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Experimental Investigation on Combined Effect of SBR and Steel Fiber on Properties of Concrete

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Abstract*—Concrete is the most widely used construction material having desirable properties like high compressive strength, stiffness and durability under usual environmental condition. Also concrete is brittle and weak in tension. Plain concrete has low tensile strength and a low strain at fracture. These shortcomings have been overcome by reinforcing concrete. The properties of ordinary cement concrete are generally improved to a great extent by latex modification. Hardened cement paste mainly has an agglomerated structure of calcium silicate hydrated and calcium hydroxide bound together by the weaker forces, and therefore, micro cracks occur easily in the paste under stress. This leads to poor tensile strength and fracture toughness of ordinary cement mortar and concrete. In the present work, experimental test are carried out to calculate compression strength on cube, flexural strength on beam, spilt tensile strength on cylinder and pull out test on cube with embedded steel bar. Casting of the specimen is done in laboratory using 15% polymer (styrene butadiene rubber) with 1% to 10% of the hooked end steel fiber. The 16 mm diameter bars are used in the pull out test. All the test on hardened concrete is carried out as per the IS code of the respective test, Specimen to be casted. It is observed that by contras in the polymer modified concrete micro cracks are bridged by the polymer film on membranes which prevent cracks propagation and simultaneously a strong cement hydrate- aggregate bond is developed. As per result flexural strength and bond strength of concrete is increased with the addition of steel fiber and constant percentage of polymer.

Keywords—Polymer modified concrete, styrene butadiene rubber, steel fibers.

I. Introduction

Concrete is the most widely used construction material has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. At the same time concrete is brittle and weak in tension. Plain concrete has two deficiencies, low tensile strength and a low strain at fracture. These shortcomings are generally overcome by reinforcing concrete. Normally reinforcement consists of continuous deformed steel bars or pre-stressing tendons. The advantage of reinforcing and pre-stressing technology utilizing steel reinforcement as high tensile steel wires have helped in overcoming the incapacity of concrete in tension but the ductility magnitude of compressive strength.

Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as an aggregate (usually made from different types of sand and gravel), that is bonded together by cement and water.

The Assyrians and Babylonians used clay as the bonding substance or cement. The Egyptians used lime and gypsum cement. In 1756, British engineer, John Smeaton made the first modern concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powered brick into the cement. In 1824, English inventor, Joseph Aspdin invented Portland cement, which has remained the dominant cement used in concrete production. Joseph Aspdin created the first true artificial cement by burning ground limestone and clay together. The burning process changed the chemical properties of the materials and Joseph Aspdin created stronger cement than what using plain crushed limestone would produce.

The other major part of concrete besides the cement is the aggregate. Aggregates include sand, crushed stone, gravel, slag, ashes, burned shale, and burned clay. Fine aggregate (fine refers to the size of aggregate) is used in making concrete slabs and smooth surfaces. Coarse aggregate is used for massive structures or sections of cement. Concrete that includes imbedded metal (usually steel) is called reinforced concrete or ferroconcrete. Reinforced concrete was invented (1849) by Joseph Monier, who received a patent in 1867. Joseph Monier was a Parisian gardener who made garden pots and tubs of concrete reinforced with an iron mesh. Reinforced concrete combines the tensile or bendable strength of metal and the compression strength of concrete to withstand heavy loads. Joseph Monier exhibited his invention atthe Paris Exposition of 1867. Besides his pots and tubs, Joseph Monier promoted reinforced concrete for use in railway ties, pipes, floors, arches, and bridges

Kardon (1967) presented review on polymer-Modified Concrete. Ru Wang (2005) studied physical and mechanical properties of styrene–butadiene rubber emulsion modified cement mortars. Lefebure (1924) studied polymer latex modified systems. Rodwell (1939) studied use of synthetic rubber latexes for polymer modified systems. Geist et. al (1954) performed study of polyvinyl acetate in modified polymer mortar. Shibazaki (1964) presentd properties of masonry cement modified with water soluble Polymers. Bing (2007) studied mechanical properties of polymer-modified concrete containing expanded polystyrene beads. Gengying et. al. (2010) used enhanced properties of polymer modified steel fiber-reinforced cement concretes. Kurugo (2008) calculated young’s modulus of fiber-reinforced and polymer-modified lightweight concrete composites. Huang (2010) evaluated permeability and strength of polymer-modified pervious concrete. Sangita et. al. (2011) studied effect of waste polymer modifier on the properties of bituminous concrete mixes. Ribeiro et. al. (2013) provided mix design process of polyester polymer mortars modified with recycled GFRP waste materials

