Polymer Modified Concrete - A Theoretical Review

1Shrikant Mishra and 2R.K. Chaturvedi,
1PG Scholar (Structural Engg.), 2Asst. Professor,
1,2Department of Civil Engineering, Millennium Institute of Technology and Science, Bhopal, India

Abstract-- Some water-soluble polymers have proved potentials for improvement in properties of Portland cements. In the past, continuous research works are devoted to the development of new low cost materials with enhanced properties. Recent advances in the field of Concrete Technologies are linked to the use of admixtures like polymers. The optimum polymer ratio and polymer emulsion are supplied on a molecular scale, improving the aeration of hydrated cement by polymeric binders. Continuous research activities have led to the development of various suitable polymers, which are now widely used. In spite of its importance, the polymer modification of concrete has been less studied and there is a huge scope for its development. This paper focuses on studying the effect of polymers in concrete and suggests conducting experimental tests on Polymer modified concrete to prepare a comparative index. The mechanical properties, such as compressive strength and the influence of a cross-linking agent need to be thoroughly investigated.

Keywords-- PVA, Polymer Concrete, Polymer Modified Cement Concrete, Poly Vinyl Alcohol

I. INTRODUCTION

Active research has taken place in the past few years in the field of polymer modified concrete, polymer concrete and polymer impregnated concrete. They offer comparatively higher performance, multi-functionality and sustainability compared to conventional cement concretes. Concrete Polymer composites are environment friendly and confirm to the concerns of saving natural resources and the longevity of infrastructures. Addition of aqueous polymer emulsions or re-dispersible polymer powders in the fresh concrete mix leads to the polymer modification of concrete. The polymer emulsion is stabilized by surfactants. The process allows building up of composite polymer cement microstructures on a nanoscale, which can avoid the negative influences of the Polymer Admixtures. Cement interactions on the shape and distribution of the cement hydrate crystals, and on the transition zones between cementitious binder matrix and aggregates.

Some polymers are water-soluble and their low solubility causes difficulties in respect to the application of concrete modifier. One of the major advantages for water soluble polymers is the absence of surfactants to keep the polymers in solution. The polymer molecules are supplied on a molecular scale, improving the approach of the relative large cement grains (up till 80 μm) by the polymers. There are various classes of water-soluble polymers that can be used for the modification of cement mortars and concrete:

1. The first class consists of nonionic polymers with an oxygen or nitrogen in the backbone of the polymer. Examples are Poly Ethylene Oxide (PEO) and Poly Ethylene Imine (PEI). These polymers can be synthesized with molecular weights up to the millions.

2. Secondly, there are water-soluble nonionic polymers containing an acrylic group, e.g. Poly Acrylic Acid (PAA) and Poly Acryl Amide (PAAm).

The water-soluble polymer, Poly Vinyl Alcohol (PVA) is frequently used for the modification of concrete, and belongs to the class of nonionic polymers containing a vinyl group. The workability of the fresh mixture is remarkably improved as compared to ordinary concrete. This happens because of the plasticizing and air entraining effects of the polymers. The modified systems show higher water retention than the ordinary systems. This may lead to superior adhesion to porous substrates such as ceramic tiles, mortars and concrete. In such cases, this type of polymers hardly contributes to an improvement in the strength of the modified system.

With the increasing demand being made on concrete technology to serve the needs of society, experts are responding positively by proposing new formulations using other materials. Hence it is understood that incorporating polymer materials into the concrete has, to some extent, contributed to this demand. This paper focuses on developing a comparative performance chart of polymer modified concretes dosed with different types of polymers. The modification is brought by adding different dosages of polymers (by cement) to the conventional concrete. The behavior of concrete needs to be studied with respect to its mechanical and structural properties by varying the polymer dosages. The optimum dosage of the individual polymer can then be found from the experimental details. Finally recommendations can be made based on the experimental investigations.

II. LITERATURE REVIEW

Blaga, A. and Beaudoin, JJ (1985), said Polymer modified concrete may be divided into two classes: polymer impregnated concrete and polymer cement concrete. The first is produced by impregnation of precast hardened Portland cement concrete with a monomer that is subsequently converted to solid polymer. To produce the second, part of the cement binder of the concrete mix is replaced by polymer (often in latex form). Both have higher strength, lower water permeability, better resistance to chemicals, and greater freeze-thaw stability than conventional concrete.

Mandel and Said (1990), conducted research on the effect of an acrylic polymer on the mechanical properties of mortar and found that the mechanical properties of mortar and the adhesion between mortar and a steel fiber improved with the addition of an acrylic polymer into the system.

