

Comparative Study on the Flexural Behavior of Conventional Concrete with Steel and Polypropylene Fibers

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Abstract

Cement concrete is the most widely used construction material in all civil engineering applications due to its well-established advantages such as availability, durability, and cost-effectiveness. However, one of its primary limitations is its low tensile strength, which raises concerns in structural applications. To address this issue, extensive research has been conducted, and findings consistently highlight that fiber reinforcement is one of the most effective and versatile methods to enhance post-cracking tensile strength and energy absorption capacity during fracture. A wide variety of fibers have been incorporated into concrete matrices, including natural, metallic, and polymer-based fibers. Common natural fibers include palm, straw, and coir, while metallic fibers are typically composed of steel or stainless steel. Polymer fibers such as polyester, polypropylene, and aramid are also commonly used. These fibers may vary in length (short or long), geometry (straight or hooked-end), and configuration (single or hybrid). In the present investigation, a combination of steel and polypropylene fibers was utilized in varying volume fractions to assess their impact on the mechanical and workability properties of fiber-reinforced concrete.

Keyword: *Fibre reinforced concrete, steel fibres, polypropylene fibres, concrete mix designs etc.*

INTRODUCTION

Concrete, as a non-homogeneous composite material, inherently contains micro-cracks even prior to the application of external loads. These micro-cracks typically originate from phenomena such as bleeding, thermal effects, and shrinkage. When subjected to external loading, the dispersed micro-cracks tend to align and coalesce, forming macro-cracks. As the loading continues to increase, these macro-cracks propagate, ultimately leading to structural failure. The incorporation of short, randomly distributed fibers into the concrete matrix can effectively influence and restrain this crack development process. These fibers not only mitigate the initiation of cracks but also contribute to localized control over their propagation and growth.

Fiber reinforced concrete (FRC) is a composite material composed of two materials: concrete matrix and randomly distributed short and discontinuous fibers. Significant research has been done from the past three decades studying the long and short term performances of fiber reinforced concrete. Different types of fibers are currently being used, which include steel, polymers, carbon, glass or natural materials. By 2012, 200,000 metric tons of fibers were used for concrete reinforcement. Out of which, steel fibers remain the most used fiber of all (50% of total tonnage used) followed by polypropylene, glass and other fibers. Extensive research has been carried out on reinforced concrete with steel fibers so far and comparatively less has been done using other types of fibers.

When incorporated in sufficiently high volume fractions, fibers can contribute to an increase in the tensile strength of the composite material. Upon reaching the tensile capacity under applied loading, the transition from micro-cracks to macro-cracks occurs. The ability of fibers to control crack opening and growth largely depends on their length and bond characteristics, as they act to bridge and restrain the propagation of macro-cracks. Consequently, in Fiber Reinforced Composites (FRCs) with low to moderate fiber volume content, a significant improvement in tensile or flexural strength may not be observed. However, such composites can still exhibit enhanced toughness in the post-cracking phase.

Fibers have been employed as discrete, randomly distributed reinforcement to enhance the tensile performance of materials inherently weak in tension. Their inclusion has been shown to significantly improve toughness and post-cracking ductility by bridging cracks and facilitating stress transfer across the cracked matrix. This stress redistribution contributes to an increased load-carrying capacity following crack initiation. The application of fibers in concrete began in the early 1960s, initially utilizing straight steel fibers, which demonstrated notable improvements in both ductility and fracture toughness.

APPLICATIONS OF FRP STRENGTHENING

RC structures are generally highly durable, the corrosion of embedded steel reinforcement remains the principal degradation mechanism. To mitigate corrosion risk, structural elements are typically designed with an increased concrete cover, providing a physical barrier against environmental ingress. This cover ensures that the carbonation process progresses slowly enough to prevent de-passivation of the steel within the service life of the structure. However, this approach often results in the use of excess concrete beyond structural necessities, driven purely by durability considerations. In specific applications, Fibre-Reinforced Polymer (FRP) reinforcements offer a sustainable and economical alternative. Composed of chemically stable high-performance fibres (e.g., carbon fibres), FRPs are inherently resistant to corrosion, thus reducing or eliminating the need for thick concrete cover layers. FRP reinforcements are inherently immune to corrosion and exhibit exceptionally high strength-to-weight ratios, enabling the design and construction of lighter and more slender structural elements with the potential for extended service life. In the context of the ongoing climate crisis, where cement production contributes approximately 5%–7% of global CO₂ emissions, the strategic integration of FRP reinforcement offers a promising path to reducing concrete consumption.

