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Polymer Modified Steel Fiber Concrete: Review

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Abstract— This paper deals with the review of combined effect of polymer and steel fiber in cement hydrant. History of the polymer from ancient days is presented. Dispersing effect of polymer in cement is described. Properties and microstructure of polymer are given. Combined effect of dry curing and wet curing on polymer with different duration on strength of concrete is presented. Applications of the PMC are presented.

***Keywords*— Polymer, composite materials, steel fiber, SBR and Bond etc.**

I. INTRODUCTION

Concrete is most widely used construction material. concrete has several desirable properties like high compressive strength, stiffness, durability under usual environmental factors. As we know concrete has high compressive strength due to the hydration of cement. Polymers on the other hand are weaker in compression but have higher tensile capacities, and provide good adhesion to other materials as well as it should have resistance to physical (i.e., abrasion, erosion, impact) and chemical attack. This increase and decrease in strength of polymer concrete is due to the development of polymer film on the surface that will retain the internal pressure for continuing cement hydration. The formation of polymer film retards the loss of water thus this remaining water will available for hydration of cement. In polymer more time is require to form a polymer structure and cement matrix, because of this reason only polymer will give high strength at old age.

We can provide polymer in several ways as a) Polymer Concrete b) Polymer Impregnated Concrete c) Polymer Modified Concrete [1]. Polymer concrete is that in which polymer is used as a binder material instead of cement. Polymer concrete is used for drains, underground boxes, manholes, acid tanks and cells. Polymer Impregnated Concrete is that in which monomer are impregnated in the cracks of already hardened concrete. PIC widely used for decks, pipes and conduits for aggressive fluids floor tiles and hazardous waste containment. Polymer modified concrete is that in which polymer is added in to concrete which give dispersion effect after adding into the concrete.

Types of PMC

- Styrene Butadiene Copolymers.
- Acrylic ester homopolymer
- Vinyl acetate copolymers
- Vinyl acetate homopolymers

II. HISTORY

Use of natural fiber including asphalt is from ancient time period in Babylonia, Egypt to modify lime and clay mortar. In Europe from the middle ages polymer in the form of blood, rice husk and white egg is used to increase strength and durability of lime mortar. Bituminous mortar in construction has been used in ancient India. But Lefbure appears to be the first person who intended to produce polymer modified cementious mixture using natural rubber latex by proportioning latex on the basis of cement content. In the nineteen century use of artificial polymer come into play with various type of polymers. Considerable research and development in PMM and PMC is conducted in 1990.

III. POLYMER MODIFIED CONCRETE

PMC is defined as the combination of cement with organic polymer which are going to disperse or re dispersed while addition with aggregate [1]. As the cement hydrates, coalescence of the polymer occurs, resulting in a co matrix of hydrated cement and polymer film throughout the concrete. The use of concrete in this chapter also includes mortar. Organic polymers are in the three forms a) Latex which disperse in water b) Re dispersible powder c) Liquid which disperse or soluble in water. The major components of a polymer modifier are the monomers that form the polymer's bulk and are generally present in levels of greater than 10% by mass of the polymer modifier. These components have major effects on the hardness of the polymer modifier and its resistance to hydrolysis and ultraviolet light. The hardness of the polymer modifier is related to its glass transition temperature Tg. In general, the higher the Tg, the harder the polymer and the higher the compressive strength of the PMC; the lower the Tg, the lower the permeability of the PMC. After adding the polymer there will be improvement in bond strength, flexural strength, tensile strength and abrasion resistance. As well as there will be decrease in the permeability and elastic modulus.

Selection of the type of polymer depends on the service life requirements and cost. It should be noted that PVACs should not be used where the PMC will be exposed to moist conditions. Essentially, mixing and handling of PMC is similar to conventional portland cement concrete (PCC). Short mixing times are recommended to ensure acceptable air contents and, because of the good adhesion exhibited by PMC, prompt clean up of mixing equipment is suggested. Curing of the PMC is different from PCC in that extended moist curing is not required. In fact, moist curing beyond 24 to 48 hr is not recommended because it slows the coalescence or formation of the polymer film. The formation of the polymer film retards the loss of water from the concrete thus making it available for hydration of the cement. Moist curing of PMC is required during the early stages of cure to prevent the occurrence of plastic-shrinkage cracks. Though polymer modification can either accelerate or retard the initial setting time it has little or no effect on the final cement hydration rate.

IV. POLYMER / HYDRATED CEMENT CO-MATRIX FORMATION MECHANISM

First phase- In this polymer resin will disperse in the cement and sand paste. As these polymer are deposited around hydrated cement there will start of hydration process.

