Effect of natural rubber latex on strength and workability of fibre reinforced high-performance - concrete with metakaolin admixture

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Abstract

To increase the applications of Natural Rubber Latex Modified Fiber Reinforced High-Performance-Concrete (NRLMFRHPC) in India, greater understanding of NRLMFRHPC produced with locally available materials such as cement , Fine aggregates , coarse aggregates, Metakaolin and Crimped Steel fibers is essential. In the present investigation, NRLMFRHPC has been produced with locally available aggregates and mineral admixture (Metakaolin) and Natural Rubber Latex based NRLMFRHPC mixes were designed by absolute volume method. Cubes of 150X150X150 mm in dimension were cast and cured for 28 days and then tested for compressive strength to assess the strength characteristics of NRLMFRHPC. Workability has been measured by conducting compaction factor test on fresh NRLMFRHPC mixes. The experimental results indicate that Natural Rubber Latex can be utilized in producing durable Fiber Reinforced High-Performance-Concrete. The various results which indicate the effect of Steel Fibers and Natural Rubber Latex on the strength and workability characteristics of high-performance-concrete are presented in this paper to draw useful conclusions.

Keywords: *Metakaoline, Natural Rubber Latex, Steel Fibers, High Performance Concrete*.

1. Introduction

The idea that concrete can be strengthened by fiber inclusion was first put forward by Porter in 1910, but little progress was made in its development till 1963.The weak matrix in the concrete, when reinforced with steel fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. Generally the ACI Committee Report No ACI 554 Guide for specifying, mixing, placing and finishing of steel fiber reinforced concrete is followed for the design of SFRC mixes appropriate to specific applications. Fiber Reinforced HPC, new generation concrete, results from the addition of either short discrete fibers or continuous long fibers to the cement based matrix. Due to the superior performance characteristics of this concrete, its use by the construction industry has significantly increased. A very good guide to various Portland cement-based composites as well as their constituent materials is available in a recently published book [Balaguru and Shah, 1992].

The latex modified concrete is defined as Portland cement and aggregate combined at the time of mixing with organic polymers that are dispersed in water. This dispersion is called a latex. The organic polymer is a substance composed of thousands of simple molecules known as monomars. The reaction that combines the monomars is called polymerization. When latex is used in mixes with port land cement, aggregates, and water, fresh concrete is produced with consistency and workability characteristics only slightly different from conventional concrete. After curing, the latex-modified concrete (LMC) consists of hydrated cement and Aggregate, all interconnected by a continuous film of latex. It is in part this continuous film which imparts the superior physical and chemical properties to latex-modified concrete [Kuhlmann, 1980]. Some indication of how latex systems function to modify the internal structure of cement paste and concrete has been provided by Ohama, [1984]

Walters [1990] and Kuhulman [1985] opined that latex modified cement mortars and concretes are attractive because the latex addition substantially increases the flexural strength and the compressive strength. . On the other hand fiber-reinforced mortars and concretes are attractive because the fiber addition substantially increases the flexural toughness and in some cases it increases the flexural strength and therefore it is appropriate to combine these two methods.

Ohama [1973] has studied extensively the properties and proportioning of polymer modified mortars. The same author dealt with the systems in both mortars and concretes. Polymer dispersions are added to mortars and concretes to improve certain desired properties of the final product including improved bond strength to concrete substrates, increased flexibility (ductility) impact resistance, improved resistance to penetration by water, dissolved salts and improved resistance to frost action [Amdur,1988].