Commercial availability of FRP reinforcement began in the 1980s, following extensive research efforts in North America, Europe, and Japan. Although its structural viability has been demonstrated, widespread adoption remains limited. Despite this, FRP has found a firm foothold in specialized applications, such as structural strengthening, retrofitting and infrastructure projects in aggressive coastal environments. The commonly cited barrier of a lack of standardized design codes no longer holds, as numerous national and international guidelines have been introduced over recent decades, supporting the design and

implementation of FRP in structural applications. Nevertheless, the comparatively higher cost of FRP materials remains a key obstacle to broader utilization, continuing to limit its mainstream application in construction.

The structural concrete industry is currently experiencing a renewed and intensified phase of research and development focused on fibre-reinforced polymers (FRP). This second wave of innovation began in technical universities in Germany, where early efforts centered on textile-reinforced concrete incorporating high-performance fibres [19,20]. Since then, the research community has expanded globally [21–28], and the scope has broadened to include a wide range of FRP reinforcement applications in structural concrete.

This progression has led to the emergence of numerous FRP products and new manufacturers, contributing to a more dynamic and competitive market. As a result, project-specific selection of the most appropriate FRP reinforcement has become more feasible, improving FRP's competitiveness relative to traditional steel reinforcement. This review of the current European FRP market (including Russia) provides essential insights into the available reinforcement systems, their material compositions, and mechanical performance characteristics. Given that the composition of FRP significantly influences its mechanical behavior, understanding this relationship is crucial for both researchers and end users. Such knowledge enables practitioners to identify suitable manufacturers more efficiently when seeking specific types of FRP reinforcements.

FRP COMPOSITES: NEED OF AN HOUR

By 2050, global cement production for concrete is projected to rise significantly, increasing from the current 4.4 billion tons to an estimated 16 billion tons annually. This surge in demand is largely attributed to population growth, with the global population anticipated to reach 9.8 billion by 2050, up from 7.6 billion as reported in 2017 (United Nations, 2017). In light of this rising demand—coupled with the pressing challenges of climate change and diminishing natural resources—there is a critical need for innovative and sustainable solutions within the construction industry.

Conventional concrete exhibits adequate resistance to compressive stresses, it demonstrates poor performance under tensile loading. This limitation has prompted the exploration of

additives aimed at enhancing the overall strength characteristics of traditional concrete. The incorporation of steel fibers has been shown to improve both the flexural strength and ductility of concrete. However, excessive fiber content or the use of fibers with a high aspect ratio can lead to a phenomenon known as balling, which results in poor fiber dispersion and can negatively impact the mechanical performance of the concrete.

Steel-reinforced concrete (RC) remains the most widely utilized construction material globally, with an estimated annual usage of approximately 30 billion tonnes. This trend is expected to continue rising, especially in rapidly developing nations such as China. RC's popularity stems from its cost-effectiveness, material availability, versatility in forming complex geometries, and its structural performance, wherein concrete efficiently resists compressive forces and embedded steel reinforcement compensates for its inherent weaknesses in tension and ductility. Steel fibers have been incorporated into concrete mixtures since the early 20th century. Initial applications involved smooth, round wires that were cut or chopped to the desired lengths. Over time, the use of straight, smooth fibers has become largely obsolete, with modern steel fibers typically featuring surface deformations such as hooked ends, crimping, undulations, or rough textures to enhance mechanical bonding with the concrete matrix. Today, commercially available steel fibers are manufactured using various methods, including drawing from steel wire, slitting sheet steel, or employing the melt-extraction technique, which produces crescent-shaped cross sections.

