Studies on Fibre Reinforced High Performance Concrete with Natural Rubber Latex

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Abstract— The impact of natural rubber latex and steel fibre volume percentage on the workability, compressive strengths, split tensile strength, and flexural strengths of high performance concrete are assessed in this study for a range of water binder ratios, including 0.325, 0.350, 0.375, 0.40, and 0.425. In a similar vein, it is also established how steel fibres and natural rubber latex affect durability properties. The mineral supplement known as "Metakaolin" was imported from Gujarat's Vadodara. Natural Rubber Latex is a polymer that comes from Calicut, which is located in North Kerala. The best polymer dose for HPC is determined by laboratory testing to be 0.5% of the binder's weight. Based on the results of this investigation, 1% is the recommended optimal intake of fibre. On the use of natural rubber latex in the creation of fiber-reinforced high-performance concrete, thorough and practical findings have been reached.

Keywords—Natural Rubber Latex, FRC, Concrete, HPC, performance

1.INTRODUCTION

One of the materials that appears simple but is very sophisticated is cement concrete. Its many complicated behaviours have not yet been fully understood in order to make profitable and advantageous use of this substance. In order to get a deeper understanding of these materials' behaviours, research is now being conducted on the behaviour of concrete with regard to long-term drying shrinkage, creep, fatigue, morphology of gel structure, bond, fracture mechanism, and polymer modified concrete and fibrous concrete. About 22 million tonnes of cement are consumed annually in India. Since concrete is created on-site, unlike other building materials, it can vary greatly in quality, characteristics, and performance since it contains natural ingredients in addition to cement.

In order to create concrete with the desired attributes from materials with different properties, one must have a thorough understanding of how the different elements work together while the concrete is both fresh and hardened. Both site engineers and concrete technologists require this expertise. The most common materials in civil engineering structures are those based on cement, due to its low cost and practical physical features.

These materials do, however, have a number of shortcomings. They are weak in tension, brittle, and have a low failure strain. Both fibre reinforcement and polymer modification have been effectively applied in practice to address these issues.

This work was an experimental investigation of the combined usage of fibres and polymers. To begin with, though, a quick explanation of the distinct roles played by fibres and polymers in concrete must be given. Concrete is a durable and robust substance. When steel reinforcement is used, it can withstand explosions, earthquakes, cyclones, and fires. In contrast to many engineering materials such as steel and rubber, the production of concrete uses less energy. Nowadays, high-quality concrete may be made with a lot of mineral admixtures, which are byproducts of other industries.

High-performance concrete reinforced with fibres and modified with natural rubber latex: This study developed a unique type of concrete called Natural Rubber Latex Modified Fibre Reinforced High Performance Concrete (NRLMFRHPC), which offers several advantages when building concrete structures with standard ingredients, mixing techniques, and curing times. Put otherwise, the NRLMFRHPC is a concrete that performs exceptionally well in the structure where it is used, in the environment where it is exposed, and under the stresses that it is subjected to during the course of its design life. Polymer modified concrete, polymer concrete, and polymer impregnated concrete have all been the subject of intensive study throughout the last few decades.

Due to their comparable high performance, multifunctionality, and sustainability when compared to traditional cement concrete, these materials are currently in great demand for construction. Concrete polymer composites are environmentally friendly and support the preservation of natural resources, the durability of infrastructure, and the preservation of the environment. Concrete undergoes polymer alteration when Natural Rubber latex is added to the newly mixed concrete.

Surfactants stabilise the polymer Natural Rubber latex, and each polymer has unique qualities that form films when exposed to the appropriate temperature range and chemical conditions during the hardening and curing processes. The 7 Fibre Reinforced Natural Rubber Latex Modified By adding natural latex fibres and polymer into HPC, high performance concrete is produced.

Need for the current study: Although latex has been used as a protective material for a long time—dating back to the 1800s—latex-modified concretes have attracted a lot of attention in the construction industry. In the 1980s, latex use grew many times. The performance parameters of hydraulic cement concrete have been improved with the addition of polymeric materials. Notwithstanding, the use of polymers into concrete must not compromise its mechanical properties or its durability attributes. The brasiliensis tree spontaneously polymerizes poly-isoprene to form Natural Rubber Latex (NRL). As opposed to being regulated, as is typically the case with emulsion polymerization, the majority of its features are therefore established during the spontaneous polymerization process.