II Classification of polymer concrete

As Polymer has different mechanical properties so we can use this polymer in different way like as

1. Polymer Impregnated Concrete
2. Polymer Concrete
3. Polymer Modified Concrete

Polymer Impregnated Concrete (PIC) is produced by infusing a monomer into the cracks and voids of already hardened concrete. The monomer is polymerized after they enter the voids by the action of chemical hardener or the application of heat. Since the polymer is ideally fills the voids and bind with cement matrix and the aggregate, there is no need of high quality concrete for PIC. PIC strength is depend on the type and amount of polymer used, and the degree of polymerization achieved, the application of PIC is limited precast thin panel and the repairs work to the highway surface.

Polymer Concrete (PC) is the materials made of aggregate and the polymer binder; there is no Portland cement in the concrete. The polymer matrix binds very well to the aggregate particle with no transition zone, unlike Portland cement concrete. Since the polymer materials are more expensive than the Portland cement materials and can generate heat and undergo shrinkage during curing. PC is made with evenly graded aggregate to achieve close packing between the aggregate particles, minimizing the space between the aggregate and to be filled with polymer. The use of PC include place of PC connection for precast concrete construction, precast PC element, and overlays for concrete surface. A possible problem with the PC is its sensitivity to the high temperature and to the cyclical temperature changes

Polymer Modified Concrete (PMC) or Polymer Portland Cement Concrete (PPCC) is the normal Portland cement concrete with the polymer admixture. The polymer and the cement hydration products comingle and create two interpenetrating matrices, which work together, resulting in an improvement in material properties of the PMC alone. The PMC is the term for such concrete with the lower dosage of polymer, typically 5% or less. For PPCC generally is the term for composite with dosage of polymer more than 5% by weight of the concrete. The PMC is made by modifying the ordinary cement concrete with organic polymer that are dispersed or re-dispersed in the water with orwithout aggregate. An organic polymer is substances composed of thousands of simple molecules combined into the large molecules. The simple molecules are called as monomer and the reaction that combines them is called as polymerization. The organic polymers are supplied into the three forms: as a dispersed in the water called as latex, as a re-dispersible powder and as a liquid that is dispersible or soluble in the water.

Polymer Modified Concrete

Polymer modified concrete (PMC) has at times been called polymer Portland cement concrete (PPCC) and latex modified concrete (LMC). It is defined as Portland cement and aggregate combined at the time of mixing with organic polymer that are dispersed or re-dispersed in the water. As the cement are hydrate coalescence of the polymer occur resulting in the co-matrix of hydrated cement and polymer film throughout the concrete.
A wide variety of polymer type has been investigated for use in PMC, the major types in use today's are as follows:

- Styrene-butadiene copolymer (S-B)
- Acrylic ester photopolymers (PAE) and copolymers, particular with styrene (S-A)
- Vinyl acetate copolymer (VAC)
- Vinyl acetate homo-polymers (PVAC)

The selection of the polymer depends on the service life requirements and cost. It should be noted that PVAC should not be used where the PMC will be exposed to moist condition. Essentially, mixing and handling of PMC is similar to conventional to Portland cement concrete (PCC). Short mixing time is recommended to ensure the acceptable air content and, because of good adhesion exhibits by PMC; prompt cleanup of mixing equipment is suggested. Curing of 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 retards the loss of water from concrete thus making it available for hydration of cement. Moist curing of PMC is required during the early stage of cure to prevent the occurrence of plastic-shrinkage cracks.