According to IRC:SP:46-1997, steel fibers generally possess equivalent diameters (calculated based on cross-sectional area) ranging from 0.15 mm to 2 mm, with lengths varying between 7 mm and 75 mm. The aspect ratio—defined as the ratio of fiber length to its equivalent diameter—typically lies within the range of 20 to 100. Steel fibers exhibit high tensile strength (ranging from 0.5 to 2 GPa) and a modulus of elasticity of approximately 200 GPa. They display a ductile or plastic stress-strain response and have low creep characteristics. Concrete reinforced with steel fibers has demonstrated significantly improved impact resistance and enhanced ductility under compressive, flexural, and torsional loading. These benefits have led to widespread use of steel fiber reinforced concrete in road overlays, airfield pavements, and bridge decks.

LITERATURE REVIEW

Prachaya Yoddumrong

The main objective of this study is to investigate the performance of low-cost glass fiber reinforced polymer (GFRP) in strengthening the extremely low strength and poorly detailed concrete columns typically found in a rural area of Thailand.

A detailed survey of these structures revealed that longitudinal reinforcement in reinforced concrete columns is comprised of round bars along with widely spaced stirrups.

Further, the compressive strength of concrete is observed very low i.e., 5.0 MPa. This type of column is referred as “Non-engineered Reinforced Concrete Column” or NRCC.

To achieve the research objectives, two reinforced concrete columns representative of existing NRCC columns were constructed and subjected to cyclic loadings.

One column was tested as built to serve as a control column, whereas second column was strengthened by using locally available low cost bi-directional GFRP.

Both columns were subjected to lateral loading along with constant axial load to simulate the effect of earthquake forces.

Test results indicate that the ultimate failure mode of the control column is very brittle. Severe crushing of concrete and spalling of concrete cover along with buckling of the longitudinal steel bars was observed at very low drift levels.

The maximum lateral strength (14.73 kN) was observed at the drift level of 0.75 %. Following this, lateral load carrying capacity was rapidly dropped and gravity collapse occurred at 1.75 % lateral drift. In contrast, the counterpart GFRP column performed very well under cyclic loading.

The maximum lateral strength (19.47 kN) was observed at the drift level of 1.22 %. The damage was almost invisible up to 3% drift and the lateral strength degradation occurred gradually up to 8% drift.

Finally, the well-known Paulay and Priestley's model based on plastic hinge theory together with the method essentially based on ACI440 equations were used to calculate the lateral resistance and drift of both control and GFRP strengthened columns.

The predicted results in terms of lateral forces are found in well agreement with the experimental results, however, predicted results in terms of lateral displacements are found on conservative side especially for lateral displacements at the onset of ultimate lateral load and 20 % drop in lateral load carrying capacity

Imad Shakir Abbood

- Competition in civil engineering markets usually imposes low-cost, low-density and environmentally resistant materials with minimum maintenance and extended service life features to withstand the undersired sever loading and aggressive environmental conditions.
- As a result, using advanced composite materials as reinforcing for many different structures has been developed acceptably in past decades through new construction and rehabilitation applications.
- “Fiber reinforced polymers” as composite materials are powerful strengthening technique for various structural applications and have been the main focus for many researchers in the latest years due to their aforementioned properties.
- FRPs technique has been successfully implemented for strengthening bridges, buildings, tunnels, silos, tanks, and underground infrastructures.
- FPRs have been conducted as high-performance materials owing to their advantages including light-weight, fatigue resistance, high tensile strength, anti-corrosion, and thermal insulation.
- This paper intends to review the design of FRP composites and the characteristics of their constituent materials.
- This review also provides a brief information about the potential of FRPs as an alternative to steel reinforcement in concrete structural members by providing evaluation of the mechanical properties of FRP composite materials in terms of compressive, shear, flexural and tensile strength against extreme loading and environmental conditions.