NRL contains 30–40% suspended rubber particles when it's fresh. While several studies have documented the use of polymers, such as natural rubber latex, to alter the workability and strength properties of regular concrete, relatively less is known about its application in fiber-reinforced HPC and hybrid Portland cement. Because HPC comprises extra raw materials including chemical and mineral admixtures, it differs from regular concrete. Therefore, it is necessary to look at how well Natural Rubber Latex works with various chemical and mineral admixtures.

There needs to be further consideration given to how NRL affects the fiber-reinforced HPC's strength, workability, and durability qualities. For improved applications, empirical models connecting the different workability and strength properties of natural rubber latex modified fibre reinforced HPC must be developed.

Furthermore, workability and compressive strength are the sole factors taken into account while designing a concrete mix. However, because HPC is primarily concerned with performance metrics, the mix design should also take into account other elements, such as permeability, tensile or flexural strength, etc., in addition to compressive strength. As a result, mix design charts for NRLMFRHPC must be created while taking all of these factors into account. In order to do in-depth research on the strength, workability, and durability features of natural rubber latex modified fibre reinforced high-performance concrete, the current study properties were adopted.

The current work's objectives are to do a feasibility study on the production of NRLMFRHPC using locally sourced raw materials, a mineral admixture (Metakaolin) made in the country, and natural rubber latex as a polymer. It is necessary to research the NRLMFRHPC's workability qualities in their fresh form. Additionally, it is necessary to assess how NRLMFRHPC behaves under the three fundamental loading modes of compression, tension, and flexure. Through laboratory experiments, the current study will examine the systematic impact of steel fibres and rubber latex on the tensile strength, flexural strength, compressive strength, and workability of NRLFRHPC. Properties such as compressive strength, tensile strength, flexural strength, and durability studies will be obtained by testing cubes, cylinders, and beams.

As a result, the current work's precise goals are outlined below.

• To do a feasibility study on the production of NRLMFRHPC utilising steel fibres, conventional curing techniques, the polymer "Natural Rubber Latex," and the mineral additive Metakaolin.
• To carry out studies on NRLMFRHPC using various mixtures and assess the cylinders' split tensile strength, flexural strength, and cube compressive strength.
• Testing several NRLMFRHPC mixes for compressive strength, split tensile strength, and flexural strength; the findings will be compared with the standard M20 concrete mix.
• To examine the findings and assess how natural rubber latex and steel fibres affect the workability and strength of HPC.
• To create appropriate mix design charts that incorporate durability and strength metrics.

To provide an appropriate mix design process for blends NRLMFRHPC. In order to test several NRLMFRHPC mixes made using the available raw materials, mineral additive Metakaolin, and natural rubber latex polymer, a thorough experimental programme will be conducted. It will have qualities like workability, compressive, tensile splitting, and flexural strengths. After analysing the data, insightful conclusions will be made. It is envisaged that this research would contribute to the ongoing development of NRLMFRHPC in India for a range of uses.

2.MATERIALS USED

A thorough experimental study on Natural Rubber Latex Modified Fibre Reinforced High Performance Concrete (NRLMFRHPC) based on Metakaolin has been planned in order to accomplish the previously stated goals. Natural rubber latex polymer is employed as an additive, while metakaolin is used as a mineral admixture. Super plasticizers made of polymers are typically employed in the manufacturing of HPC polymer-based chemical products to enhance flow characteristics and lower the water-binder ratio. In the current study, however, it is suggested to produce HPC using a naturally occurring polymer called Natural Rubber Latex (NRL), to which steel fibres with an aspect ratio of 50 are added to enhance the material's strength and ductility.

This chapter presents the physical characteristics of all the materials employed in the study programme. Cement, fine and coarse aggregate, rubber latex, metakaolin, and water are among the components employed in this experiment. This Chapter provides a full explanation of the tests done on each material to determine its appropriateness.

Cement: IS: 12269 standards-compliant ordinary Portland cement of grade 53 has been acquired, and the tests that follow have been completed in accordance with IS: 8112 – 1989.

Fine aggregate: The sand employed in this experiment was obtained locally from the Chitravathi River and confirms to grading zone II of Table 4 of IS 383-1970.

Specific Gravity of Fine Aggregates: Using a pycnometer test, the specific gravity of fine aggregate was calculated using the following formula. After conducting three experiments, the average specific gravity is taken into account.

Bulk Density of Fine Aggregates: When aggregate is filled in a normal way, its bulk density indicates how tightly it is packed.