Different Types of Polymer

LATEX: It is define as the dispersion of organic polymer particles in the water called as latex. The average particle size varies from 100 to 2000 nanometers; most latex's are made by the process known as emulsion polymerization, where polymer is directly form in the water. It is used extensively for plaster bonding application

Polyvinyl acetate concrete (PVAC): The use of this type of latex is declining because of the poor water resistance of PVAC modified mortars. When wet of the PVAC hydrolyses, in the high alkalinity of Portland cement mixtures and the reaction products are water soluble.
Acrylic ester and copolymer (PVE and S-A): These latex has been used for many years, primarily in tiles adhesive, floor overlay, exteriors insulation finish systems (EIFS) and the repairs of concrete. Were color fastness are important the choice is to be that acrylic esters.

III. Methodology and Experimental Set up

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Mix design by ACI Method:

As we know there is different method for evaluation of mix design of concrete likewise ACI method, DOE method and IS method. As we want to design for M50 grade of concrete which is high grade of concrete there for we are going for ACI method.

This mix design is done by ACI 211.1-77 code, this code s recommended for selecting proportion for normal and heavy weight concrete.

Figure 1: Concrete cubes with various mixes

For getting probable strength of concrete various proportion of mix design are checked and from that one proportion is selected.

Volume of Fine Aggregate = 1-0.2-(185÷1000)-(544.11÷3150)-(1006.6÷2760)

= 0.2583

Weight of Fine Aggregate = Volume of aggregate × Density of Fine Aggregate

= 0.2583 × 2620

= 676.75 Kg

From all the above steps we will get the right proportion of mix design.

Water: Cement: Fine Aggregate: Coarse Aggregate

0.34 : 1 : 1.24 : 1.85

Table 1: Mix proportion

Material	Proportion by Weight of Cement	Weight in Kg/m3
Cement	1	544.11
Water	0.34	185
Fine aggregate	1.124	677
Coarse Aggregate	1.85	1006

Test results:

In this experimental work "Ultratech 53 grade Ordinary Portland Cement" has been used for casting of cube, beam, cylinder and cube for bond. All properties of cement are tested by referring IS 12269 – 2013.

Table 2: Physical Properties of Cement.
(Confirming to IS 12269-2013)

Sr. No.	Property	Value	Standard value
1	Fineness (%)	4	Not exceed 10
2	Specific gravity	3.15	3.15
3	Standard consistency of cement (%)	20	<30
4	Initial setting time (min)	95	>30
5	Final setting time (min)	225	< 600
6	Compressive strength (N/mm2)		
	3- days	29.40	> 27
	7- days	40.11	> 37
	28- days	55.28	> 53

Table 3: Test results

Sr. No.	Property	Value	
1	Particle Shape, Size	12mm	20mm
2	Specific Gravity	2.98	2.76
3	Bulk density (Kg/m3)	1.69	1.78
4	Fineness modulus	4.76	7.76
5	Impact value (%)	9.39	8.77
6	Crushing value(%)	18.31	16.3
7	Water absorption (%)	1.4	1.6

Table 4: Property with values

Sr. No.	Property	Value
1	Specific Gravity	2.68
2	Fineness modulus	2.88
3	Grading	Zone 2
4	Water absorption (%)	1%
5	Bulking of sand (%)	3%
6	Silt content (%)	1.5%

Cube, beam, cylinder and cube for bond of specimens are casted to calculate mechanical properties of normal concrete and fiber polymer modified concrete

Cube: - 150mm*150mm*150mm
Beam: - 100mm*100mm*500m
Cylinder: - 150mm Diameter and 300mm length.

- Beam specimens are used to determine flexural strength and dynamic modulus of elasticity.
- Cubes are used to determine the compressive strength.
- Cylinders are used to determine the split tensile strength.
- Cube with embedded steel bar used to determine the bond strength between concrete and steel bar.

Test conducted on fresh concrete:

Workability: -

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The workability of concrete is the ease with which the concrete can be mixed, transported, placed, compacted and finished to get dense and homogeneous mass of the concrete. It is the amount of useful internal work necessary to produce full compaction. The workability of concrete is governedby water cement ratio, chemical composition of cement and its fineness, aggregate cement ratio in concrete, size shape of aggregate, porosity, water absorption of aggregate and use of admixture.