However due to increasing demand in the concrete industry to serve the needs of construction field, researchers are responding positively by proposing new formulations using other materials. In this Connection incorporating a polymer material, Natural Rubber Latex into the concrete has to some extent contributed to this demand in the society. The reason for usage of polymers in the concretes is they have good binding properties and good adhesion with aggregates. They have long – chain structure, which helps in developing long-range network structure of bonding. In contrast cement materials provide short-range structure of bonding. As a result polymer materials usually provide superior compressive strength to the concrete. Some polymer materials may selectively provide higher tensile and flexural strength to the structure compared to compressive strength. In addition they provide good adhesion to other material as well as resistance to physical damage (abrasion, erosion, impact) and chemical attack. When the performance of concrete is substantially higher than that of normal type concrete, such concrete is regarded as High Performance Concrete (HPC). Concrete may be regarded has high performance for several different reasons: High strength, High workability, High durability-and perhaps also improved visual appearance. For the first time in 1932, synthetic rubber (instead of natural rubber) latex was used for the latex-modified systems. In 1933, synthetic resin latexes (including polyvinyl acetate latexes) were used in the modified systems, and by the end of the 1930 the inventions clearly suggested that all types of polymers (natural or synthetic, elastomers or plastomers) could be used in polymer-modification. Since the late 1940s, latex-modified concretes have been used to various applications such as bridges, paving flooring, anti-corrosives, adhesives and deck coverings for ships. Stevens in 1948 and Griffiths in 1951 conducted feasibility studies on the applications of natural rubber modified systems. Ohama [1984] investigated the principle of latex modification and some typical properties of latex-modified concrete. He found the latex modification improved the properties. The hardened latex-modified concretes developed good strength, adhesion, pore structure, impermeability and durability (freeze thaw resistance, chloride penetration resistance, carbonation resistance and weather ability)

In order to achieve the high strength a detailed experimental investigation on Metakaolin based Natural Rubber Latex Modified Fiber Reinforced High Performance Concrete (NRLMFRHPC) has been planned. Metakaolin is used as a mineral admixture; Natural rubber latex polymer is used as an additive. In the production of HPC polymer based chemical super plasticizers are generally used to improve the flow properties and to reduce the water-binder ratio. However in the present work, it is proposed to use the naturally available polymer i.e. Natural Rubber Latex (NRL) in the production of HPC and steel fibers of an aspect ratio 50 are added to improve the strength and durability. The physical properties of each material which are used in the research program are presented.

2. Experimental Program

In order to study the behavior of NRLMFRHPC and also to understand the effect of natural rubber latex on Metakaoline based NRLMFRHPC, a total number of 81 mixes have been tried. In all the mixes the same type of aggregate i.e. crushed granite aggregate, river sand has been used. The proportion of cement, sand and aggregate has been maintained same for all mixes. These relative proportions have been obtained by absolute volume method. Ordinary Portland cement of 53 Grade from a single batch has been used. The test program consisted of conducting Compressive strength test on cubes and workability test on fresh concrete.

2.1 Materials

2.1.1 Cement

Ordinary Portland cement of 53 grades conforming to ISI standards has been procured and the properties of the cement are investigated in the laboratory. The cement satisfies the requirements as per I.S 12269-1987.

2.1.2 Fine Aggregate

The locally available river sand conforming to grading zone-II of IS 383-1970 has been used as Fine Aggregate. The Specific Gravity of fine aggregates is 2.69 with a fineness modulus of 2.77.

2.1.3 Coarse Aggregate

a) The locally available crushed granite material has been used as coarse Aggregate. The Specific Gravity of coarse aggregate is 2.76 and Fineness modulus is 6.99

2.1.4 Steel fibers (S.F)

Fiber is a small piece of reinforcing material which has certain characteristic properties. It can be either circular or flat. Plain concrete possesses a very low tensile strength ,limited ductility and little resistance to cracking internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of micro cracks leads to brittle fracture of the concrete. Although every type of fibers are suitable in cement and concrete not all of them can be effectively and economically used. Each type of fiber has its own characteristic properties and limitations. The fibers which could be used in the concretes are steel fibers, polypropylene, nylon, asbestos, coir, glass and carbon. In this investigation crimped steel fibers have been used. The diameter of fibers is 0.6mm and the Aspect ratio is 50.