Joris Smits

- This paper reviews the use of fiber-reinforced polymers (FRPs) in architectural and structural bridge design in the Netherlands.
- The challenges and opportunities of this relatively new material, both for the architect and the engineer, are discussed.
- An inventory of recent structural solutions in FRP is included, followed by a discussion on architectural FRP applications derived from the architectural practice of the author and of other pioneers.
- Applications vary from simple deck elements to pultruded members, and even entire load-bearing structures made of FRPs are now feasible.
- Attracted by structural and economic benefits such as weight reduction and cost saving on maintenance, engineers have developed construction solutions using FRPs that compete with conventional structures.
- In the field of architecture, the recent establishment of FRP as a building material for bridges has resulted in numerous successful projects in which FRP serves both architectural and aesthetic purposes.
- Architects and engineers have demonstrated the use of FRP as a cladding material around decks, both in a simple form or translucent and combined with light.
- They have also demonstrated more daring structural applications of FRP, including a load-bearing shell, folding structures, and non-standard curved monocoque structures.
- Furthermore, this innovative material has clearly not yet reached its maximum capabilities and requires additional research.
- In particular, improvement of the environmental impact and the embodied energy of FRPs by the substitution of renewable raw materials (natural fibers, bio-based resins) for conventional materials should be further explored.
- Finally, FRP needs to be introduced as a mature material in our educational system so that future architects are educated in how to do justice to the unique material properties and fabrication methods of this material

Marija Jelcic Rukavina

This paper presents the results of an experimental study conducted to evaluate the effect of recycled tyre polymer fibres (RTPF) on the mechanical and durability properties of concrete after high temperature exposure.

- RTPF were used as an alternative to the commonly used polypropylene fibres (PPF) in concrete.
- Therefore, five different concrete mixes were tested: plain concrete, four mixes with 1 and 2 kg/m³ of RTPF and PPF, respectively.
- The specimens were tested under ambient conditions and after exposure to a predefined elevated temperature of up to 500 °C, considering the fibre decomposition temperatures determined by the DTA/TG analysis.
- The results showed that when RTPF was used in concrete up to 2 kg/m³, high temperatures did not cause further deterioration of the mechanical and durability properties of concrete due to their melting.
- On the contrary, certain benefits of RTPF were found compared to PPF, possibly due to the higher amount of residue at high temperatures.

Riccardo Maddalena

- Formation of cracks represents one of the major causes of concrete deterioration, which can lead to durability and safety issues.
- In this work, a novel crack closure system is developed, using polyethylene terephthalate (PET) polymer fibres embedded in a mortar mix.
- The PET polymer has shape memory properties and shrinks upon thermal activation, if free to do so, or otherwise exerts shrinkage restraint forces.
- A single knot was manufactured at each end of the PET fibres to provide mechanical anchorage into the mortar matrix.
- Mortar samples with embedded knotted fibres were pre-cracked and subsequently placed in an oven to thermally activate the polymers and induce the shrinkage mechanism into the fibres.
- Crack closure was measured in the range 45–100%, depending on the geometry, dimension and distribution of the fibres, and the size of the initial crack.

Huinan Wei

- Ultra-high performance cementitious composite (UHPCC) is an advanced composite material with superior compressive strength.

- UHPCC with low steel fiber content typically fails in a single-crack mode under tension, resulting in a high risk of catastrophic structural collapse and limiting its wide application.
- However, high steel fiber content adversely affects the electrochemical corrosion resistance and long-term performance of UHPCC.
- Therefore, enhancing the tensile performance of UHPCC with low fiber content has attracted great attention. Polyvinyl alcohol (PVA) fiber is characterized by outstanding crack control ability in cementitious materials.
- In this study, the macroscale flowability, tensile and flexural properties, ductility and failure mode of UHPCC containing steel and PVA fibers at low fiber content level were explored and analyzed.
- Results indicate that the post-crack energy absorption of UHPCC improved by more than 40% following fibers hybridization.
- The failure mode of UHPCC with low fiber content shifted from single crack mode to ductile multiple cracks mode.
- Microscale observations show that PVA fibers can bridge crack and transfer load at the interface after first cracking, and impede slippage between steel fiber and matrix, thus endows UHPCC with desirable ductile multiple cracks failure mode.
- The findings of this study provide a foundation for designing UHPCC with ductile tensile performance and give an in-depth understanding of underlying mechanisms of hybrid fibers, promoting the application of ductile UHPCC in innovative structures.