Ohama et al. (1994), investigated the effect of the monomer ratio on the typical properties of polymer modified mortars with styrene butyl acrylate latexes. They found that the properties (pore size distribution, flexural and compressive strengths, water absorption, and drying shrinkage) were affected largely by both monomer ratio and polymer cement ratio.

Kim et al. (1995), studied the properties of polyvinyl alcohol (PVA) modified mortar and concrete with up to 2% polymer...
by weight based on cement and compared the structure and properties of polymer modified concrete with those without polyvinyl alcohol. The interfacial transition zone and fractured surface were examined with both polarizing optical microscopy and scanning electron microscopy. They concluded that polyvinyl alcohol modified mortar showed slower absorption of water as compared to the unmodified mortar, which was an indication of lower permeability of the polymer modified mortar.

Joshua B. Kardon (1997), briefly reviewed the history of polymers in combination with cement as a building material, where the polymer is not in the form of fiber or mesh reinforcing, but in the form of a polymerized matrix comingled with the hydrated cement paste. He described the microstructure and properties of the composite polymer-modified concrete, and some current and possible future applications were mentioned. Several recently published articles and technical papers dealing with polymer-modified concrete were also critically reviewed by him.

F.A. Shaker et al. (1997), researched on the Durability of Styrene-Butadiene latex modified concrete. According to him, the durability of reinforced concrete structures represents a major concern to many investigators. The use of latex modified concrete (LMC) in construction has urged researchers to review and investigate its different properties. This study is part of a comprehensive investigation carried on the use of polymers in concrete. The main objective of this study to investigate and evaluate the main durability aspects of Styrene-Butadiene latex modified concrete (LMC) compared to those of conventional concrete. Also, the main microstructural characteristics of LMC were studied using a Scanning Electron Microscope (SEM).

R. J. Folic and V. S. Radonjanin (1998), presented some results from experimental research on polymer modified concrete concerning testing of fresh and hardened concrete, as well as determination of optimal curing conditions. Latex dispersion on the basis of "butadiene styrene rubber" was used as a cement modifier. About 180 concrete samples of cubical, prismatic, and cylindrical shape were tested.

Aggarwal et al. (2007), studied the properties of polymer modified mortars using epoxy and acrylic emulsion, and found that these materials had superior strength properties and better resistance to the penetration of chloride ions and carbon dioxide than PMCs based on vinyl acetate, copolymers of vinyl acetate–ethylene, styrene–butadiene, styrene–acrylic, and acrylic styrene butadiene rubber emulsions.

III. MATERIAL DESCRIPTION

Concrete has high compressive strength but is relatively weak in tension and adhesion, and its porosity can lead to physical and chemical deterioration. Polymers, on the other hand, are weaker in compression but can have higher tensile capacities, and provide good adhesion to other materials as well as resistance to physical (i.e., abrasion, erosion, impact) and chemical attack. Combinations of these two materials can exploit the useful properties of both and yield composites with excellent strength and durability properties. The combination of Portland cement concrete or mortar with polymers can result in extremely durable, tough, and strong building material composites those are economical and kind to the environment. Structures in extreme environments, or inaccessible for repairs, or subject to impact, cyclic, or dynamic loading may all benefit from the use of PMC. The aging infrastructure can be repaired using PMC.

In this paper an attempt is made to discuss mainly the mechanism, use and the applications of Polymer Portland cement concrete (PPCC) which is gaining overall popularity because of its ease of handling, inexpensive cost, efficiency and satisfactory results. However, it would be appropriate to discuss in brief Polymer concrete (PC) and Polymer impregnated concrete (PIC). In this case Latex polymers & Styrene Acrylic are used.

### Table 1: Physical Properties of Latex Polymer & Styrene Acrylic

<table>
<thead>
<tr>
<th>Property</th>
<th>Latex Polymers</th>
<th>Styrene Acrylic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids</td>
<td>68% - 69%</td>
<td>44% - 46%</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1300 to 1500 Centipoises</td>
<td>50 to 400 Centipoises</td>
</tr>
<tr>
<td>pH</td>
<td>9.00 to 10.00</td>
<td>9.00 to 10.00</td>
</tr>
<tr>
<td>Weight / Gallon</td>
<td>8.8 lbs</td>
<td>9.3 lbs</td>
</tr>
<tr>
<td>Appearance</td>
<td>Milky White Liquid</td>
<td>Milky White Liquid</td>
</tr>
<tr>
<td>Particle Size</td>
<td>Avg.</td>
<td>Avg.</td>
</tr>
<tr>
<td></td>
<td>Less than 0.5 microns</td>
<td>Less than 0.2 microns</td>
</tr>
</tbody>
</table>

IV. MECHANISM INVOLVED

Polymerization is a process of reacting monomer molecules together in a chemical reaction to form linear chains or a three dimensional network of polymer chains. There are many forms of polymerization and different systems exist to categorize them. Generally, polymers are added to the fresh mixture as an aqueous dispersion. Polymers dispersions consist of very small polymer particles (0.05 - 5 μm), dispersed in water, and are generally formed by emulsion polymerization. The spherical particles with a high molecular weight are held in dispersion with the aid of surface active agents. The surfactants are not only added to allow emulsification during the production process of the dispersion but also to preserve stability of the dispersion until coalescence of the polymer particles in the material takes place. Afterwards, the surfactants badly influence the hydration reactions of the cement, the quality of the formed hydrates and the polymer film formation.