2.1.5 Rubber Latex

Natural Rubber latex: The Natural Rubber latex is collected from ASSOCIATED LATEX (INDIA) LIMITED having its Administrative Office at P.B. NO.1117, Beach Road, Calicut. The properties of Natural Rubber Latex are presented in Table 1

S.No	Property	Rubber latex
1	Colour	White
2	Total Solid Content (% By Weight)	61.5 Max
3	Dry Rubber Content (% By Weight)	60 Min
4	Non Rubber solid content	1.50 Max
5	KOH Number	0.55 Max
6	Ammonia content , NH3 %	0.70 Max
7	Mechanical stability time	600 TO 1200
8	Volatile Fatty Acid Number	0.10 Max
9	Magnesium Content	8
10	P_H	10.4 Min
11	Coagulum Content , % By Mass	0.01 Max
12	Sludge Content, % By Mass	0.01 Max
13	Copper content As PPM	5
14	IRON content As ppm	8
15	Particle size of Rubber latex	0.2 µm
16	Specific Gravity of Rubber latex	0.94

Table 1 Physical properties of Rubber latex

2.1.6 Metakaolin

The mineral Admixture Metakaolin is obtained from VADODARA IN GUJARAT, INDIA. The Metakaolin is in conformity with the general requirements of pozzolana. The Specific Gravity of Metakaolin is 2.6 and its average particle size is 1.5 um The Specific surface area is 15 m2/gm. The pozzolonic reactivity of Metakaolin is 1050 mg of Ca (oh) 2/

2.1.7 Water

Clean potable fresh water, which is free from concentration of acid and organic substances, has been used for mixing the concrete.

3. Fabrications and Casting

Cubes were cast in steel moulds of inner dimensions of 150 x 150 x 150mm for every mix. The cement, sand and Metakaolin were mixed thoroughly by manually. Then steel fiber is added to the above mixture. For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers by tamping with a tamping rod and the vibration was effected by table vibrator after filling up the moulds. The moulds are kept in vibration for one minute and it was maintained constant for all the specimens. Six cubes were cast for each mix.

4. Curing

The moulds were removed after 24 hours and the specimens were kept immersed in a clear water tank. After curing the specimens in water for a period of 28 days the specimens were removed out and allowed to dry under shade

5. Results and Discussion

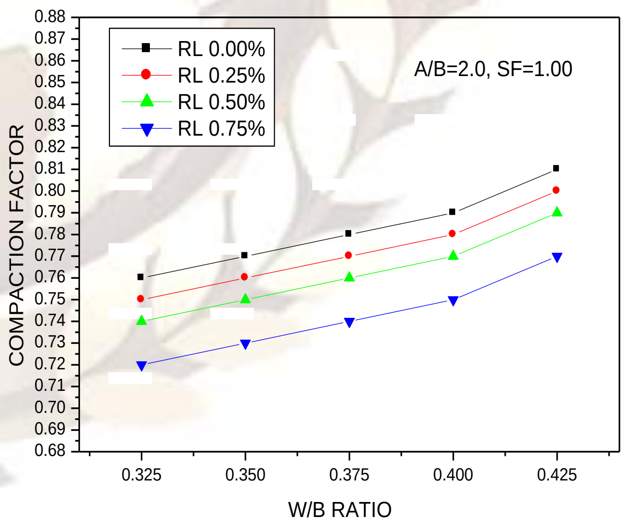

Fig 1 Compaction Factor vs. W/B ratio for Metakaoline based NRLMFRHPC (S.F=1.00)