Deeksha Jaiswal

- Nowadays, as environmental awareness is key issue among researchers, scientific community is looking for natural materials as they are biodegradable, low cost, eco-friendly and also safe for health.
- Researchers and academicians have found many natural fibers and studied their properties for their sustainable applications in various possible sectors, and studies are also going on.
- So, in that context several natural fiber like jute, sisal, banana, pineapple, flax, hemp, kenaf, bamboo, cornstalk waste, coir, etc. have been successfully utilized as a reinforcing material in polymer composites by replacing man made synthetic fiber.

- Apart from traditional natural fibers, scientific community is also looking for locally available natural fibers across the globe in different geographical locations for successful reinforcement in polymer matrix.
- This will not only decrease burden on traditional fibers and but also at the same time it would be helpful to enrich the rural economy.
- Natural fiber based composites can be used in different areas such as auto motive industry, construction industry, sports industry and food industry.
- This study is related with extraction, characterization, surface treatment thermal analysis and activation energy of different uncommon natural fibers available at different geographical locations worldwide.
- The purpose of this study is to provide a comprehensive knowledge on extraction techniques, treatment methodologies, and properties of these uncommon natural fibers so that these novel materials can be utilized efficiently as a reinforcing material in different polymer matrix.
- Discussions on traditional natural fibers like Bagasse, Wheat straw, Coir, Pineapple, Banana etc. have been compiled extensively in various review papers but compilation on these new uncommon natural fibers is rare.
- Thermal analysis along with activation energy evaluation is another aspect which has been given emphasis in discussion because this is also a very important examination to evaluate the thermal stability of these natural fibers

Geraldine Oliveux

- A complete review of the different techniques that have been developed to recycle fibre reinforced polymers is presented.
- The review also focuses on the reuse of valuable products recovered by different techniques, in particular the way that fibres have been reincorporated into new materials or applications and the main technological issues encountered.
- Recycled glass fibres can replace small amounts of virgin fibres in products but not at high enough concentrations to make their recycling economically and environmentally viable, if for example, thermolysis or solvolysis is used.

- Reclaimed carbon fibres from high-technology applications cannot be reincorporated in the same applications from which they were recovered, so new appropriate applications have to be developed in order to reuse the fibres.
- Materials incorporating recycled fibres exhibit specific mechanical properties because of the particular characteristics imparted by the fibres.
- The development of specific standards is therefore necessary, as well as efforts in the development of solutions that enable reusers to benefit from their reinforcement potential.
- The recovery and reuse of valuable products from resins are also considered, but also the development of recyclable thermoset resins.
- Finally, the economic and environmental aspects of recycling composite materials, based on Life Cycle Assessment, are discussed

Rampal

- Fiber-reinforced polymer composites (FRPCs) are used in various sectors owing to their unique and beneficial properties, such as, high strength to weight ratio, corrosion resistance, and high stiffness.
- Conventionally, drilling the FRPCs leads to severe inter-ply damages such as delamination and fiber pull-out, which alleviates useful attributes and causes rejection during the application of FRPCs.
- Research efforts have strived to optimize the process parameters while conventionally drilling holes in FRPCs.
- Various tool geometries and advanced motion between the tool and work piece are also employed.
- Therefore, the present work reviews the drilling of FRPCs and most of its related concerns.
- Moreover, non-traditional drilling techniques for FRPCs are also reviewed.
- Nontraditional drilling methods alleviated the hole damage to a larger possible extent. Microwave drilling of FRPCs can also be explored to produce good quality holes.
- Trilokinath Mishra
- Natural fibres have recently piqued the interest of researchers due to their low cost, availability, sustainability, renewable, and biodegradable properties, which can also be used as reinforcement in polymer composites.

