrocement specimens is shown in Figure 8 and also with SBR ferrocement specimens in Figure 9.

Fig. 7 Tensile specimens along with test setup

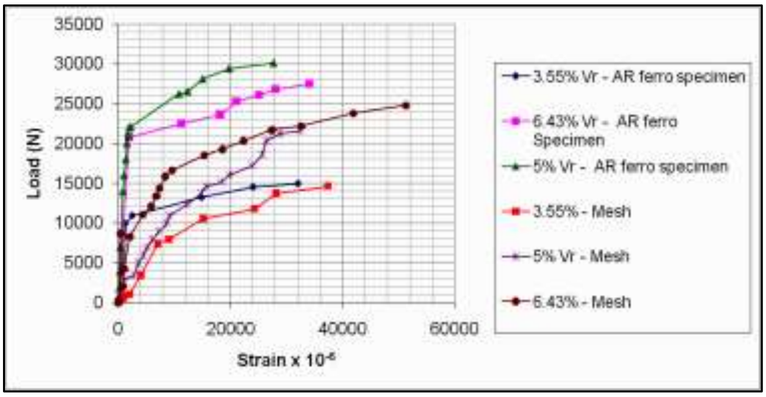


Fig. 8 Load–Strain profile for AR modified ferrocement specimens and meshes

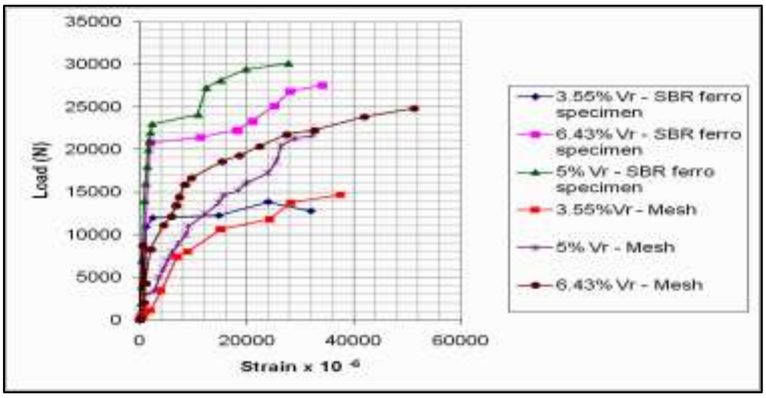


Fig. 9 Load–Strain profile for SBR modified ferrocement specimens and meshes

3. RESULTS AND DISCUSSION

The effect of three different volume fraction of mesh reinforcement on the properties of mortar was investigated. The inclusion of polymers to primary reinforcement (steel wire meshes) in a hybrid improves compressive, split tensile and flexural strength of polymer ferrocement based mortars. The material can be used for structural repairs, thin precast concrete elements, subject to shrinkage or severe impact. It was noticed that the Addition of 5%, 10%, 15% and 20% of AR latex reduces the 24 hour water absorption nearly by 60%, 66%,75% and74%. With the same percentage of AR latex additions there was a decrease in 90 min water absorption by 42%, 50%, 66% and 64% respectively. The addition of 5%, 10%, 15% and 20% of SBR latex reduces the 24 hour water absorption of mortar by 65%, 74%, 82% and 81%. There was a substantial decrease in 90 minutes water absorption with the same percentage of SBR latex additions by 36%, 64%, 78% and 76% respectively. Polymer modified mortar have a structure in which the large pores can be filled with polymer or sealed with continuous polymer films. In general, the effect of polymer filling or sealing increases with a rise in polymer content or polymer cement ratio. These features were reflected in the reduced water absorption of polymer modified mortar. Test results confirms that Styrene butadiene rubber latex based ferrocement mortars shows better performance and increases substantially the strength and reduces the rate water absorption of the mortars.

4. CONCLUSIONS

The influence of polymer modification of mortars on ferrocement has been investigated. The results lead to the following conclusions:

1. The optimum polymer content of 15% has been suggested, taking into account economical considerations as well. Addition of polymers improves fluidity, compressive strength, split tensile strength as well as flexural strength of the mortars.
2. Water absorption test on polymer modified mortar established that the effect of polymer filling or sealing increases with a rise in polymer content or polymer cement ratio up to a limit. Polymer Cement ratio of 15% with SBR latex reduces the 24 hour water absorption of mortar by 82%. Further rise in polymer content does not reduce the rate of water absorption of polymer modified mortar.
3. It has been noticed that the properties of polymer modified ferrocement can be varied enormously by varying the volume fraction of mesh reinforcement and also by the choice of types of polymers. Tensile strength of mortar is significantly enhanced by polymer modification.

4. Based on the study the polymer modified ferrocement with 5% volume fraction of reinforcement was higher in its Modulus of Elasticity under compression and 6.43% volume fraction under tension. Hence it could be understood that mortar contributes in it's towards the cracking stage and the steel towards the multiple cracking and ultimate stage.
5. In cases where the application of the reinforcement in repairing works is labour intensive, it is expected that the polymer modified ferrocement will provide more economic solutions.

REFERENCES

[1] ACI 549R-97. "State-of-the-Art Report on Ferrocement", American Concrete Institute, January (1997).

[2] IS 456: 2000, "Plain and Reinforced Concrete– Code of Practice", Bureau of Indian Standards, Fourth revision.

[3] Limaye R.J and Kamath M.K, (1992), "Experimental Studies on Polymer Modification of Cement Mortar", The Indian Concrete Journal, Vol.66, No.3, pp.153-159.

[4] Okba S.H, El-Dieb A.S, Reda M.M., (1997), "Evaluation of the Corrosion Resistance of Latex Modified Concrete (LMC)", Cement and Concrete Research, Vol.27, No.6, pp.861-868.

[5] Ohama Y. and Demura K., (1991), "Pore Size Distribution and Oxygen Diffusion Resistance of Polymer-modified Mortars", Cement and Concrete Research, Vol.21, No.2, pp.309-315.

[6] Ohama Y., Demura K., Hamatsu M., and Kakegawa M., (1991), "Properties of Polymer-Modified Mortars Using Styrene-Butyl Acrylate Latexes with Various Monomer Ratios", Materials Journal, Vol.88, No.1, pp. 56-61.

[7] Zeng L, Liu S, Wu D, "Influence of Mineral Compositions of the Cement and the Admixtures on the Brittleness of Sand Grout", Journal of Hydroelectric Engineering, Vol.2, No.1, pp.74-79.