Second Phase- Because of hydration process resin will occupied in the pores, and there will generation of flocculation process around calcium silicate and aggregate particles. Chemical reaction between polymer resin calcium, silicate and calcium hydroxide will form around aggregate surface which give rise to bond between cement hydrates and aggregate.

Third phase- After adding water in hydration process hardened polymer will surround the hydrated cement and aggregate in the form of continuous membrane, creating the monolithic structure responsible for final properties.

V. INFLUENCE OF PMC ON PHYSICAL AND MECHANICAL PROPERTIES.

Cement is a structure of calcium silicate hydrates and calcium hydroxide which bound together by the weaker wander wall forces produce to cracks. This lead to lower tensile strength and fracture toughness of cement concrete. But in PMC micro cracks are bridged together by polymer film which prevent crack propagation and simultaneously there will be formation of strong cement – aggregate bond. This effect will be there with increase in the polymer content.

General requirement for polymer latex

There should be

- Very high chemical stability towards the extremely high cations.
- Very high mechanical stability against severe action
- Low air entrain action
- Excellent water resistance, alkali resistance and weather ability of polymer film.
- Thermal ability in varying temperature.

VI. PROPERTIES OF PMC

A. Factors Affecting Strength

- Effect of nature of material.

The nature of polymer depends on monomer ratio in copolymers and the type and amount of plasticizers [1]. The strength of SBR will increase with a rise in bound styrene content. Mechanical and chemical stabilities of latexes are increased with increase in surfactant content. Suitable antifoam are used to latexes to prevent excess air entrainment.

- Effect of control factors for mix proportion

The polymer cement ratio has a more pronounced effect on the strength properties than the water cement ratio. Generally there will increase in tensile bond and flexure strength with increase in the polymer content but decrease in the compressive strength foe polymer cement ratio higher than 10%.

- Effect of sand cement ratio

With increase in the sand cement ratio there will decrease in flexure and compressive strength of PMC.

- Effect of curing condition

As SBR is aqueous polymer dispersion prefers dehydration and solidification under dry condition. Combination of wet and dry curing will give us good compressive, flexure, tensile and bond strength. The reason for this is that there will be hydration of cement in wet curing and solidification of SBR due to wet curing. Due to dry curing there will be a formation of polymer film.

B. Properties of Fresh Mortar and Concrete

- Air content

Because of surfactant used in polymer excessive amount of air can be entrain. To reduce this effect of air entrain we have to use anti foam. There will decrease in compressive strength due to air content.

- Workability

Concrete with SBR will result in the high workability compare to the normal concrete. This increase in the workability is due to dispersing effect of the polymer.

- Setting and working time

Setting time for the PMC is more than that of normal concrete. Setting time is related to hydration of cement and working time related to drying of the surface.

C. Properties of Hardened Concrete and Mortar

- Compressive strength

PMC has lower compressive strength than conventional concrete with similar cement aggregate and water content. Nature of curing will affect the compressive strength of concrete. Smaller size coarse aggregate used in PMC provides the more uniform compressive strength.

- Bond strength

A very useful aspect of SBR is there increase in bond strength. Bond strength will increase with increase in polymer content and reaches maximum value at polymer cement ratio of 10-15%. Under wet condition there will be decrease in bond strength. Bond strength of PMC to reinforced bar determined under direct tension by pull-out method. Bond strength depend upon non evaporable water content heat of hydration and calcium hydroxide content.

- Permeability

Due to improved particle packing air entrainment and enhanced cement particle dispersion of PMC, there is less bleeding and segregation and more homogeneous microstructure. This contributes to higher strength and lower permeability of concrete. There is significant decrease in permeability with increase in age beyond 28 days.

VII. APPLICATION OF PMC

Styrene-butadiene latex are used in a variety of applications with Portland-cement mixtures, ranging from concrete bridge deck overlays to thin mortar coatings on swimming pools. The properties most desired are bond strength and impermeability, although flexural strength, tensile strength, and durability are also important. Styrene-butadiene latex-modified Portland-cement mortar mixtures are used in tile grouts and adhesives, stuccos, pipe linings, skid-resistant coatings, floor leveling, swimming pool coatings, and patching concrete. Styrene-butadiene LMC is used primarily for overlays of bridges and parking decks, but also is used in the repair of stadiums and patching of concrete pavements.