Fineness Modulus (FMO) and Grading Zone of Fine Aggregates (FA) have been ascertained using sieve analysis.

granular aggregate The regionally accessible 50% of the crushed granite metal passed through a 12.5 mm filter and was retained on a 10 mm sieve, whereas 50% passed through a 20 mm sieve and was retained on a 12.5 mm sieve.

Metakaolin: M/S KOAT MANUFACTURING COMPANY, Regd office at 49 Shalina Complex, Vadodara, Gujarat, India, is the source of the mineral adjuvant metakaolin. The Metakaolin complies with the pozzolana criteria.

Natural Rubber Latex: The provider of the natural rubber latex, ASSOCIATED LATEX (INDIA) LIMITED, whose administrative office is located at P.B. NO. 1117, Beach Road, Calicut, provides it. The supplier's specifications are shown in Table 1.

TABLE I. TABLE 1. PHYSICAL PROPERTIES OF RUBBER LATEX

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	600-1200
8	Volatile Fatty Acid Number	0.10 Max
9	Magnesium Content	8
10	pH	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 □m
16	Specific Gravity of Rubber latex	0.94

STEEL FIBRES: Crimped steel fibres, obtained from STEWELS COMPANY in Nagpur, Maharashtra, are utilised in this investigation. Fibre has an aspect ratio of 50 and a density of 7840 kg/m3.

WATER: Water is a crucial component of concrete because it actively engages in the chemical process that forms the strong gel with the cement.

3.EXPERIMENTAL WORK

General: The goal of this study is to assess how natural rubber latex (NRL) additive affects fiber-reinforced HPC. According to the suggestions of previous studies, a predetermined amount of 10% is substituted with Metakaolin in place of cement. In this experiment, steel fibres with an aspect ratio of 50 have been utilised. Despite the fact that steel fibres come in a variety of aspect ratios, previous study has recommended using steel fibre with a diameter of 0.6 mm and a length of 30 mm and an aspect ratio of 50. In order to assess compressive strength, split tensile strength, and flexural strength, respectively, cubes, cylinders, and beams of different NRLMFRHPC were cast. For the durability test, specimens with a diameter of 100 mm and a height of 50 mm were also cast. The tests are also carried out to see if NRLMFRHPC mixtures are workable. Rapid Chloride Ion Permeability Tests (RCPT) were used to assess NRLMFRHPC's durability. Programme for testing: To investigate the behaviour of NRLMFRHPC and comprehend the impact of the polymer (rubber latex), a total of sixteen cubes, sixteen cylinders, and sixteen beams were cast and their corresponding compressive strength, split tensile strength, and flexural strength were assessed. The 135 (A/B=2.0) test programme is run through with an Aggregate Binder ratio of 2.0.

Since 10% is the optimal proportion, it is also set at that level. There is a range of 0.325 to 0.425 for the W/B Ratio.and the percentages of steel fibre range from 0% to 1.0%. River sand and crushed granite aggregate are the same sort of aggregate that has been utilised in all of the mixtures. For every mix, the same ratio of cement, sand, and aggregate has been used. One batch of ordinary Portland cement, grade 53, has been utilised. Below are the different parameters that were evaluated for this test programme. A/B=2, the aggregate-binder ratio Ratios of water to binder (W/B) are 0.325, 0.350, 0.375, 0.40, and 0.425. 10% of cement is being replaced with metakaolin. Volume of Steel Fibre Percentage = 0.5, 1.0%, 0.75, and 0.0. Natural rubber latex dosage is 0.0, 0.25, 0.5 and 0.75 %. Terminology for Mix Designation: The mix designation is five letters long. The letter "L" stands for natural rubber latex, or latex. "Mix" is denoted by the second letter M. The proportion of fibre in the mixture is indicated by the third letter. The volume percentage of fibre for "A" is 0%, for "B" it is 0.5%, for "C" it is 0.75 percent, and for "D" it is 1.0%. The proportion of NRL in the mixture is shown by the fourth letter. Q denotes 0.25%, R denotes 0.5%, S denotes 0.75%, and P denotes 0% NRL. The fifth letter is a numerical digit that represents the mix's W/B ratio. The values of the first five digits are as follows: W/B = 0.325 for digits 1, 2, and 3, W/B = 0.375 for digits 3, 4, and 0.4% for digits 5.

