Studies on Natural Rubber Latex Modified Fibre Reinforced High Performance Concrete

Akula Diva Prasad [1], Pasupuleti Nageswara Rao[2], Dr. Kusuma Sundara Kumar[3*]

[1]M.Tech Student, Dept. of Civil Engineering, Bonam Venkata Chalamayya Engineering College-Odalarevu Konaseema, Andhra Pradesh, India.
prasad.lovely28@gmail.com
[2]Asst.Professor, Dept. of Civil Engineering, Bonam Venkata Chalamayya Engineering College-Odalarevu Konaseema, Andhra Pradesh, India
pnr.bvce@bvcgroup.in
[3]Professor, Dept. of R &D, Bonam Venkata Chalamayya Engineering College-Odalarevu Konaseema, Andhra Pradesh, India.
*skkusuma123@gmail.com

Abstract. Studies on Natural Rubber Latex Modified Fiber Reinforced High Performance Concrete (NRLM-FR-HPC) represent a significant area of research aimed at enhancing the properties and performance of concrete materials. This research focuses on incorporating natural rubber latex (NRL) and fibers into high-performance concrete (HPC) to improve its mechanical, durability, and sustainability characteristics. The present study explores the impact of volume percentages of natural rubber latex and steel fibre on the strength and flow properties of high performance concrete. 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. Studies on Natural Rubber Latex Modified Fiber Reinforced High Performance Concrete represent a promising avenue for enhancing the properties and performance of concrete materials. By incorporating NRL modification and fiber reinforcement, NRLM-FR-HPC offers improved mechanical properties, enhanced durability, and increased sustainability compared to traditional concrete mixtures.

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. [1]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

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K. R. Madhavi et al. (eds.), *Proceedings of the International Conference on Computational Innovations and Emerging Trends (ICCIET 2024)*, Advances in Computer Science Research 112,
https://doi.org/10.2991/978-94-6463-471-6_65

concrete and fibrous concrete.[2] 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.[3]

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.[4]

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.[5]

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.[6]

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. [7] 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.[8]

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. [9] 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.[10]

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.[11]

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.[12]

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.[13-15]

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.[16-18]

There needs to be further consideration given to how NRL affects the fiber-reinforced HPC's strength, workability, and durability qualities. 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. [19] 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 rubber latex on the strength properties of NRLFRHPC.

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 strength properties.
- 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 is envisaged that this research would contribute to the ongoing productiont of NRLMFRHPC in India for a range of uses.

2 Materials Used

A thorough experimental study on Fibre Reinforced High Performance Concrete added with Natural Rubber Latex (NRLMFRHPC) based on Metakaolin was conducted in order to accomplish the previously stated goals. Super plasticizers made of polymers are typically employed in the manufacturing of HPC polymer-based chemical products to enhance flow characteristics and lower the ratio of water-binder. However, it is suggested to produce HPC using a naturally occurring polymer called Natural Rubber Latex (NRL), to which fibres of steel having aspect ratio of 50 are mixed to enhance the material's structural properties

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. In order to assess compressive strength, split tensile strength, and flexural strength, respectively, cubes, cylinders, and beams of different NRLMFRHPC were 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 natural rubber latex on concrete, cubes, cylinders, and beams were cast and their corresponding strengths 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 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.

First step involves setting up the initial values for the FPO optimization process. This process involves initializing parameters of FPO and selected transformer network. Parameters for FPO, such as population size, pollination coefficients (α,β), and maximum iterations, are initialized. Hyperparameters for Transformer network, like number of layers, attention heads, and learning rate, are also initialized. Suitable transformer for image segmentation will be vision transformers and also the selection depends on the requirements of applications.

Next step is performing global and local pollination process. During this process FPO iteratively explores the solution space. Flowers represent sets of Transformer hyperparameters exchange information globally and locally, imitating the pollination behavior of flowers. Fitness can be based on metrics like Dice coefficient, representing the accuracy of segmentation. Flowers with higher fitness values are selected for the next iteration. Hybridization can be used in the process of flower pollination depending on the complexity of problem, dimension of solution space and computational resources. Considering these aspects FPO can be combined with optimization methods such as genetic algorithm, differential evolution, particle swarm optimization. This method ensures a comprehensive search across solution space while fine-tuning solutions in promising regions, leading to better optimization results. By integrating diverse algorithms, HFPO can utilize the strengths of each method to converge faster towards optimal solutions.

