Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 16s (2025)
https://www.jneonatalsurg.com
OPEN ACCESS

Performance of Polymer Modified Fibre Reinforced High Strength Concrete

M. Chandra Shekhar[1], D.V. Tanuja[2], B. Sudharshan Reddy3

[1]M. Tech Student, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India

[2]Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.

[3]Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.

***Correspondence Author:**

M Chandra Sekhar,

Email ID: mjrdesigns23@gmail.com

Cite this paper as: M. Chandra Shekhar, D.V. Tanuja, B. Sudharshan Reddy, (2025) Performance of Polymer Modified Fibre Reinforced High Strength Concrete. *Journal of Neonatal Surgery*, 14 (16s), 231-236.

ABSTRACT

The report outlines the findings of an experimental study on the properties of polymer-modified steel fiber-reinforced concrete. The investigation encompasses compressive, flexural, and shear strength, employing styrene-butadiene rubber latex as the polymer. The fiber volume ranges from 1% to 10% at 1% intervals by weight of cement, while the polymer content varies at 5%, 10%, and 15% by weight of cement. The water within the polymer is considered part of the total water content. The research delves into the impact of polymer and fibers on the workability and wet density of fresh concrete. Additionally, the influence of dry curing on various strengths of fiber-reinforced concrete is explored. Various physical properties, including dry density, crack width, are also investigated. The workability of fiber-reinforced concrete diminishes with increasing fiber content, while enhancements in strengths are observed compared to normal concrete. In essence, the study evaluates the performance of polymer-modified fiber-reinforced high-strength concrete..

Keywords: *High Strength Concrete, SBR latex, Steel Fibre, PMFRC, Strengths, Toughness, Deformations, Stress-Strain, Number of Fibres, Elastic constants, Micromechanics..*

1. INTRODUCTION

Concrete has been one of the most widely used construction materials globally for over seventy years, thanks to its strength, moldability, structural stability, and relatively low cost. The design of concrete is both an art and a science, constantly evolving with new technologies, knowledge, and innovative materials. Rapid advances in construction materials have allowed civil and structural engineers to achieve significant improvements in the safety, economy, and functionality of structures, ultimately enhancing the quality of life and well-being of individuals. The incorporation of high-strength, high-stiffness structural fibers into concrete has led to composite materials that substantially improve the mechanical properties and durability of concrete structures. The use of fibers in concrete is expected to become increasingly common in repair and rehabilitation projects for structures such as bridges, industrial floors, airport pavements, overlays, high-rise buildings, TV towers, parking garages, offshore structures, and historic monuments. Concrete is a versatile material, and few other construction materials match its utility. However, it also has notable disadvantages, such as delayed hardening, low tensile strength, significant drying shrinkage, and low chemical resistance.

To address these drawbacks, efforts have been made to enhance concrete by incorporating polymer additives, such as thermoplastics like epoxy, resins, thermosets, elastomers, and rubbers. Polymers are favored in cement concrete composites due to their high performance, multifunctionality, and sustainability. Synthetic polymers like epoxy, resins, and hardeners, as well as natural polymers like cellulose, lignin, and protein, are commonly used in concrete composites. Polymer-modified concrete consists of a monolithic co-matrix where the organic polymer matrix and the cement gel matrix are homogenized. Various polymers, including latex, redispersible polymer powders, water-soluble polymers, liquid resins, and monomer-modified concretes, are used in the production of polymer-modified concrete. When polymers and monomers are used in cement composites, it is crucial that cement hydration and polymer phase formation proceed effectively to create a strong, interpenetrating monolithic matrix. This co-matrix binds the aggregates, resulting in a superior polymer-modified concrete with enhanced properties. Polymer-modified cement composites are environmentally friendly and align with goals of resource conservation, infrastructure longevity, and environmental protection.

Fibers have been used since ancient times to reinforce brittle materials—horsehair in plaster, straw in sun-baked bricks, and asbestos fibers in Portland cement. The application of fibers in concrete is growing rapidly, as they can significantly improve the mechanical properties of the material. The low tensile strength and brittleness of concrete have been mitigated by the use of fibers, which can be added to select areas of precast, prestressed, and cast-in-place concrete. Fiber-reinforced concrete is particularly useful for foundations subjected to shock and vibratory loads. Steel fiber-reinforced concrete, a composite material containing randomly dispersed steel fibers, has seen increasing use in construction due to advancements in the physical and mechanical properties of steel fibers and extensive laboratory research.