For reference, the letter "R" stands for the Reference mix of M20 grade cast. The Absolute Volume Method has been used to determine the mix proportions for different trail mixes. Features of the compressive strength of NRLMFRHPC mixes: Tables 2 and 3 display the 28-day and 90-day compressive strengths of NRLMFRHPC, respectively, derived from the current study.

TABLE II. 28-DAYS CUBE COMPRESSIVE STRENGTHS OF NRLMFRHPC MIXES

S. No	Designation of mix	Compressive strength (MPa)	% Variation with respect to reference mix M20 (R)	% Variation w.r.t. corresponding 0% Steel Fibre&0% NRL mix
1	R	27.76	--	---
2	LMAP 1	76	173.78	0.00
3	LMAP 2	74.6	168.73	0.00

4	LMAP 3	72.8	162.25	0.00
5	LMAP 4	70.3	153.24	0.00
6	LMAP 5	68.2	145.68	0.00
7	LMAQ 1	82.2	196.11	8.16
8	LMAQ 2	80.8	191.07	8.31
9	LMAQ 3	77.65	179.72	6.66
10	LMAQ 4	74.68	169.02	6.23
11	LMAQ 5	70.84	155.19	3.87
12	LMAR1	85.84	209.22	12.95
13	LMAR2	82.35	196.65	10.39
14	LMAR3	81.02	191.86	11.29
15	LMAR4	77.8	180.26	10.67
16	LMAR5	73.84	165.99	8.27
17	LMAS1	83.46	200.65	9.82
18	LMAS2	80.72	190.78	8.20
19	LMAS3	78.36	182.28	7.64
20	LMAS4	75.26	171.11	7.06
21	LMAS5	72.44	160.95	6.22
22	LMBP1	80	188.18	5.26
23	LMBP2	77.8	180.26	4.29
24	LMBP3	73.4	164.41	0.82
25	LMBP4	71.5	157.56	1.71
26	LMBP5	69.2	149.28	1.47

TABLE III. 90-DAYS CUBE COMPRESSIVE STRENGTHS OF NRLMFRHPC MIXES.

S. No	Designation of mix	Compressive strength (MPa)	% Variation with respect to reference mix M20 (R)	% Variation w.r.t. corresponding 0% Steel Fibre&0% NRL mix
1	R	30.51	–	–
2	LMAP1	83.6	174.01	0.00
3	LMAP2	82.06	168.96	0.00
4	LMAP3	79.64	161.03	0.00
5	LMAP4	77.33	153.46	0.00
6	LMAP5	75.02	145.89	0.00
7	LMAQ1	90.42	196.36	8.16
8	LMAQ2	88	188.43	7.24
9	LMAQ3	85.41	179.74	7.25
10	LMAQ4	82.14	169.22	6.22
11	LMAQ5	77.92	155.39	3.87
12	LMAR1	94.42	209.47	12.94
13	LMAR2	90.58	196.89	10.38
14	LMAR3	89.12	192.1	11.90
15	LMAR4	85.58	180.5	10.67
16	LMAR5	81.22	166.21	8.26
17	LMAS1	91.8	200.88	9.81
18	LMAS2	88.79	191.02	8.20
19	LMAS3	86.19	182.5	8.22
20	LMAS4	82.78	171.32	7.05
21	LMAS5	79.68	161.16	6.21
22	LMBP1	89	191.71	6.46
23	LMBP2	85.58	180.5	4.29
24	LMBP3	81.26	166.34	2.03
25	LMBP4	79.49	160.54	2.79

4. RESULTS AND DISCUSSION

EFFECT OF DOSAGE OF NATURAL RUBBER LATEX ON COMPRESSIVE STRENGTH:

Figures 1 through 10 show the variance in 28- and 90-day cube compressive strength with different percentages of rubber latex.

Fig .1. Variation Of 28-Days Compressive Strength With % Of Rubber Latex (W/B- 0.325)

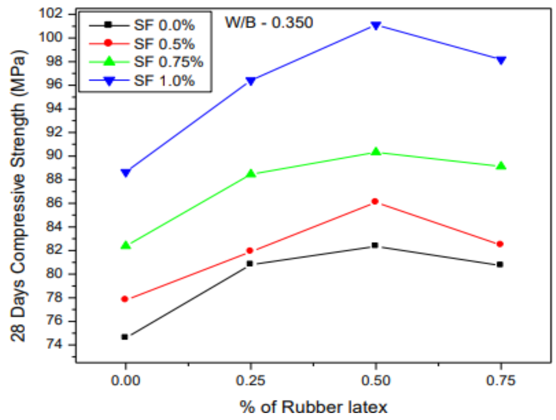

Fig.2. Variation of 28-Days Compressive Strength with % of Rubber latex (W/B- 0.350)