VIII. STEEL FIBERS

SFRC is made up of hydraulic cement containing fine and coarse aggregate and discontinuous discrete steel fibers. Mechanism of strengtning of fiber reinforcement is extending from elastic precreck state to plastic post crack state [2]. In steel fiber crack arrest mechanism is based on fracture mechanism. Steel fiber are defined as short discrete with length to diameter from 20 to 100. Steel with aspect ratio more than 100 tend to interlock to form a mat or ball after shaking and it is very difficult to separate this by vibration alone. And steel fiber with aspect ratio less than 50 are not able to interlock and can easily be dispersed by vibration. Addition of fiber will increase toughness much more than that first crack strength in these tests. Bond due to steel fiber is depending upon aspect ratio. Long term loading will not going to influence the mechanical property of steel fiber. Properties of SFRC in its freshly mixed state are affected by its aspect ratio, fiber geometry and its volume fraction. Fiber imparts post crack ductility to the cementious matrix that would behave and fail in brittle manner. With addition of steel fiber their slight affect in compression strength but significant effect on direct tension, flexure and fatigue behavior. Steel fiber has more advantages as a replacement to the vertical stirrups like as 1) random distribution of steel Leeds to distributed cracking with reduced crack size. 2) First crack tensile strength and ultimate tensile strength of the concrete may be increased by the fibers. 3) Shear friction strength is increased by resistance to pull out and fiber bridging crack. Addition of steel fiber is not going to decrease amount of shrinkage but it can increase the number of cracks and thus reduce the average crack width. Steel fibers can reliably confine cracking and improve resistance to material deterioration as a result of fatigue impact and shrinkage. Steel fibers are also effective in supplementing or replacing the stirrups in beams.

IX. EXAMPLES FROM LITRATURE

Rossignolo et al [3] describes “Mechanical properties of polymer modified light weight aggregate concrete”. In this paper effect of SBR with light weight aggregate on compressive strength tensile strength flexural strength and water absorption is studied. With decrease in water to cement and silica content there will be increase in water absorption split tensile and flexural strength. While use of light weight concrete structural efficiency is more important than that strength of concrete. Light weight aggregate concrete is very cohesive and workable in nature. Addition of 5% of SBR will result in 15% reduction in water content and 20% reduction with 10% of polymer addition. With increase in SBR content there will increase in air content which will result in less compressive strength. Addition of SBR will give us very high efficiency. From this study we conclude that we can produce thin precast components using SBR modifiers.

Huang et.al [4] in their technical paper titled “Laboratory evaluation of permeability and strength of polymer-modified

Pervious concrete” used polymer to increase strength of concrete. As pervious concrete has more voids in nature which result in less strength and use of this type of concrete are decreases. This study focused on balance between permeability and strength properties of polymer modified pervious concrete. Test result indicates that combination of latex and sand will result in acceptable permeability and strength. SBR used in this study is manufactured by anionic solution polymerization using an oregano lithium initiator. It is product of medium styrene and high vinyl content. Addition of SBR and fiber inhabits and controls the formation of intrinsic cracking in concrete, which reinforces against impact forces, reinforces against the effect of shattering forces and provides improved durability. Addition of SBR and sand will result in less permeability.

The paper by Li [5] describes “Properties of polymer modified steel fiber reinforced concrete.” In this paper effect of addition of both steel fiber and polymer modifier is discussed. From result it is concluded that with addition of SBR there will be increase in flexure strength but decrease in compressive strength. Optimum 5% of SBR is added in concrete to achieve high compressive strength. With addition of SBR in range of 10 to 16% will result in less compressive strength. In this it is seen that addition of both steel and polymer modifier does not have much influence on behavior of hardened concrete before peak load. However there is significant influence on energy absorption after peak load. Ultimate deformation and dissipated energy will increases with increase in dosage of fiber. In this load displacement curve without SBR decreases more sharply with increase in displacement, indicating that concrete with SBR has more ductility. Bond between steel fiber aggregate and cement is weak therefore big pores and deboning between aggregate and cement are observed which reduces flexural strength. With addition of polymer bond is increases so there will be increase in flexural strength with fiber. Also there will be increase in porosity with increase in polymer content.

Sangita et[6] al discuss “Effect of waste polymer modifier on the property of bituminous concrete mixes”. In present study effect of waste polymer modifier on various mechanical properties such as marshal stability flow marshal quotient resilient modulus permanent deformation potential of bituminous concrete has been evaluated. Waste polymer modifier with 8% shows improvement in various mechanical properties of mix compared to conventional bituminous concrete. Here there are two different methods to commercialize the production of bituminous concrete mixes. Wet method involve the use of ready mixed modified bitumen while dry process involve adding waste polymer to aggregate followed by bitumen during mixing process. Thermo-gravimetric curve of waste polymer modifier shoes that WPM is thermally stable up to 2000c with now weight loss. This suggest that we can use modifier up to this temperature. It is also seen that marshell stability of modified mixes is higher than that of the convention mixes. As we icrease polymer modifier from 6% to 8% there will increase in stability by

50%. With further increase in polymer modifier there will decrease stability which reduces adhesiveness of mix. Therefore maximum content of polymer modifier is of 8%. There is initial incrase in flow with polymer modifier up to 8% but this will decrease gradually as percentage of modifier further increases. Resilient modulus obtained at low and high temperature showed that 8% WPMB has high RM value compare to normal concrete.