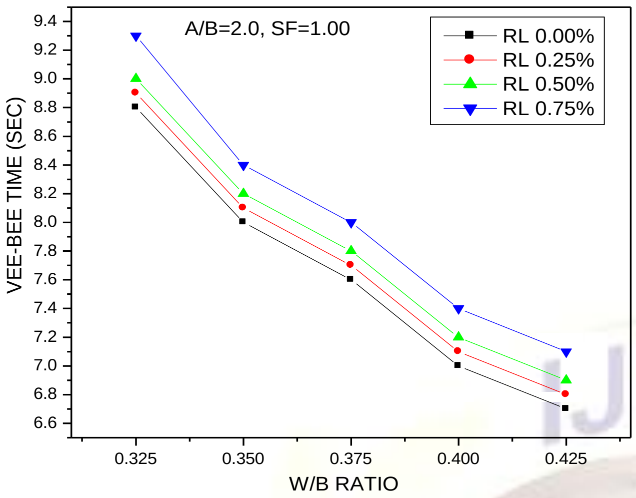

Fig 2 Vee - Bee time vs. W/B ratio for Metakaoline based NRLMFRHPC (SF=1.00)

Observing from Fig 1, it can be noticed that the compaction factor of NRLMFRHPC mixes increases with increase in w/b ratio and decreases with increase in the percentage of rubber latex indicating a decrease in workability. For 0% rubber latex at w/b ratio 0.325, A/B ratio 2.0 the compaction factor observed is 0.76. When the percentage of rubber latex is increased to o.25%, the compaction factor observed is 0.75. Similarly the compaction factor at 0.5% of rubber latex is 0.74. But further increase in the percentage of rubber latex from 0.5% to 0.75% the compaction factor observed is 0.72 which shows that the decrease in compaction factor is marginal up to 0.5% of rubber latex after that the sudden decrease in compaction factor is observed. This indicates that the decrease in workability is marginal up to 0.5%. Hence in this investigation the percentage of rubber latex is restricted to 0.5% in order to make workable concrete.

Observing from Fig 2 it can be noticed that the Vee-Bee time of NRLMFRHPC mixes decreases with increase in w/b ratio and increases with increase in the percentage of rubber latex indicating a decrease in workability. For 0% rubber latex at w/b ratio 0.325, A/B ratio 2.0, the Vee-Bee time observed is 8.0 seconds. When the percentage of rubber latex increased to 0.25% the Vee-Bee time observed is 8.5. Similarly the Vee-Bee time at 0.5% of rubber latex is 9.0. But further increase in the percentage of rubber latex from 0.5% to 0.75% the Vee-Bee time observed is 9.4 which shows that the increase in Vee-Bee time is marginal up to 0.5% of rubber latex after that the sudden increase in Vee-Bee time is observed, which indicates the decrease in workability up to 0.5% is marginal. Hence it is recommended that 0.5% of rubber latex may be adopted in order to make workable Fiber reinforced High performance concrete.

5.1 Effect of Rubber Latex and Steel Fibers on cube compressive strength of NRLMFRHPC

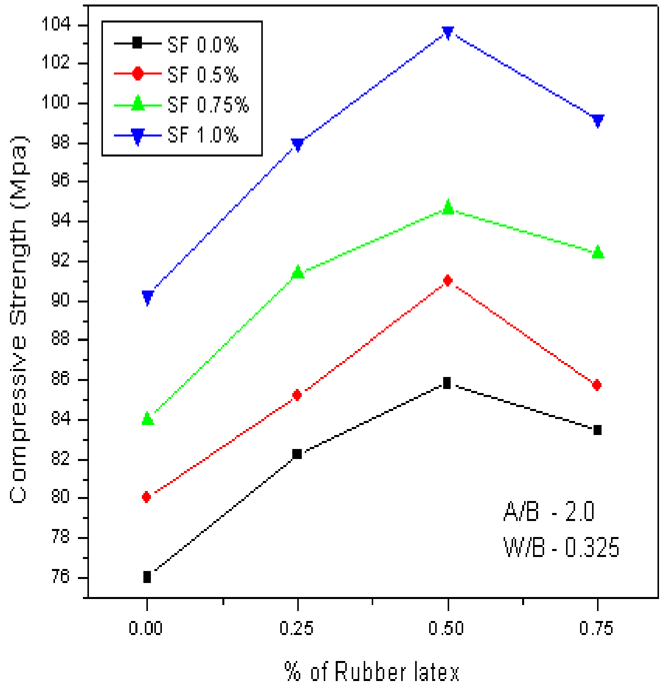

Fig 3 Variation of 28-Days Compressive Strength with % of Rubber latex (R.L) .