Fibers used in reinforcing concrete include steel, glass, ceramics, and organic polymers, as well as natural vegetable fibers like jute, cotton, coconut, and sisal. These fibers come in various shapes and sizes, and their aspect ratio (fiber length divided by equivalent diameter) is an important parameter for defining their geometry. Fiber orientation has a significant impact on the composite properties of the material, including its strength and stiffness.

Necessity of Research and Development

The development of the construction industry is driven by ongoing research, development, and the design of new and improved materials. As the need for mega-structures grows, materials with enhanced properties—particularly in terms of strength, stiffness, toughness, ductility, durability, and chemical resistance—are increasingly required. Concrete's inherent brittleness and relatively low tensile strength are often addressed by the addition of fibers, though fiber inclusion can increase voids and lead to high porosity, which is undesirable.Contemporary research into cement matrix materials focuses on incorporating additives, polymer admixtures, and fibers to improve specific physical and mechanical properties while maintaining the material's strength, cost-effectiveness, and adaptability to various shapes. Key research areas include enhancing adhesion, permeability, ductility, flexural strength, thermal and acoustic insulation, fire resistance, and viscous damping.

In recent years, the demand for high-quality concrete and mortar has grown significantly, driven in part by durability challenges in concrete structures. Environmental conditions, including pollutants in water, soil, and air, contribute to concrete deterioration and steel corrosion in industrial and other structures. Ordinary Portland Cement (OPC) concrete has several inherent weaknesses, including poor tensile strength, chemical resistance, and bonding ability with both old and new concrete.To address these issues, Polymer Modified Fiber Reinforced Concrete (PMFRC) has been developed, offering enhanced mechanical performance and durability. This material is gaining acceptance in the construction industry due to its focus on safety, economy, and functionality. Numerous studies have been conducted to assess the potential of fiber-reinforced concrete for structural applications, and over the past four decades, it has been successfully employed in a wide range of applications. One of the most promising uses of steel fiber-reinforced concrete is as shear reinforcement. Despite the widespread use of concrete, few are familiar with the detailed considerations necessary to design strong, durable, and high-quality concrete structures.

The main objectives of this experimental study were focused on developing a comprehensive methodology and deriving meaningful contributions in several key areas. First, the study aimed to analyze the stress-strain behavior of polymer-modified steel fiber-reinforced concrete (PMSFRC) under different stress conditions, including flexure, compression, single shear, and double shear. Additionally, it sought to calculate important parameters such as toughness, toughness indices, and the shear transfer law, which are critical to understanding the material's performance. The study also involved determining the elastic constants of PMSFRC. Furthermore, mathematical models were developed to predict various strengths based on volume fraction (Vf) and compressive strength (fcu).

2. LITERATURE REVIEW

Concrete structures are susceptible to tensile cracks, which allow moisture and chlorides to penetrate, leading to reinforcement rusting and a subsequent weakening of the structure. To enhance concrete's properties, such as waterproofing, resistance to moisture or air permeation, chemical resistance, freeze-thaw durability, and improved bond strength, polymers are often added. Various types of polymer dispersions can be used for these purposes. Brittle materials typically lack significant post-cracking ductility, but fiber-reinforced composites have been developed to improve the mechanical properties of otherwise brittle materials. When unreinforced brittle matrices are subjected to tension, they initially deform elastically, followed by microcracking, localized macrocracking, and eventual fracture. The incorporation of fibers into concrete modifies its post-elastic behavior, with the degree of improvement in load-bearing capacity depending on factors such as matrix strength, fiber type, fiber modulus, fiber aspect ratio, fiber strength, bonding characteristics, fiber content, fiber orientation, and aggregate size.

The greatest advantage of using fiber reinforcement is the enhancement of a structure's long-term serviceability. Fibers in concrete offer substantial time and cost savings by reducing the need for labor-intensive reinforcement placement and control. Winterberg [01] explored fiber-reinforced concrete as a modern, cost-effective construction material, while Katherine et al.

[02] demonstrated improvements in ductility, toughness, flexural strength, and shear strength in cementitious composites with fiber reinforcement. Additionally, fiber reinforcement has been shown to reduce shrinkage cracking, permeability, and improve resistance to fatigue and impact, while also enhancing the overall brittle nature of cementitious materials.

Serviceability refers to the ability of a structure or its components to maintain strength, integrity, and functionality throughout its intended lifespan. One key aspect of serviceability that fibers enhance is crack control. Fibers help limit the formation of wide cracks, which are aesthetically undesirable and may allow water and contaminants to infiltrate, leading to reinforcement corrosion and potential concrete deterioration.