Next, the optimized set of hyperparameters obtained from FPO is used to construct a Transformer network. The network architecture is set up according to selected hyperparameters. Constructed Transformer network is trained using image dataset. The network learns to map input images to segmented output using a supervised training approach. Training involves minimizing a loss function, often related to the dissimilarity between predicted and ground truth segmentations. trained Transformer models are evaluated using validation data. The model with best performance, usually measured by accuracy, Dice coefficient, and other metrics, is selected as the optimized model configuration. Final output of the proposed method is accurately segmented images, obtained by optimizing the Transformer network's hyperparameters through the FPO process. The steps of the proposed HFPO-Transformer algorithm is specified be

4 Results and Discussions

This section presents the discussion on the results obtained in the experimental work. Figures 1 & 2 show the variance in 28- and 90-day compressive strength with different percentages of latex. Tables 1 display some results of 28d strengths of NRLMFRHPC, derived from the current study.

Table 1. The results obtained

S. No	Mix	Compres-sive strength in MPa	S. No	Mix	Compres-sive strength in MPa
1	R	27.86	27	LMBQ1	85.34
2	LMAP 1	76.21	28	LMBQ2	81.23
3	LMAP 2	74.82	29	LMBQ3	79.34
4	LMAP 3	72.41	30	LMBQ4	76.28
5	LMAP 4	70.13	31	LMBQ5	74.48
6	LMAP 5	68.64	32	LMBR1	90.28
7	LMAQ 1	82.45	33	LMBR2	86.78
8	LMAQ 2	80.66	34	LMBR3	82.38
9	LMAQ 3	77.55	35	LMBR4	80.66
10	LMAQ 4	74.78	36	LMBR5	77.12
11	LMAQ 5	70.14	37	LMBS1	85.14
12	LMAR1	85.14	38	LMBS2	82.24
13	LMAR2	82.45	39	LMBS3	80.26
14	LMAR3	81.32	40	LMBS4	78.23
15	LMAR4	77.82	41	LMBS5	75.23
16	LMAR5	73.44	42	LMCP1	84.12
17	LMAS1	83.56	43	LMCP2	82.25
18	LMAS2	80.42	44	LMCP3	79.22
19	LMAS3	78.56	45	LMCP4	77.14
20	LMAS4	75.66	46	LMCP5	74.16
21	LMAS5	72.34	47	LMCQ1	91.33
22	LMBP1	80.33	48	LMCQ2	88.98
23	LMBP2	77.23	49	LMCQ3	85.67
24	LMBP3	73.34	50	LMCQ4	82.59
25	LMBP4	71.12	51	LMCQ5	79.57
26	LMBP5	69.24	52	LMCR1	94.61

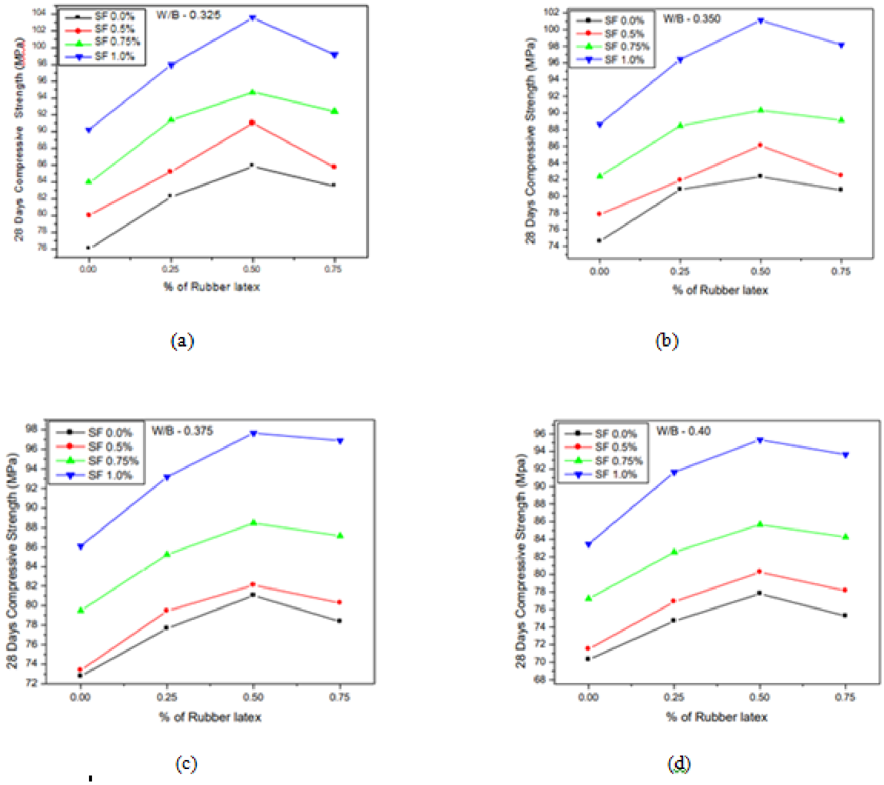
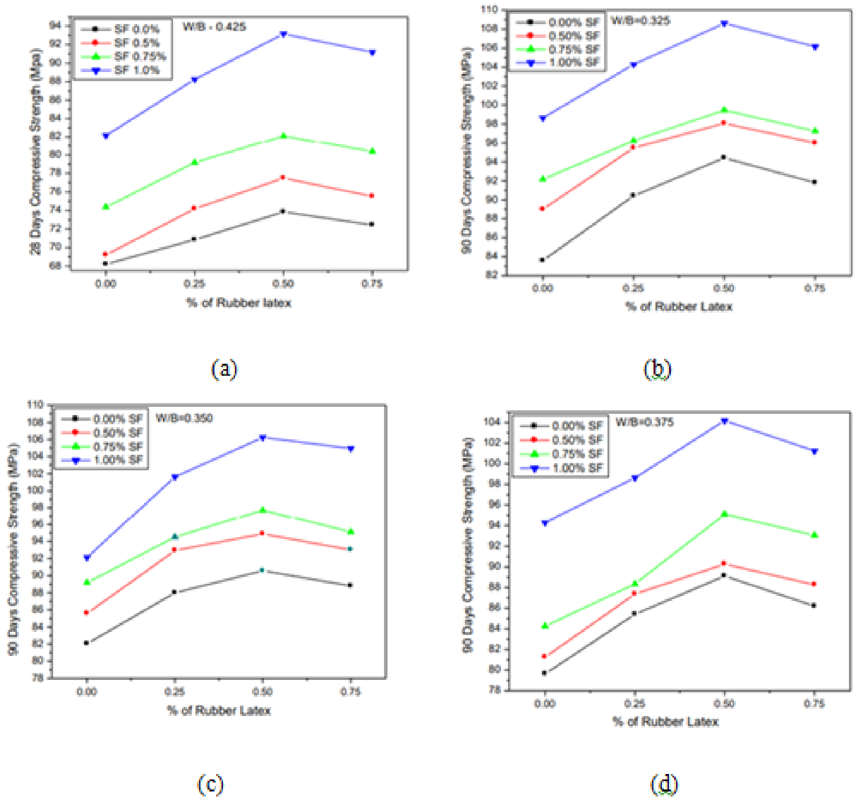