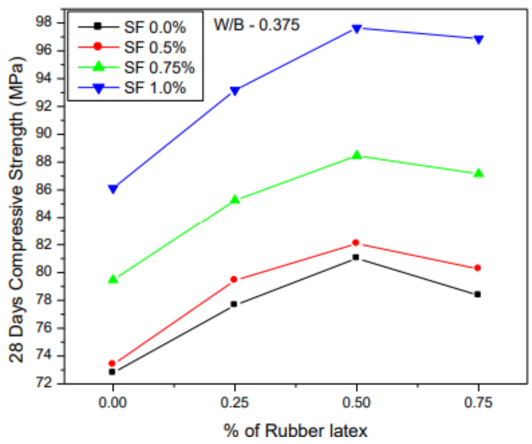

Fig.3. Variation of 28-Days Compressive Strength with % of Rubber latex (W/B - 0.375)

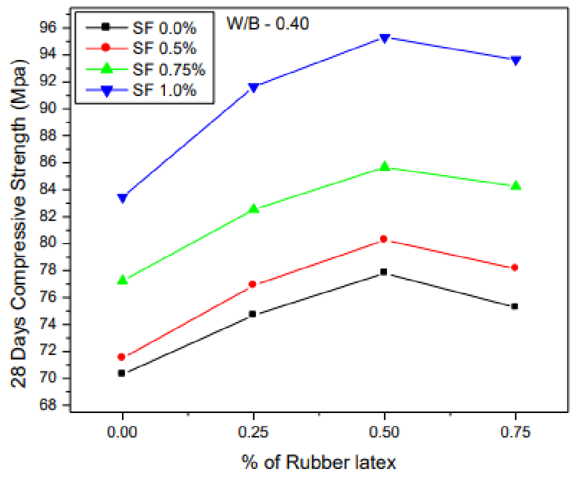

Fig.4. Variation of 28-Days Compressive Strength with % of Rubber latex (W/B - 0.40)

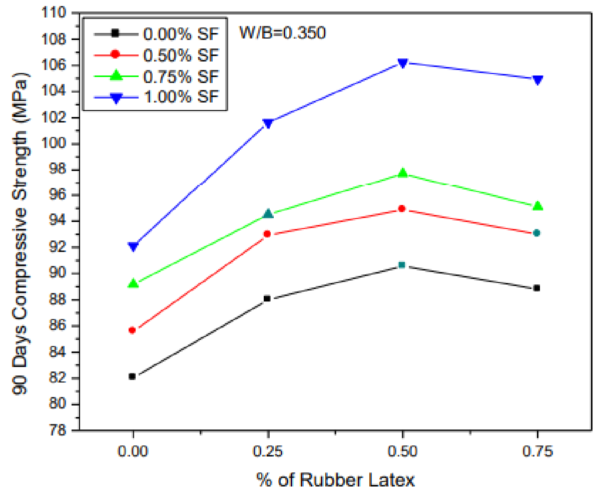

Fig.7. Variation of 90-Days Compressive Strength with % of Rubber Latex (W/B -0.35)

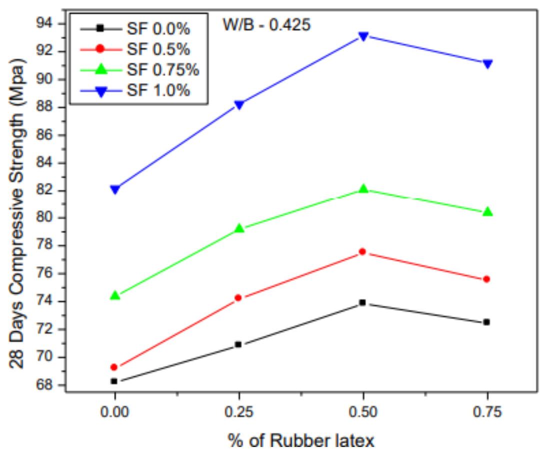

Fig.5. Variation of 28-Days Compressive Strength with % of Rubber latex (W/B 0.425)