Polymer dispersions introduce significant air into concrete, improving its workability but reducing its strength. To counteract this, adjustments to the water-cement ratio in polymer-modified concrete mixes are necessary. Mangat [76] proposed reducing water content and using defoaming agents to limit entrained air. Current research focuses on additives, admixtures, and fibers to enhance concrete's physical and mechanical properties while maintaining strength, cost-effectiveness, and flexibility. Key areas of study include adherence, permeability, insulation, ductility, flexural strength, and fire performance.

Polymeric admixtures, such as polymer latex, redispersible polymer powder, and water-soluble or liquid polymers, are widely used to modify cement-based materials. Polymer latex is the most common. Barluenga and Hernan [77] found that polymer-modified mortars improve mechanical properties, with polymer film formation and cement hydration working together to create a strong co-matrix. Stabilizing systems are used in polymer dispersions to prevent agglomeration of polymer particles.

Neelagmegam [78] highlighted that flexural strength improves with polymer modification using SBR latex and a combination of wet-dry curing. Wet curing enhances cement matrix strength, while dry curing aids SBR film formation, improving adhesion. Bing and Liu [79] support this combination for optimal strength development. Chen and Teng [80] emphasized the non-uniform stress distribution in FRP-reinforced concrete beams at shear failure, which impacts strength modeling.

Gengying Li [81] explored polymer-modified steel fiber-reinforced concretes (PSC) for roadway and underground applications, using SBR to improve ductility and flexural strength. Despite the high cost of steel fibers and SBR, the focus remains on finding optimal, cost-effective mixes. Khan et al. [82] studied the impact behavior of SBR-latex-modified fiber-reinforced concrete beams, observing that fiber and latex additions improve dynamic behavior and residual strength. Soni and Joshi [83] also found that increasing SBR latex content improves both the workability and strength of concrete mixes.

3. MATERIALS AND METHODOLOGY

For the preparation of Polymer Modified Concrete (PMC) and Polymer Modified Steel Fibre Reinforced Concrete (PMSFRC), materials used included cement, fine and coarse aggregates (20 mm, 10 mm), crimped steel fibers, polymer latex, and water. The research is experimental, and tests were conducted on the materials as follows:

3.1.1 Cement:

Ultratech-53 grade Ordinary Portland Cement was used, with tests conforming to IS: 12269:1987 standards.

3.1.2 Aggregates:

Aggregates are natural materials crucial for giving body to concrete, reducing shrinkage, and ensuring economy. They form 70-80% of the concrete volume and are categorized into fine aggregates (size ≤4.75 mm) and coarse aggregates (size >4.75 mm).

3. 1.3 Fine Aggregates:

Locally sourced natural sand from the Krishna River (zone II) was tested, showing a silt content of 1.2%, specific gravity of 2.8, water absorption of 1.2%, and fineness modulus of 2.9.

3. 1.4 Coarse Aggregates:

Basalt rock-derived aggregates of two sizes (20 mm and 10 mm) were tested. The 20 mm aggregate had a specific gravity of 2.61, water absorption of 0.4%, and fineness modulus of 7.25, while the 10 mm aggregate had similar specific gravity with slightly higher water absorption (0.5%) and fineness modulus of 6.87.

3. 1.5 Steel Fibres:

Crimped steel fibers conforming to ASTM A820 M04 Type-I standards were used, sourced from Stewols India Pvt. Ltd. Key properties include fiber thickness of 1 mm, length of 50 mm, tensile strength >1100 MPa, and an aspect ratio of 30.

3. 1.6 Polymer: '

Monobond' polymer latex (SBR Latex) was used, containing 44% solids and 56% water. Its properties include a specific gravity of 1.01 and a viscosity of 20 Cp. Water from this polymer was included in the total mix water content.

3.1.7 Water:

Ordinary tap water was used, with quality parameters ensuring a pH between 6 and 8 and freedom from organic matter, silt, and suspended particles.

3.2 Tests Conducted on Fresh Concrete

3.2.1 Workability of Concrete

Workability is a key property determining the ease of handling and compacting concrete. Factors such as water content, aggregate ratio, and the use of admixtures influence workability. The slump test, as per IS: 1199-1959, was used to measure this property. Slump loss between normal and composite concrete.

3.2.2 Wet and Dry Density of Concrete

Wet density refers to the weight of concrete specimens immediately after casting, while dry density represents the weight after 28 days of curing.

3.3 Tests Conducted on Hardened Concrete

Tests were performed to determine the strength characteristics of normal concrete, PMC, and PMSFRC after 28 days of curing. These tests included compressive strength, flexural strength, and shear tests, as per IS: 516-1959. The average of three specimens was recorded unless variations exceeded ±15%.