"Performance of natural rubber latex modified concrete in acidic and sulfated environment" is described by Muhammad et al [7]. This paper describes the effect of natural rubber latex modified concrete in acidic and sulfated environment. In this natural and modified concrete were developed and subjected to two simulated aggressive curing medium 1) 5% of sulfuric acid 2) 2.5% of sodium sulfate. Latex to water is in range of 0 to 20%. Concrete phases were studied from SEM. As concrete matrix consist of voids resulting from incomplete consolidation of fresh mix or from evaporation of mix water which is not used while hydration of cement. Presence of moisture is the reason for chemical aggression on concrete. So to reduce this effect polymer is added in this concrete. As polymer modifier has ability to check moisture ingress thereby increase in its permeability and consequently saving the concrete from undue deterioration due to aggressive attack. Polymer particles in polymer modified concrete were observed to be partitioned between the inside of hydrates and the surface of anhydrous cement grains. Absence of latex particle in the capillaries and voids as in the case of normal concrete might have render the matrix vulnerable to attack through ingress of surrounding Na2SO4 ions. Inclusion of NRL into concrete transforms fairly porous microstructure features of NC into relatively denser matrix result shows that inclusion of appropriate Results has shown that inclusion of appropriate quantity of latex into concrete plays a significant role in curbing attack from H2SO4 and Na2SO4. For instance, considering Na2SO4 alone, strength gain in the modified concrete was 86.2% higher than the corresponding value in normal concrete within a period of 84 days. However, physical observations revealed a high volume change associated with latex in the modified specimens subjected to H2SO4 which suggests attack by acidic agents on hydrocarbon substances.

Ahmad et al [8] gives "Use of polymer modified mortar in controlling cracks in reinforced concrete beams". This paper discusses the effect of polymer in strengthening the existing cracked RC member. In this beams are firstly tested under the load up to the cracks of 1mm and then we add the polymer in the cracks for increase in strength of that beam. Generally cracks in the beam are occur due to plastic state as well as hardened state owing to the internal stresses. Along with polymer modified mortar we use different methods for strengthening of cracked beamlike as conventional upgrading technique, use of shotcrete overlay, steel cage , fiber reinforced plastic, epoxy injection etc. But PMM are related to setting shrinkage control thermal properties and temperature dependence they are not only strengthen the RCC structural member but also make this concrete highly durable. Pre packed PMM are highly helpful in improving handling procedure and to avoid the errors. The RC beams with PMM exhibit the same or slightly higher initial stiffness than their counter part control beams. Which indicate that PMM will help to restore their initial pre cracked stiffness.

This paper presents an "Experimental investigation of the flexural and shear bond characteristics of thin layer polymer cement mortared concrete masonry" given by Thamboo et al [9]. This paper reports a study on the examination of the effect of mortar compositions, dispersion methods and unit surface textures to the flexural and shear bond characteristics of thin layer mortared concrete masonry. In this non contact image correlation method is used for measurement of strains at unit mortar interface. unit surface texture and the mortar dispersion methods are found to have significant influence on the flexural and shear bond characteristics. Bond strength of thin layer mortared masonry is affected by surface texture of blocks. In the conventional masonry, the bond between the units and the cementatious mortar is derived from the penetration of the cement hydration products, such as the calcium silicate hydrates in the mortar, into the units through the surface voids and pores. Type of mortar, type of masonry unit and workman ship are the factors on which bond between motor joint and masonry unit is depend. Depending on unit surface roughness and pressure applied to fill the mortar into these valleys response of bond to flexure and shear will vary. Non-polymer cementatious mortars that cure well under moist condition, polymer mortars will not require additional moisture for curing, which is an advantage for its sustainability. In this uniaxial tensile test on couplets four point beam test and bond wrench pier test are taken for characteristic of tensile and shear bond behavior of the unit mortar surface. In this couplet and triplet test are used to calculate shear bond strength of masonry.