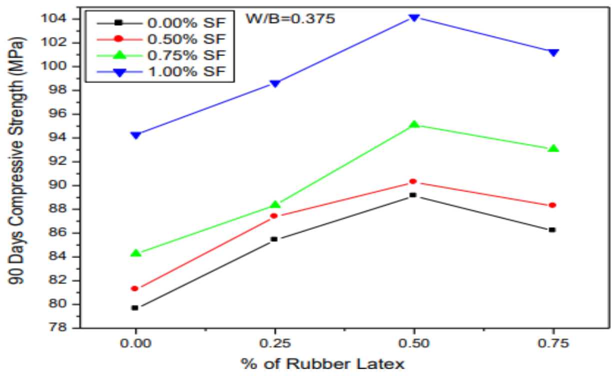

Fig.8. Variation of 90-Days Compressive Strength with % of Rubber Latex (W/B-0.375)

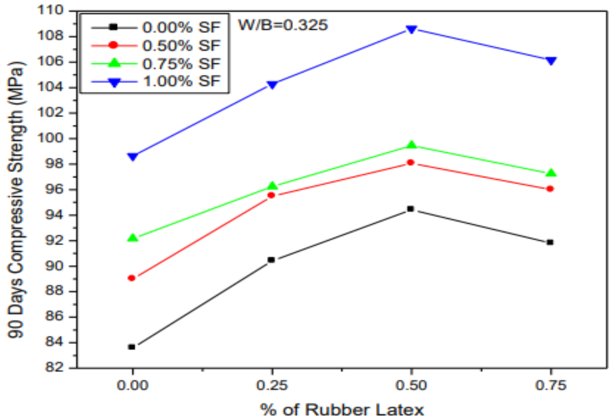

Fig.6. Variation of 90-Days Compressive Strength with % of Rubber Latex (W/B-0.325)

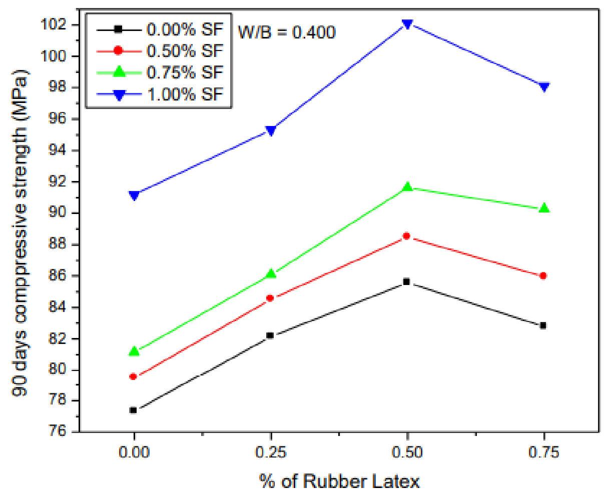

Fig.9. Variation of 90-Days Compressive Strength with % of Rubber Latex (W/B- 0.4)

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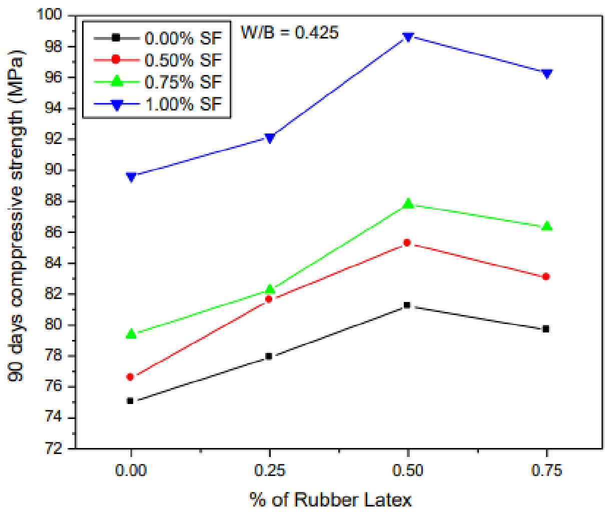

Fig.10. Variation of 90-Days Compressive Strength with % of Rubber Latex (W/B - 0.425)

These numbers show that the NRLMFRHPC mixes' 28- and 90-day compressive strengths rise as the amount of rubber latex increases up to 0.5%. Up to a maximum of 0.5%, the Compressive Strength rises as the Rubber Latex percentage increases. The compressive strength falls as the fraction of R.L. increases more. Table shows that as the RL rises from 0 to 0.25%, the increase in 28-day compressive strength over the comparable plain mix is in the range of 0% to 8.16%. When RL rises from 0.25% to 0.5%, the increase in compressive strength varies from 8.16% to 12.95%. When rubber latex is increased further, from 0.5% to 0.75%, the compressive strength falls between 12.95% and 9.82%.