- Numerous researches are going on to improve the mechanical and tribological properties of these engineered biocomposites with the filling of the appropriate amount of inorganic nanoparticles like ZrO₂, SiO₂, CuS, ZnO, CuO, and TiO₂ into polymer matrices.
- The composites were made with different weight fractions of nanoparticles using various moulding techniques, such as hand lay-up, vacuum-assisted resin transfer moulding, pultrusion, injection moulding, and so on.
- Before fabrication, the natural fibers undergo different chemical treatments, such as alkaline, silane, acetylation, or benzylation, etc.
- Mechanical tests (tensile, compression, flexural, hardness, and impact), tribological tests (coefficient of friction and wear rate), and water absorption tests were commonly performed.
- The purpose of this review is to discuss the mechanical, flame retardant, thermal, tribological, water adsorption, and biodegradable properties of the inorganic nanoparticle-filled natural reinforced polymer composite and their applications.
- Our review reveals that the incorporation of inorganic nanoparticles into a natural fiber reinforced polymer composite improved mechanical and tribological properties, it is also enhanced thermal stability and flame retardancy and reduced the water absorption capacity of biocomposites.
- Inorganic nanoparticle-filled natural reinforced polymer composite has higher degradability and causes less environmental pollution and these biocomposites show their utility in construction, packaging, furniture, automotive industries, and biotechnological fields.

Andrew Y. Chen

- Carbon-fiber reinforced polymer composite materials are used throughout industry for their excellent mechanical properties; in particular, these composites boast high specific stiffnesses and specific strengths.
- However, current limitations on manufacturing, which vary greatly based on the technology that is utilized, restrict access to composite materials in a variety of applications.
- Traditional wet handlayups offer a large diversity of viable constituent materials, but the fabrication geometry is limited and the manual process is time-consuming.

- In contrast, fiber 3D-printing (F3DP) allows for the production of complex geometries and requires little manual labor.
- In this study, laminates with continuous carbon fiber reinforcement printed using a commercially-available 3D printer are compared to carbon fiber fabric-resin composites produced using manual layup techniques.
- Cross-ply [0,90,0,90,0]T laminates were fabricated and subject to mechanical testing in uniaxial tension and flexure.
- After normalization with respect to fiber volume fraction, we found that the tensile strength and stiffness of cross-ply carbon fiber composites manufactured using F3DP were higher than the tensile strength and stiffness of crossply specimens manufactured by a traditional hand-layup method; however, the hand-layup specimens exhibited higher strength and stiffness in flexure.
- The difference in material properties evident between the two fabrication methods suggests that each has its own suitable application.
- We anticipate that further studying the failure response of printed, fiber-reinforced composite materials to various loading modalities will give insight into potential areas of improvement for F3DP material selection and printing processes, particularly relating to void reduction.
- On a broader scale, comparing and analyzing the mechanical properties of composite laminates produced in these various methods will provide perspective on the viability of novel additive manufacturing methods for large-scale production and industrial applications.

EXPERIMENTAL INVESTIGATION

The concrete mix design was carried out in accordance with the guidelines specified in IS 10262:2009. The target compressive strength for the conventional concrete mix was 48.25 N/mm², while the target flexural strength was 4.86 N/mm². Concrete cubes were cast incorporating varying proportions of polypropylene fibers and steel fibers, as detailed in the table below:

Specification of Cubes and Beams Cast for Strength Testing of Fiber-Reinforced Concrete (FRC)

Table no: 1

S.No.	Percentage of Polypropylene fibre	Percentage of Steel fibre	Number of Cubes (size 150mm) casted	Number of Beams (Size 500×100×100 mm) Casted
1.	0.15	0.25	6	6
2.	0.15	0.35	6	6
3.	0.15	0.75	6	6
4.	0.15	0.85	6	6
5.	0.25	0.25	6	6
6.	0.25	0.35	6	6
7.	0.25	0.75	6	6
8.	0.25	0.85	6	6

The 28-day compressive strength of concrete cubes and the flexural strength of concrete beams were experimentally evaluated and documented. Based on the analysis, the optimum content of polypropylene fiber was identified as 0.15% by volume. Figures 1 and 2 present the results obtained for concrete mixes containing 0.15% polypropylene fiber combined with various percentages of steel fibers. Using the experimental data, regression equations were developed to model both compressive and flexural strength characteristics of the fiber-reinforced concrete. Additionally, a predictive equation was derived to establish the relationship between compressive strength and flexural strength for Steel–Polypropylene Reinforced Fiber Concrete (SPRFC).