Slum cone test (As per IS: 7320 – 1974)

The slum cone test is simplest test method to determination of the workability of concrete, andwhich is very useful in detecting variation in uniformity of the mix for a given nominal proportion. The standard slum cone (bottom diameter 200mm, top diameter 100mm and height 300mm), with standard tamping rod 16mm diameter and 600mm in length along with bullet end. Some standard slum value are given below,

Table 5: standard slum value

Sr.No.	Degree of	Slum value in	Suitability
1	Very low	0 - 25	Concrete road
2	Low	25-50	Lightly reinforced
3	Medium	50-100	Manually compacted flat
4	High	100 - 175	Highly reinforced section

IV. Experimental Results

The compression strength of concrete is tested for normal concrete specimen and constant content of 15% polymer (styrene butadiene rubber) with different percentage of steel fiber from 1% to 10% by weight of cement. All the tests are conducted after 28 days from casting date. The tests are conducted on UTM and results are shown in table 6.

The strength is calculated from following formula

Compression strength (σ) =

$$\frac{P}{A}$$

Where,

σ = Compression strength

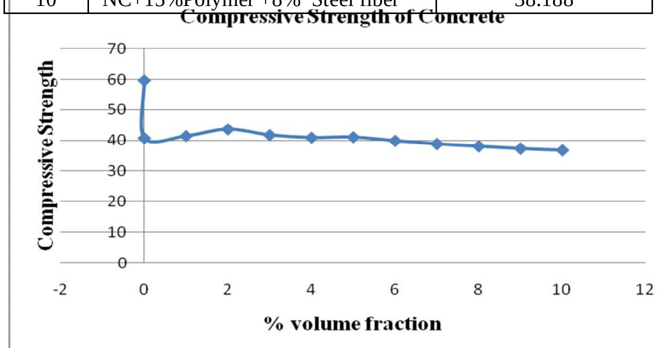
P = load at which cube fails in N

A = cross sectional are of cube in mm2

Figure 2 : Experimental set up with test specimen

Table 6: Compressive strength for various mix proportion

Sr.	Mix Proportion	Compression strength
1	NC	59.73
2	NC+15%Polymer	40.838
3	NC+15%Polymer +1% Steel fiber	41.52
4	NC+15%Polymer +2% Steel fiber	43.74
5	NC+15%Polymer +3% Steel fiber	41.83
6	NC+15%Polymer +4% Steel fiber	40.985
7	NC+15%Polymer +5% Steel fiber	41.127
8	NC+15%Polymer +6% Steel fiber	39.94
9	NC+15%Polymer +7% Steel fiber	38.916
10	NC+15%Polymer +8% Steel fiber	38.188
11	NC+15%Polymer +9% Steel fiber	37.45
12	NC+15%Polymer +10% Steel fiber	36.93



From the above table it is observed that as the percentage of steel fiber with 15 % of constant polymer content concrete, the compression strength is more than that of polymer concrete and as the percentage of steel fiber (from 1% to 10 %).

Figure 3 : Compressive strength for different % volume fraction

Enhancement in the compressive strength of the concrete is observed after addition of steel fiber up to 2%. After another increase in the steel fiber from 3% to 10% there will be decrease in compressive strength.

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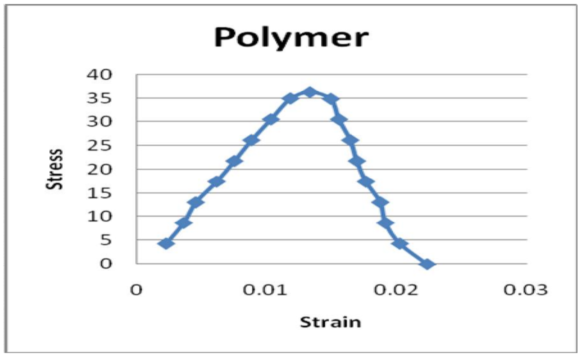