3.3.1 Compressive Strength Test

Compression tests were conducted on cubic specimens (150 mm × 150 mm × 150 mm) in a 2000 KN capacity machine.

3.3.2 Flexural Strength Test

To evaluate flexural strength, prism specimens (150 mm × 150 mm × 700 mm) were tested under two-point loading.

4. RESULTS AND DISCUSSIONS

4.1 Workability of Concrete

The workability of normal concrete, polymer modified concrete (PMC), and polymer modified steel fibre reinforced concrete (PMSFRC) was assessed using the slump cone test. The results of workability with 5%, 10%, and 15% SBR latex variations are shown in Table 1. Workability increased significantly with the addition of polymer (PMC) compared to normal concrete. In PMSFRC, workability decreased as fibre content increased. However, at 10% fibre content, the slump values were 75 mm, 80 mm, and 82 mm for 5%, 10%, and 15% SBR latex content, respectively, which are sufficient for practical applications in reinforced concrete structures.

4.2 Wet Density and Dry Density of Concrete

The wet density of concrete is measured immediately after casting, while the dry density is assessed after 28 days of curing. The results (Table 2) indicate that specimens containing fibres with polymer exhibit a slight reduction in density compared to normal concrete. This reduction may be attributed to air entrainment caused by the addition of polymer.The inclusion of fibres in polymer modified concrete (PMC) also leads to a decrease in slump, with polymer modified steel fibre reinforced concrete (PMSFRC) showing a higher rate of slump loss. This change in workability makes the concrete harder to handle, especially for mixes with higher fibre content. As a result, concretes with maximum fibre content become noticeably more difficult to work with, impacting their practicality in construction applications.

4.3 Compressive Strength

The compressive strength of normal concrete (NC), polymer modified concrete (PMC), and polymer modified fibre reinforced concrete (PMSFRC) was calculated, and the results demonstrate significant differences based on the varying fibre content and SBR latex dosages. It was observed that the compressive strength of PMC decreased compared to that of NC. Furthermore, in PMC, compressive strength decreased with an increase in polymer dosage.

The maximum compressive strengths of PMSFRC were recorded at 59.11 MPa, 56.89 MPa, and 56.83 MPa for fibre contents of 2%, 4%, and 2% with SBR dosages of 5%, 10%, and 15%, respectively. A decreasing trend in compressive strength was noted up to 10% fibre content. Notably, the compressive strength values for PMSFRC at 6% fibre content exceeded those of both NC and PMC. At this fibre content level, the enhanced workability of PMSFRC proved advantageous for reinforced concrete structures, particularly those with congested reinforcement.

The variation of compressive stress with compressive strain for NC, PMC, and PMSFRC under different SBR dosages highlighted the material behaviors under compression.

4.4 Flexural Strength

The flexural strength of polymer modified fibre reinforced concrete (PMFRC) was determined. Results for flexural load (P), of normal concrete (NC), polymer modified concrete (PMC), and the correlation constant are detailed. The load-deflection curves for varying fibre dosages are also included.

It was observed that the flexural strength of PMC increased compared to NC and that this strength improved with increasing polymer dosage. The maximum flexural strengths of PMSFRC reached 5.97 MPa, 5.80 MPa, and 6.79 MPa at fibre contents of 10%, 9%, and 10% with polymer dosages of 5%, 10%, and 15%, respectively. This translates to percentage increases in flexural strength of 32.08%, 31.42%, and 50.22% compared to NC at 5%, 10%, and 15% polymer dosages, attributed to the synergistic effects of polymer and fibre.

From the flexure tests on PMSFRC specimens, strain hardening—an increase in strain with load—was evident in both elastic and inelastic ranges, with elastic strain capacity rising as fibre volume fraction increased. The addition of fibres reduced cracking risk and shifted the mode of failure from brittle to ductile, influenced by the low fibre volume fraction and matrix strength.

5. CONCLUSIONS

An investigation was conducted on polymer modified steel fibre reinforced concrete with 3 days of moist curing followed by 25 days of air curing, focusing on the synergistic effects of polymer and steel fibres on workability and mechanical properties. The results of elastic constants for the polymer modified fibre reinforced concrete, obtained through experimental and theoretical means, are discussed. The following conclusions were drawn:

- In polymer modified fibre reinforced mixes, workability improved with the addition of polymer but decreased with higher fibre contents. However, even at high fibre volume fractions, workability remained better than that of normal concrete.
- Density: Normal concrete exhibited higher density than polymer modified composites. As the fibre content increased in polymer modified concrete, density marginally increased but remained lower than that of normal concrete.
- Compressive Strength: The inclusion of polymer in the normal mix did not significantly enhance compressive strength.
- Flexural and Shear Strength: Significant improvements in flexural and shear strength were observed with the inclusion of polymer and steel fibres, highlighting the synergistic effects of these materials.