$$F_{flex} = 1.529 * \sqrt{F_{ck}}$$

Table no: 2

Sr. no.	%SF Fibres	Predicted Comp. Str. F_{ck} With Fibres in Mpa	Sqrt (F_{ck})	Predicted Flex. Str. F_{flex} in Mpa	$F_{flex}/\sqrt{f_{ck}}$
1	0.35	51.05	7.1450	10.66321	1.4924
2	0.45	53.13	7.2893	11.08129	1.5202
3	0.55	54.81	7.4033	11.39449	1.5391

4	0.65	56.08	7.4883	11.60281	1.5494
5	0.85	57.38	7.5751	11.70481	1.5452
					Average (1.5293)

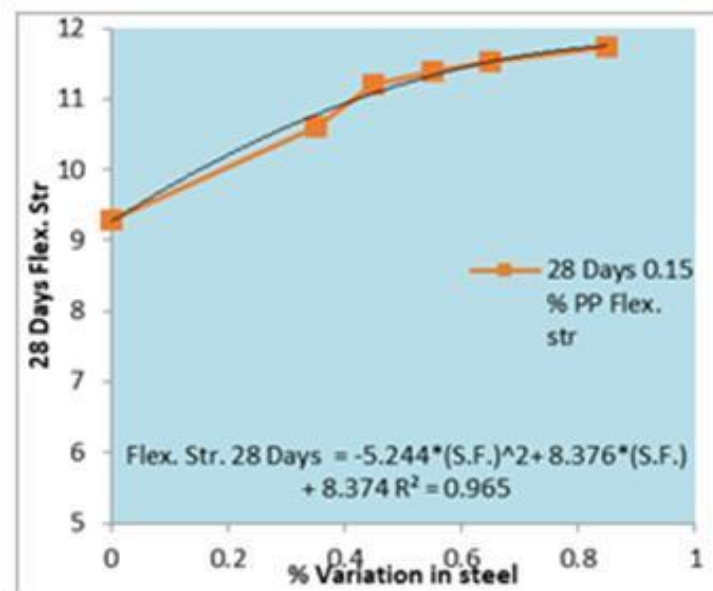


Figure:1 -28 Days Compressive Strength (Mpa) for 0.15 % PP fibres with % var. Crimped Steel

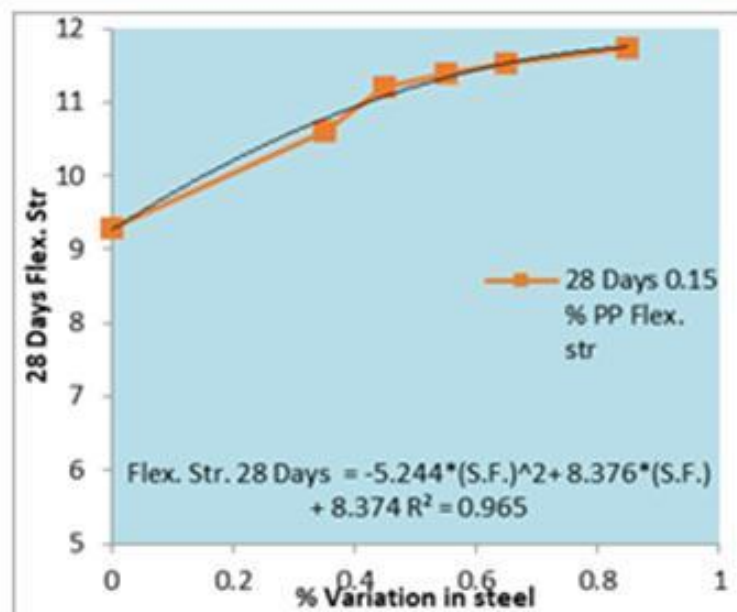


Figure:2-28 Days Flexural Strength (Mpa) for 0.15 % PP fibres with % var. Crimped Steel fibres

RESULT & CONCLUSION

The incorporation of a hybrid fiber system consisting of polypropylene and steel fibers led to a marginal increase in compressive strength, ranging between 5% and 15%. The compressive strength improved from 48.25 MPa (for conventional concrete) to a maximum of 57.38 MPa, depending on the steel fiber content and with an optimum polypropylene fiber content of 0.15%. The addition of polypropylene and steel fibers resulted in a significant enhancement of flexural strength—exceeding a 100% increase. The flexural strength rose from 4.86 MPa to 11.70 MPa, corresponding to variations in steel fiber content and the optimum polypropylene dosage of 0.15%.

