STUDY ON LATEX STEEL FIBRE REINFORCED CONCRETE

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Abstract - *Concrete is the most widely used construction material because of its specialty of being cast into any desirable shape. Ductility, durability and energy absorption capacity are the main requirements of earthquake resistant structures and water retaining structure. However, the conventional concrete has low tensile strength, lower energy absorption and little resistance to cracking. Therefore, it cannot cater the requirements of the earthquake or seismic resistant structure. The study is to enhance the properties of concrete in direction of strength, water retaining capacity, toughness using mixing of SBR Latex and steel fiber. A uniform percentage of SBR Latex and two varying percentage of steel fibers has been used to prepare concrete cube specimens. Different types of specimens were tested on 7 and 28 days of maturity to find variation in the workability and mechanical properties of the concrete.*

Key Words: Fiber reinforced concrete, Polymer concrete, Compressive strength, Tensile strength, Flexure strength

1. INTRODUCTION

Due to useful physical properties and relatively low cost of concrete, cement-based materials being the most widely used civil engineering materials. However, these materials have a number of drawbacks: they are brittle, have a low failure strain, and are weak in tension. To mitigate these problems, both polymer modification and fiber reinforcement has been used successfully in practice. In the work reported here, the combined use of polymers and fibers was studied experimentally. However, it is necessary first to describe briefly the separate effects of polymers and fibers in concrete. Generally, there are three principal types of concrete containing polymers:

1. Polymer Concrete (PC) - is a composite containing a polymer as the binder instead of the conventional Portland cement.
2. Polymer Impregnated Concrete (PIC)- is generally a precast concrete, which is dried and evacuated, and is then impregnated with a low viscosity monomer that polymerize in the field to form a continuous polymer network within the pore system.
3. Polymer Modified Concrete or Polymer Portland Cement Concrete (PMC or PPCC) —modified concrete in which part of the cement binder is replaced by a synthetic organic polymer. It is produced by incorporating a monomer, pre-polymer-monomer mixture, or a dispersed polymer (latex) into a Portland cement concrete.

Amongst these three types of polymeric materials, PMC (PPCC) is most widely used, due to its relatively low cost and quite similar processing technology to that of conventional concrete. Polymer latex is most commonly used in PMC. Synthetic latex was suggested for concrete in the early 1930's. But practical applications of PMC only became widespread in the early 1960s. By now, thousands of projects, such as bridge deck construction or repair, and parking garage repairs, have been completed in North America using styrene-butadiene latex. Acrylic latex and epoxy polymer modifiers have also been developed and have played important roles in repair projects. Much research and construction experience has demonstrated that cement based composites with a suitable polymer latex exhibit superior bonding to old concrete and to steel rebar possessing good ductility, lower permeability and better durability characteristics such as improved resistance to freeze-thaw cycling, decreased depth of carbonation, and reasonable chemical resistance. Polymer latex modified concrete also provides increased strength and higher impact resistance.

Fiber reinforcement is another common approach for improving the toughness of cementitious materials. Fibers are very effective for controlling cracking, improving ductility, and providing impact resistance. Steel fibers and synthetic fibers (such as polypropylene, polyethylene, PVA and carbon fibers) are now the most common fiber types.

A full understanding of the combined use of fibers and polymers in one system (PMFRC) i.e. Polymer Mixed Fiber Reinforced concrete is still not available. Progress in the area of PMFRC has been fairly slow, partly due to the high material cost which may discourage industrial applications, and partly due to the lack of experimental data on the new composites; thus, the potential high performance of these materials have been neglected. Polymer modification is one of the methods which can improve both the properties of the fresh concrete and the hardened concrete matrix, thereby enhancing the life span of the structure. Thus polymer modified concrete can be reinforced by short fibers, (or fiber reinforced concrete can be modified with polymers), and a composite with the beneficial effects of both fibers and polymers may be useful for more extensive applications. The objective of this study has been to optimize the cementitious system containing polymer, and to establish stable mix proportions for polymer modified high strength concrete (PMHSC) along with analyzing the effects of the basic mix and of the variables of polymer-fiber composites on the workability and mechanical properties of concrete.