REFERENCES

[1] Winterberg R., "Fibre Reinforced Concrete – A Modern Cost-efficient Construction Material", ICI Journal, Vol.11, No.3, October-December 2010,pp. 34- 45.

[2] Katherine G. Kuder, Nilufer Ozyurt, Edward B.Mu. & Surendra P. Shah, "Rheology of Fiber- Reinforced Cementitious Materials", Cement and Concrete Research, 37, 2007, pp. 191-199.

[3] Balaguru P., and Najm H., "High-Performance Fiber-Reinforced Concrete Mixture Proportions With High Fiber Volume Fractions", ACI Materials Journal, July-August 2004. pp. 281-286.

[4] Balaguru P. and Andrew Foden, "Properties of Fiber Reinforced Structural Lightweight Concrete," ACI Structural Journal, Jan-Feb -1996, pp. 62-78.

[5] Parameswaran V.S., "High- Performance Fibre Reinforced Concretes", The Indian Concrete Journal, November 1996, pp. 621-627.

[6] ACI Committee 548 (ACI 548.5R), "Guide for Polymer Concrete Overlays", ACI Materials Journal, Sept- Oct 1993, pp. 499-522.

[7] ACI Committee 548 (ACI 548.1 R.86), "Guide for the Use of Polymers in Concrete", ACI Journal, Vol. 83, Sept- Oct 1986, pp. 798-829.

[8] Singh Anupam, Lakhani Rajni and Rajkumar, "A Review on Polymer Modified Cementitious System for Building Applications", Civil Engineering & Construction Review (CE & CR), Oct 2006, pp. 33-38.

[9] Siddiqi Z. A., Hameed R., Saleem M., Khan Q. S. and Jawad A. Qazi, Determination of compressive strength and water absorption of styrene butadiene rubber latex modified concrete, Pakistan journal of science, Vol.13(1), 2013,pp.124-128.

[10] Radhakrishnan R., Prakash Syam. V, Prasad C.K., Verma Thampan, Performance of Styrene Butadiene Rubber As A Concrete Repairs Material Intropical Climate, International Journal of Advancement In Research And Technology, Vol.6(1), 2012, pp1-5.

[11] Sivakumar.M.V.N., Effect of Polymer Modification On Mechanical And Structural Properties Of Concrete-An Experimental Investigation, Interational Journal Of Civil And Structural Enggneering,Vol.4,2011,pp.730-740.

[12] Wang R., Lackner R. and Wang P.M, Effect of Styrene Butadiene Rubber Latex On Mechanical Properties of Cementitious Materials Highlighted By Means Of Nanoindentation, International Journal For Experimental Mechanics, 2009, pp.117-126

[13] Davidson James S., "Failure Mechanisms of Polymer- Reinforced Concrete Masonry Walls Subjected to Blast", Journal of Structural Engineering, ASCE, Aug 2005, pp. 1194-1205

[14] ACI Committee 548 (ACI 548.4), "Standard Specification for Latex-Modified Concrete (LMC) Over Lays", ACI Materials Journal, Vol.89, Sept-Oct 1992, pp. 521-526.

[15] Fowler, D. W., Polymers in concrete Handbook of structural concrete, Mc- GrawHill publication, New York,1983.

[16] Ohama Y.,Concrete Admixtures Handbook (Properties, Science and Technology), Noyes publication, Park ridge, New Jersey, U.S.A.,1994.

[17] Ghugal Y.M., Polymer modified mortar: A material for strengthening of earthquake damaged structures, Proc. Tenth Symposium on Earthquake Enginnering, Roorkee,1994, pp.16-18.

[18] Kordan Joshua B., Polymer Modified Concrete-Review, Journal of materials in civil engineering, Vol.9, 1997, pp.85-92.

[19] Elyamany Hafez E (2013) "Experimental investigation of the effect of latex solid/water ratio on latex modified co-matrix mechanical properties." Alexandria Engineering Journal, 2013, pp. 83-98.

[20] Fang Xu, Mingkai Zhou, Jianping Chen , ShaoqinRuan, "Mechanical performance evaluation of polyester fiber and SBR latex compound-modified cement concrete road overlay material", Cement and Concrete Composites,2014, pp.45-51

..