For Steel–Polypropylene Fiber Reinforced Concrete (SPFRC), the flexural strength (F_{flex}) was found to correlate with compressive strength (F_{ck}) according to the equation: $F_{flex} = 1.529 \times \sqrt{F_{ck}}$

This relationship is notably different from the conventional expression for plain concrete: $F_{flex} = 0.7 \times \sqrt{F_{ck}}$

The above equation indicates that the conventional formula is not valid for SPFRC.

REFERENCES

1. Prachaya Yoddumronga, Kittipoom Rodsinb, Sakda Katawaethwarag (2020) “Seismic strengthening of low-strength RC concrete columns using low-cost glass fiber reinforced polymers (GFRPs)” Journal of Case Studies in Construction Materials, Volume – 13, Thailand.
2. Imad Shakir Abbood, Sief aldeen Odaa, Kamalaldin F. Hasan, Mohammed A. Jasim (2021) “Properties evaluation of fiber reinforced polymers and their constituent materials used in structures – A review” Journal of Materials Today: Proceedings, Volume – 43, Iraq.
3. Joris Smits (2016), “Fiber-Reinforced Polymer Bridge Design in the Netherlands: Architectural Challenges toward Innovative, Sustainable, and Durable Bridges” Journal of Engineering, Volume – 2, Netherlands.
4. Marija Jelcic Rukavina, Ana Baricevic, Marijana Serdar, Martina Grubor (2021), “Study on the post-fire properties of concrete with recycled tyre polymer fibres” Journal of Cement and Concrete Composites, Volume – 123, Croatia.
5. Riccardo Maddalena, Lorenzo Bonanno, Brunella Balzano, Cristina Tuinea-Bobe, John Sweeney, Iulia Mihai (2020) “A crack closure system for cementitious composite

- materials using knotted shape memory polymer (k-SMP) fibres” *Journal of Cement and Concrete Composites*, Volume – 114, UK.
6. Huinan Wei, Tiejun Liu, Ao Zhou, Dujian Zou, Yang Liu (2021) “Multiscale insights on enhancing tensile properties of ultra-high performance cementitious composite with hybrid steel and polymeric fibers” *Journal of Materials Research and Technology*, Volume – 14, China.
 7. Deeksha Jaiswal, G.L. Devnani, G. Rajeshkumar, M.R. Sanjay, Suchart Siengchin (2022), “Review on extraction, characterization, surface treatment and thermal degradation analysis of new cellulosic fibers as sustainable reinforcement in polymer composites” *Journal of Current Research in Green and Sustainable Chemistry*, Volume – 5, India.
 8. Géraldine Oliveux, Luke O. Dandy, Gary A. Leeke (2015), “Current status of recycling of fibre reinforced polymers: Review of technologies, reuse and resulting properties” *Journal of Progress in Materials Science*, Volume – 72, United Kingdom.
 9. Rampal, Gaurav Kumar, Sanjay Mavinkere Rangappa, Suchart Siengchin, Sunny Zafar (2022), “A review of recent advancements in drilling of fiber-reinforced polymer composites” *Journal of Composites Part C: Open Access*, Volume – 9, India.
 10. Trilokinath Mishra, Paulami Mandal, Arun Kumar Rout, Dibakar Sahoo (2022), “A state-of-the-art review on potential applications of natural fiber-reinforced polymer composite filled with inorganic nanoparticle” *Journal of Composites Part C: Open Access*, Volume – 9, India.
 11. Andrew Y. Chen, Sebastian Baehr, Austin Turner, Zilan Zhang, Grace X. Gu (2021), “Carbon-fiber reinforced polymer composites: A comparison of manufacturing methods on mechanical properties” *International Journal of Lightweight Materials and Manufacture*, Volume – 4, USA.