Fig.1. Compressive Strength Vs % Of Rubber Latex (28-Days) (a) W/B- 0.325, (b) W/B- 0.35, (c) W/B- 0.375, (d) W/B- 0.40

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. With further addition of fraction of R.L. the strength falls. Table shows that when the RL rises from 0 to 0.25%, the 28-day compressive strength rises over the comparable plain mix is in the range of 0% to 8.16%. When RL increases from 0.25% to 0.5%, the growth 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.



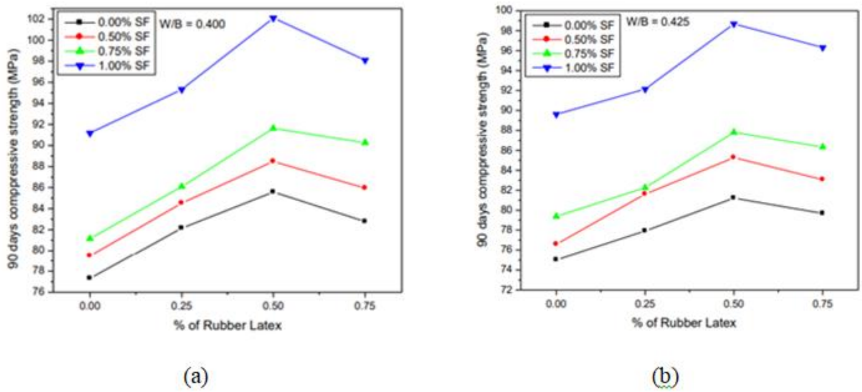


Fig.2. Compressive Strength Vs % Of Rubber Latex (90-Days) (a) W/B- 0.325, (b) W/B- 0.35, (c) W/B- 0.375, (d) W/B- 0.40

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 Conclusion

Rubber tree tapping yields the polymer known as natural rubber latex. By casting and testing NRLMFRHPC mix specimens, the impact of addition of rubber latex on the 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 natural rubber latex is added by 0.5% by the weight of binder. When the amount of steel fibres and rubber latex grows to 1.0% and 0.5% respectively, 28-day strength of NRLMFRHPC mixes increases as well. It is discovered that the maximum compressive strength of 103.67 MPa is achieved when 0.5% rubber latex and 1.0% steel fibre, with a W/B of 0.325 is used. 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 latex percentage up to 0.5% both boost the 90-day's strength of NRLMFRHPC mixtures. It is also found that maximum compressive strength of 90-day was obtained as 108.62 MPa at 0.5% latex, 1.0% steel fibre, and W/B of 0.325. It is also observed that when Latex is increased to 0.75% the compressive strength drops to 106.16 MPa. 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% latex for the NRLMFRHPC's for better workability, strength, and durability.

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