2. EXPERIMENTAL PROGRAMME

2.1 Aggregate: For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates, which account for 70 to 80 percent of the total volume of concrete, are divided into two distinct categories-fine and coarse. Although some variation in aggregate properties is expected, characteristics that are considered included are as grading, durability, particle shape and surface texture, abrasion and skid resistance, unit weights and voids, absorption and surface moisture.

2.2 Water: The principal considerations on the quality of mixing water are those related to the effect on workability, strength and durability. Limits are placed on the contribution of mixing water to the total alkalis, chloride and sulfate of all concrete ingredients in order to control the durability of the concrete.

2.3 Polymer: Polymer latexes (or dispersions) which consist of very small (0.05-5 pm in diameter) polymer particles dispersed in water are usually produced by emulsion polymerization. Although polymer-based admixtures in any form such as polymer latexes, water-soluble polymers and liquid polymers are used in cementitious composites such as mortar and concrete, it is very important that both cement hydration and polymer film formation (coalescence of polymer particles and the polymerization of resins) proceed well to yield a monolithic matrix phase with a network structure in which the cement hydrate phase and polymer phase interpenetrate. In polymer-modified mortar and concrete structures, aggregates are bound by such a co-matrix phase, resulting in superior properties compared with conventional cementitious composites.

2.4 Steel Fiber: Round steel fiber the commonly used type are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick. Fiber made from mild steel drawn wire. Conforming to IS:280-1976 with the diameter of wire varying from 0.3 to 0.5mm have been practically used in India.

2.5 Workability: Generally, latex-modified mortar and concrete provide an improved workability over conventional cement mortar and concrete. This is mainly interpreted in terms of improved consistency due to the 'ball bearing' action of polymer particles, the entrained air and the dispersing effect of surfactants in the polymer latexes. The water-cement ratio of the latex-modified mortar and concrete at a given consistency (flow or slump) is markedly reduced with an increase in the polymer-cement ratio. This water reduction effect is found to contribute to a strength development and drying shrinkage reduction. Slump test is used to determine the workability of fresh concrete.

Fig-1: Slump Test

2.6 Concrete Mix Design: The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. Mix design is the process of selection of suitable ingredients of concrete and to determine their properties with object of producing concrete of certain maximum strength and durability, as economical as possible. The purpose of designing is to achieve the stipulated minimum strength, durability and to make the concrete in the most economical manner.

Design Data required:

- Grade designation: M30
- Types of cement: OPC 53 grade confirming to IS 12269- 1987
- Max. nominal size of aggregate: 20 mm
- Min. cement content :320 kg/ m^3
- Max. water cement ratio: 0.45
- Workability: 100 mm slump
- Exposure condition: Moderate
- Method of concrete placing: Hand
- Degree of supervision: good
- Types of aggregate: crushed angular

Table -1: Mix Proportion of the Trial Mix

Constituents of Trial Mix	MIX 1 is the control (Plain) concrete with 0% fiber (PCC) and 0% SBR latex.	MIX 2 consist of 1% of Steel fiber (straight) with aspect ratio 60, by volume and 5% SBR latex.	MIX 3 consist of 2 % of Steel fiber (straight) with aspect ratio 60, by volume and 5% SBR latex
Cement	492.5 kg/m^3	492.5 kg/m^3	492.5 kg/m^3
Water	197 kg/m^3	197 kg/m^3	197 kg/m^3
Coarse Aggregate	1115.11 kg/m^3	1073.8 kg/m^3	1073.8 kg/m^3
Fine Aggregate	671.2 kg/m^3	646.3 kg/m^3	646.3 kg/m^3

Water Content ration (W/C)	0.4	0.4	0.4
Polymer		24.77 kg/m³	24.77 kg/m³
Fiber		24 kg/m³	48kg/m³
Mix Proportion	1:1.36:2.26	1:1.31:2.18	1:1.31:2.18

Table -2: Details of Specimen Casting

Name of specimen	Size of specimen in cm	Number of specimen
Cube	15×15×15	6
Cylinder	15×30	9
Beam 1	10×10×50	3
Beam 2	12.5×15×100	3

Table -3: Mix proportion of M30 (1:1.36:2.26)

Mix	Latex/cement Ratio m_l/m_c	Water/cement Ratio m_w/m_c	Total fluid/cement Ratio m_{w+l}/m_c	Cement content m_c in Kg/m³	Latex content m_l in kg/m³	Water Content m_w in Kg/m³	Fiber in kg/m³
Mix1	0	0.40	0.40	492	0	197	0
Mix2	0.05	0.34	0.39	492	24.77	167	24
Mix3	0.05	0.34	0.39	492	24.77	167	48

3. RESULTS AND DISCUSSION

3.1 Compressive Strength Test: Compressive strength of concrete cube having dimension 15cm×15cm×15cm of 30 N/mm² has been casted and it has been tested at various interval such as 7 days and 28 days of different types of mixes. Compressive strength results of cubes are tabulated below.