Figure 4 : Stress strain curve for normal concrete

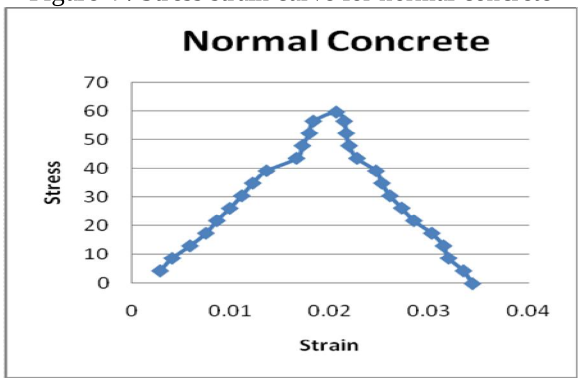

Figure 5 : Stress strain curve for polymer concrete

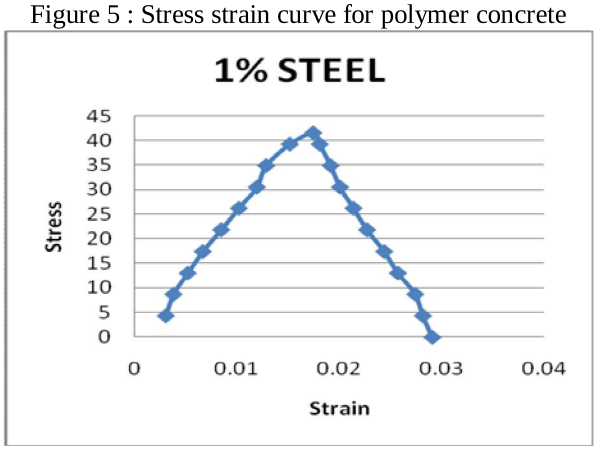

Figure 6 : Stress strain curve for concrete with 1 % steel

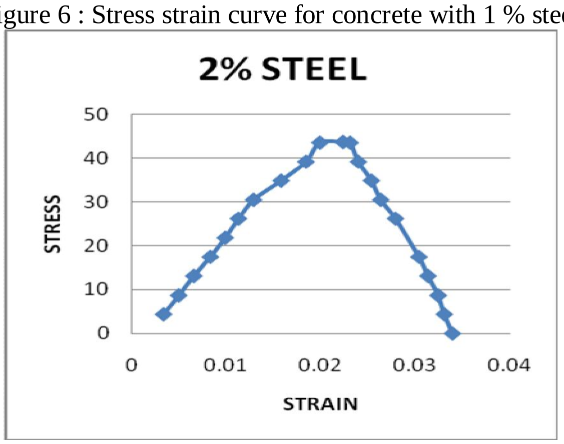

Figure 7 : Stress strain curve for concrete with 2 % steel

From above graph it is observed that with addition of polymer there will be decrease in the compressive strength as compare to normal concrete. There is enhancement in the compressive strength of the concrete after addition of steel fiber up to 2%. After another increase in the steel fiber from 3% to 10% there will be decrease in compressive strength.

V. Conclusion

Workability of Polymer Modified Concrete is increased as compare to that of normal concrete. This increase in workability of polymer concrete is due to ball bearing action of polymer particles among cement particles. As per result, table and graph compressive strength of concrete will be decrease with the addition of polymer and steel fiber. Hardened cement paste mainly has as agglomeration structure of calcium silicate hydrate and calcium hydroxide which are bound together by weaker van der was forces and therefore micro cracks occurs easily in paste under stressthis leads to pore tensile strength and fracture toughness of ordinary cement mortar and concrete. By contras in the polymer modified concrete micro cracks are bridged by the polymer film on membranes which prevent cracks propagation and simultaneously a strong cement hydrate- aggregate bond is developed. As per result, table and graph tensile strength of concrete will be increases with the addition of polymer and steel fiber. As per result, table and graph flexural strength and bond strength of concrete will be increase with the addition of steel fiber (1% to 10%) and constant percentage of polymer (15% by the weight of cement).

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