The favorable properties of the presence of the polymer at the interface between aggregates and binder can be counteracted by additional air entrainment due to the presence of the surfactants. The properties of the fresh mixture are influenced to a large extent by the surfactants, present at the surface of the polymer particles. The cement particles are better dispersed in the mixture and a more homogeneous material is formed. In most cases, a better workability of the fresh mixture and a lower mixing water requirement is noticed. The hydration of the cement particles is also influenced by the presence of the surfactants. The surfactants hold the water, needed for hydration, more thoroughly than in the case of the unmodified mixtures. The water is partly bound to the hydrophilic part of the surfactants by hydrogen bonds. The release of water takes time, so hydration is retarded.

Additionally, at places where the polymer film starts to develop, the cement hydrates may be partly or completely covered by the polymer film and hydration may be stopped temporarily or completely. So, in the modified mortar or concrete, the presence of surfactants can lead to an excessive air entrainment, improved workability, reduced bleeding, retention of the water and retarded cement hydration. In
this respect, nonionic surfactants or high polymer protective colloids are preferable to anionic or cationic surfactants to stabilize the dispersion if used in combination with cement. It is typical of PMC to show an improvement in the workability and the prevention of dry out, and it also leads to superior adhesion to porous substrates such as ceramic tiles, mortars and concrete.

V. PROPOSED APPROACH

1. The concrete mix M30 will be investigated in the subsequent study
2. It will be prepared with standard 43 grade Portland cement and polymers which are conformed to Indian standards.
3. Mix design will be carried out according the IS 10262: 2009.
4. Continuously graded crushed basalt aggregate with nominal particle size of 20 mm will be used.
5. Well graded quartzite sand, with a fineness modulus of 2.74, will be employed.
6. The relative density values of the coarse aggregate and sand to be used are 2.90 and 2.56, and their absorption rates are 0.8% and 1%, respectively.
7. All concrete mixes will be prepared in batches in a rotating planetary mixer.
8. The batching sequence will consist of homogenizing the sand and coarse aggregate for 30 seconds, and then adding about half of the mixing water into the mixer and continuing to mix for one more minute.
9. The mixer is to be covered with plastic bags to minimize the evaporation of the mixing water and to let the dry aggregates in the mixer absorb the water.
10. After 5 minutes, the cement and polymer will be added and mixed for another minute.

A. Following tests will be conducted in order to evaluate the structural performance of concrete:

a. Compressive strength:

Standard cube specimens should be casted and tested for compressive strength after 7 days and 28 days. After obtaining the certain strength for nominal concrete and mixing the dosages of polymer proportion, casting of specimens for modified concrete should be done. The compressive strength will obtained on cubes of 150 x 150mm x 150 mm size according to IS: 5161959. Six specimens of each mixture are to be tested and the mean value is to be reported.

b. Flexural strength:

The flexural strength will be determined at 7 days and 28 days on beams of size 100 mm x 100 mm x 5000 mm. The specimens should be cured in water until the date of test according the IS: 516-1959. Three specimens of each mixture will be tested and the mean value is to be reported.

c. Split tensile strength:

The splitting tensile strength of conventional concrete and polymer modified concrete is determined at 7 days and 28 days on cylinders measuring 150 mm diameter and 300 mm height. These specimens will be cured in water until the date of test according to IS: 5816-1999. Three specimens of each mixture are to be tested and the mean value is to be reported.

CONCLUSION

This paper describes the results of a theoretical study performed to gain insight into the performance of polymer modified concrete and its mechanism. Further experimental studies are needed to find the optimum dosage of PVA polymer that influences the mechanical and structural properties of concrete in the best possible way. These experimental studies will help us in studying the effect of polymers in concrete and to prepare a comparative index. The mechanical properties, such as compressive strength and the influence of a cross-linking agent need to be thoroughly investigated in these cases.

References

[9] ACI Committee, (1995), State of the Art Report on Polymer Modified Concrete, American Concrete Institute, ACI 548.3R95, 147.