Table -4: Compressive Strength test results

S. No.	Type	Compressive Strength(N/mm²)			
		7 Days		28 Days	
		Individual	Avg.	Individual	Avg.
1	MIX 1	24	23.71	32.44	31.11
		22.67		30.67	
		24.44		30.22	
2	MIX 2	25.77	25.18	34.66	34.96
		22.67		37.33	
		27.11		32.89	
3	MIX 3	30.67	27.85	38.67	38.82
		27.11		40.88	
		25.77		36.89	

Table -5: Comparison of Compressive Strength test results

TESTING TIME	MIX 1	MIX 2	MIX 3	% INCREASE M_{12}	% INCREASE M_{23}	% INCREASE M_{13}
7 DAYS	23.71	25.18	27.85	6.19	10.6	17.46
28 DAYS	31.11	34.96	38.82	12.37	11.04	24.78

Table -6: Split Tensile Strength test results

S NO.	Type	Split Tensile Strength(N/mm²)			
		7days		28days	
		Individual	Avg.	Individual	Avg.
1	MIX 1	1.98	2.21	3.39	3.44
		2.40		3.69	
		2.26		3.25	
2	MIX 2	2.82	2.68	4.39	4.06
		2.69		3.69	
		2.55		4.10	
3	MIX 3	3.11	3.11	4.38	4.81
		3.39		5.1	
		2.97		4.95	

Table -7: Comparison of Split Tensile Strength test results

Testing Time	Mix 1	Mix 2	Mix 3	%Increase M_{12}	%Increase M_{23}	%Increase M_{13}
7 DAYS	2.21	2.68	3.11	21.26	16.04	40.72
28 DAYS	3.44	4.06	4.81	18.02	18.47	39.82

Table -8: Flexural Strength Test results

S NO.	Type	Flexural Strength(N/mm²)	
		28days	
		Individual	Avg.
1	MIX 1	4.25	4.58
		5.0	
		4.5	
2	MIX 2	8.5	7.85
		8.0	
		7.0	
3	MIX3	9.0	9.17
		10.0	
		8.5	

Table -9: Comparison of hardened state test results

Name of specimen	Compressive Strength (N/mm^2) in 28 days	% Increment	Split Tensile Strength ($N/m m^2$) in 28 days	% Increment	Flexural Strength ($N/m m^2$) in 28 days	% Increment
MIX 1	31.11	-	3.44	-	4.58	-
MIX 2	34.96	12.36	4.06	18.02	7.85	71.39
MIX 3	38.82	24.78	4.81	39.82	9.17	100.21

4. CONCLUSIONS

The addition of the steel fibers to a PMC affects the bonding in concrete matrix. The packing density decrease due to higher content of finer particles which are required to compensate for it. In conventional concrete by addition of polymer increases the workability of concrete at the same time addition steel fiber in PMC reduces the workability. Additional of short steel fiber (30mm) improves the flexure strength, split tensile strength and compressive strength of concrete. The inclusion of fiber and polymer eliminates the sudden type of failure during compression, the flexure and split tensile test. By mixing polymer and fiber in conventional concrete which have brittleness property of concrete decreases.

- With addition of fiber and polymer in conventional concrete, an increase in compressive strength up to 24.82 % for 2% steel fiber and 5% polymer and up to 12.36% increase for 1% steel fiber and 5% polymer has been noted.
- With addition of fiber and polymer in conventional concrete, an increase in split tensile strength up to 18.02 % for 1% steel fiber and 5% polymer and up to 39.82% increase for 2% steel fiber and 5% polymer has been noted.
- With addition of fiber and polymer in conventional concrete, an increase in flexural strength up to 71.5 % for 1% steel fiber and 5% polymer and up to 100.21% increase for 2% steel fiber and 5% polymer has been noted.

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