Aggarwal et al [10] presents "Properties of polymer modified mortars using epoxy and acrylic emulsions" Presently latexes of a single or combination of polymers like SBR, polyvinyl acetate etc are used but they will re-emulsify in humid alkaline condition. To reduce this effect epoxy emulsion based polymer system has been developed. In this paper the properties of the cement mortar modified with this newly developed epoxy emulsion are compared with those of the acrylic- modified mortar. The results showed that the mortars with the newly developed system have superior strength properties and better resistance to the penetration of chloride ions and carbon dioxide. Epoxy emulsion was prepared by emulsifying epoxy resin, based on diglycidyl ether of biphenyl-A, and amino-amide based hardener in water by using a non-ionic surfactant. The required quantity of water decreases with the addition of both polymers. However, the decrease is relatively more in case of acrylic emulsion. A reduction in water requirement was expected not only due to the presence of surfactants in the polymers but also due to the lower surface tension of polymer molecules, which facilitates better flow of the mix at the same water content. With same polymer cement ratio epoxy emulsion modified mortar have better compressive strength than acrylic modified mortar. As polymer fills the voids in the cement matrix. Polymer modified cementatious mortars are therefore expected to be more resistant towards humid environments than plain cement mortar.

Chen et al [11] reports "Mechanical properties of polymer-modified concretes containing expanded polystyrene beads". In this SBR is applied in light weight expanded polystyrene concrete. In effect of polymer cement ratio and curing condition on compressive and flexure is investigated. The strength development of the polymer-modified EPS concretes strongly depends on the curing conditions. Combined dry and wet curing enable to develop both the strengths of cement matrix and SBR films together. In this study, the addition of SBR latex to EPS concrete is tried to improve the bonding between EPS particles and cement paste and the tensile and flexural strengths of EPS concrete. SBR latex as an aqueous polymer dispersion prefers dehydration and solidification under the dry conditions. In this water curing in early days will result in hydration of cement matrix and solidification of polymer is by dry curing. Hence adhesion and strength of both cement matrix and SBR film are developed well.

X. CONCLUSIONS

Addition of polymer in cement and aggregate act as an polymer modified concrete which has very effective results as compare to that of the conventional concrete.

The addition of polymer will go to improve workability flexural strength tensile strength and bond strength. After addition of polymer there is desperation effect of polymer in cement which will fill the pores present in the voids. Polymer also form the layer on the cement and aggregate paste which result in the less permeability of concrete and therefore less water retention property.

Because of less water retention property moisture in the concrete is reduced and there by their is reduction in the corrosion and environmental causes to the concrete.

Polymer is also used for strengthening the cracked structure which results strength improvement in cracked structure after adding the polymer mortar in cracks of hardened concrete.

As hydration and solidification are important part of polymer modified concrete both wet and dry curing is require for the better results in strength.

Polymer form a skin or crust in the surface if it is in contact with air for more time which causes rapid hydration of the moisture from the surface and it will result in tearing of the surface. Water curing will also impart less strength of concrete.

XI. REFERENCES

[1] ACI Committee 548 Polymer Modified concrete. ACI548.3R-03

[2] ACI Committee 544 State of the Art report on Fiber Reinforced Concrete. ACI544.1R-96

[3] Rossignolo et.al "Mechanical properties of polymer modified light weight aggregate concrete". Cement and Concrete research, vol 32, pp 329-334, 2002.

[4] Huang et al, "Laboratory evaluation of permeability and strength of polymer-modified pervious concrete" Construction and Building Materials, Vol. 24, pp. 818–823, 2010.

[5] Gengying Li et al, "Properties of polymer modified steel fiber reinforced concrete." Construction and Building Materials, Vol. 24, pp. 1201-1206, 2010.

[6] Sangita et al, "Effect of waste polymer modifier on the properties of bituminous concrete mixes", Construction and Building Materials, Vol. 25, pp. 3841–3848, 2011.

[7] Bala Muhammad et al "Performance of natural rubber latex modified concrete in acidic and sulfated environment" Construction and Building Materials, Vol. 31,pp.129-134,2012.

[8] Ahmad et al "Use of polymer modified mortar in controlling cracks in reinforced concrete beams". Construction and Building Materials, Vol. 27, pp. 91-96,2012.

[9] Thamboo et al "Flexural and shear bond characteristics of thin layer polymer cement mortared concrete masonry" Construction and Building Materials, Vol.46, pp. 104-113,2013.

[10] Aggarwal et al, "Properties of polymer modified mortars using epoxy and acrylic emulsions" Construction and Building Materials, Vol. 21, pp. 379-383,2007.

[11] Bing Chen et al "Mechanical properties of polymer-modified concretes containing expanded polystyrene beads". Construction and Building Materials, Vol. 21, pp. 7-11, 2007.