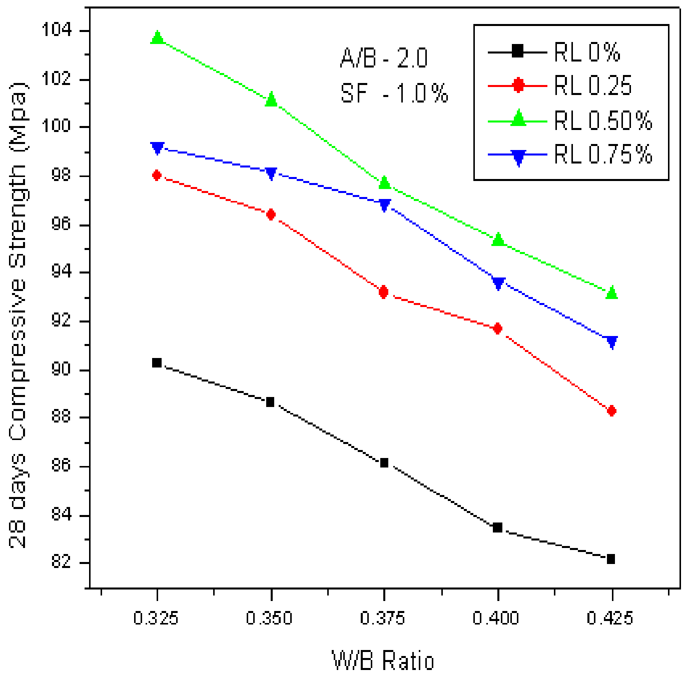

Fig 4 Variation of 28-Days Compressive Strength with % of W/B Ratio for 1% of Steel fibers (S.F) .

From Fig.3 and 4 it can be observed that the Compressive Strength increases with percentage increase in Rubber Latex up to 0.5% only. Further increase in percentage of R.L the Compressive strength starts decreasing. .At 0.5% RL and 1.0%

SF with W/B 0.325and A/B =2.0 the compressive strength observed is 103.67 MPa. The increase in percentage of rubber latex from 0.5% to 0.75% the decrease in compressive strength is observed. Similarly the percentage of Steel fibers increases the compressive strength is increased. As the percentage of steel fibers increases from 0.0 % to 1.0 %, the compressive strength is increasing. Although the compressive strength is increased with the percentage increase in steel fibers, the maximum percentage of steel fibers is restricted to 1.0% in order to avoid lumping of fibers during mixing. Hence it can be concluded that the maximum value of compressive strength is achieved at RL is 0.50% .

6. Conclusions

From the experimental work carried out and the analysis of the results following conclusions seem to be valid with respect to the utilization of Natural Rubber Latex and steel fibers in the production of NRLMFRHPC.

- Compaction factor: workability of NRLMFRHPC mixes decreases with increase in the percentage of Natural Rubber Latex and steel fiber
- It is observed that, at 0.5 % of rubber latex , the decrease in the compaction factor is very much marginal. i.e. about 10.71%. Also it is observed that these mixes are quite cohesive even at lower water-binder ratio of 0.325 because of the polymer (Natural Rubber Latex) used in the mix. Hence, it can be concluded that 0.5 % of Rubber latex and 1.0 % of steel fiber can be used in the production of NRLMFRHPC with sufficient workability.
- The compressive strength of NRLMFRHPC mixes increases up to 0.5% dosage of Natural Rubber Latex. There after a decrease in compressive strength is observed.
- The 28-day compressive strength of NRLMFRHPC mixes increases with increase in percentage of Rubber latex up to 0.5%. It can further be observed that the maximum compressive strength of 103.67 MPa is achieved at 0.5 % dosage of natural rubber latex and 1.0 % of steel fiber at water binder ratio of 0.325.

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