By reducing voids and increasing density, the addition of Natural Rubber Latex to concrete results in a microstructure that is denser and more refined. Up to a 0.5% dose improvement in compressive strength is primarily the result of this modification. If the compression strength decreases more than 0.5% of the NRL dose, it might be because too much latex was used—more than what is ideal for achieving maximum strength. The presence of micro structural fractures and cavities in the hardened HPC caused by excess latex may hinder the aggregate particles from being firmly packed, creating weak areas that might lead to excessive cracks during compression. As a result, it has been found that dosages higher than 0.5% cause NRLMFRHPC to lose compressive strength.

Even over ninety days, a comparable pattern of increasing compressive strength is seen. The increase in compressive strength is 0% to 8.16% for variations in rubber latex between 0% and 0.25%, 8.16 % to 12.94% for variations in rubber latex between 0.25% and 0.50%, and 12.94 % to 9.81% for variations in rubber latex between 0.5% and 0.75%. The mix LMAR1 has a maximum 90-day compressive strength of 94.42 MPa on record.From the perspective of compressive strength, the ideal dose of rubber latex is determined to be 0.5% based on the findings of the experiments carried out in this study.

5.CONCLUSIONS

Rubber tree tapping yields the polymer known as natural rubber latex. By casting and testing NRLMFRHPC mix specimens, the impact of rubber latex addition on the compressive, tensile, and flexural strengths of NRLMFRHPC mixes has been determined. The best result for cube compressive strength, split tensile strength, and flexural strength in the creation of NRLMFRHPC is found when 0.5% of natural rubber latex is added by weight of binder.

When the amount of steel fibres grows to 1.0% and the percentage of rubber latex climbs to 0.5%, the 28-day compressive strength of NRLMFRHPC mixes increases as well. It is discovered that at 0.5% rubber latex and 1.0% steel fibre, with a W/B of 0.325, the maximum compressive strength of 103.67 MPa is achieved. It is also observed that the compressive strength drops to 99.24 MPa when Rubber Latex is increased to 0.75%. The ratio of steel fibre up to 1.0% and the percentage of rubber latex up to 0.5% both boost the 90-day compressive strength of NRLMFRHPC mixtures. It is also found that at 0.5% rubber latex, 1.0% steel fibre, and W/B of 0.325, the maximum 90-day compressive strength of 108.62 MPa is achieved. It is also observed that the compressive strength drops to 106.16 MPa when Rubber Latex is increased to 0.75%.

When the amount of steel fibres grows to 1.0% and the percentage of rubber latex climbs to 0.5%, the 28-day tensile strength of NRLMFRHPC mixes increases as well. It can be shown that a mixture containing 0.5% rubber latex, 1.0% steel fibre, and a W/B ratio of 0.325 has a maximum tensile strength of 7.57 MPa. It is also observed that the tensile strength drops to 7.48 MPa when Rubber Latex is increased to 0.75%.

When the amount of steel fibre is increased to 1.0% and the percentage of rubber latex is increased to 0.5%, the 90-day tensile strength of NRLMFRHPC mixes likewise rises. It is also evident that the mixture containing 0.5% rubber latex, 1.0% steel fibre, and a W/B ratio of 0.325 yields a maximum 90-day tensile strength of 8.06 MPa. It is also observed that the tensile strength drops to 7.95 MPa when Rubber Latex is increased to 0.75%. At a 0.5% dose of natural rubber latex, the maximum compressive strength, tensile strength, and flexural strength are achieved. Therefore, for Natural Rubber Latex modified fibre reinforced high-performance concrete (NRLMFRHPC), a 0.5% addition of natural rubber latex is thought to be the ideal amount based on strength considerations.

The NRLMFRHPC's tensile, flexural, and compressive strengths all rose by up to 1% as the volume proportion of steel fibres increased. The maximum amount of fibre content is limited to 1.0% since higher amounts cause the fibres to ball. Therefore, 0.5% is considered the ideal dosage of rubber latex based on permeability parameters. Based on the study, it is advised to utilise a dose of 1.0% steel fibres and 0.5% natural rubber latex for the NRLMFRHPC's workability, strength, and durability.

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